Sciences Methods and Technologies International Journal (SciMeTech)

ISSN: 3085-5284, journal homepage: www.scimetech.com

Operational Optimization and Performance Assessment of a Brackish Water Reverse Osmosis Plant: A real Case of Study Demineralization Plant

Yassine ELYAAKOUBY [1], **Amine TILIOUA**[1]

[1] *Research Team in Thermal and Applied Thermodynamics (2.T.A.). Department of Engineering Sciences, Faculty of Sciences and Techniques Errachidia, Moulay Ismaïl University of Meknès, B.P. 509, Boutalamine, Errachidia, Morocco.*

How to cite:
Yassine ELYAAKOUBY, Amine TILIOUA, "Operational Optimization and Performance Assessment of a Brackish Water Reverse Osmosis Plant: A real Case of Study: Demineralization Plant", Sciences Methods and Technologies International Journal (SciMeTech), Vol 2, Issue 2, p 14-17

Abstract

The findings of this study reveal that the integrated assessment of pretreatment performance, chemical-conditioning method, and RO system setup acts as a powerful framework for the continuous supply of permeate with the required quality and also for the establishment of strong operating conditions in the case of brackish-water desalination plants. The fine-tuning of dosing rates and cleaning schedules resulted in better membrane protection, lower fouling pressure, and improved hydraulic stability thus prolonging the operational lifetime and reducing maintenance needs. In conclusion, the research proves that performance-based monitoring and systematic operational optimization are vital means of enhancing the reliability, service continuity, and lifecycle sustainability of Reverse Osmosis plants in arid and resource-constrained situations.

Keywords:
Reverse Osmosis
Brackish Groundwater
Sustainable Water Supply
Operational Optimization
Pretreatment Performance
Membrane Protection
Resilient Infrastructure
Arid and Semi-Arid Regions
Continuity of public service
Sustainability of the territory

I. Introduction

Water scarcity and groundwater salinity are the two main challenges that Southern Morocco faces in its arid areas; the overuse of water resources and very limited natural recharge have caused a drop in both the quantity and quality of water. In the South-Eastern part of the country, drinking water supply is mainly from brackish aquifers, which contain saline water that is not suitable for drinking, hence the need for treatment processes such as Reverse Osmosis (RO) demineralization to secure water supply without conventional water sources. Even though RO is a well-established and efficient desalination method, its reliability during operation is highly dependent on inflow water quality, the success of pre-treatment, the manner in which the membranes get fouled and scaled, and the requirement for inputs like chemicals and energy. This research work revolves around the application of a brackish-water RO plant situated in a desert setting of South-Eastern Morocco, involving a multi-faceted approach comprising the design, simulation and operational performance evaluation, with the emphasis on pretreatment, RO configuration, chemical conditioning and performance metrics pertaining to membrane safeguarding, water quality and operating efficiency.

This study's goal is to analyze and enhance the performance at the RO plant in the hydraulic, chemical and membrane levels, with the following objectives:

- bettering the permeate quality and its conformity with drinking-water standards,
- diminishing the fouling and scaling risks owing to optimized pretreatment and reagent dosing,
- prolonging the membranes life and bolstering the reliability of the operations,
- the development of an engineering model that can be adopted by RO plants in dry, resource-poor areas.

II. Methods

The Methods part of this paper reveals the technical implementation framework for the project, which includes the system architecture, configuration of the treatment process, and the operational workflow. Furthermore, it describes the evaluation and optimization of the system through the use of real operating conditions, the tools, engineering parameters, and performance-monitoring procedures involved.

a. Process Line and Treatment Stages

The facility under investigation is a brackish-water demineralization plant that is located in a dry region of South-East Morocco. The treatment process is based on a conventional RO-based configuration that includes the following steps:

1. Pre-chlorination and initial disinfection, - 2. Dual-media sand filtration for removal of suspended solids, turbidity, and fine particles,-3. Cartridge micro-filtration used as a polishing barrier prior to membrane feed, - 4. Chemical conditioning and scaling control, - 5. Two-stage Reverse Osmosis system with 75% global recovery, - 6. Lime-based remineralization of permeate water, - 7. Final disinfection, storage, and distribution.

This sequence of processes was chosen to provide the required pretreatment, protect the membranes, and maintain stable operation in the brackish-water conditions that are characteristic of the groundwater systems in arid areas.

b. Pretreatment Design

- Sand Filtration

system includes pressure sand filters that are built to decrease: The feedwater quality was assessed considering the suspended solids, turbidity, colloidal and fine particles, and the RO fouling index. The hydraulic design of the filtration system was computed taking into account the filtration area, bed height, nominal and maximum filtration velocities, and the permissible head-loss range. In addition, the analysis revealed the essential backwash flow rate and cleaning frequency to secure proper operation and fouling control.

The backwash cycles were adjusted to keep the head losses stable, to use as little water as possible, and to prevent compaction of the filter media. The filters are crucial for the prevention of particulate fouling and for the maintenance of the quality of feed water to the stages of downstream treatment

- Cartridge Filtration

The installation of a cartridge micro-filtration stage takes place after sand filtration to keep the remaining particles and prevent the RO membranes from getting fine solids and fibers released.
The design criteria taken into account were: Nominal retention threshold, flow rate per housing, evolution of head-loss during operation, and the associated cartridge replacement frequency in relation to fouling propensity were all considered for the evaluation of the cartridge filtration stage.
Daily monitoring of operation comprised of the change in pressure drop across the housings that indicated clogging and pretreatment effectiveness.

- Chemical Conditioning Strategy

The objective of the chemical conditioning strategy was to counteract the scaling of the minerals and their precipitation, to reduce the fouling and the biological activity on the membranes, and to keep the feed-water chemistry stable prior to pressurization. A three-step treatment process was thus designed, which included essentially three chemical reagents: sulfuric acid for pH adjustment and carbonate-scaling risk reduction; an antiscalant (sequestrant) that was continuously injected to inhibit the precipitation of minerals in the RO stages; and sodium metabisulfite (SMBS), which was applied for dechlorination to avoid membrane oxidation. The chemical dosing was calculated based on the raw-water characteristics, such as pH and alkalinity, the saturation and scaling indices, the total recovery rate and concentration factor, as well as the guidelines given by the membrane manufacturer. The phase of optimization aimed at gaining a harmonious operating condition where scaling control, chemical usage, and membrane protection would be going on simultaneously during long-term operation

- .RO System Configuration

The demineralization unit has a two-stage RO system configuration with a total global recovery of about 75%. The design parameters which were looked into included: feed pressure and hydraulic loading, conversion rate per stage, salt passage and permeate conductivity, concentrate salinity and pressure limits, energy demand and operating margins. The stage distribution was chosen to limit the concentration of the first stage modules, control the increase of osmotic pressure along the train, and to improve the consistency of the permeate quality.
Simulation and operational interpretation were used to assess the following points: permeate conductivity stability, membrane fouling trends, pressure evolution and cleaning needs.

- Monitored Operational Indicators

The evaluation of the operational performance was based on both the continuous and periodic monitoring of the following indicators:

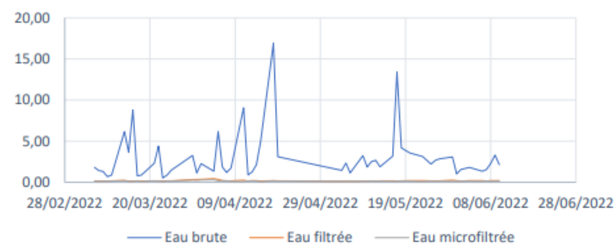
The monitoring program encompassed a wide range of indicators, including turbidity and suspended solids at the pretreatment outlet, head losses across sand filters and cartridge housings, RO feed and concentrate pressures, permeate conductivity and salinity, membrane cleaning frequency, and chemical dosing stability. The result was the combination of all these factors that helped not only to evaluate the pretreatment performance but also to characterize the fouling and scaling behavior, optimize cleaning and backwash cycles, and assesses membrane life and operational reliability.

III. Results and discussion

a. Pretreatment Performance (Turbidity and Head Losses)

The pretreatment stage played an essential part in maintaining the quality of the feed-water and decreasing the fouling effect at the inlet of the RO system. Turbidity readings taken before and after the filtration devices showed a clear and constant reduction, thus corroborating by the sand filtration step the elimination of suspended solids and fine particles.

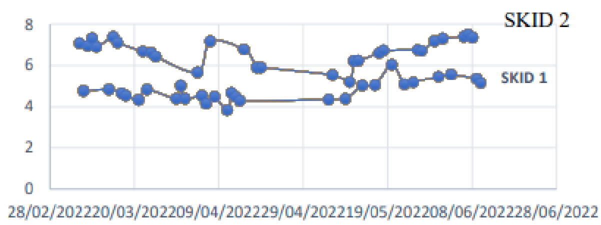
This performance trend is illustrated in:



- **Figure 1 — Turbidity variation before and after sand filtration**

The outlet turbidity has not exceeded the limits set for the operation of membranes, which resulted in a lower fouling index at the RO feed. Monitoring the head loss across the sand filters gave a clear picture of the particulate loading changes. The slow rise of differential pressure during the filtration cycles was a sign of normal retention and accumulation of solids, which then was followed by recovery after each backwash sequence.

This evolution is presented in:



- **Figure 2 — Head-loss evolution across sand filters over operating cycles**

The stability of the post-backwash head-loss values is an indication of the filter media's good hydraulic behavior, the absence of pronounced compaction phenomena, and the retention of filtration capacity over time. The pressure-drop behavior confirmed the polishing effect of cartridge filtration. The gradual increase in differential pressure across the housings was a reflection of the efficiency of the particle capture, while the frequency of replacement remained in line with the pretreatment performance targets.

This is shown in:

- **Figure 3 — Differential-pressure evolution across cartridge filtration units**

Together, the two pretreatment barriers:

- ✓ reduced particulate fouling risk,
- ✓ improved feed-water stability,
- ✓ and contributed to membrane-lifetime preservation.

In combination, the two pretreatment obstacles:

- ✓ mitigated the probability of particulate fouling,
- ✓ stabilized the feed water,
- ✓ helped extend the lifetime of the membrane.

b. Operational Reliability and Sustainability Interpretation

The objective of the chemical conditioning strategy was to counteract the scaling of the minerals and their precipitation, to reduce the fouling and the biological activity on the membranes, and to keep the feed-water chemistry stable prior to pressurization. A three-step treatment process was thus designed, which included essentially three chemical reagents: sulfuric acid for pH adjustment and carbonate-scaling risk reduction; an antiscalant (sequestrant) that was continuously injected to inhibit the precipitation of minerals in the RO stages; and sodium metabisulfite (SMBS), which was applied for dechlorination to avoid membrane oxidation. The chemical dosing was calculated based on the raw-water characteristics, such as pH and alkalinity, the saturation and scaling indices, the total recovery rate and concentration factor, as well as the guidelines given by the membrane manufacturer. The phase of optimization aimed at gaining a harmonious operating condition where scaling control, chemical usage, and membrane protection would be going on simultaneously during long-term operation.

IV. Conclusion

The present article offered proof that the integrative assessment of pretreatment efficiency, chemical-conditioning strategy and RO system configuration forms an effective method for keeping the permeate quality within the limits and having trouble-free operation in a brackish-water RO plant located in an arid region. The two-stage RO system that worked at approximately 75% recovery and optimized dosing and cleaning strategies together with membrane protection enhancement also reduced fouling pressure and improved hydraulic stability. Overall, the conclusions of the research indicate that performance-based monitoring and systematic operational optimization are necessary to reinforce reliability, service continuity and lifecycle sustainability of RO facilities in water-scarce environments.

References

Add references from googlescholar in APA format

[1] Holmes, J., Sacchi, L., & Bellazzi, R. (2004). Artificial intelligence in medicine. *Ann R Coll Surg Engl*, *86*, 334-8.