Journal of Chemical Health Risks
www.jchr.org
JCHR (2023) 13(6), 1664-1673 | ISSN:2251-6727

Treatment and Analysis of Reverse Osmosis Rejected Water from Industrial Processes

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(Received: 07 October 2023 Revised: 12 November Accepted: 06 December)

KEYWORDS
Reverse Osmosis, Reject Water, Water Treatment, Environmental Sustainability, Analytical Techniques, Industrial Processes.

ABSTRACT:

This research study delves into the treatment and analysis of reverse osmosis (RO)-rejected water generated from industrial processes. As industries increasingly rely on RO technology for water purification, the management and proper disposal of the rejected water have become critical concerns. This study aims to investigate effective treatment methods for RO-rejected water, emphasizing sustainable and environmentally friendly approaches. The investigation encompasses in-depth analyses of the rejected water, aiming to discern its chemical composition both before and post-treatment. Various treatment methodologies, including simple distillation, fractional distillation, and coagulation using both coagulant alone (Al_2SO_4) and coagulant-flocculant (Al_2SO_4-polymer) combinations, were employed. The findings indicate that simple distillation proves most effective in reducing pH, turbidity, total suspended solids (TSS), alkalinity, and chlorides in reverse osmosis-rejected water. Conversely, fractional distillation demonstrates superior efficacy in treating conductivity, total dissolved solids (TDS), biochemical oxygen demand (BOD), and hardness. This nuanced approach to treatment underscores the importance of tailored strategies to address specific contaminants within the rejected water.

1. Introduction

In the realm of industrial water purification, reverse osmosis (RO) has emerged as a preeminent technology, offering unparalleled efficacy in the removal of contaminants. As industries globally grapple with the imperative of sustainable water management, the widespread adoption of RO processes has become integral to meeting stringent quality standards. However, this advancement in water purification has challenges [1–2]. At the heart of the RO process lies a consequential byproduct—rejected water—that poses a critical environmental and logistical concern. Characterized by elevated salinity, concentrated pollutants, and a diverse array of chemical constituents, the proper treatment and analysis of reverse osmosis rejected water have become imperative for ensuring both environmental stewardship and the viability of industrial operations [3].

This research embarks on a comprehensive exploration into the intricate landscape of treating and analyzing reverse osmosis rejected water generated from diverse

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industrial processes [4–5]. It addresses the pressing need for innovative, sustainable, and context-specific solutions that not only mitigate the environmental impact of rejected water but also potentially harness its value [6–7]. By delving into the chemical composition and employing various treatment methodologies, this study aims to contribute essential insights toward the development of robust strategies for the management of reverse osmosis-rejected water, fostering a harmonious balance between industrial progress and ecological preservation [8–10].

2. Methodology

This section details the experimental setup for the treatment and analysis of RO reject water. It includes information on sample collection, treatment techniques employed, and analytical methods for water quality assessment.

2.1. Sample Collection

To collect representative samples, start by wearing appropriate personal protective equipment. Use clean, chemical-free containers made of materials suitable for water sampling, such as high-density polyethylene (HDPE) or glass. Rinse the containers with RO-rejected water before collection to minimize contamination. Identify strategic sampling points, covering various stages of the rejection process, and collect samples both before and after treatment. Utilize a bailer or dedicated sampling device to collect water at the desired depth, ensuring minimal contact with the container's interior. Clearly label each sample with essential information, such as date, time, location, and specific treatment stage. Record any relevant observations and maintain a chain of custody if required. Transport the samples promptly to the laboratory, minimizing exposure to sunlight and adhering to any preservation requirements. Following these guidelines ensures the collected samples accurately represent the RO rejected water, facilitating reliable analyses and informed decision-making in the treatment process.

2.2. Treatment Technologies

Various treatment technologies are explored, including simple distillation, fractional distillation, and coagulation. Each method is evaluated based on its efficiency in reducing pH, turbidity, total suspended solids (TSS), alkalinity, chlorides, conductivity, total dissolved solids (TDS), biochemical oxygen demand (BOD), hardness and ensuring the environmental sustainability of the treated water [11-12].

Simple Distillation Treatment Technique for RO Rejected Water

The methodology for implementing simple distillation as a treatment technique for reverse osmosis (RO) rejected water involves a systematic process aimed at effectively separating contaminants and purifying the water. The initial step entails the collection of RO rejected water, characterized by its heightened salinity and concentrated pollutants. The collected water is then introduced into a distillation apparatus, where controlled heating is applied to induce vaporization. As the water vapor rises, it travels through a condensation system, causing it to revert to its liquid state. This condensate, now purified, is collected as distillate. The simplicity of this methodology lies in its ability to selectively vaporize water, leaving behind non-volatile contaminants [13].

Fractional Distillation Treatment Technique for RO Rejected Water

Fractional distillation is applied, utilizing a column with multiple condensation points. The collected water is subjected to controlled heating, inducing vaporization, and the vapor rises through the column. As the vapor ascends, it encounters condensation points, allowing for the separation of components based on their boiling points. This staged condensation process enables the isolation of contaminants with varying volatility, facilitating the removal of a broader range of pollutants than simple distillation alone [14].

Coagulation and Flocculation for Treatment of RO Rejected Water

The application of coagulation and flocculation emerges as a pivotal treatment strategy for reverse osmosis (RO) in the rejected water. It also provides an effective means to mitigate the challenges posed by its complex composition. In this method, a coagulant (Al_2SO_4) is introduced to the rejected water, initiating the formation of destabilized particles through neutralization or charge neutralization mechanisms. Subsequently, flocculant (polymer) is introduced, fostering the aggregation of these destabilized particles into larger, settleable flocs. These flocs encapsulate suspended impurities and contaminants, facilitating their separation from the water matrix. The coagulation and flocculation process is adept at addressing a wide range of contaminants, including colloidal particles, organic matter, and certain ions, contributing to the reduction of turbidity and the overall improvement of water quality [15–16].

2.3. Analytical Techniques

The treated water was purified through simple and fractional distillation, coagulation, and flocculation. They undergo a detailed analysis to assess the efficacy of the process in reducing parameters such as pH, turbidity, total suspended solids (TSS), alkalinity, chlorides, conductivity, total dissolved solids (TDS), biochemical oxygen demand (BOD), and hardness.

pH is commonly determined using a pH meter or colorimetric methods, providing insight into the water's acidity or alkalinity. Turbidity, indicative of suspended particles, is measured using nephelometry or turbidimetry. TSS levels are quantified through gravimetric or filtration methods. Alkalinity, essential for buffering capacity, is assessed via titration. Chlorides are determined using ion-selective electrodes or titration methods. Conductivity, reflecting ion concentration, is measured through conductivity meters. TDS are determined by gravimetric or conductivity-based methods. BOD, an indicator of organic pollution, is analyzed via biochemical assays. Water hardness, associated with mineral content, is assessed using titration methods. The integration of these analytical techniques provides a comprehensive understanding of the treated RO-rejected water, ensuring compliance with regulatory standards and guiding sustainable water management practices in industrial processes [17-21].

3. Results and Discussion

The analysis of RO reject water before and after treatment involves a detailed examination of its chemical composition. The results are then compared with regulatory standards to assess the water's suitability for discharge or reuse.

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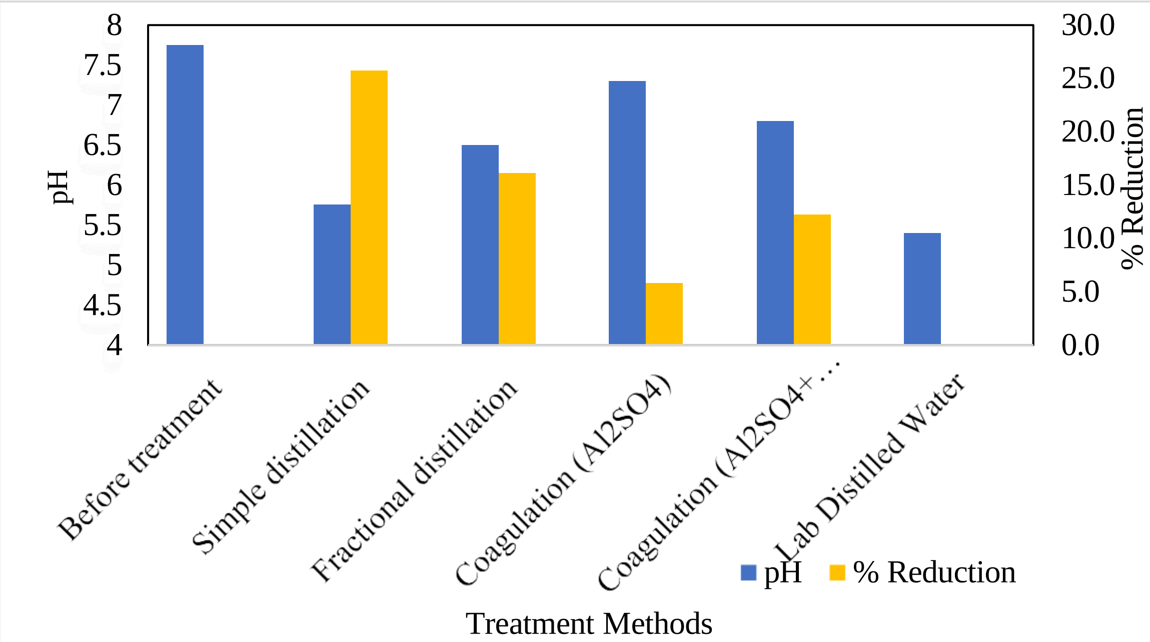

Fig.3.1. Comparison of pH in RO Rejected Water Before and After Treatment along with Distilled Water.

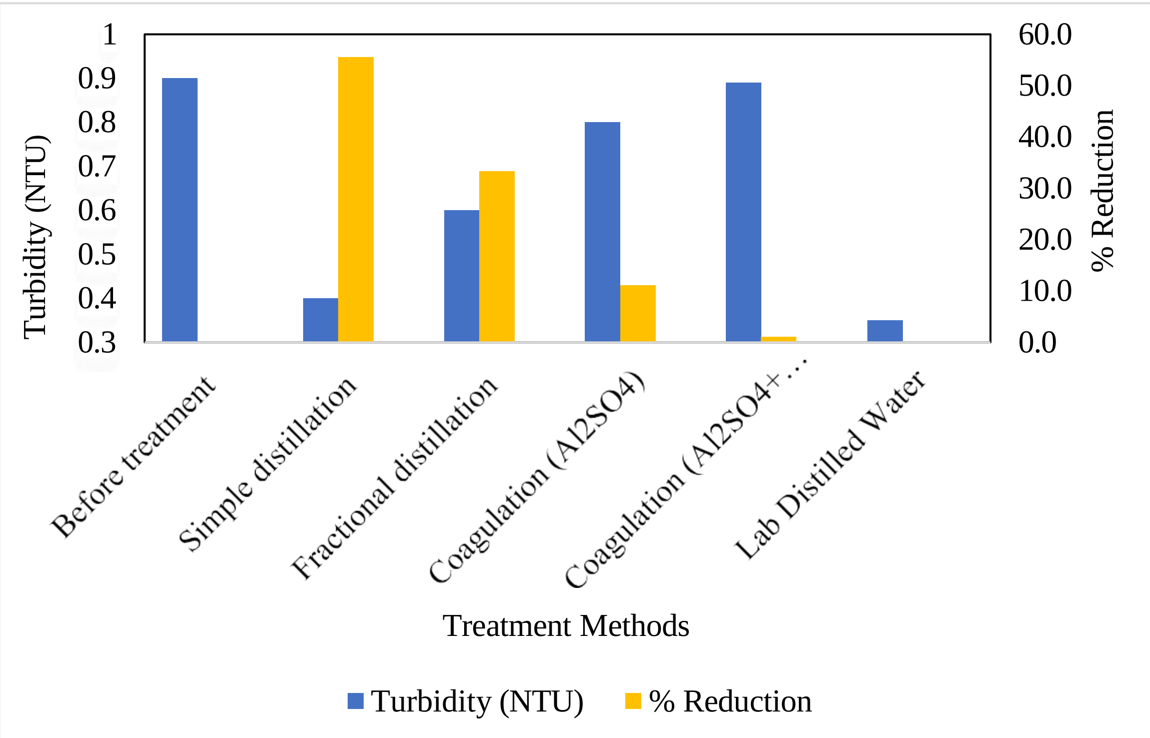

Fig.3.2. Comparison of Turbidity in RO Rejected Water Before and After Treatment along with Distilled Water.

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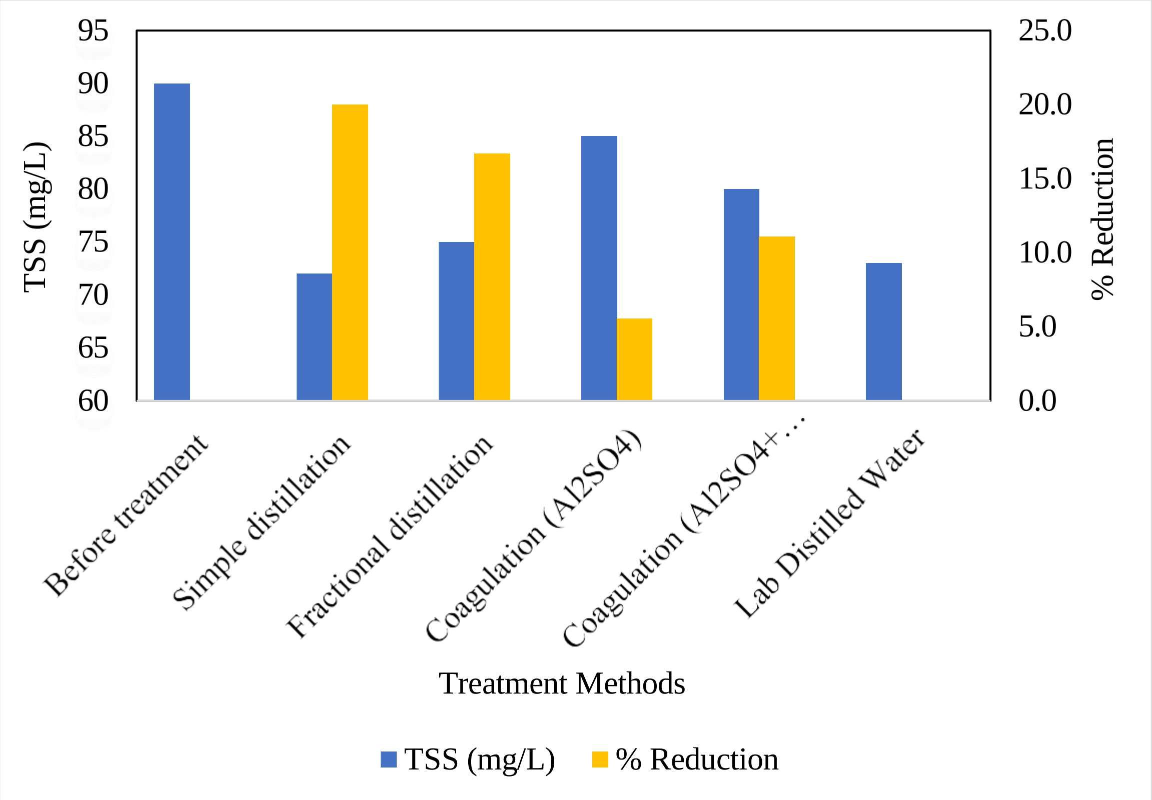

Fig.3.3. Comparison of TSS in RO Rejected Water Before and After Treatment along with Distilled Water.

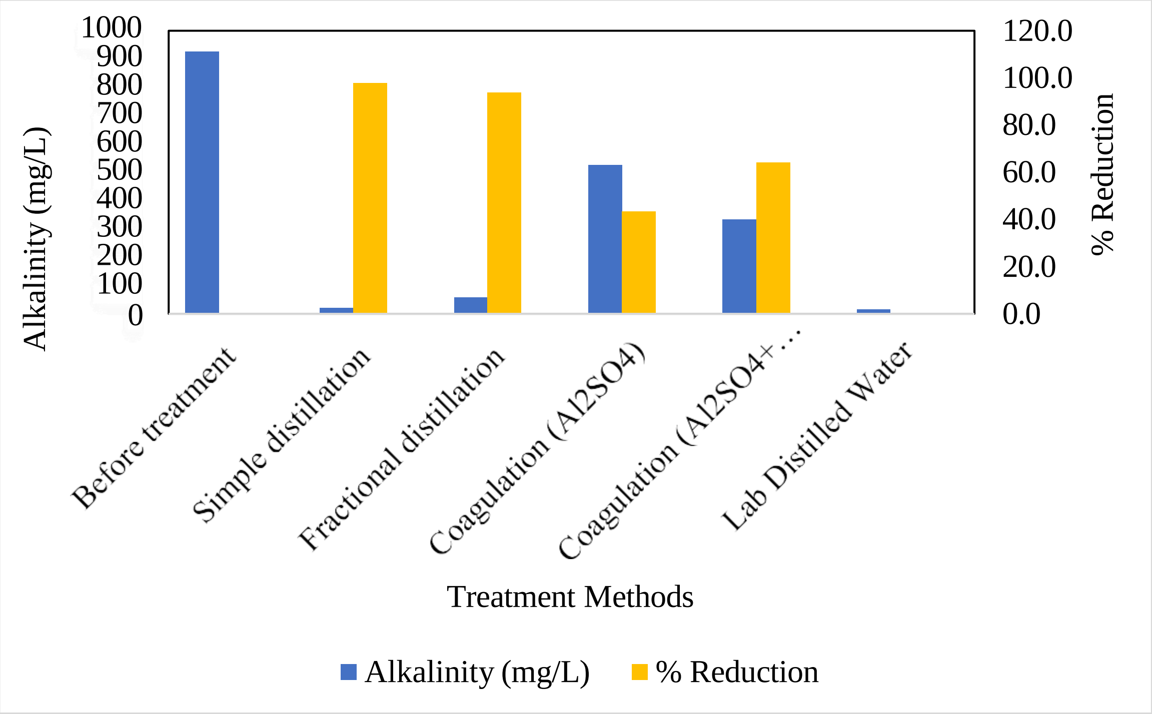

Fig.3.4. Comparison of Alkalinity in RO Rejected Water Before and After Treatment along with Distilled Water.

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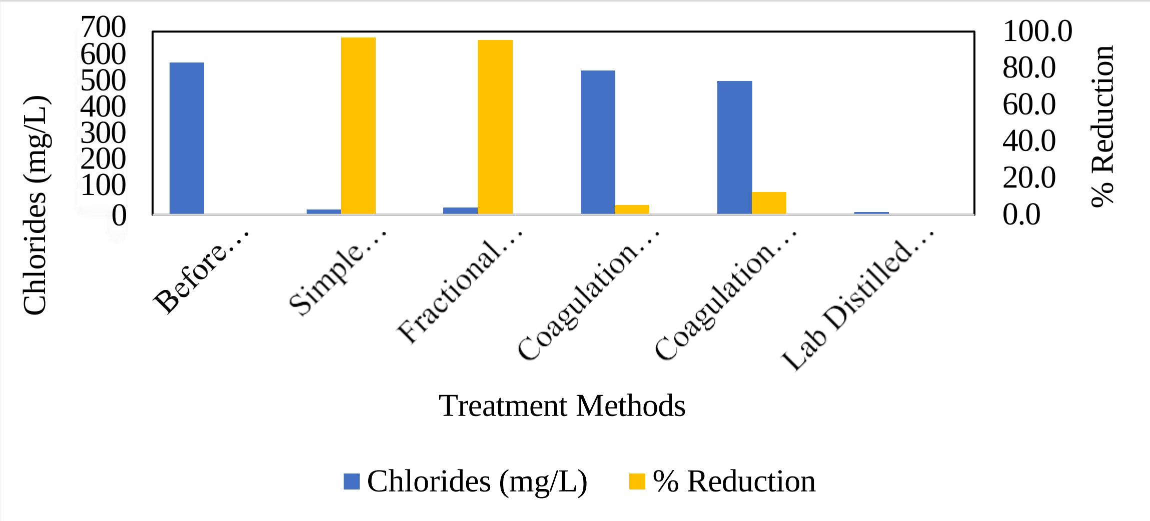

Fig.3.5. Comparison of Chlorides in RO Rejected Water Before and After Treatment along with Distilled Water.

Figures 3.1 to 3.5 highlight the superior efficacy of simple distillation for the removal of key parameters, including pH, turbidity, total suspended solids (TSS), alkalinity, and chlorides. The results depicted in Figure 1 underscore the notable efficiency in pH reduction, achieving a substantial 25.7% decrease, bringing the pH levels remarkably closer to those of laboratory-distilled water. Similarly, figures 3.2 to 3.5 illustrate a significant reduction in turbidity (55.6%), TSS (20%), alkalinity (97.8%), and chlorides (96.6%), with values closely aligning with the benchmarks set by laboratory-distilled water. These findings collectively reinforce the effectiveness of simple distillation as a prominent method for enhancing the quality of water by mitigating multiple parameters, thereby underscoring its potential for practical applications in water treatment processes.

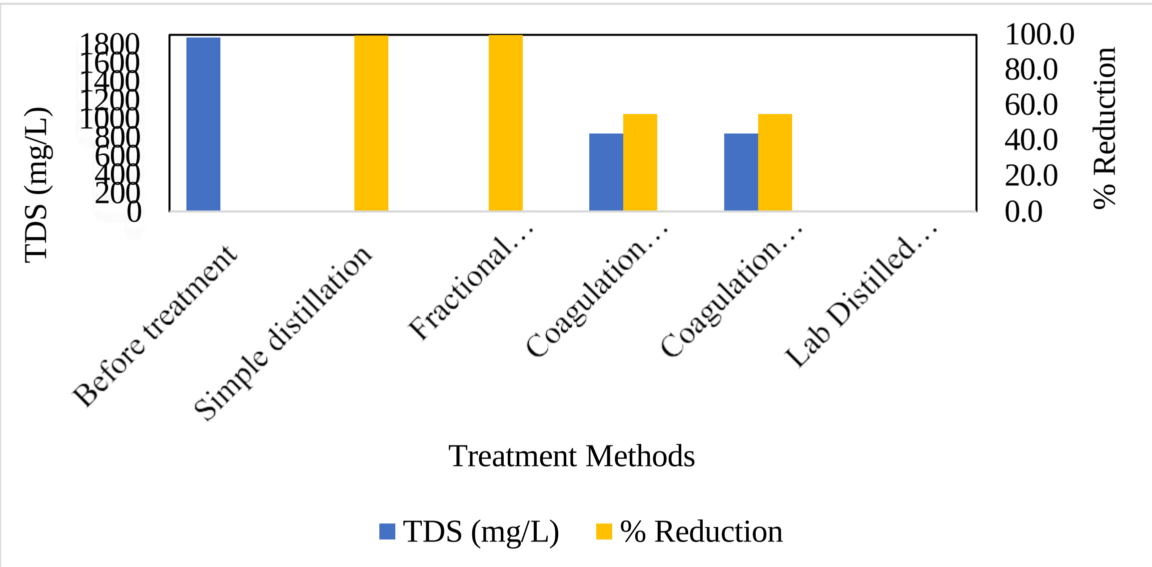

Fig.3.6. Comparison of TDS in RO Rejected Water Before and After Treatment along with Distilled Water.

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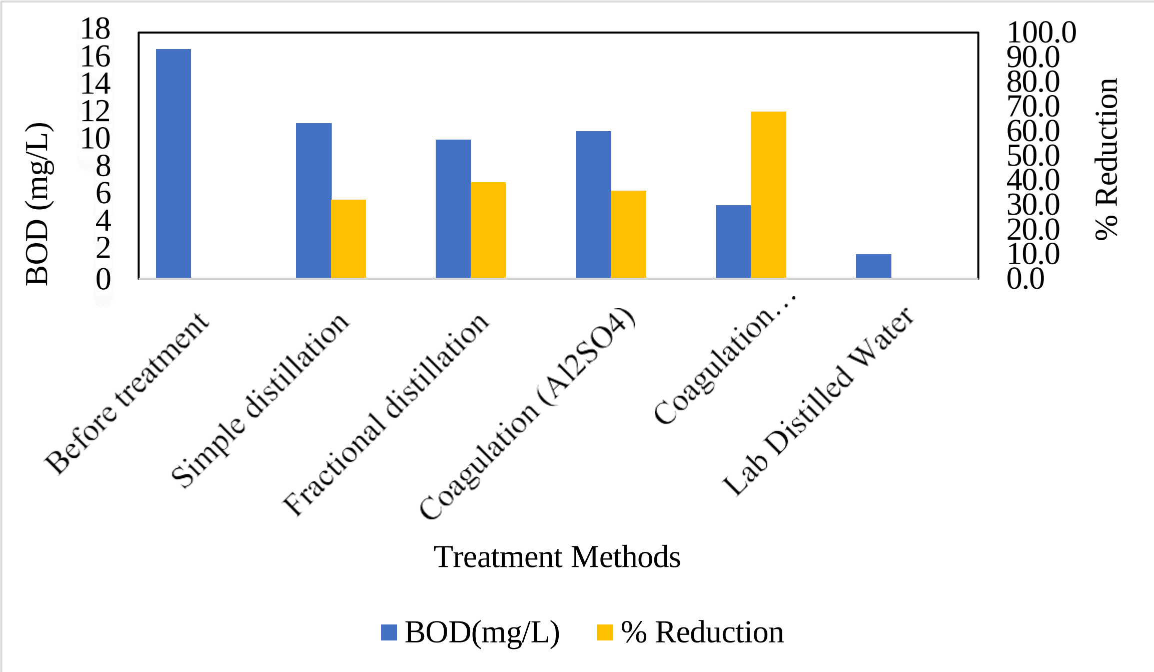

Fig.3.7. Comparison of BOD in RO Rejected Water Before and After Treatment along with Distilled Water.

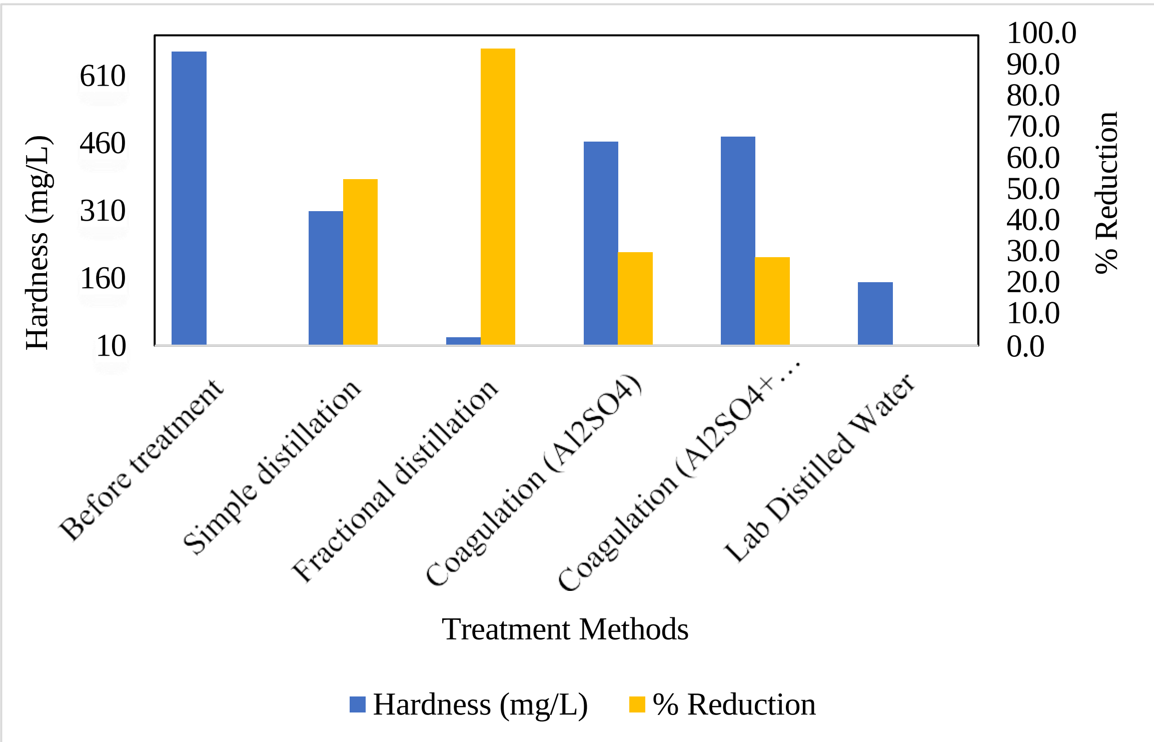

Fig.3.8. Comparison of Hardness in RO Rejected Water Before and After Treatment along with Distilled Water.

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JCHR (2023) 13(6), 1664-1673 | ISSN:2251-6727

Figures 3.6 to 3.8 illuminate the effectiveness of fractional distillation. As the optimal method for addressing critical parameters, specifically total dissolved solids (TDS), biochemical oxygen demand (BOD), and hardness. Figure 6 highlights the exceptional efficiency of fractional distillation. Reducing TDS, achieving an impressive 99.9% reduction, surpassing even the levels observed in laboratory-distilled water. Similarly, figures 3.7 to 3.8 depict substantial reductions in BOD (39.3%) and hardness (95.8%), with values closely mirroring those found in laboratory-distilled water. These results collectively affirm the superior capacity of fractional distillation in purifying water by significantly mitigating TDS, BOD, and hardness. Underscoring its applicability in advancing water treatment processes for enhanced quality and sustainability.

The methodologies of simple and fractional distillation prove to be sophisticated. It targeted a technique, contributing significantly to the comprehensive treatment of RO-rejected water and advancing the pursuit of sustainable water management practices in industrial settings.

4. Conclusion

This research study illuminates the imperative challenges associated with reverse osmosis (RO)-rejected water from industrial processes. It also presents a comprehensive exploration of treatment methodologies, with a strong emphasis on sustainability. The utilization of various techniques, including simple distillation, fractional distillation, and coagulation-flocculation, has provided nuanced insights into the multifaceted nature of RO reject water. Notably, the findings underscore the effectiveness of simple distillation in mitigating key parameters such as pH, turbidity, total suspended solids (TSS), alkalinity, and chlorides. Fractional distillation emerges as a robust method for addressing conductivity, TDS, BOD, and hardness.

This research not only contributes valuable data to the arsenal of treatment strategies but also highlights the significance of tailored approaches for specific contaminants within the rejected water. As industries strive for water management practices that align with environmental sustainability, these insights serve as a guide toward implementing responsible and efficient treatment protocols. By integrating these findings, this research aims to foster a paradigm shift toward responsible water management, safeguarding both industrial processes and the broader environment.

Acknowledgment

We express our heartfelt gratitude to **Shima Ali Sharar Bait Ali** for her invaluable assistance in facilitating the experimental work. Additionally, we extend our thanks to **Dhofar Beverages & Food Stuff Company** for generously providing the RO-rejected water essential for conducting our research. Special appreciation goes to the Head of the Department of Engineering for his encouragement and support in conducting our research activities.

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