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HEALTH AND ENVIRONMENTAL CONCERNS OF ANTISCALANT APPLICATION IN WATER PURIFIERS

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ABSTRACT

The widespread use of antiscalants in water purifiers has become essential for preventing scale formation and enhancing the operational efficiency of membrane-based and thermal water treatment systems. However, the long-term implications of antiscalant use on human health and the environment are emerging as significant concerns. This review critically examines the chemical composition of commonly used antiscalants, their degradation products, and potential toxicity. Continuous exposure to residual antiscalants in drinking water may pose health risks, including gastrointestinal disturbances, renal stress, and bioaccumulation of certain heavy metals. Environmentally, improper disposal and discharge of antiscalant-laden water can lead to aquatic toxicity, disruption of microbial ecosystems, and contamination of soil and groundwater. The study emphasizes the need for stricter regulations, improved monitoring protocols, and the development of eco-friendly alternatives to minimize adverse effects while maintaining effective scale control. Future research directions include comprehensive risk assessments and advanced treatment methods to mitigate these emerging challenges.

INTRODUCTION

Reverse osmosis (RO) systems are widely adopted for the purification of drinking water, seawater desalination, and industrial effluent treatment. However, membrane fouling due to scaling remains a critical operational challenge that impairs membrane life, increases operational cost, and affects water quality [2], [4], [5]. Scaling primarily results from the supersaturation of sparingly soluble salts such as calcium carbonate, calcium sulfate, barium sulfate, strontium sulfate, and silica, which precipitate and form hard deposits on membrane surfaces during prolonged operation [3], [6]. Even minor scale formation can lead to a significant decline in membrane permeability, elevated transmembrane pressure, increased energy consumption, and frequent shutdowns for chemical cleaning, which further escalates operational expenses [5], [7].

To mitigate these issues, antiscalants are frequently dosed into feed water to prevent the precipitation of these salts by interfering with nucleation, crystal growth, and agglomeration processes [3], [6]. Antiscalants can function through multiple mechanisms including threshold inhibition, chelation, dispersion of scale-forming particles, and lattice distortion, thereby maintaining membrane integrity and prolonging system performance [4], [7]. The efficiency of antiscalants allows RO plants to operate at higher recovery rates without compromising membrane lifespan or product water quality, which is particularly critical in regions facing freshwater scarcity or where seawater desalination is a primary water source [5], [8].

Despite their efficacy, increasing attention has been drawn to the long-term health and environmental implications of antiscalant use. Many antiscalants are composed of complex organic and phosphonate-based compounds that may not fully degrade in treated water systems, leading to residual contamination in drinking water supplies [1], [9]. Their discharge into the environment through brine streams can also affect aquatic ecosystems, alter microbial communities, and contribute to bioaccumulation in marine organisms [3], [6]. Furthermore, there is limited but emerging evidence linking prolonged human exposure to antiscalant residues with potential health risks such as renal stress, gastrointestinal disorders, and endocrine disruption [1], [7]. These growing concerns underscore the necessity for comprehensive risk assessments, the development of environmentally benign alternatives, and stricter regulatory frameworks to ensure safe and sustainable operation of RO facilities [2], [5].

II. Why Use Antiscalant in RO Plant?

Scaling occurs when the concentration of dissolved ions exceeds their solubility limits, leading to crystal formation on membrane surfaces [2], [5]. The most common scale-forming compounds in RO systems include calcium carbonate ($CaCO_3$), calcium sulfate ($CaSO_4$), barium sulfate ($BaSO_4$), strontium sulfate ($SrSO_4$), and silica (SiO_2) [3], [5]. When these salts precipitate on membrane surfaces, they form dense, adherent layers that obstruct water flow and increase hydraulic resistance. As a result, transmembrane pressure rises significantly, leading to a reduction in permeate flux, increased energy consumption, and reduced membrane efficiency [5], [7].

In addition to reducing throughput, scaling also accelerates membrane degradation by creating localized stress points, increasing the likelihood of membrane damage, irreversible fouling, and shortened service life [5], [6]. Frequent membrane cleaning cycles become necessary to restore system performance, further increasing operational downtime, labor costs, and chemical consumption [3], [5]. Moreover, improper or excessive cleaning can deteriorate membrane surfaces, leading to permanent loss of performance and costly replacements [5].

Antiscalants serve as a preventive solution by interfering with the initial stages of scale formation. They work by multiple mechanisms: threshold inhibition, which prevents salts from reaching their crystallization point even in supersaturated conditions; crystal distortion, which alters the morphology of forming crystals making them less likely to adhere to membrane surfaces; and dispersion, which keeps precipitated particles suspended in the feed water and prevents agglomeration [3], [4], [5].

Several studies have reported that even minor scaling can reduce membrane permeability by more than 20% within a short operational period, demonstrating the critical role of antiscalants in maintaining system stability [2], [4], [9]. Furthermore, the application of antiscalants allows RO systems to operate at higher recovery rates, which is economically beneficial, particularly in seawater desalination and high-recovery brackish water treatment plants where scale-forming ions are present at elevated concentrations [5], [6].

In addition to protecting the membrane, the use of antiscalants also reduces the frequency of membrane cleaning and extends membrane lifespan, leading to substantial cost savings over the lifetime of an RO system [4], [7]. Without antiscalants, RO plants would require highly aggressive pretreatment processes or operate at significantly reduced recovery rates to avoid scaling, both of which are less economically and operationally desirable [3], [5].

III. Benefits of Utilizing Antiscalant in Your RO Plant

The application of antiscalants provides multiple operational, economic, and sustainability benefits that make them indispensable for modern RO systems. Firstly, by preventing the nucleation and growth of scale-forming salts, antiscalants significantly extend membrane lifespan, reduce membrane fouling rates, and preserve the mechanical integrity of membranes under prolonged operational conditions [4], [5]. This directly minimizes unexpected downtime and reduces the frequency of membrane replacements, which can be a major capital expenditure for large-scale desalination and industrial RO plants [5], [7].

Secondly, antiscalant use maintains consistent permeate quality by stabilizing membrane performance. Stable membranes ensure uniform salt rejection and water production rates, which is crucial for facilities that require highly purified water for critical applications such as pharmaceuticals, semiconductors, food processing, and power generation [3], [7]. Any fluctuation in water quality can have significant downstream consequences in these industries, making reliable antiscalant performance a vital operational parameter [7].

Economic analysis from multiple studies has demonstrated that correct antiscalant dosing can significantly reduce operational costs by decreasing the frequency of chemical cleaning cycles (Clean-In-Place or CIP procedures) [4], [9]. Frequent cleanings not only consume costly cleaning chemicals but also result in plant downtime, labor costs, and increased wear on membrane surfaces [4], [5]. By maintaining cleaner membranes for longer periods, antiscalants help maximize uptime and increase the return on investment for expensive RO infrastructure [5].

Moreover, antiscalants allow RO systems to operate at higher recovery rates, often exceeding 75–85%, without risking accelerated scaling or membrane degradation [5]. Higher recovery rates translate to better water utilization, which is particularly important in arid and water-scarce regions where maximizing freshwater yield from limited sources is critical [5], [6]. In seawater desalination, where feed water contains high concentrations of calcium, sulfate, silica, and other scaling ions, antiscalants enable efficient operation even under challenging ionic conditions [3], [5], [7].

Additionally, antiscalants contribute to reduced environmental impact by minimizing the need for harsh acid pre-treatments and high-energy membrane cleaning processes [5]. This indirectly supports sustainability goals by lowering chemical usage, reducing waste streams, and decreasing energy consumption associated with pumping and cleaning operations [5], [7]. Some newer antiscalant formulations are also being designed for better biodegradability, further enhancing their environmental compatibility while maintaining performance [1], [4].

IV. What Does Antiscalant Contain? Is It Harmful?

Antiscalants are complex chemical formulations designed to target multiple scale-forming species in reverse osmosis (RO) systems. They typically consist of active functional groups that inhibit precipitation, modify crystal morphology, or disperse suspended particles [6], [7]. The major categories of antiscalant compounds include phosphonates (such as aminotris(methylenephosphonic acid) [ATMP], and diethylenetriamine penta(methylene phosphonic acid) [DTPMP]), polyacrylates, polymaleates, and proprietary copolymers tailored for specific scaling challenges [6], [7]. These compounds operate by sequestering metal ions, interfering with the lattice structure of developing crystals, or dispersing fine particles to prevent agglomeration on membrane surfaces [4].

In addition to these primary components, antiscalant formulations often include various auxiliary agents such as:

- **Surfactants**, to reduce surface tension and improve membrane wetting.
- **Dispersants**, to maintain the suspension of colloidal particles.
- **Stabilizers**, to prevent degradation of the active ingredients during storage and use.
- **Biocides**, in some formulations, to provide antifouling benefits [4], [7].

While these chemical mixtures effectively enhance operational performance, growing concerns exist regarding their long-term health and environmental impacts [1], [6]. Many phosphonate-based antiscalants exhibit limited biodegradability and can persist in treated water or brine discharges, entering the aquatic environment [2], [3]. Once released, these compounds may bioaccumulate in aquatic organisms, disrupt microbial community structure, and interfere with aquatic food chains, potentially leading to ecosystem imbalance [3], [6].

Moreover, some antiscalants, particularly those based on polyacrylates and polymaleates, may degrade into smaller organic molecules under certain conditions, forming low molecular weight organic acids or monomers, which may pose further risks to water quality [6], [7]. Studies have demonstrated that these breakdown products can exhibit cytotoxicity, mutagenicity, or endocrine-disrupting properties, although the full extent of their impacts remains under investigation [1], [7].

For humans, chronic exposure to low concentrations of antiscalant residues through drinking water is a potential concern. Possible health effects suggested by preliminary toxicological studies include gastrointestinal disturbances, nephrotoxicity, reproductive issues, and potential interference with metabolic enzymes due to long-term bioaccumulation of trace contaminants [1], [7]. However, most of these effects have been observed in laboratory or animal models, and comprehensive long-term epidemiological studies in human populations are still lacking [1].

Additionally, the indirect effects of antiscalant disposal must also be considered. Improper disposal of spent RO brine containing concentrated antiscalant residues can lead to soil contamination, altered microbial activity in wastewater treatment plants, and contamination of underlying groundwater aquifers [2], [3], [6]. The cumulative impact of continuous low-level discharges could contribute to persistent organic pollution in sensitive environments.

Given these concerns, recent research is actively exploring green antiscalants based on biodegradable or bio-inspired compounds such as amino acids, polyaspartates, and phosphonate-free alternatives that offer reduced environmental persistence and toxicity profiles [1], [4], [7]. Regulatory bodies and industry standards are also beginning to emphasize the importance of life-cycle assessments and toxicity evaluations for antiscalant products used in drinking water and seawater desalination applications [3], [6].

V. Classification of Antiscalants [12]

Antiscalants can generally be classified into several major categories based on their chemical composition, mechanism of action, and compatibility with various feedwater compositions. The selection of an appropriate antiscalant is critical for the effective management of scale formation in RO plants, as water chemistry can vary greatly depending on the source and pretreatment processes.

1. Phosphonate-based Antiscalants

Phosphonate antiscalants are among the most commonly used due to their excellent chelating properties and superior inhibition of carbonate, sulfate, and metal oxide scales. Their functional groups contain multiple phosphonic acid moieties, which bind strongly to metal ions, thereby preventing nucleation and crystal growth [6], [7]. Common examples include:

- **Aminotris(methylenephosphonic acid) (ATMP)**
- **Diethylenetriamine penta(methylene phosphonic acid) (DTPMP)**
  These phosphonates are particularly effective at controlling calcium carbonate scaling, even under high supersaturation conditions, and are known for their high calcium tolerance [6], [7]. Their ability to form stable complexes with multivalent cations also makes them useful in systems where iron or manganese may be present. However, phosphonates generally exhibit low biodegradability and may accumulate in brine concentrate and aquatic environments [6].

2. Polymeric Antiscalants

Polymeric antiscalants consist of long-chain organic molecules, such as:

- **Polyacrylic acid (PAA) and its salts**
- **Polymaleic acid and polymaleic anhydride derivatives**
- **Polycarboxylates and co-polymers of acrylic and maleic acids**
  These compounds work primarily through dispersion and crystal growth modification mechanisms. By adsorbing onto the surface of forming crystals, they distort crystal lattice structure, inhibit further growth, and keep particles dispersed in the bulk solution [4], [5]. Polymeric antiscalants are highly effective against calcium sulfate and silica scales, which are typically harder to control with phosphonate-based agents [5]. Many of these polymers offer better biodegradability than phosphonates, but their breakdown products may still pose ecotoxicological concerns depending on local environmental conditions [4].

3. Blended Antiscalants

Blended or hybrid antiscalants combine the benefits of phosphonates and polymers to provide comprehensive protection against a wide range of scaling species, including mixed salts often encountered in complex feedwaters [3], [5]. These formulations are specifically engineered for systems where multiple types of scales may coexist, such as:

- **Calcium carbonate + silica systems**
- **Barium sulfate + calcium sulfate mixtures**
- **Iron-affected feedwaters with high organic load**
  Blended antiscalants can be customized to address specific operational conditions such as pH, temperature, recovery rates, and ion concentrations [3], [5]. They often include synergistic additives like dispersants, threshold inhibitors, and stabilizers that optimize performance across multiple scaling thresholds [5].

4. Environmentally Friendly (Green) Antiscalants

Recent advancements have introduced a newer class of **eco-friendly or green antiscalants**, which include:

- **Polyaspartic acids**
- **Biodegradable polycarboxylates**
- **Natural amino acid derivatives**
  These antiscalants are designed to minimize environmental persistence, improve biodegradability, and reduce toxicity to aquatic organisms [1], [4], [7]. Although still emerging, these products are becoming increasingly important as environmental regulations tighten, particularly for facilities discharging large volumes of concentrate into sensitive ecosystems [1], [7].

VI. Interfering Impurities

While antiscalants are highly effective at inhibiting the formation of scale from sparingly soluble salts, their performance can be significantly influenced by the presence of interfering impurities in the feed water. These impurities include various dissolved metals, organic compounds, colloidal particles, and microbial by-products that can negatively affect the stability, efficiency, and longevity of antiscalant formulations [5], [9].

1. Metal Ions (Iron, Manganese, Aluminum, Copper)

Elevated levels of **iron (Fe^{2+}/Fe^{3+})**, **manganese (Mn^{2+})**, and **aluminum (Al^{3+})** in the feed water can react with phosphonate- or polymer-based antiscalants, forming insoluble organometallic complexes that reduce the availability of the active antiscalant species [5], [6]. These insoluble complexes may precipitate and deposit directly on the membrane surface, initiating fouling rather than preventing it [6].

- Iron and manganese oxides can serve as strong nucleation sites for heterogeneous crystallization, accelerating the growth of calcium carbonate or calcium sulfate scales even in the presence of antiscalants [4], [5].
- Additionally, aluminum ions can cause destabilization of negatively charged polymer chains, reducing their dispersant capacity and inhibiting their ability to interfere with crystal growth [5].

2. Natural Organic Matter (NOM) and Organics

Natural organic matter, such as humic and fulvic acids, can interact with antiscalants by adsorbing onto their functional groups or forming secondary complexes that limit the antiscalant's ability to bind with target scale-forming ions [5], [9].

- NOM may also act as a colloidal foulant itself, coating membrane surfaces and promoting biofilm development, which creates additional surfaces for heterogeneous scale nucleation [4], [5].
- Furthermore, the interaction between NOM and antiscalants may lead to chemical degradation or polymer chain breakage, reducing the overall efficacy of the antiscalant in long-term operation [6].

3. Silica and Silicate Interactions

High silica concentrations in the feed water present additional challenges. Although many antiscalants are specifically formulated to inhibit silica scaling, the presence of interfering impurities can reduce their effectiveness [5], [7].

- Metal ions such as magnesium and aluminum can catalyze the polymerization of silica into colloidal or gelatinous forms, which are extremely difficult to remove once deposited on the membrane surface [5].
- The presence of organics may also accelerate silica polymerization, increasing the risk of irreversible membrane fouling despite adequate antiscalant dosing [5].

4. Microbiological Impurities

The presence of **bacteria, algae, and biofilm-forming organisms** can further interfere with antiscalant function:

- Biofilms can trap and concentrate dissolved ions at the membrane surface, creating micro-environments where localized supersaturation occurs, overwhelming the antiscalant's protective mechanisms [5], [7].
- Some microbial metabolic by-products may chemically degrade antiscalant molecules, reducing their functional lifetime and requiring higher or more frequent dosing to maintain control over scaling [6].

5. Particulates and Turbidity

Suspended solids and colloidal particles contribute to membrane fouling by physically blocking membrane pores and providing nucleation surfaces for scale formation [5], [9].

- These particles can adsorb antiscalant molecules, effectively removing them from solution and lowering their concentration in the feed stream [4], [5].
- Poor pretreatment may allow these particulates to accumulate and overwhelm the antiscalant capacity, necessitating additional chemical or physical pretreatment steps to ensure effective scale control [3], [5].

CONSLUSION

The widespread application of antiscalants in reverse osmosis (RO) water purification systems has undeniably enhanced operational efficiency by mitigating membrane scaling, prolonging membrane life, and reducing maintenance costs. Their ability to inhibit the crystallization of sparingly soluble salts allows RO systems to achieve higher recovery rates, optimize energy usage, and deliver consistently high-quality permeate. However, despite these operational advantages, growing evidence highlights the potential health and environmental risks associated with prolonged antiscalant use.

Phosphonate- and polymer-based antiscalants, which dominate current formulations, exhibit limited biodegradability and environmental persistence. Their release into the environment through brine discharges may lead to bioaccumulation, ecological imbalances, and adverse effects on aquatic organisms. In humans, chronic exposure to residual antiscalants or their degradation products, though not yet fully understood, may pose risks such as renal stress, gastrointestinal disturbances, and endocrine disruption. The presence of interfering impurities such as metals, organics, and microbial contaminants can further complicate antiscalant efficacy, requiring careful feedwater analysis and pretreatment strategies.

To ensure the long-term sustainability of water purification technologies, future research must focus on developing environmentally benign, biodegradable antiscalants with minimal toxicological profiles. Additionally, comprehensive regulatory guidelines and monitoring frameworks are needed to assess antiscalant residues in treated water and their ecological impacts in receiving environments. Striking a balance between operational efficiency and environmental safety is crucial for the continued viability of RO systems in addressing global water scarcity challenges.

REFERENCES

- S. A. Kaushik, D. Armbruster, J. Dittmer, D. Bruniecka-Sulewski, B. Wendler & M. Ernst, "Investigation of scaling inhibition and biofouling potential of different molecular weight fractions of a PAA antiscalant," *npj Clean Water*, vol. 7, Art. 36, 2024.
- A. Sweity, T. R. Zere, I. David, S. Bason, Y. Oren, Z. Ronen & M. Herzberg, "Side effects of antiscalants on biofouling of reverse osmosis membranes in brackish water desalination," *J. Membr. Sci.*, vol. 481, pp. 172–187, May 2015, doi:10.1016/j.memsci.2015.02.003.
- M. Castrillón Tobón, "Antiscalants in seawater desalination: Bacterial growth potential and community structure," M.S. thesis, Biol. & Environ. Sci. & Eng., KAUST, 2024, doi:10.25781/KAUST-2N61E.
- J. Spitsov, H. Zaw Aung, A. Pervov, S. Mareev, D. Butylskii & M. Porozhnyy, "The selection of efficient antiscalant for RO facility, control of its quality and evaluation of the economical efficiency of its application," *Membranes (Basel)*, vol. 13, no. 1, Jan. 2023, doi:10.3390/membranes13010085.
- D. Spitsov, H. Z. Aung, A. Pervov, et al., "Effectiveness of antiscalants in preventing calcium phosphate scaling in reverse osmosis applications," *J. Membr. Sci.*, vol. 623, Apr. 2021.
- D. Armbruster, U. Müller & O. Happel, "Characterization of phosphonate-based antiscalants used in drinking water treatment plants by anion-exchange chromatography coupled to electrospray ionization time-of-flight mass spectrometry and inductively coupled plasma mass spectrometry," *J. Chromatogr. A*, vol. 1590, 2019.
- J. Wei, D. Song, W. Chen & H. Yang, "Antiscalants in RO membrane scaling control," *Water Research*, Sept. 15, 2020.
- K. Martinez-Herrera, "Evaluation of antiscalant performance in reverse osmosis systems," *TIMAAS*, 2024.
- M. Ahmed, S. Amin & A. Mohamed, "Fouling in reverse osmosis membranes: monitoring, characterization, mitigation strategies and future directions," *Heliyon*, Apr. 1, 2023. en.wikipedia.org
- D. Spitsov, "The effect of phosphonate-based antiscalant on gypsum precipitation kinetics and habit in hyper-saline solutions: Experimental and modeling approach," *Desalination*, Dec. 2020.
- Tanya S Murthy,Prakash, K. L."Spatio-Temporal Variation in Water Quality of Selected Lakes in Eastern Dry Agro Climatic Zone of Karnataka State, India"*International Journal of Ecology and Environmental Sciences , Vol. 50 No. 5* (2024)
- Pushoo, S.H., Kaur, M., Mushtaq, M., Var, M.H. and Kumar, S. "Statistical review on change in water qualities of Dal Lake". *European Chemical Bulletin, 12(Special Issue 5, Part-A),* 4561-4568.(2023)
- M. S. Nambiar, A. Ramakrishnan, A. Lakshman, A. P V and G. P, "Autonomous Water Quality Monitoring Surface Vehicle," *2023 IEEE International Conference on Recent Advances in Systems Science and Engineering (RASSE)*, Kerala, India, 2023, pp. 1-5, doi: 10.1109/RASSE60029.2023.10363576.
- Haiqing Chen and Kai Ju, "Surface water quantity and quality assessment in Xi'an moat river, China," *2012 International Symposium on Geomatics for Integrated Water Resource Management*, Lanzhou, 2012, pp. 1-5, doi: 10.1109/GIWRM.2012.6349556.
- J. Y. Chan *et al.*, "Design and Development of Aqua Sense Robot for In-Situ Automatic Water Quality Monitoring," *2024 10th International Conference on Control, Automation and Robotics (ICCAR)*, Orchard District, Singapore, 2024, pp. 116-121, doi: 10.1109/ICCAR61844.2024.10569649.
- S. Li, H. Gong, S. Wang and Z. Wang, "Analysis of urban water quality based on GIS," *2010 18th International Conference on Geoinformatics*, Beijing, China, 2010, pp. 1-4, doi: 10.1109/GEOINFORMATICS.2010.5568081.
- M. Kassim, M. S. Jamri, M. S. M. Aras, N. A. Wahab, A. K. R. A. Jaya and T. Yasuno, "Development of Unmanned Surface Vehicle with Real-time Water Quality Monitoring System," *2023 3rd International Conference on Computing and Information Technology (ICCIT)*, Tabuk, Saudi Arabia, 2023, pp. 567-572, doi: 10.1109/ICCIT58132.2023.10273974.
- X. Xue and Y. Chen, "Water quality evaluation of surface water based on back propagation neural network," *2011 International Symposium on Water Resource and*

Environmental Protection, Xi'an, China, 2011, pp. 524-527, doi: 10.1109/ISWREP.2011.5893059.

- H.Zhang, Q. Chen, X. Zhou, J. Dong and M. Chen, "Surface Water Quality Evaluation and Pollution Characteristics Analysis in Xinyang," *2011 5th International Conference on Bioinformatics and Biomedical Engineering*, Wuhan, China, 2011, pp. 1-5, doi: 10.1109/icbbe.2011.5780839.
- W. Guo, J. Chen, Y. Sheng and J. Wang, "Integrated evaluation of water quality and quantity of the Wei River reach in Shaanxi Province," *2011 International Symposium on Water Resource and Environmental Protection*, Xi'an, China, 2011, pp. 863-866, doi: 10.1109/ISWREP.2011.5893148.
- Sweity, A., Zere, T. R., David, I., Bason, S., Oren, Y., Ronen, Z., & Herzberg, M. (2015). Side effects of antiscalants on biofouling of reverse osmosis membranes in brackish water desalination. Journal of membrane science, 481, 172-187.
- Huang, N., Wang, W. L., Xu, Z. B., Wu, Q. Y., & Hu, H. Y. (2019). UV/chlorine oxidation of the phosphonate antiscalant 1-Hydroxyethane-1, 1-diphosphonic acid (HEDP) used for reverse osmosis processes: Organic phosphorus removal and scale inhibition properties changes. Journal of environmental management, 237, 180-186.
- Greenlee, L. F., Testa, F., Lawler, D. F., Freeman, B. D., & Moulin, P. (2010). The effect of antiscalant addition on calcium carbonate precipitation for a simplified synthetic brackish water reverse osmosis concentrate. Water research, 44(9), 2957-2969.
- Shahalam, A. M., Al-Harthy, A., & Al-Zawhry, A. (2002). Feed water pretreatment in RO systems: unit processes in the Middle East. Desalination, 150(3), 235-245.
- Shahalam, A. M., Al-Harthy, A., & Al-Zawhry, A. (2002). Feed water pretreatment in RO systems: unit processes in the Middle East. Desalination, 150(3), 235-245.
- Al-Ahmad, M., Aleem, F. A., Mutiri, A., &Ubaisy, A. (2000). Biofuoling in RO membrane systems Part 1: Fundamentals and control. Desalination, 132(1-3), 173-179.
- Lee, H. J., Halali, M. A., Baker, T., Sarathy, S., & de Lannoy, C. F. (2020). A comparative study of RO membrane scale inhibitors in wastewater reclamation: Antiscalants versus pH adjustment. Separation and Purification Technology, 240, 116549.
- Ghafour, E. E. (2003). Enhancing RO system performance utilizing antiscalants. Desalination, 153(1-3), 149-153.
- Sweity, A., Oren, Y., Ronen, Z., & Herzberg, M. (2013). The influence of antiscalants on biofouling of RO membranes in seawater desalination. Water research, 47(10), 3389-3398.
- He, F., Sirkar, K. K., &Gilron, J. (2009). Effects of antiscalants to mitigate membrane scaling by direct contact membrane distillation. Journal of Membrane Science, 345(1-2), 53-58.