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State-of-the-art of reverse osmosis desalination pretreatment

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HIGHLIGHTS

- Pretreatment has progressed significantly, driven by growth in the municipal industry.
- Many of the improvements have been enabled by a better understanding of fouling.
- Pretreatment advancements are leading to RO use in new industries and water sources.

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ABSTRACT

Pretreatment plays the critical role of removing source water constituents, like sediment and microbes, which could hinder the downstream reverse osmosis (RO) desalination process. While some source waters require negligible pretreatment, others like surface waters, require rigorous treatment to protect the RO process operation.

The RO industry grew rapidly between 1995 and 2010. Growth pushed the industry to find cost-effective and robust large-scale pretreatment solutions. Over the last two decades, RO manufacturers have also developed membranes with greater fouling resistance and advocated system designs that reduce fouling potential. As a result, the state of the art in pretreatment has progressed significantly since the mid 1990s.

Many of the improvements in pretreatment were enabled by a better understanding of fouling processes. Because fouling is complex and dynamic, with biofouling contributing to its complexity, significant research and development have been necessary to identify improvements.

This paper provides a basis to understand the various fouling mechanisms found in RO systems and to describe the current state-of-the-art of the pretreatment technologies for fouling control. The paper addresses pretreatment of the myriad water sources in which RO technology is applied, with greater emphasis on seawater RO SWRO pretreatment as the largest single pretreatment market segment.

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1. Introduction

Pretreatment is frequently considered the Achilles heel of a reverse osmosis (RO) desalination treatment system [9]. This is in contrast to the comparably predictable and robust behavior of the RO system when the RO feed water has been sufficiently pretreated for the application. That is to say, the RO system reliably desalts water as long as the foulants have been removed upstream. By definition, the purpose of the pretreatment system is to remove foulants from the water source and to provide any chemical additives necessary to enable efficient desalination.

Though adoption of new technology by the desalination industry has been very slow, the failures of early seawater RO facilities in the Middle East spurred significant research through the 1980s and 1990s, particularly in the area of pretreatment. This research led to critical changes in design and technologies used in pretreatment, which facilitated the tremendous growth in the industry in the 1995–2010 period. In fact, it could be argued that had the industry not addressed the poor performance of the pretreatment systems in the 1980s and 1990s, the boom of the 1995–2010 period would not have occurred.

This phenomenon can be easily demonstrated by comparing a pretreatment system from a seawater RO plant in 1995 to one of today. The comparison would demonstrate a shift not only to more cost efficient and robust unit operations, but also to one of lower energy and chemical use and environmental impact. Not only have the systems improved in terms of the pretreated water quality they produce, but also they now often have to be capable of responding to foulants and hazards that were unlikely or unheard of in the source waters of twenty years ago.

The science of pretreatment in desalination is complicated by the innate variation in the water quality associated with the many water sources which can be desalted by membrane processes. These applications generally include:

- brackish groundwater
- brackish surface water
- seawater
- municipal and industrial wastewater
- produced water and flowback water
- ultrapure water applications.

Even within each of these different water sources, water quality can change frequently and sometimes abruptly. Natural water systems, especially those heavily influenced by anthropogenic and weather related events, are particularly variable in quality relative to potential foulant. For instance, a desalination plant that treats water downstream of a large river can expect heavy silt and solid loading after a significant rain event. This variation places an additional burden on the pretreatment system, which is fundamentally limited by its respective design and operating parameters, but must respond to different types and levels of foulant. Industrial source waters, though still prone to water quality fluctuations due to upsets or changes in the upstream treatment process, tend to have fewer environmental influences and are often more stable in water quality with regard to the demands put on the pretreatment system.

RO pretreatment systems generally consist of a series of unit operations which address each of the expected foulant risks. All RO desalination systems use some level of pretreatment as a function of the water source and the expected water quality over the course of the life of the facility. Some source waters, such as brackish groundwater and ultrapure water applications, may require only chemical dosing, while an open ocean seawater intake, at risks of algal blooms or oil contamination from within the vicinity of a seaport, may utilize five or more unit operations in series.

In general, a RO membrane pretreatment system will be comprised of one or more of the following unit operations, as a function of the source water quality:

- intake or well screening
- chemical dosing for biological control
- flotation

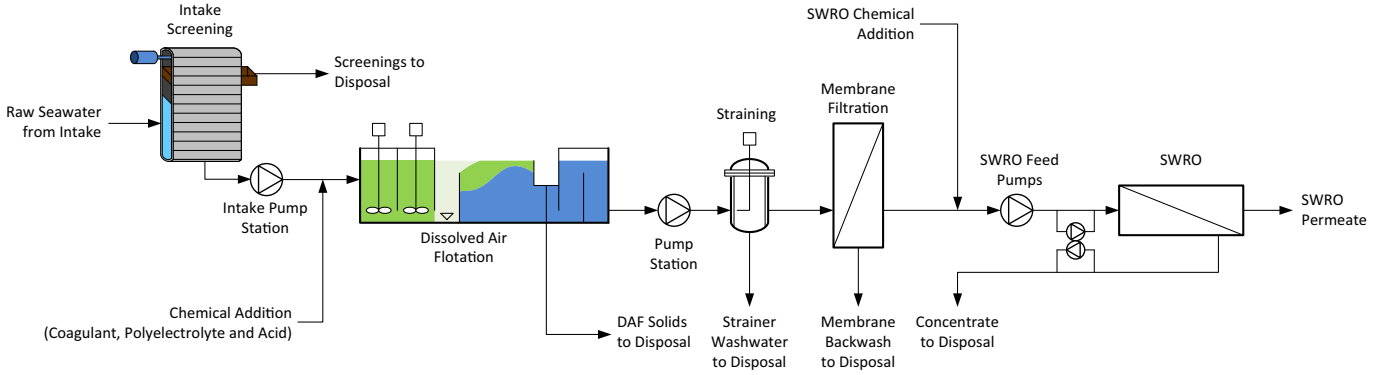

Fig. 1. Pretreatment system schematic of an open ocean seawater RO plant.