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A comparative study of RO membrane scale inhibitors in wastewater reclamation: Antiscalants versus pH adjustment

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ABSTRACT

Scaling is the most common challenge that reverse osmosis (RO) membranes encounter in potable reuse applications due to the high product recovery. Usage of antiscalants or pH adjustment can suppress scale formation on membranes without sacrificing overall recovery. A series of experiments was conducted to evaluate the effectiveness of two different antiscalants (phosphonate-based and acrylic acid-based) and pH adjustment for the inhibition of scaling on polyamide RO membranes during the separation of microfiltration (MF) treated secondary effluent wastewater. Product recovery was targeted at 50%, increasing the residual concentration of scale forming ions by a factor of 2 in the feed. Substantial scale formation, dominated by calcium carbonate, was observed during the separation of the feed. In the presence of antiscalants, calcium carbonate scaling was successfully abated, while iron based scalants did not significantly decrease. Phosphonate-based antiscalants were found to be more effective in inhibiting calcium carbonate scaling as compared to acrylic acid-based antiscalants. As such, RO membranes treated with phosphonate-based antiscalants demonstrated lower permeate flux decline and less calcium scale deposition on membrane surfaces under the tested conditions. The addition of a strong acid to control scaling is a less expensive alternative to antiscalant addition. pH adjustment using sulfuric acid was effective for the inhibition of calcium carbonate scaling. However, acid addition resulted in corrosion of piping leading to considerable leaching of iron and copper into the feed. The presence of iron and copper adversely increased the scaling potential of the membranes.

1. Introduction

Strategies to reclaim wastewater are increasingly important as more regions around the world experience water scarcity. Membrane processes, including reverse osmosis (RO) coupled to microfiltration (MF), have been established as reliable technologies to provide highly purified water for potable water reuse [1–4]. However, RO membrane processes are often challenged by fouling which cause a significant reduction in membrane performance associated with permeate flux and salt rejection [5,6].

Inorganic fouling known as membrane scaling is formed by the deposition or crystallization of inorganic salts onto membrane surfaces. This occurs when sparingly soluble salts are supersaturated and precipitate in the feed stream near or at the membrane surface as the concentration of scale forming ions increases beyond their solubility levels. The potential to form mineral scale increases as the product recovery (i.e., the percentage of water that permeates the membrane with respect to the feed) increases. As a result, it is critical to manage the solubility of those sparingly soluble inorganic mineral ions in the system design and during RO operation. RO membrane processes used in potable reuse applications frequently encounter scaling problems since reuse processes target higher recoveries (60–85%) than conventional seawater desalination processes (~50%) [9–12]. Scale formed on RO membranes can be classified as alkaline, non-alkaline and silica-based scale. Common inorganic scale includes calcium carbonate ($CaCO_3$), gypsum ($CaSO_4 \cdot 2H_2O$), barite ($BaSO_4$), strontium sulphate ($SrSO_4$), and silica (SiO_2) that precipitate or crystallize from the feed stream onto the surface of the membrane [7,8].

RO membrane scaling can be mitigated by lowering solution pH through the addition of acid and/or by the addition of antiscalants. Acid addition – commonly sulfuric acid or hydrochloric acid – decreases pH of the feed water and increases the solubility of alkaline scale. For

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