Comparative Study of NF/RO Membranes for Sustainable Desalination of Produced Water and Frac Flowback Wastewater Following Biological Pretreatment

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Development of unconventional oil and gas (O&G) resources is reshaping the energy landscape of the United States. Technological advances in hydraulic fracturing and horizontal drilling have made previously unrecoverable resources economically viable. However, extraction from these formations requires hundreds of thousands of gallons of clean water per well and generates substantial (and unavoidable) volumes of wastewater. These wastewaters (e.g., hydraulic fracturing flowback and produced water (PW)) contain varying concentrations of total dissolved solids (TDS), ranging from 10,000 mg/L to more than 200,000 mg/L, oil, grease, hydrocarbons, and various organic and inorganic matter. Consequently, a multi-barrier approach is required to effectively treat O&G waste streams for beneficial reuse.

Biological and membrane processes are promising methods to treat O&G wastewaters. Biological technologies have proven effective at removing organic material from a variety of waste streams including domestic waste streams, landfill leachate, and oily wastewaters; tight/dense membranes are most established in desalination of seawater and brackish waters. For sustainable membrane treatment, optimizing water recovery, and reducing fouling propensity, pretreatment targeting removal of organic constituents and suspended solids is critical. Integration of biologically-active filtration (BAF), ultrafiltration (UF), and nanofiltration/reverse osmosis (NF/RO) results in comprehensive removal and degradation of contaminants, reducing membrane fouling propensity due to BAF pretreatment, and producing a high quality permeate suitable for reuse applications such as hydraulic fracturing fluid and irrigation.

The current study evaluates the performance of NF/RO membranes following BAF and UF pretreatment of Denver-Julesburg (DJ) basin PW and frac flowback wastewater. The main objectives include (a) optimizing BAF and UF pretreatment for maximum removal of organic compounds, (b) evaluating NF/RO fouling propensity and membrane performance based on solids, inorganic, and organic rejection, and water flux, and (c) identifying favorable NF/RO membranes for treatment of PW and flowback, based on membrane characterization and performance. Bench-scale experiments with BAF have been conducted to acclimate a biofilm and optimize degradation of organic matter. In addition, experiments with UF were conducted to further reduce the turbidity of the BAF effluent and prepare it for NF/RO desalination. Ongoing NF/RO experiments compare the performance of various membranes (e.g., NF90, NF270, BW30 (DOW Chemical Company, Midland, MI), and NFX (Synder Filtration, Vacaville, CA)). Following rejection tests, membrane properties for each NF/RO membrane are being investigated using scanning electron microscopy (SEM) and atomic force microscopy (AFM) (morphology), contact angle (hydrophobicity), zeta potential (surface charge), and Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR) (surface chemistry) to evaluate variations in fouling.