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Colloidal silica and silica-rich nanoparticles through stages of reverse osmosis (RO) treating coal seam gas associated water: occcurrence, evolution and speciation

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ABSTRACT

Reverse Osmosis (RO) membrane filtration is a very common process for treating a wide range of groundwater types including produced water from coal seam gas (coalbed methane) wells. Mineral scaling limits water recovery for RO membranes and costs money in terms of treatment and downtime. Silica scaling can be particularly troublesome as it is often irreversible. Mitigating silica scaling requires an understanding of its occurrence, speciation mechanism and its interdependency with other operation factors.

This study uses a range of techniques to show that silica colloids form during later stages of an RO process with very high recovery. This happens at silica concentrations above the saturation limit that would normally indicate high risk of silica scale. However, instead of scale, colloids preferentially formed which means the process can operate at high recoveries with RO performance maintained by regular cleaning cycles. The concentration of the colloidal silica through the RO stages has been measured through the difference in total and dissolved silica. Once the existence was established with this technique, the particles were trapped and their size, morphology and composition were investigated with Scanning Electron Microscopy (SEM) in conjunction with Energy Dispersive X-Ray Spectroscopy (EDS). This revealed the particles to be predominantly silica with limited other elements involved.

RESEARCH OBJECTIVE

To develop an understanding of the presence of colloidal forms of silica and the evolution of colloidal population through RO reject stages.

To develop an understanding of the relationship between colloidal particles and other components in CSG water during RO, predominantly the effect of hardness cations (Ca2+ and Mg2+)

RESEARCH QUESTIONS

1. How colloidal and silica-rich nanoparticles change during stages of RO?
2. Is there any impact of hardness cations (mainly Ca & Mg) on colloidal silica speciation?

RESEARCH BENEFITS

The study has taken steps towards enhancing our understanding of the origin and existence of colloidal silica in full-scale RO plant treating groundwater. It also sheds lights on the evolution of silica-rich nanoparticles through the consecutive stages, which can then help us with a better

understating of scaling mechanism on membrane as well as other equipment surfaces. The effect of Ca and Mg on colloidal silica formation will also be studied. This will help improve understanding of RO pre-treatment processes, especially Ion Exchange column (Weakly Acidic Cation type).

FINDINGS TO DATE

In five stage RO plants, colloidal silica species are observed in the reject streams of the last two stages, and would be expected to precipitate and form amorphous colloidal silica.

In the third stage, the occurrence of colloidal species could not be confirmed across all plants.

Energy Dispersive X-ray Spectroscopy (EDS) spectra for these samples containing spherical silica-rich nanoparticles usually exhibit high silicon signals, corroborating that the trapped nanoparticles are rich in silica/silicate species.

The formed nanoparticles can contribute to scaling, on, not only, membrane surfaces and pressure vessel housing compartments, but also, other equipment including downstream pipework.