

Reactive silica in natural waters — A review

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ABSTRACT

Polymeric (colloidal) silica formed from reactive silica in water deposits on equipments and membranes used in the desalination and treatment of water and wastewater. Fouling of the equipment used has caused problems leading to numerous investigations into silica removal processes and fouling prevention methodologies. This review of literature from a wide scientific field is undertaken seeking insight on the known chemistry of reactive silica, and how it can be investigated and managed. Due to the wide field covered, the review is necessarily not exhaustive. However, key points of reactive silica chemistry are presented. Keywords and references can be used for deeper searches of the literature. This review defines reactive silica as primarily monomeric silicic acid – $\text{Si}(\text{OH})_4$, which spontaneously polymerizes by dehydration reaction to form a dimer, oligomers and ultimately high silica and silicate polymers. It is primarily the only molecule that reacts with molybdic acid colorimetric reagent that we use to quantitate silica. The condensed silicic acid does not react sufficiently with molybdic acid to give the yellow to blue color in standard assay method, hence as a group is called non-reactive silica. When the non-reactive silica molecules grow to nanometer-sized range they take on colloidal silica properties. In ultimate highly dehydrated states, it can be represented as silica $(\text{SiO}_2)_n$, where n is a very large number. Copolymerization with hydroxides of aluminum, iron, magnesium and other metals give rise to the clays, silt and rocks as mixed silicates. As designed by nature, the condensation reactions are reversible. For this reason, the review is presented under the headings of characterization of reactive silica, hydrolysis of rocks, polymerization reactions and silicification of plants and animals as models of fouling mechanisms in desalination and water treatment. The key point noted as they apply to desalination and water treatment is that reactive silica undergoes reversible dehydration polymerization with itself and commonly with hydroxide molecules of iron, aluminum, magnesium and calcium to form silica and silicates, respectively. When water is highly concentrated during desalination, it is a complex reaction mixture of monomer, oligomer and polymer of silicic acid that lead to silica fouling. The deposition of silica and silicate on surfaces of membranes and equipment arise from the surface properties of unstable colloidal particles of sizes and shapes not yet understood.

Keywords: Silicic acid; Reactive silica; Non-reactive silica; Colloidal silica; Hydrolysis of rocks; Silicates; Polymerization; Silicification; Oligomeric silicic acid; Biosilicification; Biomineralization; Fouling mechanisms
