Desalination Pretreatment and Biofouling Control Using Electrolytic Ferrate

Harmful algal blooms increase organic matter and solid loads in desalination plant seawater feeds. These conditions raise the risk of fouling and damage to reverse osmosis (RO) membranes. To maintain plant performance, effective pretreatment is required to prevent membrane fouling and failure. Conventional pretreatment methods typically rely on oxidation followed by filtration to remove problematic particles and organic matter. The choice of treatment chemicals greatly impacts both process effectiveness and cost. Proper oxidation and removal of algal organic matter (AOM) are vital for reducing membrane biofouling.

A study was conducted to evaluate electrolytic sodium ferrate as an alternative oxidant, disinfectant, and coagulant for treating algae-impacted seawater. The performance of sodium ferrate was compared to traditional bulk ferric chloride treatment.

Ferrate Use in Water Treatment

Historically, a ferrate solution has not been commercially available or widely used in treatment processes because it decomposes rapidly and cannot be manufactured, transported, or stored. As a result, hazardous bulk ferric chloride has been commonly used as a treatment chemical in applications requiring oxidation, disinfection and coagulation.

SafeGuard™ H2O is a proprietary in situ electrolytic ferrate reagent generation system that overcomes these limitations. The system produces sodium ferrate reagent on demand, enabling its practical and commercial use. In seawater desalination facilities that currently rely on bulk ferric chloride, electrolytic sodium ferrate offers a non-toxic, environmentally friendly alternative for treating algae-impacted seawater, removing AOMs, and reducing membrane biofouling.

Comparative Study: Electrolytic Ferrate and Bulk Ferric Chloride

The comparative study included two phases. Phase I assessed and quantified the effect of sodium ferrate reagent dose on key seawater parameters such as Total Organic Carbon (TOC) and bacteria (BQ); evaluating the effectiveness of algae oxidation/coagulation and separation. Phase II assessed the disinfecting effect of the sodium ferrate reagent on Total Active Solids (TAS) biofilm growth under flow conditions.

An electrolytic sodium ferrate solution (7,000 ppm) and a commercially available ferric chloride solution (35%) were used for Fe(III) coagulant addition. Seawater samples were collected from Galveston Bay Seaside Park in Texas for use in the study. Preliminary dosage rates of sodium ferrate and ferric chloride were conducted in the range of 0.60 – 2.0 ppm. It was found that a 0.80 ppm dose was most effective; spiked seawater samples were analyzed for TOC, pH, and BQ (Table 1).

Table 1. Water Quality Analysis of 0.80 ppm Spiked Seawater Samples

Parameter	Original Seawater Sample	Electrolytic Sodium Ferrate	Bulk Ferric Chloride
TOC	41.5 ppm	7.12 ppm (82.9% reduction)	38.9 ppm (6.26% reduction)
pH	8.30	9.44	9.00
BQ	1,443	110 (92.3% reduction)	1,000 (30.69% reduction)

Phase I Summary: The electrolytic sodium ferrate reagent demonstrated high effectiveness in reducing TOC and BQ, high algae cell-disrupting capability, and fast-settling floc, resulting in effective liquid/solid separation by decanting. Whereas the bulk ferric chloride reagent had little effect on seawater constituents or on algae removal.

Phase II Summary: A sodium ferrate dose rate of 1.00 ppm maintained a disinfectant environment and deterred further bacterial growth over a 14-day period. The flow-through study showed that untreated seawater bacteria allowed biofilm formation on the stainless-steel coupon, whereas the sodium ferrate-treated culture inhibited bacterial growth and prevented biofilm formation. The enhanced oxidative reaction of the sodium ferrate reagent had disrupted the cellular walls of the bacteria, thus reducing further mitosis. Additionally, the residual effects over the 14 days prevented further algal blooms. Microscopic examination of an algae culture flask treated with sodium ferrate indicated disrupted cellular walls. After five days, all greening of the algae broth had turned brown, indicating no chlorophyll cycles occurred even under optimal light exposure.

Conclusion

Electrolytic sodium ferrate is an effective pretreatment solution for protecting RO membranes from biofouling and damage. It offers significant advantages over traditional ferric chloride for treating algae-impacted seawater in desalination plants. It effectively reduces organic and bacterial loads, disrupts algal and bacterial cells, and prevents biofilm formation, all while offering an environmentally friendly and non-hazardous alternative.

Compared to bulk chloride, sodium ferrate offers effective performance while eliminating the hazards associated with chemical storage and handling. Its non-toxic and sustainable profile makes it a strong candidate for improving pretreatment reliability and protecting RO membranes in desalination facilities.

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