Why Is It Important to Remove Iron from Frac Water?

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Removing iron from frac water is very important in oilfield operations. Some iron compounds form scale. Scale adheres to equipment surface and impedes fluid flow. Other iron compounds cause corrosion. Corrosion damages metallic equipment used for well completion and oil production. Common problematic iron compounds are iron oxide (Fe₂O₃), iron sulfide (FeS), and iron carbonate (Fe₂CO₃).

Iron can be present in frac water in two forms: water-insoluble compounds and water-soluble compounds. Leaving soluble iron in frac water can cause scaling and corrosion problems as the soluble form of iron is easily converted to troublesome iron compounds which impair topside or downhole production equipment.

Insoluble iron compounds are readily removed by filtration; however, removal of soluble iron is more difficult. Chemicals must be added to the frac water to convert soluble iron into insoluble iron compounds so that filtration can remove the iron.

Iron undergoes reversible oxidation and reduction reactions. (See Chemistry Terms sidebar). These oxidation-reduction reactions occur when iron interacts with chemicals and materials used in frac operations. In particular, dissolved iron must be removed from frac water because ferrous ion is continually oxidized to ferric ion as frac water is exposed to new sources of oxygen. Oxygen is ubiquitous during frac operations; oxygen being introduced from impounded surface waters or from the physical pumping of frac water itself.

The chemistry of iron oxidation is complex. However, it is useful to understand how iron is oxidized in order to determine the best and lowest cost frac water treatment for iron removal. Below is a simplified depiction of iron oxidation chemistry:

1. Ferrous ion (Fe²⁺) and oxygen (O₂) react to form ferric (Fe³⁺) ion and hydroperoxide radical (HOO⁻).
   \[ \text{Fe}^{2+} + \text{O}_2 \rightleftharpoons \text{Fe}^{3+} + \text{HOO}^- \]

2. The hydroperoxide radical reacts with another ferrous ion to form more ferric ions and hydrogen peroxide.
   \[ \text{Fe}^{2+} + \text{HOO}^- \rightleftharpoons \text{Fe}^{3+} + \text{H}_2\text{O}_2 \]

### Chemistry Terms

- Iron dissolved in water exists in the ferrous ion form and is represented by the formula Fe²⁺.
- Ferrous ion combines with oxygen to form ferric ion and is represented by the formula Fe³⁺.
- Most ferric ion compounds are water insoluble.
- The scientific principal for the reversible conversion of ferrous to ferric form is called oxidation-reduction.
- In other words, Fe²⁺ loses an electron to form Fe³⁺, whereas Fe³⁺ gains an electron to form Fe²⁺.
- OILRIG – Oxidation is Loss and Reduction is Gain - is a helpful mnemonic to remember the distinction.
3. The hydrogen peroxide generated from the previous step further reacts with ferrous ion to form more ferric ion, hydroxyl radicals (HO\(^{-}\)) and water (H\(_2\)O).

\[
Fe^{2+} + H_2O_2 \rightleftharpoons Fe^{3+} + HO^- + H_2O
\]

4. Finally, the formed hydroxyl radicals react with additional ferrous ion to form ferric ion and water.

\[
Fe^{2+} + HO^- \rightleftharpoons Fe^{3+} + H_2O
\]

Artesia understands this complex chemistry and uses its knowledge to develop cost effective solutions for produced water recycling. Many competitors boast “straightforward and inexpensive” methods to remove iron by using chlorine derivatives, such as bleach and chlorine dioxide, while other competitors go to great lengths to generate less common oxidants such as ozone, sodium chlorite, and mixed oxidants, such as hypochlorite/hypochlorous derivatives. Yet, as the chemical equations 1-4 suggest, chlorine and complex oxygen sources are not directly involved in the chemical oxidation of iron and are not needed to remove dissolved iron.

Artesia believes prudent use hydrogen peroxide is directly indicated by the chemistry. We design treatment processes that use very economical chemicals such as hydrogen peroxide and/or peroxyacetic acid, a simplified organic hydroperoxide derivative.