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What is the Difference?

Fenton's reagent, Fenton-like reactions, catalyzed hydrogen peroxide, modified Fenton's reagent, or catalyzed hydrogen peroxide propagations: are there any differences?

By Dr. Dan Bryant

Within the in-situ chemical oxidation (ISCO) industry, many different terms are utilized to attempt to differentiate various methodologies that utilize hydrogen peroxide as the primary chemical reagent. Hydrogen peroxide itself is not a strong enough chemical oxidant to rapidly destroy the contaminants we routinely encounter in soil and groundwater remediation. Thus, all hydrogen peroxide ISCO technologies rely upon reaction of hydrogen peroxide with a catalyst or another reactive compound, whether injected in association with the hydrogen peroxide or present naturally in the soil or groundwater, in order to generate more reactive species. It is those secondary reactive species, such as the hydroxyl radical or superoxide radical, that react with and destroy the target contaminants.

The catalytic reaction of hydrogen peroxide with ferrous iron to rapidly destroy organic compounds was first described by H.J.H. Fenton in 1894. Haber and Weiss (1934) first proposed formation of hydroxyl radicals as the underlying mechanism, while Merz and Waters (1947) utilized the term "Fenton's reagent" for the combination of hydrogen peroxide and ferrous iron to generate a powerful oxidant for a wide variety of alcohols. In several articles in the early 1990's evaluating the potential applications of hydrogen peroxide for ISCO treatment of soil and groundwater, Watts and coworkers (e.g., Watts et al., 1991; Tyre et al., 1991) utilized the terms "Fenton-like" and "catalyzed hydrogen peroxide" to describe the suite of reactions involved with hydrogen peroxide and ferrous iron. This was because the approaches utilized differed significantly



from the range of chemical conditions first utilized by Fenton (1894). Rodgers et al. (2001) introduced the term "modified Fenton's reagent" to differentiate the use of chelated iron catalysts from ferrous salt-based catalysts. Watts and Teel (2005) proposed the term "catalyzed H₂O₂ propagations" to describe catalysis of relatively high concentrations of hydrogen peroxide (as typically utilized in ISCO), regardless of the type of catalyst, to yield a suite of reactive oxygen species generated through propagation reactions and to differentiate these systems from "classical" Fenton's reagent.

Thus we arrive at the central topic of this article: Is there any real difference in the technologies to which these terms are applied? As recognized by Watts and coworkers, all peroxide-based ISCO technologies differ significantly from the range of chemical conditions utilized by Fenton (1894), therefore the use of the term "Fenton's reagent" is not very accurate. However, the suite of reactions involved in the systems described as "Fenton-like," "catalyzed hydrogen peroxide," "modified Fenton's reagent," or "catalyzed H₂O₂ propagations" are very similar to each other in many respects: All utilize relatively high concentrations of hydrogen peroxide, all are effective over a range of pH conditions from acidic to slightly basic, all involve the reaction of hydrogen peroxide with iron in both the ferrous (Fe⁺²) and ferric (Fe⁺³) valence states (or other transition metals with the ability to transfer electrons), and all form a wide variety of reactive species including hydroxyl radicals, superoxide radicals, perhydroxyl radicals, and hydroperoxide anions. Therefore, from a pragmatic, ISCO field-application perspective, there are really no meaningful differences between these terms despite the fact that some vendors continue to use terms such as "modified Fenton's reagent" in order to try to commercially differentiate themselves. A responsible ISCO practitioner adapts their approach based upon site-specific conditions, and therefore the use of terms such as "modified Fenton's reagent" become vague and meaningless when the application varies from site to site.



We feel the use of "catalyzed H₂O₂ propagations," or CHP as first proposed by Watts and Teel (2005) is the most accurate and encompassing term. CHP provides sufficient generality to include all types of potential catalysts (such as ferrous salts or chelated iron injected as part of the ISCO program, or autochthonous iron or other transition metals present in the subsurface) and formation of a wide spectrum of reactive species from catalyzed hydrogen peroxide. CHP also provides sufficient specificity to differentiate it from other oxidants utilized in ISCO, such as permanganate or catalyzed persulfate. We therefore utilize CHP in our description of the chemical reactions underlying hydrogen peroxide ISCO.

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