Redox Tech

Providing Innovative Soil and Groundwater Solutions

Oxygen Scavenging Compounds

To promote reducing conditions in the subsurface, particularly when reductive bioaugmentation is planned, it is often necessary to neutralize oxygen or other oxidizing compounds that are present in the injection solution. Potable water (tap water) is the most commonly used fluid to make up injection solutions. Nearly all potable water contains oxygen and some residual additional disinfecting oxidant (e.g., chlorine or chloramine). Approaches commonly utilized in the past include combined sugar and yeast, sulfite, sodium ascorbate, ascorbic acid (vitamin C), zero valent iron, and nitrogen sparging. Whatever methodology is employed, care must be taken to minimize agitation of the injectate. It is remarkable how quickly oxygen dissolves in water.

One way to remove oxygen from water is to foster the growth of biological organisms such as yeast by adding a fast metabolizing food source (e.g., sugar) to the oxygenated water. Oxygen is rapidly consumed as the organisms use it to metabolize their food to grow and reproduce. Although not as rapid (often takes several hours) in removing oxygen as adding specific chemical-reducing agents, this method has the advantage of providing extra food (ethanol) and nutrients (Vitamin B12) for enhancing the growth of the dehalogenating bacteria. One of the drawbacks of this method is that the deoxygenation rate is directly dependent on temperature. During the summer or in warmer climates, Redox Tech has typically added about 5 to 10 pounds of sugar per 1,000 gallons of water, along with 2 to 3 pounds of brewer's yeast. Deoxygenation can take a few hours and sometimes as long as a day. This method is advantageous for preparing large batches in large tanks, such as frac tanks.

Chemical-reducing agents neutralize oxygen quickly and are relatively simple to utilize in the field. A small amount of soluble salt is added and stirred with the injectate. Commonly used reducing chemicals include sodium sulfite, sodium ascorbate, sodium metabisulfite, and occasionally zero valent iron. These chemicals stimulate very rapid reactions with oxygen (often within minutes) and are relatively low cost. One of the potential drawbacks of the sulfite chemicals is that after a reaction with oxygen or oxidants, they are converted to sulfate, which in high concentrations, can impede the reduction of some of the contaminants. However, Mao *et al.* (2017) have shown that as long as sulfate concentrations are below approximately 500 parts per million (ppm), there should be no inhibition of dehalogenating bacteria such as *Dehalococcoides* (DHC). Nonetheless, there will still be competition for hydrogen. When using sulfite, care must be taken not to overdose because He *et al.* (2005) have shown that sulfite concentrations above 50 ppm completely inhibit dechlorination. However, if properly dosed, the sulfite is bound or converted to sulfate, which is less inhibitory. Soluble salt approaches act very quickly, often in a matter of minutes, and are widely utilized. Ascorbate is more expensive and generally less available than sulfite, but with ascorbate the chance of overdosing is minimal.

An alternative method for removing oxygen from water is by sparging with a relatively inert gas such as nitrogen. Although often used in laboratory settings, this method requires efficient mixing/contact of the inert gas with the oxygenated water to remove the oxygen and is often difficult, inefficient, and expensive to use at bioremediation sites.

Table 1 below summarizes the commonly applied methods for deoxygenating anaerobic bioremediation injectate. We typically recommend reducing oxygen to below 1 ppm. Others recommend also reducing the oxidation-reduction potential (ORP) to below -75 millivolts (mV). It is our experience that ORP measurements take a long time to stabilize and may not always be reliable. Decreasing the ORP to below -75 mV can take longer, and it may not be important if the aquifer is not -75 mV.

Table 1. Advantages and Disadvantages of Deoxygenating Compounds

Approach	Pros	Cons
Sugar and Yeast	- Sugar and ethanol are electron donors - Sugar and yeast readily available - Inexpensive - No toxicity concerns - Produces vitamin B12	- Can be slow reacting in cold water
Sulfite Salt	- Very fast reaction rate - Inexpensive - Neutralizes chlorine	- Toxicity concern if overdosed
Ascorbate	- Reasonably fast reaction - Neutralizes chlorine - Carbon substrate	- More expensive than sulfite
Zero Valent Iron	- Creates strongly reducing conditions	- Slower than sulfite or ascorbate - Requires flow through bed
Nitrogen Sparge	- Does not produce by-products	- Does not remove residual chlorine - More difficult to implement

A spreadsheet for estimating the amount of reducing chemical to be added is provided on our website free of charge (www.redox-tech.com/abc-ole). We recommend applying a 50 percent safety factor as long as the sulfate concentration will be below 500 ppm. Redox Tech sells sodium sulfite and ascorbate for deoxygenation. If the estimated sulfate concentration will be greater than 500 ppm, ascorbate should be considered.

References

He, J. Y. Sung, R. Krajmalnik-Brown, K. Ritalahti, Frank E. Löffler, Isolation and characterization of *Dehalococcoides* sp. strain FL2, a trichloroethene (TCE)- and 1,2- dichloroethene-respiring anaerobe, 2005. Environmental Microbiology, 7(9), 1442-1450.

Mao X, Polasko A, Alvarez-Cohen L. Effects of Sulfate Reduction on Trichloroethene Dechlorination by Dehalococcoides-Containing Microbial Communities. Appl Environ Microbiol. 2017 Mar 31;83(8):e03384-16.

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