Mass Magnetic Susceptibility Measurement for Estimating Intrinsic Abiotic Degradation Rates: Recommendations to Improve Interpretation Reliability

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Background/Objectives. Measurement of mass magnetic susceptibility (χ), or “magnetization potential”, of subsurface materials has been part of the practice of geologic and environmental researchers since at least the 1970s. The χ analysis provides an inexpensive estimate of the concentration of ferrimagnetic mass (e.g., magnetite), canted antiferrimagnetic mass (e.g., hematite), and (if present) ferromagnetic mass (e.g., ZVI). Typically, the presence or absence of magnetite is assumed to dominate the χ measurement. In the 2000s, researchers including the USEPA applied the χ concept and commercially available laboratory measurement equipment to the characterization of subsurface geologic samples for the purpose of estimating magnetite mass concentration and relating the estimated magnetite concentration to abiotic rates of intrinsic chlorinated aliphatic hydrocarbon (CAH) organic pollutant transformation. This development was motivated by the realization that certain minerals of geologic origin and products of recent biogeochemical activity could abiotically degrade certain organic pollutants. In particular, bench treatability and field characterization work had demonstrated significant abiotic degradation of CAH compounds by magnetite (Fe_3O_4).
In interpreting χ data for the purpose described above, the analyst should consider the specific nature of the potentially reactive mineral(s) indicated to be present by the χ measurement. A relevant question: Can CAH pollutant degradation be expected if the identified potentially reactive mineral is not in direct physical contact with the CAH molecule? This question is typically not considered but was considered at a Department of Defense site in Colorado where detailed biogeochemical characterization was conducted to support a biogeochemical reductive dechlorination (BiRD) groundwater remedy.

Approach/Activities. Two Denver Formation samples consisting of weathered sandstone were characterized using tests including XRD, XRF, SEM-EDS, and acid digestions and extractions followed by ICP. A calibrated Bartington MS2 laboratory system in low frequency mode was used to generate χ measurements. The various lines of evidence involving elemental and mineralogical composition, morphological nature, and microbial ecology were synthesized and interpreted to augment the BiRD design basis and assess intrinsic abiotic attenuation potential, including simulation of plume transport.

Results/Lessons Learned. The Rocky Mountain intrusive-extrusive igneous genesis and erosional setting is representative of many areas across North America. Sample total iron content exceeds seven percent weight basis and ferrimagnetic and canted antiferrimagnetic grains were identified. Titaniferous Fe_3O_4 predominate and χ measurements (8.96E-05 ± 4.01E-06 and 1.87E-05 ± 1.38E-06 m^3/kg) are at least an order of magnitude higher than “elevated” literature values. A high relative intrinsic abiotic CAH reaction rate for these samples is implied from published correlations. However, past and future CAH abiotic degradation potential is low because the Fe_3O_4 grains are coated with smectite and illite. Plume transport analysis is supportive. Insights on crystal/grain morphology and surface composition of potentially reactive minerals in subsurface settings can influence χ data interpretation and can improve confidence in conceptualization of fate and transport.