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Iron biogeobatteries: Interactions with bacteria and metal contaminants

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Microorganisms, including bacteria, account for 50% of the carbon biomass on the planet and dictate whether our air is breathable, water drinkable or soils productive. Some bacteria “breathe” solid phase iron (Fe) minerals, in soils and sediments, as energy sources. Fe is one of the most abundant elements in the Earth’s crust and, because the Fe(II)/Fe(III) redox couple lies between major carbon, nitrogen, oxygen and sulphur redox couples, it participates in a large variety of energy-yielding biogeochemical reactions. Furthermore, microbial Fe(II) oxidation and Fe(III) reduction coupled to the formation and dissolution of Fe minerals is linked to the mobility of contaminants and production of greenhouse gases. Iron-respiring microbes therefore play an important role in many environmental processes.

The bulk of published understanding of biogeochemical Fe cycling by Fe-metabolizing bacteria is often restricted to electron transfer from or to single valence phases such as $Fe^{2+}{}_{aq}$, complexed Fe, or short range Fe(III) ordered minerals. However, mixed valence iron minerals such as oxides (e.g. magnetite), Fe-bearing clays (e.g. nontronite), sulphides (e.g. greigite) or green rust, are ubiquitous in the environment. Despite their abundance however, the interactions between mixed-valence Fe minerals and Fe metabolizing bacteria are still relatively underexplored, and many questions remain about how these interactions can affect the mobility of nutrients and metals.

In previous research, it was shown that magnetite can act as both an electron source and sink to Fe(II)-oxidizing and Fe(III)-reducing bacteria, respectively, depending on the geochemical conditions that are present. These experiments provided evidence that magnetite can behave as a natural battery (Fe-biogeobattery). These Fe-biogeobatteries are thus naturally occurring mixed valence iron minerals which can act as both electron sources and sinks to bacteria, without undergoing transformation to a different mineral phases. In this presentation, we review current understanding of Fe-biogeobatteries and especially focus on their importance in the context of metal contaminants including chromium, copper and cadmium. Overall, this work will highlight the importance of Fe-biogeobatteries and their implications towards to water quality, and the release of toxic metals and metalloids into aquifers, soils and sediments.