Minerals, Metals, Molecules and Microbes: Environmental Mineralogy and Sustainability

Vaughan, David[1]
[1]University of Manchester

Mineralogy is central to understanding many of the contaminated environments at the Earth's surface. Here, a molecular scale understanding of materials and processes is essential to acquiring the knowledge needed for the safe containment of wastes, assessment of the risks of environmental damage, or the amelioration of contaminated sites, all of which are critical for the sustainable use of natural resources. Examples of the role of mineralogy at key stages in the study of such contaminated environments will be considered in this overview presentation.

The breakdown of metalliferous (sulphide) minerals at current and former mining operations, which causes acidification of natural waters and release of toxic metals (Cu, Pb, Zn, Cd, Hg, As etc) as part of the Acid Mine Drainage (AMD) phenomenon, often entails complex electrochemical reaction sequences. Research on these breakdown processes is focussed on mechanisms, rates and reaction products, with emphasis on surface reactivity at nanometre to micron scales.

Toxic metals released at AMD sites may be incorporated into secondary minerals or form stable or transient solution species. Much recent work has been concerned with understanding the critical role of microbes in these systems, particularly in their ability to facilitate redox reactions. Anthropogenically introduced contaminants are involved in similar processes. Such contaminants can range from organic molecules to engineered nanoparticles, and from uranium from mining or depleted uranium from munitions to the wider range of radioactive wastes from the nuclear industry.

Secondary mineral products are often very fine particle (nanoparticulate) materials such as the iron oxyhydroxides found in oxidising environments , or the sulphides (FeS, CuS etc) found in reducing environments such as those just beneath the surface of many marine sediments. These materials, along with certain of the major rock-forming minerals (clays, feldspars, calcite) play a critical role in facilitating either the transport of contaminants in flowing water or their short or longer term immobilisation in sediments and soils. This may occur through diverse interactions and reactions at mineral surfaces (precipitation, replacement, sorption/desorption). The contaminants are often only trace components of such systems, so that surface interactions at very low concentrations need to be understood.

The mobility and, therefore, potential bioavailability of contaminants is a product of all these factors, together with others such as the hydraulic conductivity of soils and sediments which, in turn, may be influenced by the behaviour of nanoparticle mineral phases, or the coating of minerals by microbially generated biofilms, and even the airborne transport of contaminants in association with mineral dusts.

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submitted by: **Vaughan, David**
email: **david.vaughan@manchester.ac.uk**
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