

Editorial

## Mine Waste Characterization, Management and Remediation

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Mining is a vital part of the Global economy, but the extraction of metals, metalloids, and other mineral products generates vast quantities of liquid and solid waste. Currently the volume is estimated at several thousand million tons *per annum*, but is increasing exponentially as demand and exploitation of lower-grade deposits increases. The high concentrations of potentially toxic elements in these wastes can pose risks to ecosystems and humans, but these risks can be mitigated by implementing appropriate management or remediation schemes. Although there are a large number of such schemes available, there is still a need to research the processes, products, and effectiveness of implementation, as well as the nature of the mine wastes themselves. This Special Issue is aimed at bringing together studies in the areas of mine waste characterization, management, and remediation, to review the current state of knowledge and to develop improvements in current schemes. Fourteen manuscripts are published for this Special Issue, and these are summarized below.

Due to the large-scale nature of mine wastes, characterization is often done at regional scales. In this regard, Buzzi *et al.* [1] describe a method whereby hyperspectral high spatial resolution HyMap data can be used to map mainly abandoned massive sulfide mine wastes from the Iberian Pyrite Belt, Southwest Spain. Pattelli *et al.* [2] describe the flood-related mobilization of sediment-borne Hg from the Mount Amiata mining district in southern Tuscany, Italy, the fourth largest Hg district worldwide, which produced 102,000 metric tons of Hg from the 1860s to 1980. The processes and products of contaminant mobility at redox-transition zones, leading to diffuse metal contaminant inputs into river systems, is reviewed by Lynch *et al.* [3].

Acid generation from oxidation of sulfide minerals, such as pyrite and pyrrhotite, in mine wastes is one of the most significant issues facing the mining industry [4]. Dold [5] reviews the complex biogeochemical and mineral dissolution processes in sulfidic mine tailings leading to the formation of acid mine drainage (AMD). Mumford *et al.* [6] and Langman *et al.* [7] describe long-term acid generation from sub-Arctic oil shales and waste rock from the Diavik Diamond Mine in the Northwest Territories of the Canadian Arctic, respectively. In both cases, the acid generation potential is dependent on the concentrations of sulfide, neutralization reactions with carbonates and Al-bearing minerals and temperature.

Secondary Fe-bearing oxyhydroxysulfate, hydroxide and oxyhydroxide minerals play a major role in sequestering metals and metalloids from mine wastes [8]. The formation of jarosite and soluble Fe-sulfates in the tailings' impoundments at the Zn-Pb-Ag Pan de Azúcar mine, NW Argentina, is described by Murray *et al.* [9]. Alarcón *et al.* [10] investigate the potential for As retention by secondary jarosite, schwertmannite, ferrihydrite, and goethite from coastal tailings under a marine flood scenario.

Large volumes (~100s of millions of tons) of smelting slags are produced annually worldwide, and these contain elevated concentrations of metals including Al, Cr, Cu, Fe, Mn, Pb, and Zn [11]. The primary phases and secondary weathering products of smelting slag at an abandoned mine site in SW Japan are described by Sueoka and Sakakibara [12]. High concentrations of Zn occur in willemite, and of Fe, Zn, Cu, Sn, Pb, As, and Cd in matte drops, but these weather to form Fe hydroxides, releasing the metals and metalloids to local aqueous and soil environments.

Several promising avenues for the management and remediation of mine wastes are outlined in this special issue. Due to increasing amounts of mine wastes generated annually, and environmental and social issues surrounding disposal on land, mining companies are seeking alternative methods of disposal. Dold [13] reviews the mineralogical and geochemical issues arising from submarine tailings disposal. Diaby and Dold [14] continue the marine disposal theme by describing the results of the implementation of artificial wetland remediation cells on oxidizing marine shore tailings deposits. The wetland implementation is most effective and rapid when the system is water saturated, and when pH and redox are favorable for precipitation and immobilization processes.

Other techniques for managing and remediating mine wastes involve the use of heat and other waste products. The use of thermal desorption to volatilize Hg from Hg-contaminated soil and mine wastes is described by Navarro *et al.* [15], and Mäkitalo *et al.* [16] outline the properties of green liquor dregs (GLD), alkaline residual materials produced by sulfate paper mills. Johnson [17] reviews recent advances in biotechnologies using microorganisms that can reduce the reactivity of potentially hazardous mine tailings and selectively remove metals and other contaminants from mine waters.

The studies published in this special issue contribute to knowledge of how mine wastes are mobilized, neutralized and weathered, and of novel methods for how these wastes can be managed and remediated. The more novel biotechnological, *in situ* and perhaps, nanotechnological, mitigation methods hold the most promise for future development, given their potentially low environmental impacts and economic benefits. The future of mine waste mitigation depends on the type of knowledge presented in this special issue, and on ongoing regional- to atomic-scale research on the characteristics and short- to long-term behavior of mine wastes. This work is essential, given the huge physical, toxic element and carbon footprints of mine wastes, the uncertainties around the impacts of current

management and remediation schemes, new types of wastes generated from new types of commodities (e.g., oil sands, lithium, heavy rare earth elements (HREEs)), and the growing global amounts of mine waste.

### Conflicts of Interest

The authors declare no conflict of interest.

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