



Managing Spontaneous Combustion at Mine Sites

Earth Systems' Environmental Geochemistry Division is a world leader in understanding, identifying and managing issues associated with slow, moderate and rapid sulfide oxidation. Spontaneous combustion (very rapid oxidation) of iron sulfides can create major and long-lived air and water quality impacts. Identifying, quantifying and effectively managing these impacts is vital.

Spontaneous combustion is a process that affects a broad range of mining operations, including gold, silver, copper, lead-zinc, nickel, tin, iron ore and coal (brown and black). The process is initiated by the spontaneous oxidation of extremely reactive iron sulfide minerals (largely pyrite, marcasite or pyrrhotite), in a highly exothermic process that generates sulfur dioxide gas (SO₂) — a sulfide fire.

These types of fires are relatively common in waste rock piles, and can persist for decades given sufficient reactive fuel (FeS₂ or FeS) and access to oxygen. Although common, outward signs of sulfide fires can be relatively subtle. They do not produce smoke and the formation of SO₂ gas, CO₂ gas and water vapour can be difficult to distinguish on warm days. Cool mornings and high-humidity days are a good time to see condensing water vapour and gas plumes from subtle to obvious vents in the upper surface of waste rock piles. Small deposits of native sulfur (S₈) can form via sublimation on the margin of these gas vents in environments where highly reducing conditions prevail. In aggressively combusting waste rock piles, these discharging vents can represent a serious but localised health hazard.

The quantity and rate of localised acid generation from the spontaneous combustion of iron sulfides will depend on how much of the SO₂ is released to the atmosphere, and how much combines with water to form sulfuric acid within the waste rock.

COMBUSTION OF CARBON

The spontaneous combustion of iron sulfide minerals becomes a far more serious health, safety and environment issue when carbon is an abundant secondary fuel source. Reactive carbon is surprisingly widespread in a range of rock types, including brown, black coal, bituminous shales, oil shales and various graphitic shales. Hence, there are many geological settings and ore types that include iron sulfide minerals and reactive carbon.

At the elevated temperatures induced via the spontaneous combustion of iron sulfides, various carbon phases can ignite and burn in the presence of oxygen. This process can generate what is regarded

as a more conventional fire; the production of carbon dioxide and carbon monoxide from the oxidation of carbon.

Carbon-bearing fires produce smoke, often from waste rock materials, which can continue for decades if left unmanaged. Almost all management activities at mine sites focus on extinguishing carbon-based combustion issues, rather than sulfide oxidation issues. Indeed, once carbon combustion is the dominant process at a mine site, it is not clear whether sulfide oxidation is a major ongoing issue.

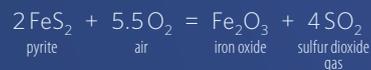
MANAGEMENT

During the pre-mining stages of a project, careful static and kinetic characterisation of ore and waste materials can help clarify the risk of spontaneous combustion of sulfides and related carbon combustion.

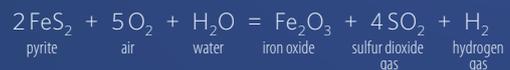
Once either sulfide and/or carbon combustion has occurred, the focus of remedial measures is on limiting air entry to hotspots. This can be achieved in a number of ways, but requires some understanding of the mechanisms of air entry to source of the fire. Strategic use of rock, water and inert gases (nitrogen and carbon dioxide) have all been used successfully to limit the spread and extinguish mine site fires related to spontaneous combustion. The use of water is the most controversial and potentially most dangerous.

Spontaneous Combustion Reactions

A typical initiation and combustion reaction for pyrite or marcasite would be:



If water is added to this reaction, in an attempt to douse the fire, the result is the potentially explosive production of hydrogen gas, which only serves to fuel the reaction.



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