

Acid Mine Drainage

Remining Information Series

What is Acid Mine Drainage (AMD)?

AMD is water emanating from mines that is characterized as acidic by having a low pH (i.e. less than 6.0), elevated concentrations of metals (e.g., iron, manganese and/or aluminum) and raised concentrations of sulfate (SO₄). AMD tends to form as a result of the disruption of minerals and enclosing strata from mining activities when exposed to the atmosphere. AMD can be associated with coal mining (surface and underground) as well as metal mining operations. The water can eventually become alkaline, but may continue to have elevated metals as well as sulfate.



AMD from an abandoned underground mine complex near New Philadelphia, Ohio.



Toxic surface mine spoil material at an unreclaimed site in Noble County, Ohio.

How does AMD form?

During mining, the coal and associated strata containing varying amounts of sulfide minerals (commonly pyrite—FeS₂) are exposed to atmospheric oxygen. Studies have shown that when the sulfur concentration from pyrite exceeds 0.5 percent, the strata have the potential to form AMD. The sulfide minerals oxidize, forming soluble sulfate salts. These salts are easily dissolved when contacted by water and the reaction releases acidity (H⁺), while dissolving iron and sulfate ions. Once the water becomes acidic from the dissolution of the sulfate salts, it can dissolve other minerals (commonly aluminum and manganese) from rocks it contacts. A secondary chemical reaction (i.e. hydrolysis) allows for continuing pyrite oxidation, even in the absence of atmospheric oxygen, which releases additional acidity, dissolved iron, and sulfate.

What are the impacts of AMD?

AMD can be highly detrimental to the aquatic life of receiving streams. The impacts are twofold: 1) the most severe being the direct, toxic effects on organisms if mine drainage is severely acidic, or if dissolved metal concentrations are high enough, and 2) dissolved metals (mostly iron) can further oxidize and precipitate, which can affect respiration for aquatic organisms by clogging gills and precipitates on the bottom of streams, affecting the benthic organisms' physical habitat. All of these effects impair aquatic ecosystems through lack of diversity and reduce the number of organisms present. In severe cases, AMD can cause a stream to be essentially devoid of an aquatic ecosystem.

In addition to ecosystem effects, AMD causes the deterioration of infrastructure features, such as bridges, public water and power plant supplies, locks and dams, and numerous other man-made structures on streams and rivers.

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How long do mines continue to produce AMD?

The length of time that mines will continue to discharge AMD is dependent on: overall sulfur content of strata, type and structure of mine, post-mining hydrology of operation, continued contact of atmospheric oxygen to sulfide minerals, and various other factors. It is not unusual for surface or underground mines to continue to yield AMD for many years or decades after mining has ceased. Legacy mining in the Appalachian Coal Region has numerous mines that continue to yield AMD more than 100 years after closure. An example of an extreme case is a tin mine in England that was mined by the Romans more than 2,000 years ago and it still produces AMD from pyrite oxidation.

When the acid-forming materials of a surface or underground mine are completely flooded, the acid production tends to cease. Experience has shown that when at least 50 percent of an underground mine is kept flooded, the discharging water ultimately tends to become net alkaline, but the mines often continue to yield water with elevated metals and sulfate for a long period time after flooding.

How can remining reduce AMD?

Unreclaimed coal mines tend to yield much higher amounts of AMD than those that are reclaimed. Studies have shown that basic, reclamation techniques of regrading and revegetating of abandoned mines conducted as part of remining, can significantly reduce acid and metals loads from these sites. The regrading removes much of the sulfide-rich materials from the atmosphere and creates positive drainage. The vegetation and soil work to intercept oxygen entering the subsurface. In some instances, daylighting (surface mining of an underground mine or past auger mining into final highwall) has caused the water quality to change from highly acidic to highly alkaline. This is because accessing of the alkaline strata in the overburden and removal of acid-producing coal substantially alters the groundwater regime. Reclamation of abandoned mine land (AML) sites in Ohio typically yields an acid load reduction of 60 to 80 percent.