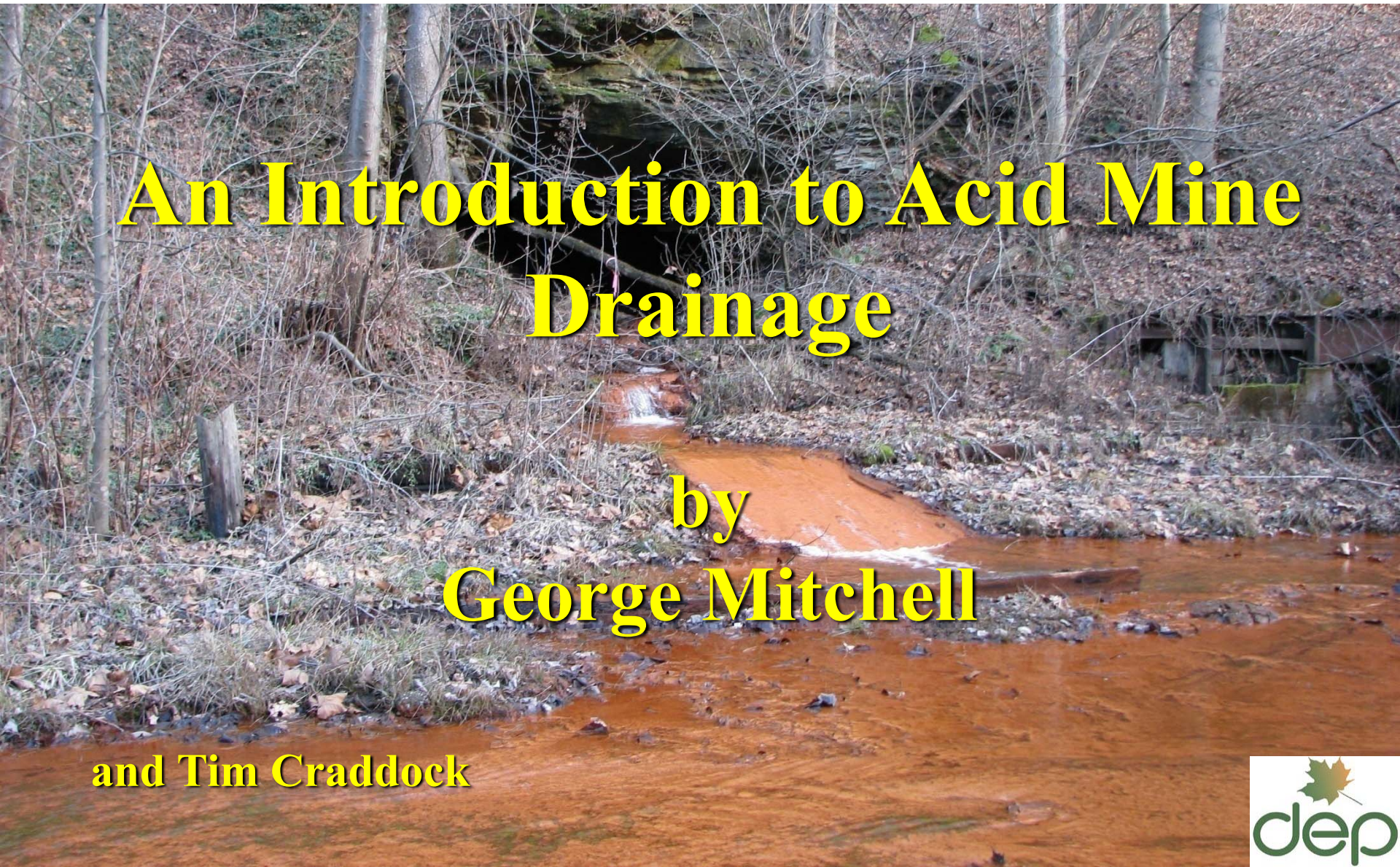
west virginia
department of environmental protection



An Introduction to Acid Mine Drainage

by

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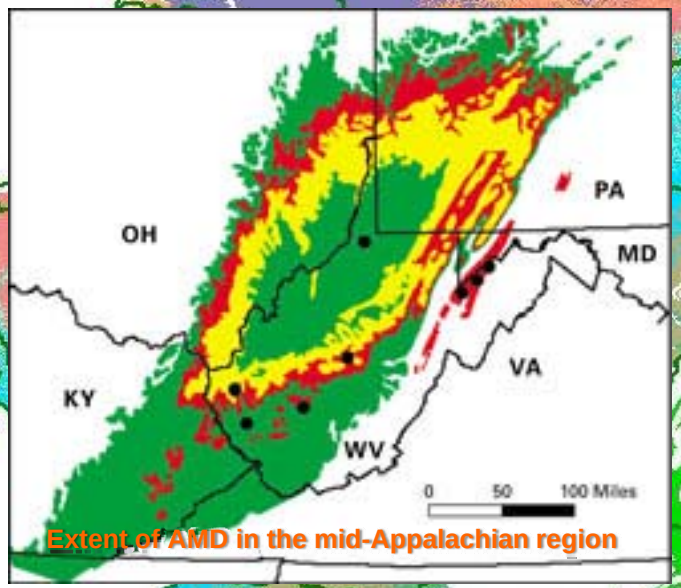
and Tim Craddock

AMD affects over 2000 miles of streams in West Virginia



Extent of AMD in the mid-Appalachian region

Major river basins
Limestone
Coal geology
Elk Lick, Bakerstown, Mahoning
Freeport, Kittanning, Clarion
Iaeger, Sewell, Welch, Raleigh
Beckley, Fire Creek, Pocahontas Nos. 8 and 9
Pocahontas Nos. 1-7
Stockton, Coalburg, Winifrede, Chilton, Williamson
Cedar Grove, Alma, Peerless, Campbell Creek
Powellton, Eagle, Gilbert, Douglas
Washington
Waynesburg, Uniontown, Sewickley
Redstone, Pittsburgh

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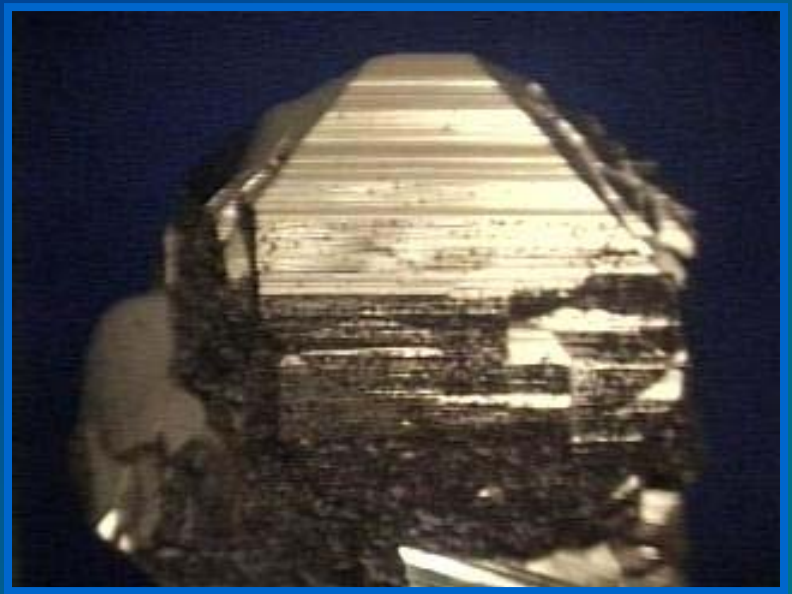
What is Acid Mine Drainage?

Basically, AMD formation is an oxidation process

Oxidation is defined as the interaction between oxygen molecules and all the different substances they may contact, from metal to living tissue. Technically, however, with the discovery of electrons, oxidation came to be more precisely defined as the loss of at least one electron when two or more substances interact. Those substances may or may not include oxygen. (Incidentally, the opposite of oxidation is reduction — the addition of at least one electron when substances come into contact with each other.)

The culprit



Pyrite

or other sulfide minerals

Pyrite **Oxygen** **Water**

Acid Mine Drainage

The chemistry of oxidation of pyrites, the production of ferrous ions and subsequently ferric ions, is very complex, and this complexity has considerably inhibited the design of effective treatment options. Although a host of chemical processes contribute to AMD, pyrite oxidation is by far the greatest contributor. General equations for this process are:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

The oxidation of the sulfide to sulfate solubilizes the ferrous iron (iron(II)), which is subsequently oxidized to ferric iron (iron(III)):

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O$$

Either of these reactions can occur spontaneously or can be catalyzed by microorganisms that derive energy from the oxidation reaction. The ferric irons produced can also oxidize additional pyrite:

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+$$

The net effect of these reactions is to release H^+, which lowers the pH and maintains the solubility of the ferric ion.

When pyrite is enclosed within rock, only minimal amounts of pyrite are oxidized through natural weathering, thereby generating only small amounts of acid. When fully exposed to air and water, the chemical reactions forming AMD occur at a faster rate.

This acid is sometimes naturally diluted or neutralized by surrounding alkaline rocks.

Remember, pyrite is exposed only when large volume of rocks are disturbed, as in mining or other major land disturbances.

The acid produced eventually finds its way to the ground and surface waters.

Why is AMD Harmful?

The resulting acid and dissolved metals stress or are toxic to aquatic life.

Common metals found in AMD

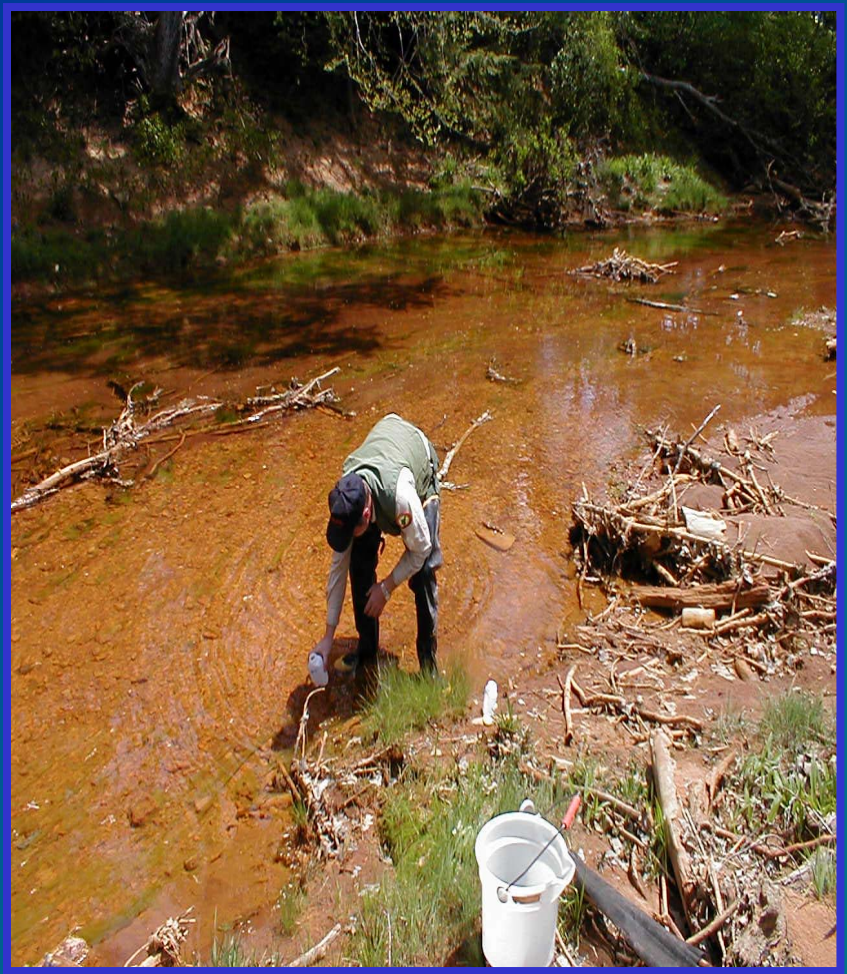
Iron (Fe)
Aluminum (Al)
Manganese (Mn)

Clear streams do not necessarily mean clean streams

When acid levels are high, the pH is low. In low pH conditions, the metals are dissolved and leave no physical indication of their presence.

However, acid mine drainage eventually leaves its mark.

Water samples are collected to determine the extent of acid mine drainage.



Discharge is the most important measurement.

Pollutant load calculations

L = F x C x D, where
F = conversion factor/units
C = concentration
D = discharge

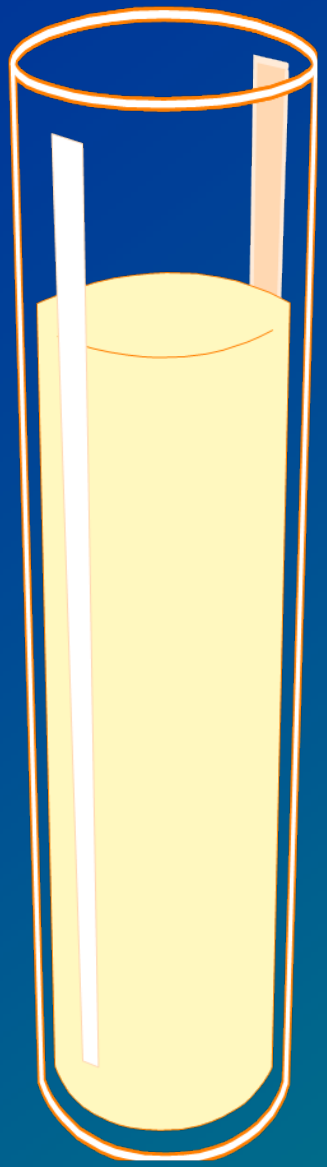
Discharge determines the loading, or volume, of metals and acid found in the water.

Common field parameters

- pH
- Specific conductivity
- Water temperature
- Dissolved oxygen
- Discharge

Laboratory parameters

- pH
- Specific conductivity
- Acidity
- Alkalinity
- Sulfates
- Total Iron
- Aluminum
- Manganese



Once the volume of metals and acid are known, a treatment system can be designed.

Chemical Treatment Examples

Anhydrous ammonia

Hydrogen peroxide

Calcium oxide

Passive Treatment Examples

Wetlands

Alkaline beds

Open limestone channels

The best method to treat AMD is prevention

This can be done by using proper reclamation methods, which prevents air and/or water from reaching the pyritic materials.

West Virginia's waters can and will be protected from the degradation of AMD.