INTRODUCTION TO ACID MINE DRAINAGE

Ondra Sracek

Acid Mine Drainage (AMD): types of mining wastes

There are 2 basic types of mining wastes: mine tailings and waste rock;

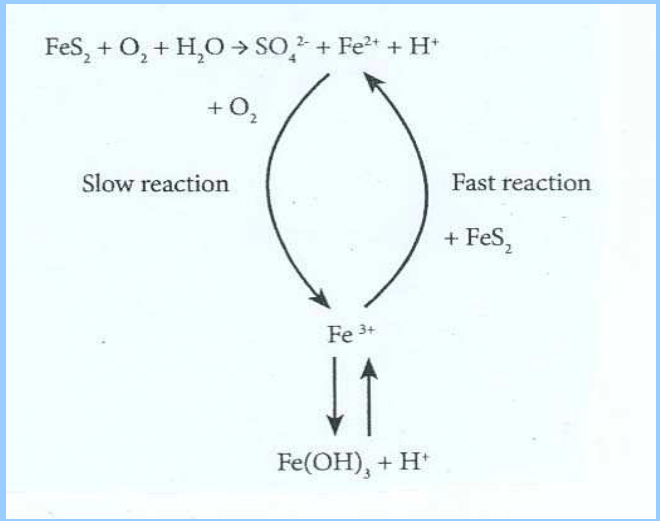
- mine tailings: fine grain particles, highly saturated by water, oxygen transport by difussion, they are in topographic depressions and thickness of unsaturated zone is low (generally 1 - 5 m),

- waste rock piles: highly variable size of particles, oxygen transport by both diffusion and convection, fast oxidation of pyrite results in high temperatures, they form topographic elevations and thickness of unsaturated zone is frequently high (> 30 m, sometimes 100 m);

Mine tailings, Mindolo, Copperbelt, Namibia

Waste rock pile, Mine Doyon, Québec, Canada

Principal process responsible for formation of acid mine drainage is the oxidation of sulphides such as pyrite:



Stumm, Morgan, 1981

Balanced equations are:

(1) $FeS_2(s) + 3{,}5O_2(g) + H2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$

(2) $Fe^{2+} + 0{,}25O_2 + H^+ = Fe^{3+} + 0{,}5H_2O$

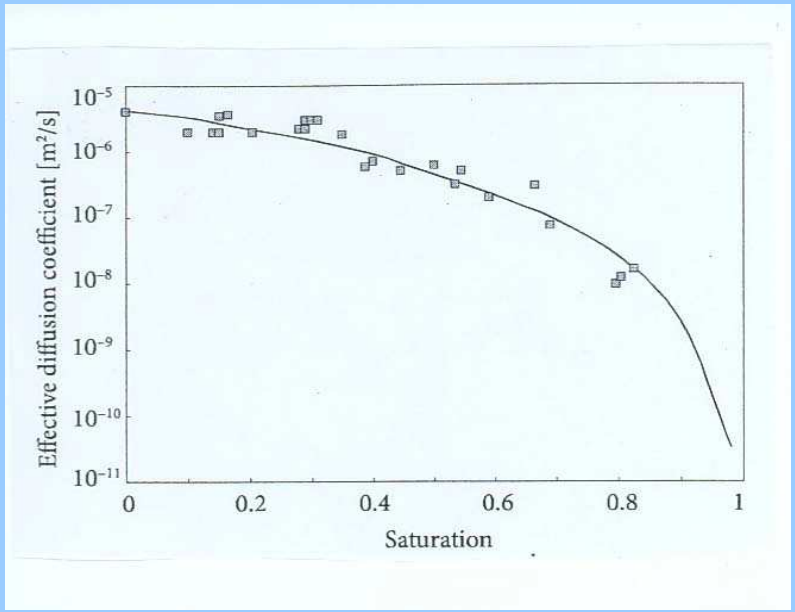
(3) $Fe^{3+} + 3H_2O = Fe(OH)_3(s) + 3H^+$

(4) $FeS_2(s) + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16H^+$

Oxygen transport in mine tailings is by diffusion, described by 1. Fick`s Law:

$$J_{O_2} = -D_{O_2} \cdot \frac{\partial C_{O_2}}{\partial x}$$

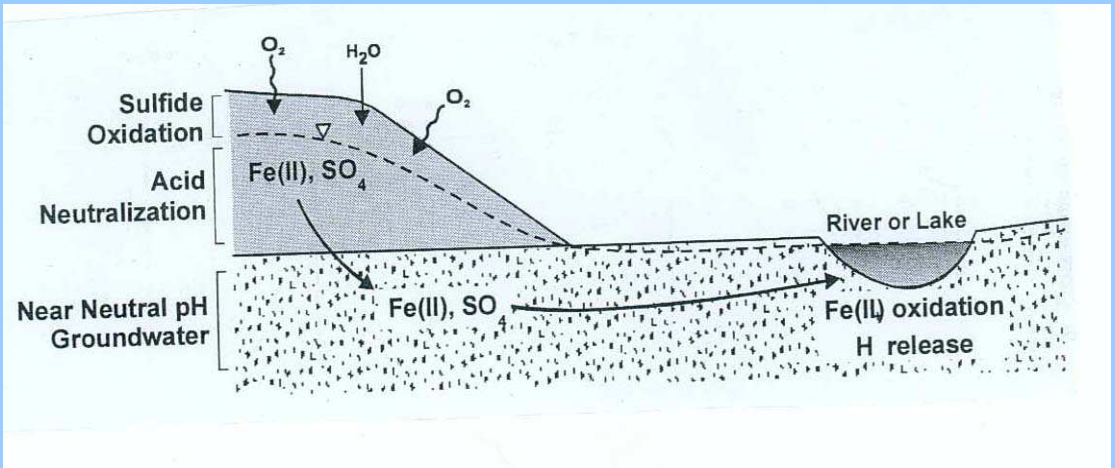
where D_{O2} is effective diffusion coefficient for oxygen, which depends on water saturation of mine tailings:



Elberling, Nicholson, 1996

There are several geochemical zones in and around mine tailings:

(1) pyrite oxidation zone, (2) neutralization zone in mine tailings, (3) plume out of mine tailings and (4) discharge of the plume to surface water bodies (lakes, creeks etc.):



Blowes, Ptacek, 2003

Neutralization reactions:

(1) Calcite dissolution

$CaCO_3(s) + H^+ = Ca^{2+} + HCO_3^-$

(2) Siderite dissolution

$FeCO_3(s) + H^+ = Fe^{2+} + HCO_3^-$

(3) Aluminium hydroxide dissolution

$Al(OH)_3(s) + 3H^+ = Al^{3+} + 3H_2O$

(4) Ferric hydroxide dissolution

$Fe(OH)_3(s) + 3H^+ = Fe^{3+} + 3H_2O$

(5) Dissolution of silicates

$Silicate(s) + 4H^+ = Na^+ \text{ etc.} + Al^{3+} + H_4SiO_4$

- calcite dissolution is fast and buffers pH around 6.0

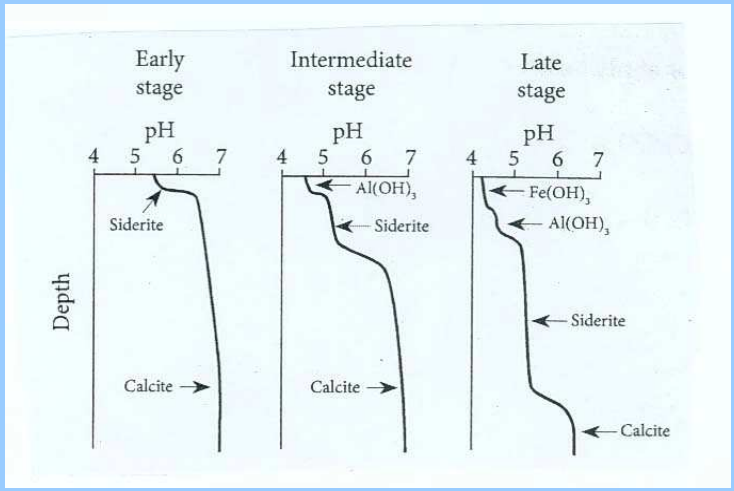
- dissolution of siderite is slower and buffers pH around 5.0

- dissolution of $Al(OH)_3$ is slow, buffers pH around 4.0 and produces Al

- dissolution of $Fe(OH)_3$ is slow and buffers pH around 3.0

- dissolution of silicates is very slow and produces Al

Neutralization zones are moving with time:



Blowes, Ptacek, 1994

Reactions in discharge zone:

(a) Precipitation of aluminium hydroxide:

$Al^{3+} + 3H_2O = Al(OH)_3(s) + 3H^+$

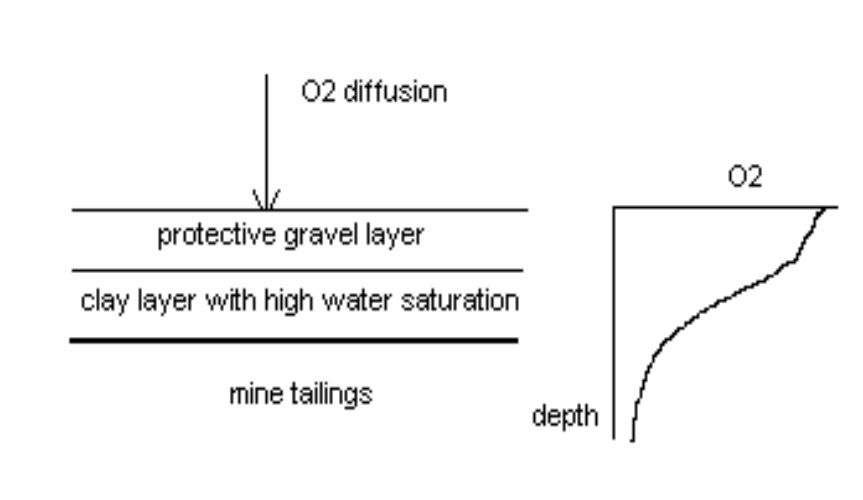
(b) Oxidation of Fe(II) and precipitation of ferric hydroxide:

$Fe^{2+} + 0.25O_2 + 2.5H_2O = Fe(OH)_3(s) + 2H^+$

Both reactions produce acidity, but hydroxides are adsorbents of contaminants like Pb, Zn, Cd etc.

Prevention of acid mine drainage:

(1) Aplication of clay layers as oxygen penetration barriers



(2) Aplication of surface layers with organic matter for oxygen consumption

(3) Complete flooding of mine tailings

CONCLUSIONS

- There are 2 principal types of mining wastes: mine tailings and waste rock, in mine tailings oxygen is transported by diffusion, in waste rock by diffusion and by convection;

- transport of oxygen by diffusion depends on effective diffusion coefficient for oxygen which depends on water saturation of mine tailings;

- principal geochemical zones in mining wastes are: - pyrite oxidation zone, - neutralization zone, - plume out of mining wastes, and – zone of plume discharge into surface water;

- neutralization reactions sequence is: calcite, siderite, aluminium hydroxide and ferric hydroxide;

CONCLUSIONS (continuation)

- in discharge zone reactions like aluminium hydroxide precipitation and ferric hydroxide precipitation produce acidity;

- principal method of acid mine drainage prevention is the installation of oxygen penetration barriers on the surface of mining wastes (clay layers with high water saturation and organic matter layers, where oxygen is consumed); prevention is always better than remediation;