Biotechnology Final Project - Universitat Autònoma de Barcelona - June 2014

APPLICATION OF SULFATE REDUCING BACTERIA IN ACID MINE DRAINAGE ACTIVE REMEDIATION

Author: Judith Matavacas Martínez - Tutor: Antoni Solé Cornellá

WHAT IS ACID MINE DRAINAGE?

Acid mine drainage (AMD) is one of the main contaminating problems derived from the mining industry and metallurgy, as it is an acidic metal and sulfate-containing wastewater.
It is mainly a consequence of the exposure of iron pyrite (FeS_2) among other sulfide minerals to both oxygen and water during mining and processing of metal ores and coal, which triggers the accelerated oxidation of these minerals.

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

PROBLEMS ASSOCIATED WITH AMD

» Contaminated drinking water.

» Affected growth and reproduction of plants and animals.

» Corroding effects of acid on infrastructures.

AIMS

Among all the bioremediation strategies for AMD, this work focuses on active technologies. The two principal standards will be described and compared. Therefore, real examples will be analyzed.

APPLICATION OF SULFATE REDUCING BACTERIA (SRB) FOR AMD REMEDIATION

Under anaerobic conditions, SRB catalyze the reduction of sulfate to sulfide, generating alkalinity by transforming a strong acid (sulfuric) into a relatively weak acid (hydrogen sulfide):

$$SO_4^{2-} + 2\,CH_2O + 2\,H^+ \rightarrow H_2S + 2\,H_2CO_3$$

Many metals react with the produced H_2S to form highly insoluble sulfides:

$$Fe^{2+} + H_2S \rightarrow FeS\,(s) + 2H^+$$

AMD BIOREMEDIATION
- Decrease of sulfate concentration
- Removal and recovery of metals

SULFIDOGENIC BIOREACTORS

Sulfidogenic bioreactors contain SRB, which treat the entering AMD. They are designed to optimize the production of H_2S in order to obtain clean process water of neutral pH and low metal concentration. Metals are removed as insoluble sulfides.

Two main technologies using sulfidogenic bioreactors have been described: *Thiopaq* and *Biosulfide*.

Electron donor for SRB

SRB require the addition of an electron donor to achieve sulfate reduction . To this efford, they use several low molecular weight substrates, such as ethanol and hydrogen.

Ethanol
» Small-scale applications.
» High operational costs.

$$3\,SO_4^{2-} + 2\,C_2H_5OH \rightarrow 3\,HS^- + 3\,H_2O + 3\,HCO_3^- + CO_2$$

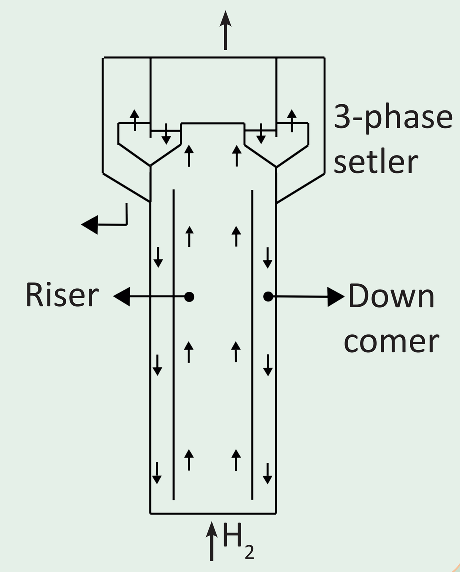
Hydrogen gas
» Large-scale applications.
» Low production of biomass.
» Produced on site by reforming natural gas.
» High investment costs.

$$SO_4^{2-} + 4\,H_2 + H^+ \rightarrow HS^- + 4\,H_2O$$

Reactor type

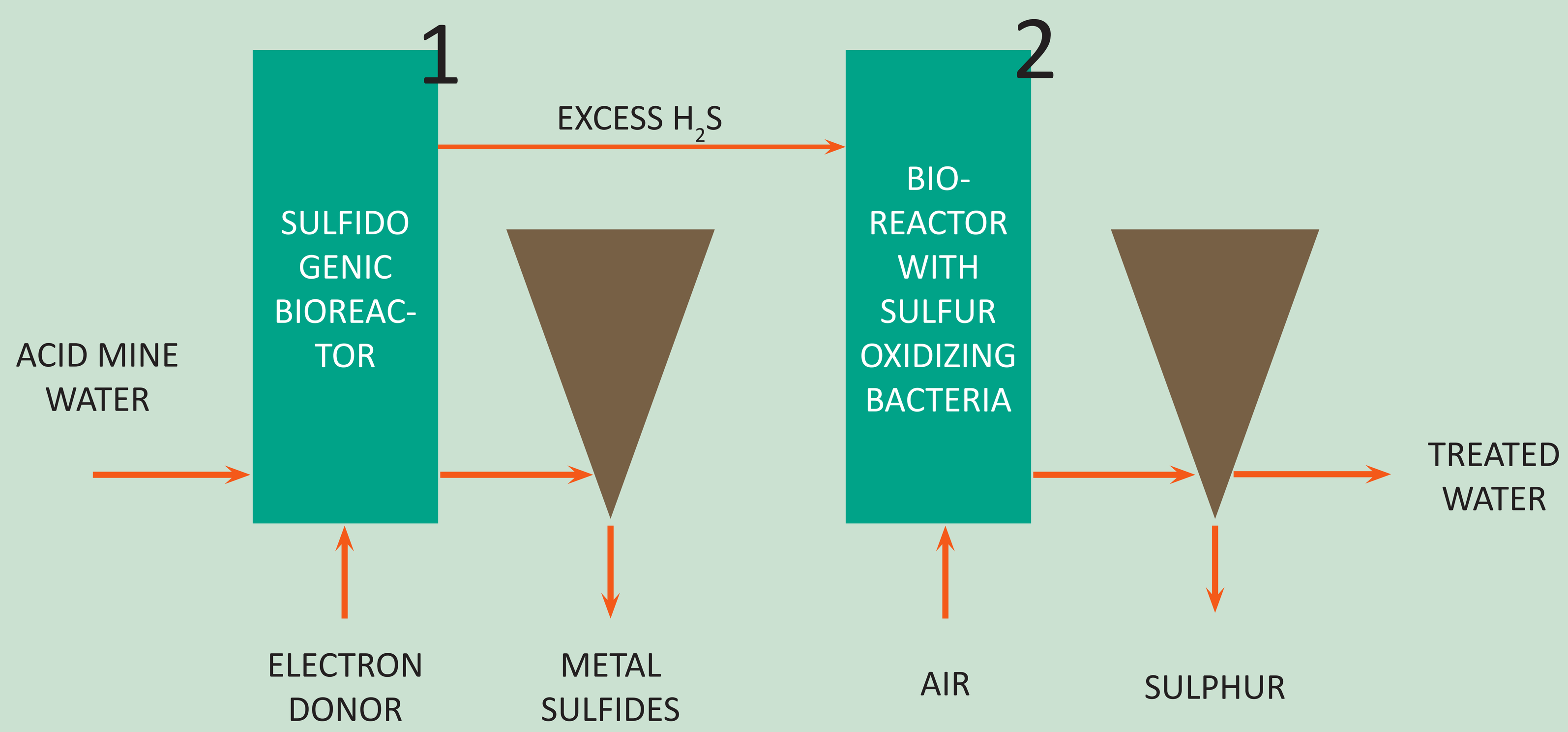
CIRCOX® gas-lift loop

» Optimum mixing and mass transfer of H_2.
» 3-phase separator: safeguards biomass retention. Enhance gas/liquid separation.
» Bacteria grow into agregates. Excess must be removed.



THIOPAQ

» Anaerobic sulfate reduction by SRB and metal precipitation in a single tank (1).
» (Optional) Aerobic oxidation of any excess H_2S to elemental sulfur by sulfide-oxidizing bacteria (2).



- *Thiopaq* technology can treat effectively low metal concentration streams.
- However, the process has limitations, especially when it comes to the treatment of high metal concentration streams:
  » Sensitivity of SRB to low pH and high metal concentration.
  » Difficulty to maintain the optimum conditions due to seasonal fluctuations of the entering mine water.
  » Plugging in the bioreactor, as a consequence of precipitation of sulfide sludge.
  » Sludge contains a mixture of metals.
  » Sludge also contains biomass.
  } Greater volume of sludge increases disposal expense

Case of Study. Budel Zinc Refinery (Netherlands)

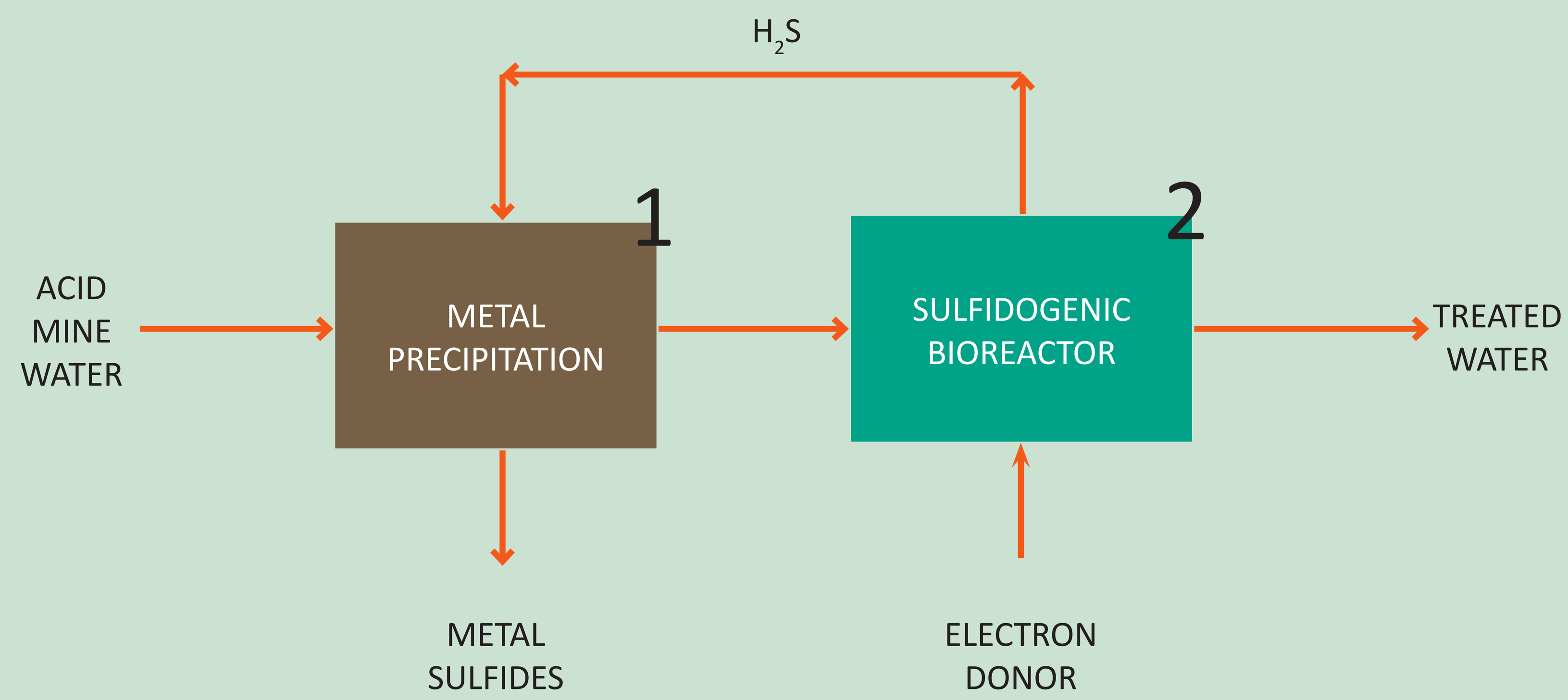
Treatment of AMD by neutralization with lime: producion of gypsum → **Legislative restrictions** for further production of residues → ***Thiopaq* technology:** treatment of sulfate and recovery of zinc sulfide, which is recycled to the refinery

» Industrial treatment plant (2000)
» Influent = 40 m^3/h
» Electron donor: hydrogen

Component	Influent (mg/l)	Effluent (mg/l)
Sulfate	15,000	<250
Zinc	10,000	<0.3

BIOSULFIDE

» Chemical precipitation of metal sulfides (1) separated from biological sulfate reduction (2).
» In chemical tank, raw AMD contacts with H_2S generated in the biological tank.



- *Biosulfide* technology is useful with low and high metal concentration streams.
- It presents some advantageous aspects compared to *Thiopaq* technology:
  » SRB receive very low concentration of metals.
  » Optimum conditions easily maintained.
  » Sulfide sludges isolated in chemical circuit.
  » Selective separation and removal of metals by using several precipitation tanks.

Case of study. Kennecott Utah Copper (USA)

***Biosulfide* technology:**
Treatment of a contaminated groundwater stream with high levels of metals and sulfate.

» Pilot treatment plant (1995)
» Influent = 0.2 m^3/h
» Electron donor: hydrogen

Component	Influent (mg/l)	Effluent (mg/l)
Sulfate	30,000	<500
Copper	60	<0.1
Iron	675	<0.3
Zinc	65	<0.1
Manganese	350	0.3
Aluminium	2,200	<2

CONCLUSIONS

» AMD remediation with sulfidogenic reactors can address the threat that mine wastes pose to the environment.
» In addition to the environmental benefit, it can trigger economic advantages by recovering valuable metals.
» *Biosulfide* technology has many upsides in comparison to *Thiopaq* technology. However, every situation requires an individualized design of the treatment process.
» There is a lack of awareness in the mining industry and metallurgy in the aspect of implementing active and biological technologies.

REFERENCES

[1] Johnson, D.B., Hallberg, K.B., Acid mine drainage remediation options: a review, *Science of the Total Environment* (2005), 338 : 3–14.
[2] Van Lier, R.J.M., Buisman, C.J.N., Piret, N.L., Thiopaq technology for the mining and metallurgical industries, Paques Bio Systems B. V., The Netherlands.
[3] Rowley, M.V., Warkentin, D.D., Yan, V.Y., Piroshco, B.M., The biosulfide process: integrated biological/chemical acid mine drainage treatment - results of laboratory piloting, International Land Reclamation and Mine Drainage Conference, Pittsburgh (1994), 24 – 29.