Biological Source Treatment of Acid Mine Drainage

- an applied study

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Acknowledgements

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Outline

- Remedies for acid mine drainage (AMD)
- Biological Source Treatment (BST)
- Field pilot studies

Active and Passive Treatments

AMD Source

$$2FeS + 7O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+ \quad (1)$$

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

$$4Fe^{3+} + 12H_2O \rightarrow 4Fe(OH)_3 + 12H^+ \quad (3)$$

$$FeS + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \quad (4)$$

Active and Passive Treatments

Chemical

- Lime injection (active)
  - Increase pH and precipitate metals as hydroxides
  - Expensive
  - Production of waste contaminated with heavy metals
    - Metal remobilization at landfill
- Anoxic limestone drains (passive)
  - Increase alkalinity
  - Need to avoid precipitation of metal hydroxides
    - Metal hydroxide precipitation decreases permeability
  - High-concentrations of metals can build up precipitates and cause failure of drain

Active and Passive Treatments

Biological (Sulfate-Reducing Bacteria)

$$2\ CH_3CHOHCOO^- + 3SO_4^{2-} + 2H^+ = 6HCO_3^- + 3H_2S$$

$Metal^{2+} + S^{2-}$ = Metal-S (precipitates) + microbial growth (biofilm)

- Sulfidogenic bioreactor (active)
  - Utilize SRB to increase pH and immobilize metals
- Anaerobic wetlands (passive)
- Compost bioreactor (passive)

Active and Passive Treatments

AMD recharge drives up cost of both active and passive treatments due to long term maintenance

Performance variations may be caused by seasonal changes in biological systems

Biological Source Treatment (BST)

Creation of an reduced environment at the AMD-producing sources

Prevention of oxygen from oxidizing AMD source materials

Biological Source Treatment (BST)

I. AMD Source Identification

- Site history
- Hydrogeological assessments
- Electromegnatic survey

II. SRB Enhancement and Establishment

- Injection of adequate substrate
- Inoculation of SRB
- Bio-barrier formation on AMD source surface

Biological Source Treatment (BST)

- Creates a biological barrier composed of microbial cells and extra-cellular polymers
- Strongly limits diffusion of oxidants (e.g., DO)
  - Provides a “reductive” barrier
- Covers AMD source surface with biogeochemical structures (e.g., biofilm)
  - Prevents oxidation and re-oxidation

Key Components of BST

- Source of SRB
- Survival of SRB in low pH environment
- Adequacy of organic contents or substrate amendments to achieve and sustain bio-barrier and the reducing condition

SRB Sources

high populations and acid tolerance

- Wetland or lagoon sediments
  - Anaerobic sediments
- Sewage Sludge
  - Oxygen tolerant SRB
  - SRB re-activate in anoxic storage
  - Other associated microbial populations

Substrate Sources

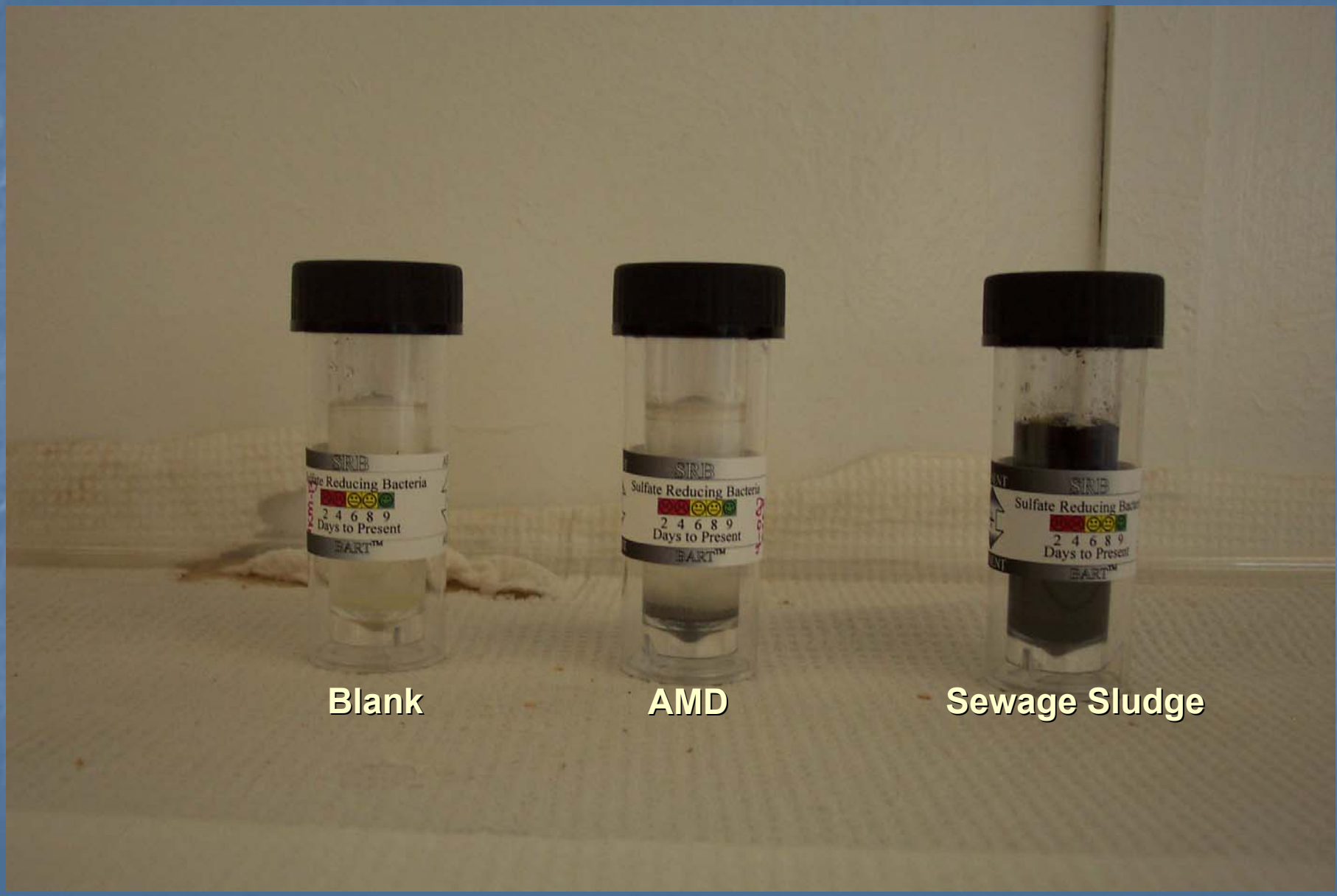
high organic content and simple structure

- Chemicals
  - Lactate
  - Polymers (e.g., HRC)
- Waste Products
  - Dairy wastes
  - Brewery wastes

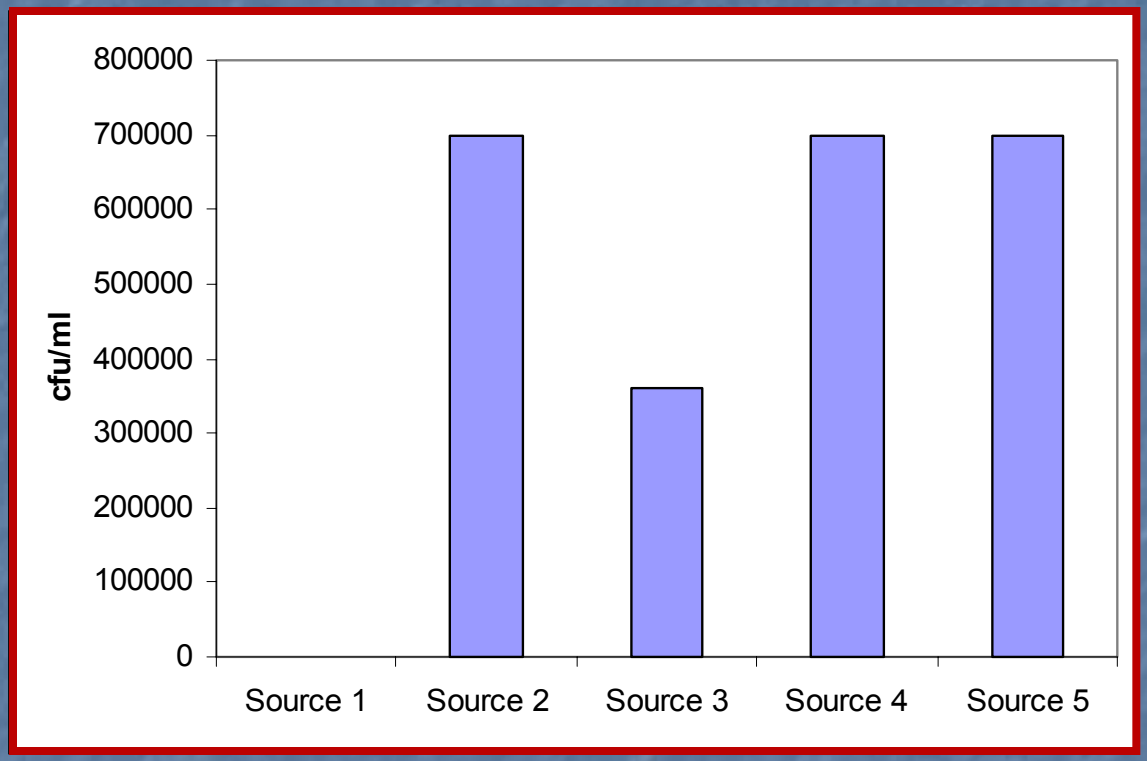
SRB in Aerated Sludge

- Oxygen exposure results in temporary metabolic inactivation
  - No cell death
- Potential rapid reactivation in anaerobic environment

Kjeldsen, K.U., C. Joulian, and K. Ingvorsen. 2004. Oxygen tolerance of sulfate-reducing bacteria in activated sludge. Environ. Sci. Technol. 38:2038-2043


SRB
Sulfate Reducing Bacteria
2 4 6 8 9
Days to Present
BART™
Blank
AMD
Sewage Sludge

SRB Activity Screening



		cfu/ml
Source 1	AMD Water, SVC, TN	200
Source 2	Sewage Sludge, Dunlap, TN	700000
Source 3	Sewage Sludge, Laramie, WY	359000
Source 4	Sewage Sludge, Cheyenne, WY	700000
Source 5	Sewage Sludge, Fort Collins, CO	700000

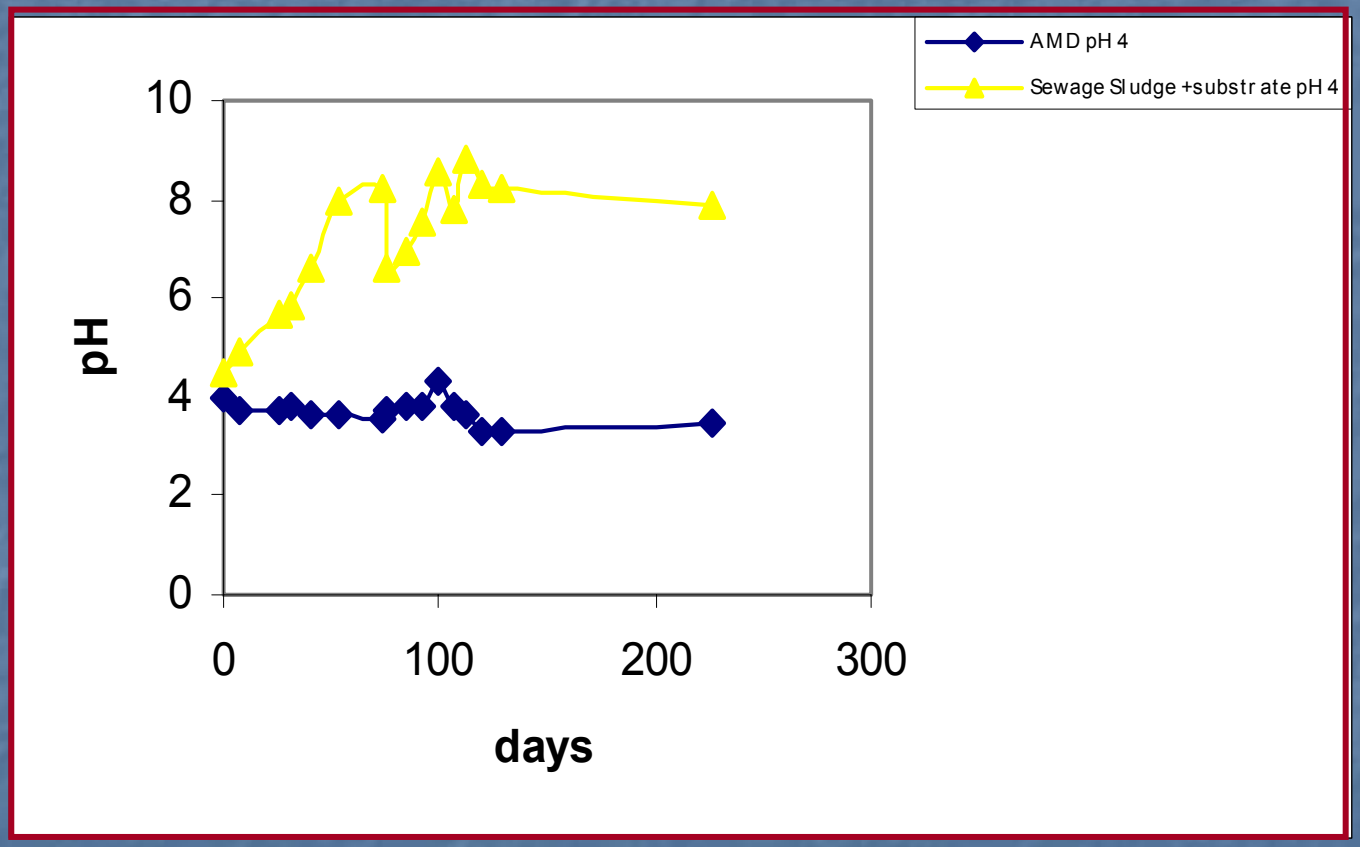
Benefits of BST

- **"Few or No Reapplications "**
  - One injection of SRB source
  - One or few injections of substrate
  - Increased alkalinity
  - Metal precipitation and alkalinity increase
  - Long term prevention of AMD source oxidation
- **Cost-effective**

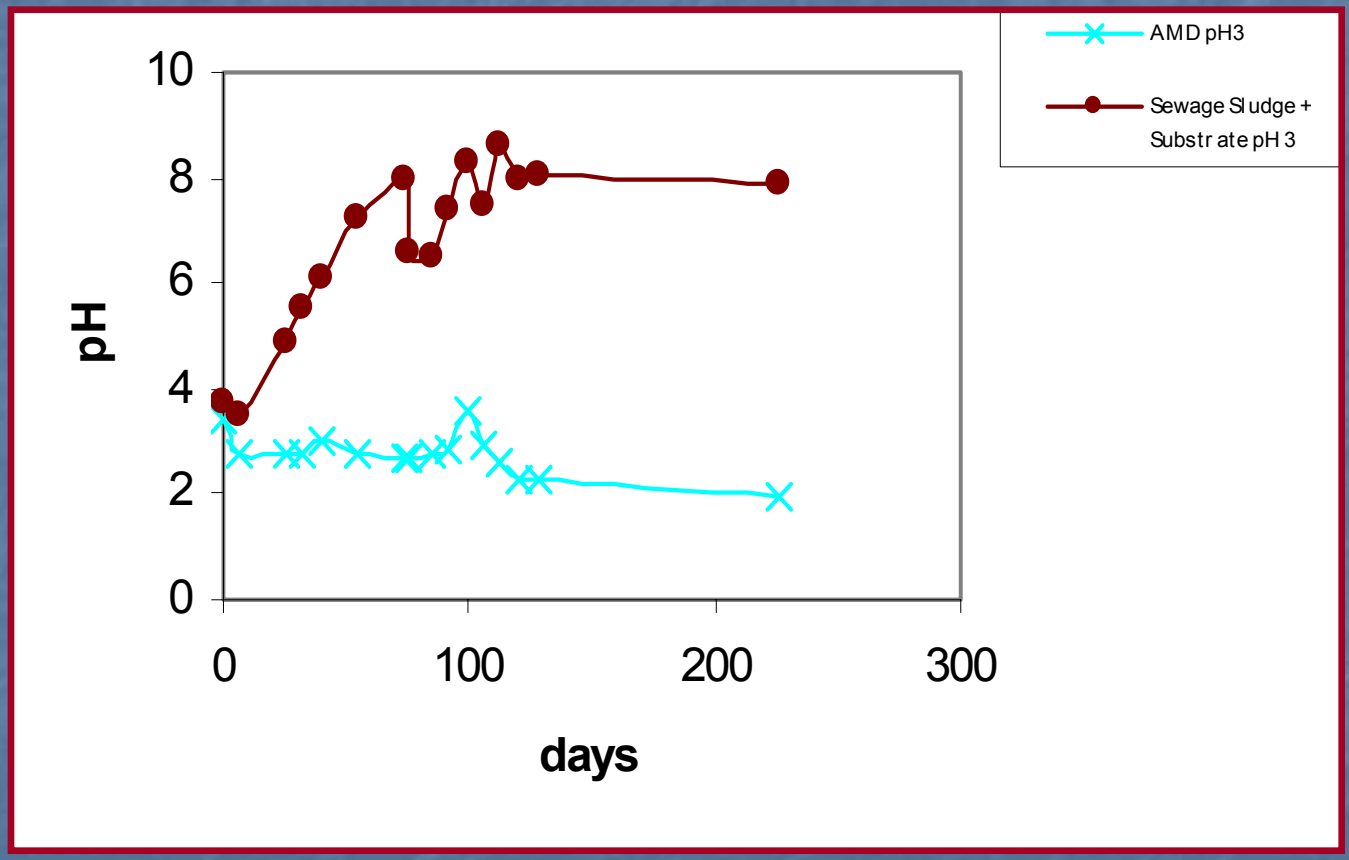
Microcosm Studies

- Microcosms
  - AMD water samples from a reclaimed coal mine
  - Sewage Sludge
  - Dairy waste (milk) as substrate
- pH threshold
- pH longevity

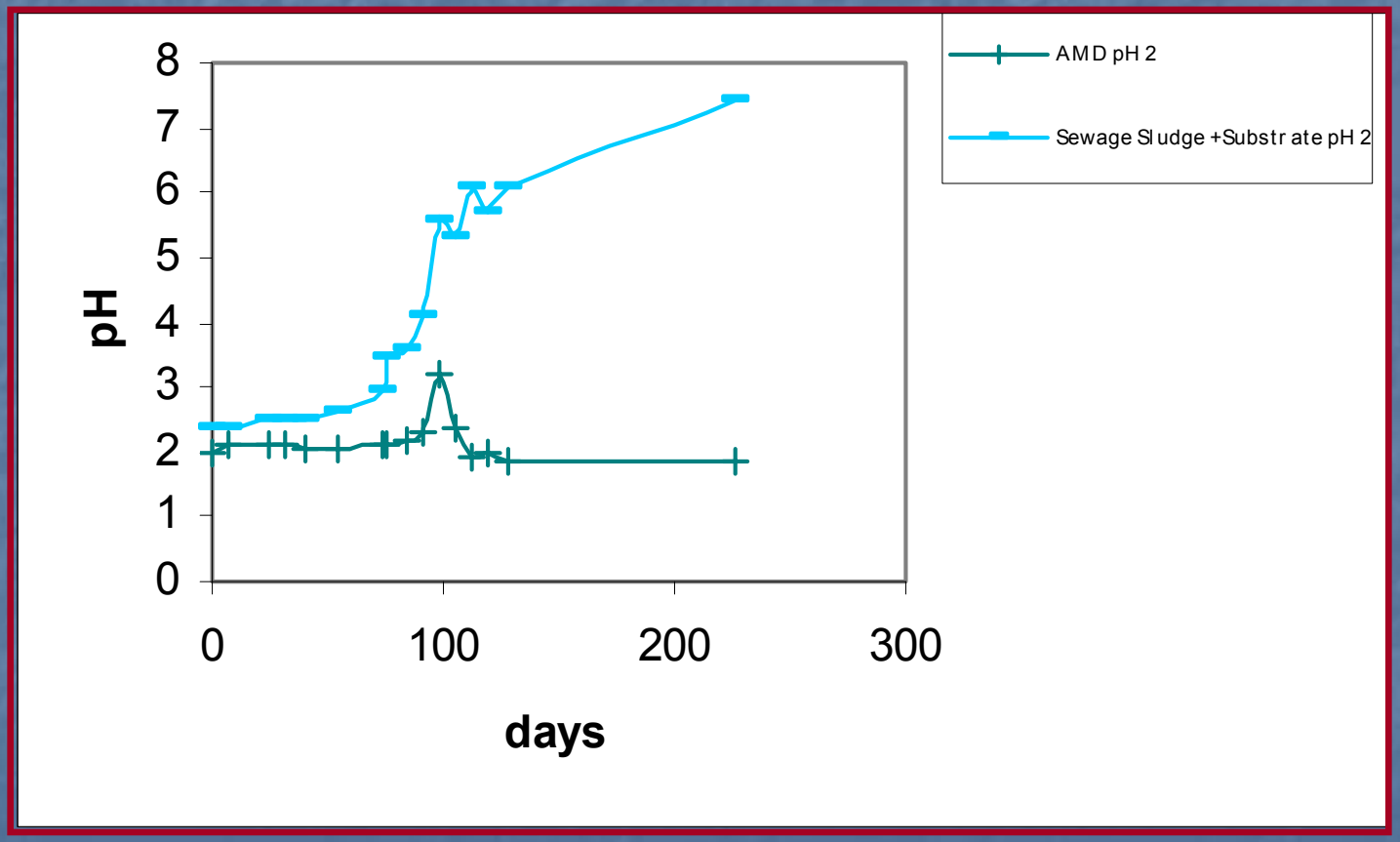
pH Threshold



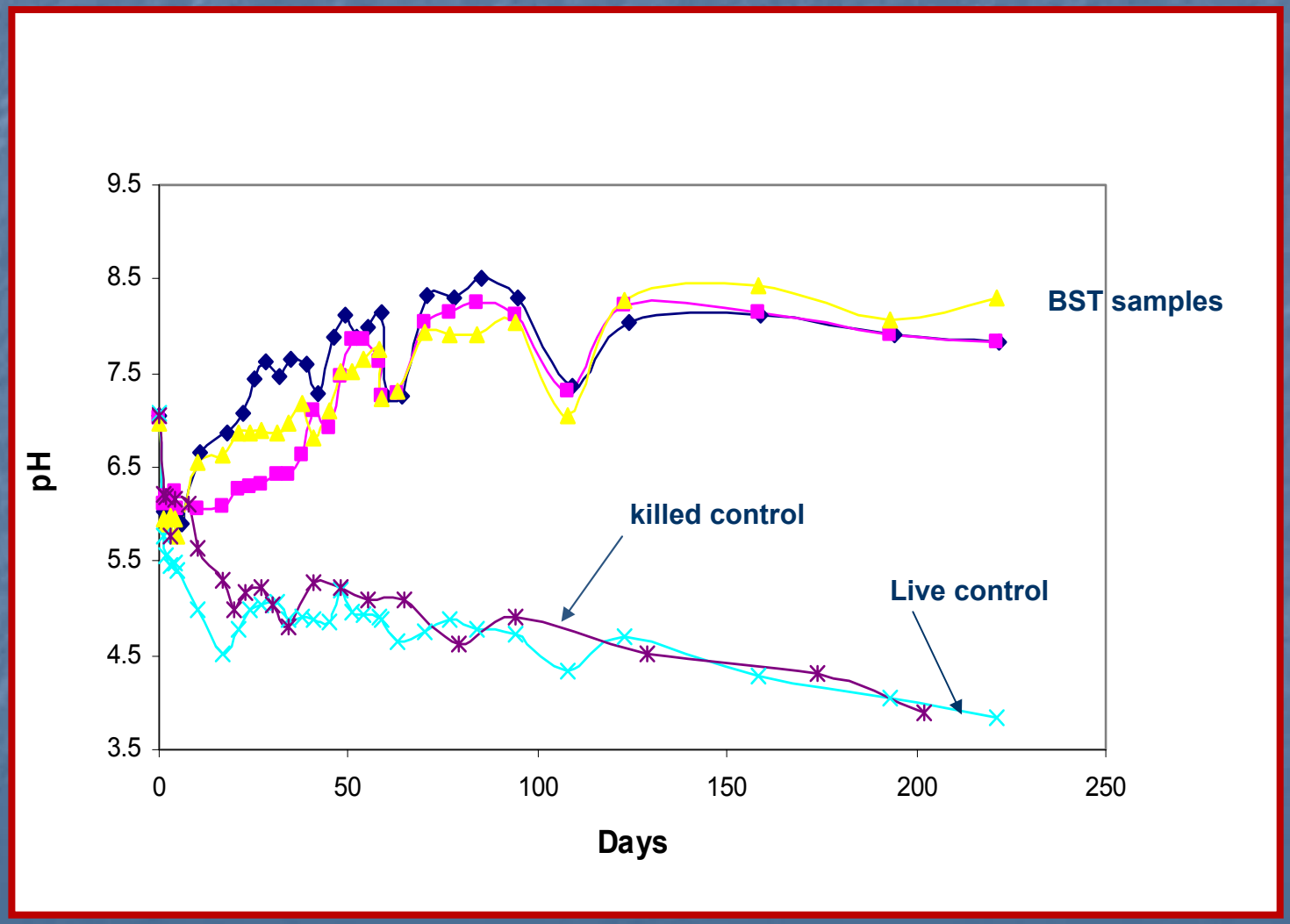
pH Threshold



pH Threshold



AMD Bio-treatment in Laboratory Samples



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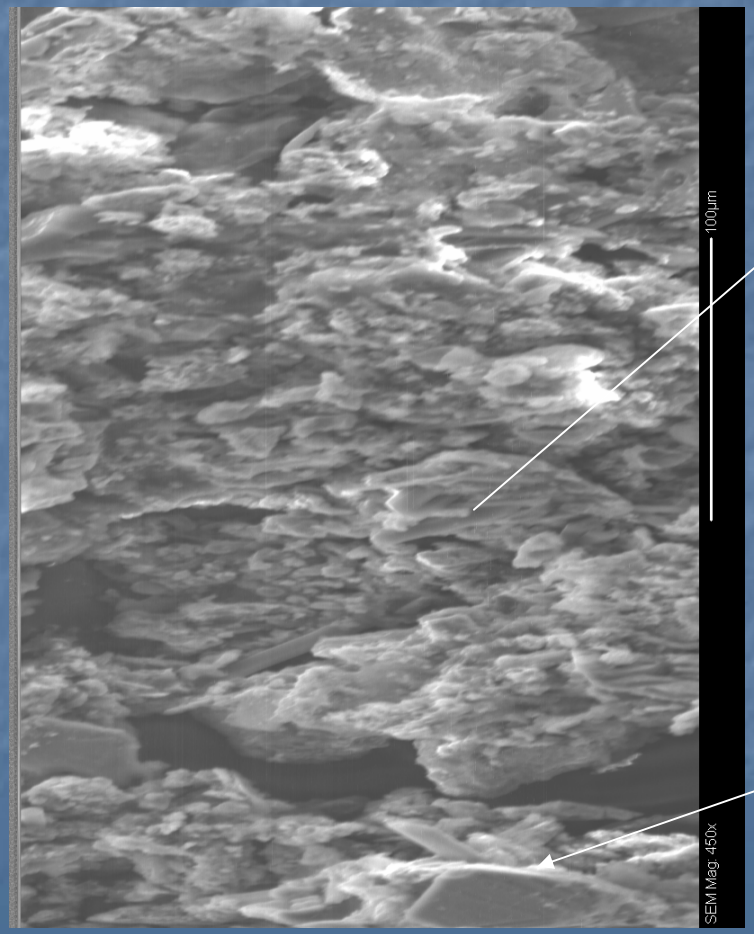
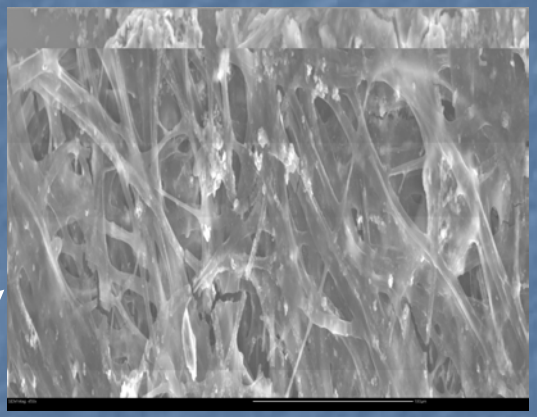




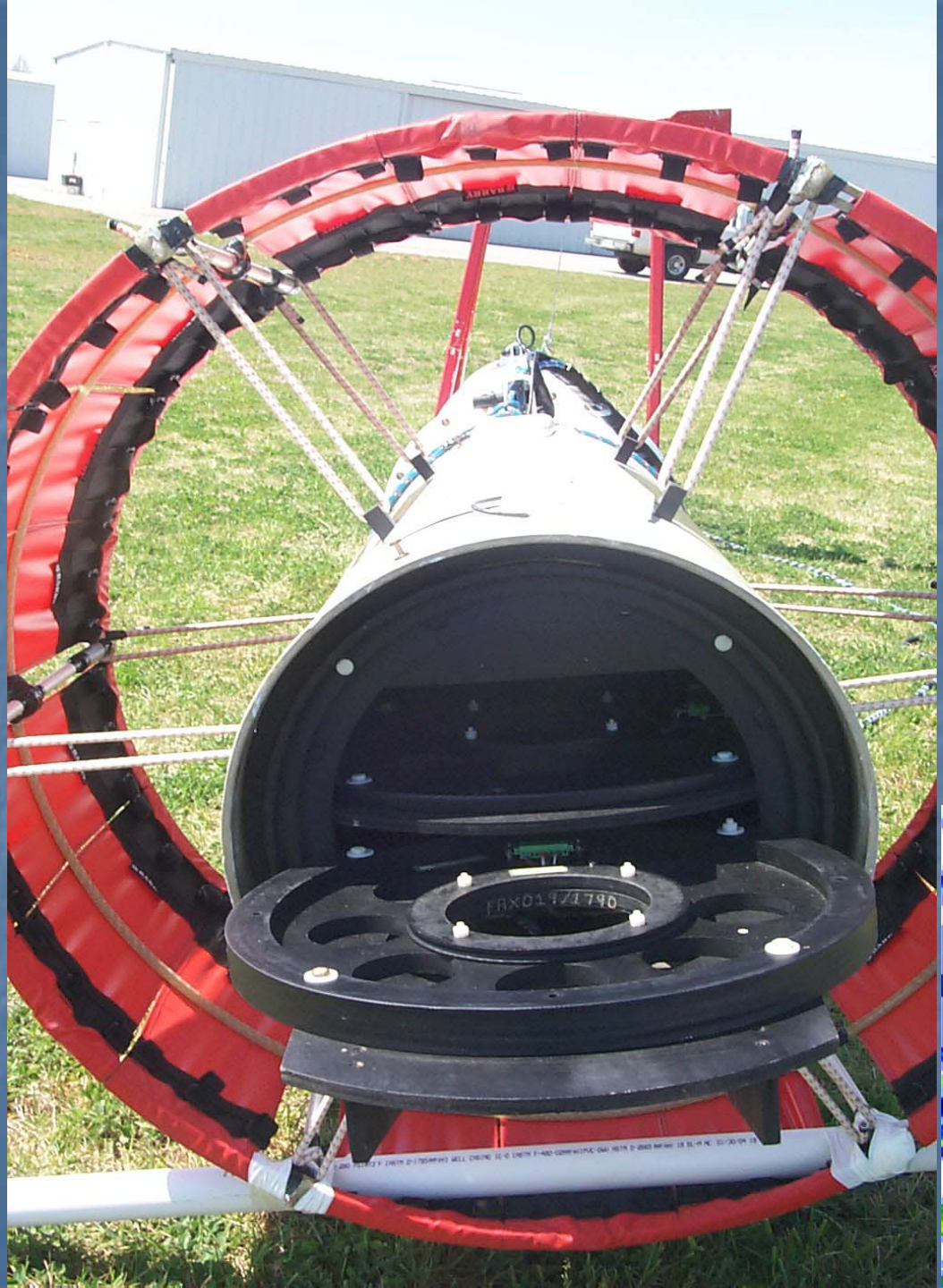
Biological Formation

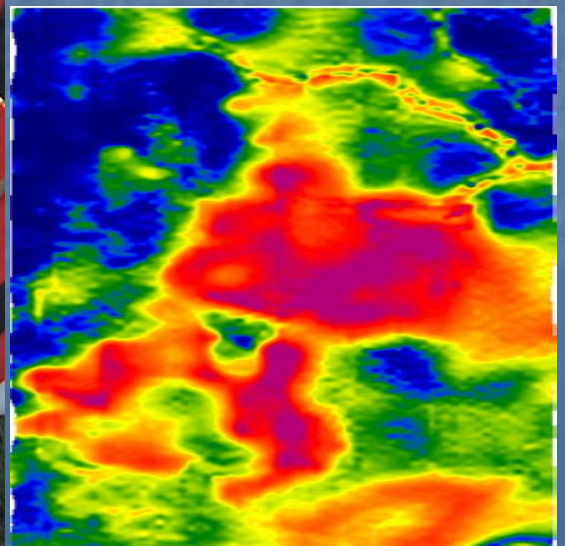
Pyrite Surface

Pilot Field Study

- Identification of “hot spots” by helicopter electromagnetic survey
- Injection well establishment at hot spots
- Injection of sewage sludge and substrate at hot spots
- Monitoring

EM Scanning of AMD Source





FUGRO
RESOLVE

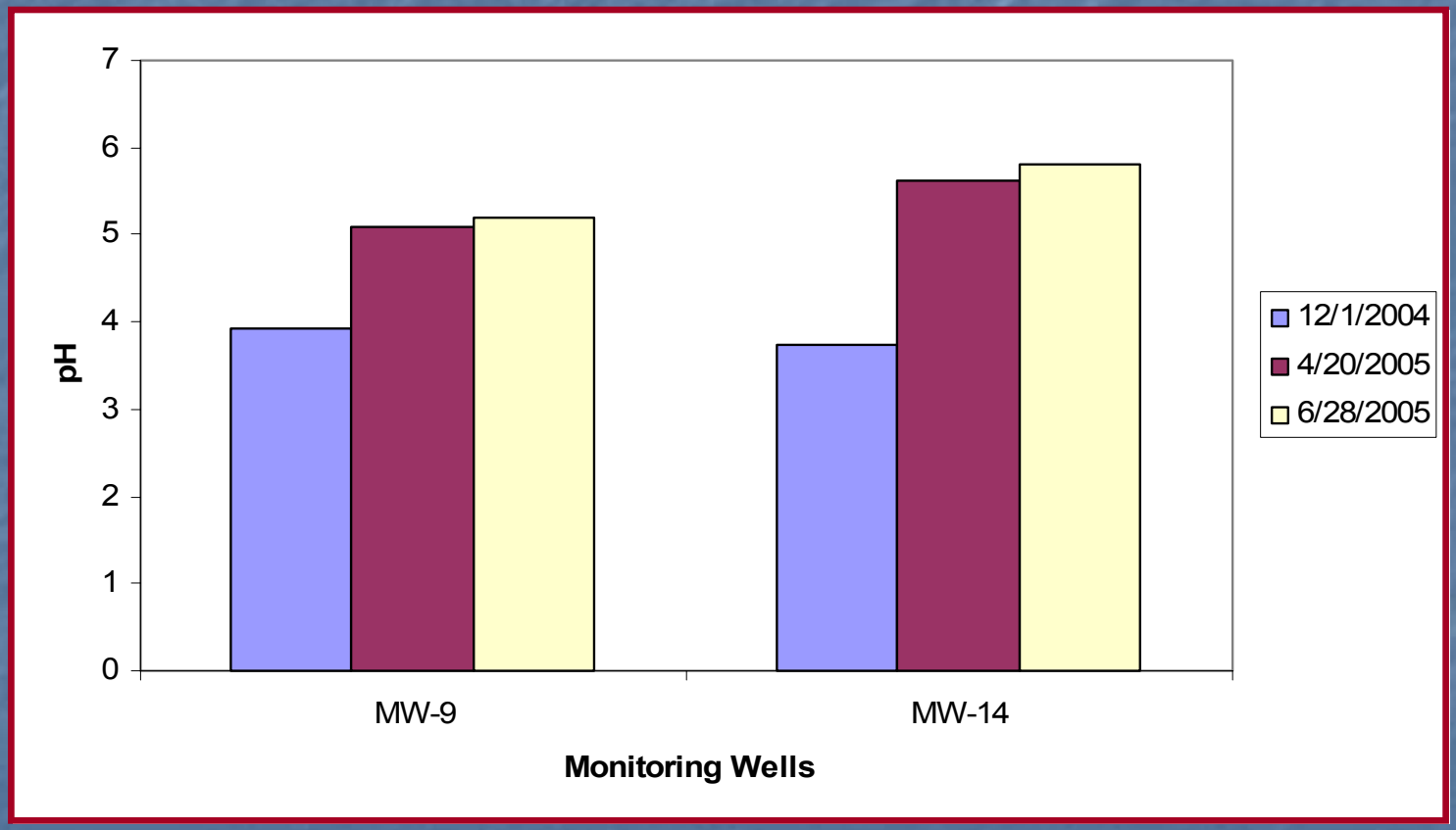
RESOLVE

BST Field Applications

Drilling of Injection of BST 'cocktail' at a Mine Site

Acid Mine Drainage From a Site in Tennessee

BST Field Data



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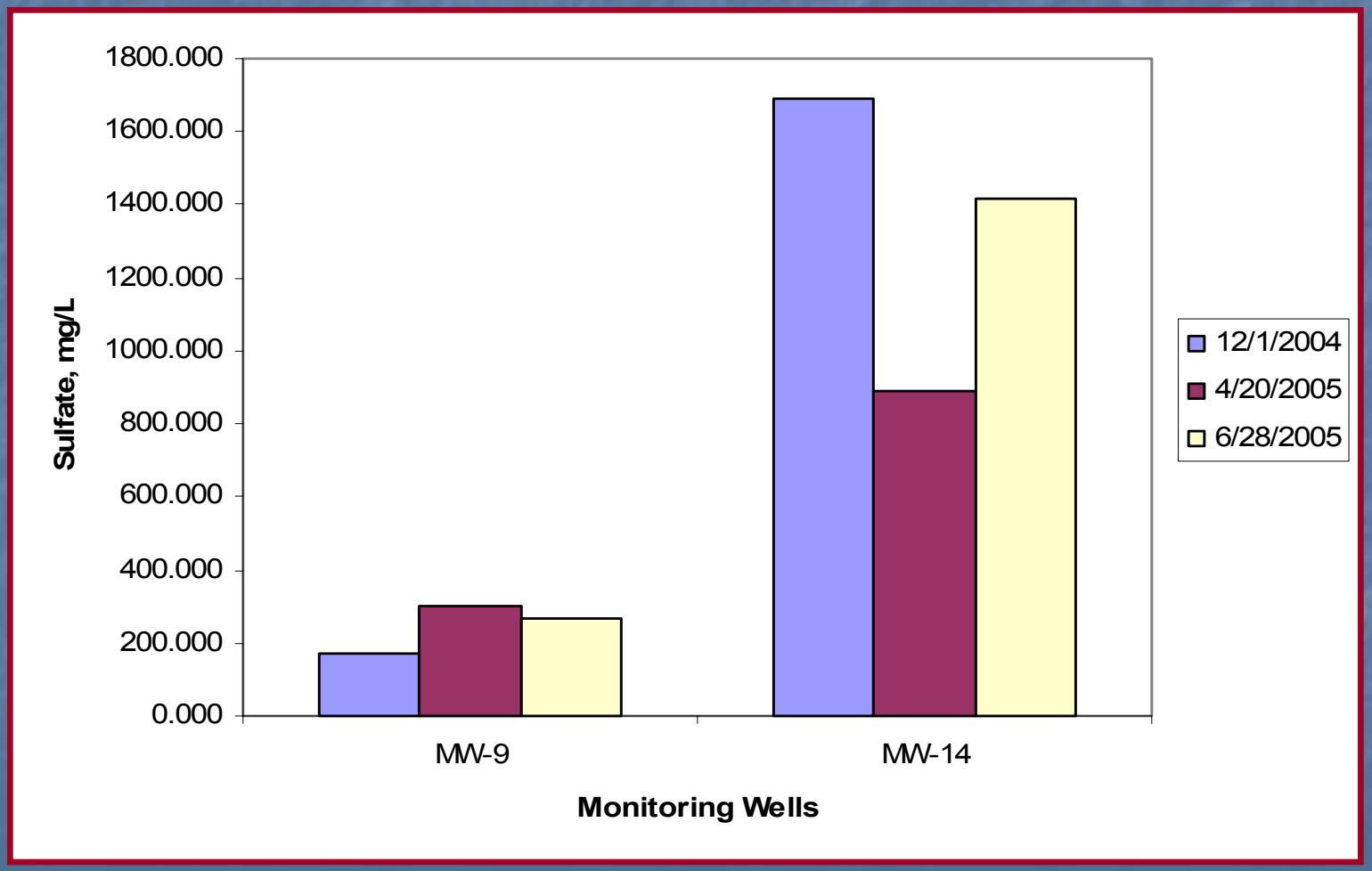

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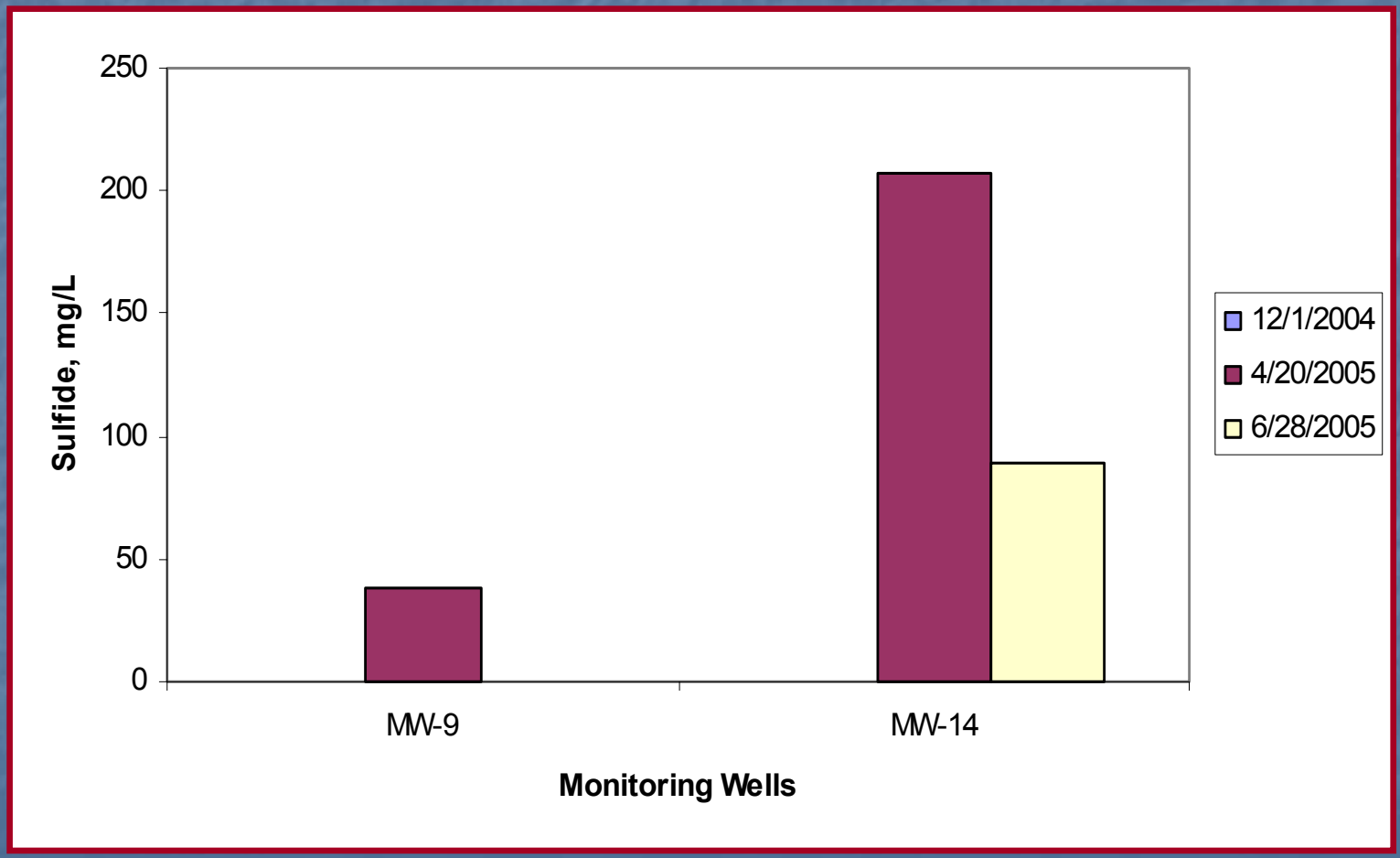

Findings from BST Studies

- AMD treatment by using BST has shown >1 year of pH stabilization.
- SRB exist ubiquitously in high populations in aerated sludge
- Sewage sludge is a viable and economical source for SRB in treating AMD, SRB from sewage sludge maintain activity at pH ~2.0
- Sulfide production may be controlled by manipulating organic input

Other Parameters

- Anions and cations
- Total organic carbon
- Alkalinity
- Metals
- SRB population density

Conclusions

- Results from the laboratory and field pilot studies indicate that BST is a viable and cost-effective method for AMD treatment.
- More scaled-up applications in additional sites will be attempted.
- Identification of the SRB populations in aerated sludge is needed

Ideal Sites for BST Application

- Sites with distinguishable AMD source locations
- Sites with indigenous organic deposits
- Easy access to substrate and SRB sources