Microbial ecology of iron-reducing bacteria (IRB) in two types of Cu-Zn tailings

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Mine tailings

- Abandoned mine sites (Cu, Zn, Ni, Au, etc.) and exposed toxic mine tailings result from mining practices in Canada.
- Generation of acid-mine drainage (AMD) caused by the oxidation of sulfide minerals.
- Microbial ecology of Fe- and S-oxidizing bacteria have been extensively studied over the last 2 decades.
- Microbial ecology of anaerobic bacteria is not well known.

Sulfate-reducing bacteria

- In mine tailings, sulfate-reducing bacteria (SRB) are present and sometimes metabolically active (Fortin et al., 2000; 2002).
- SRB prefer neutral pH conditions and use various organic electron donors and sometimes H_2.
- SRB can sporulate.
- Their presence depends on the availability of organic electron donors and sulfate, pH,and redox potential.

$$2(CH_2O) + SO_4^{2-} \Rightarrow H_2S + 2HCO_3^-$$

$$H_2S + Fe^{2+} \Rightarrow FeS_{(s)} + 2H^+$$

Iron-reducing bacteria (IRB)

- IRB have been isolated in environments impacted by mine tailings (Wielinga et al., 1999), but never recovered from mine tailings.
- Strictly anaerobic bacteria and require an electron donor (organic compounds and/or H_2).
- They can reduced various forms of Fe(III)-oxides.
- IRB can compete with SRB for some electron donors.
- Reduction of iron(III)-oxides ultimately increases the mobility of contaminants. (Urrutia et al., 1999).

$$(CH_2O) + 4FeOOH + H_2O \Rightarrow HCO_3^- + 4Fe^{+2} + 7OH^-$$

Objectives

- Assess the competition for common electron donors between IRB and SRB isolated from Cu-Zn mine tailings
- Determine the effect of pH on the competition for electron donors

Hypotheses

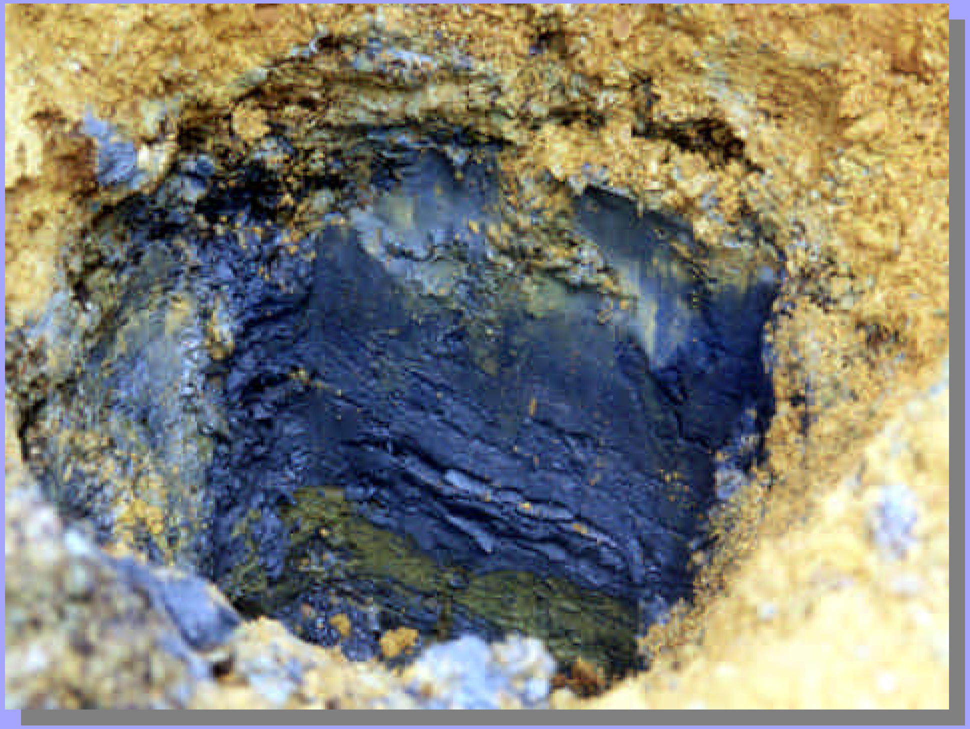
- Competition might occur for acetate, an electron donor used by both SRB and IRB
- Microbial iron reduction should dominate over sulfate reduction under acidic conditions

Experimental setup

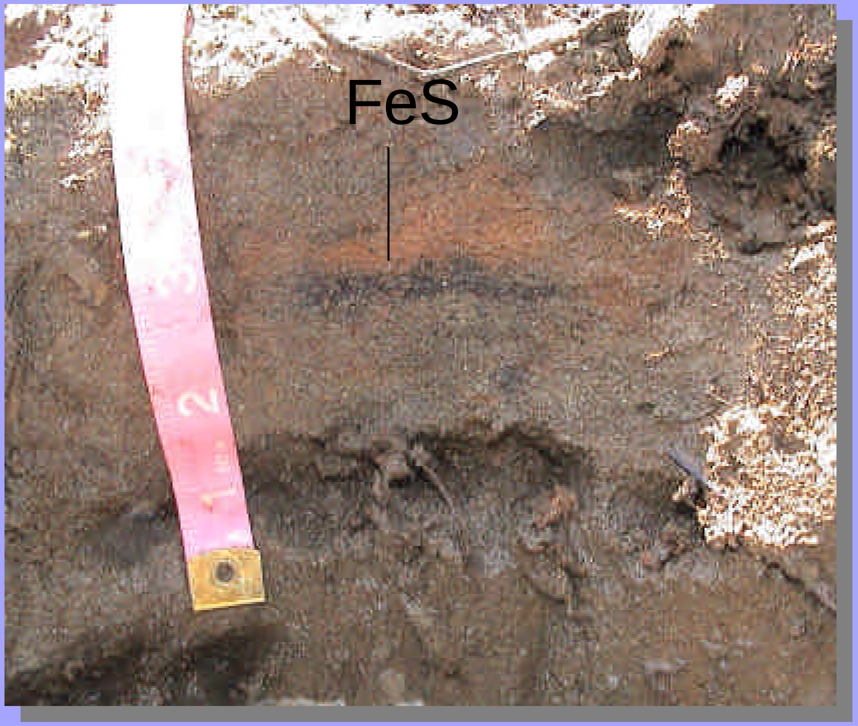
- Inoculated a chemically defined growth medium with acidic (pH 5.26) and alkaline (pH 7.36) mine tailings.
- Microbial sulfate reduction was inhibited in half of the systems with 10 mM sodium molybdate.
- Two replicates for each system (inhibited) and (non-inhibited) and a single control system (autoclaved tailings) were prepared. They each contained lactate, formate or acetate as electron donors.
- Systems from both sites were sampled bi-weekly over a period of six months.
  - pH — pH electrode
  - Fe(II) — Ferrozine method
  - HS^- — Cline method
  - IRB/SRB populations — Most Probable Number (MPN)
- Other parameters to analyze; Fe_{tot}, SO_4^{-2}, DOC and DIC

Cu-Zn tailings

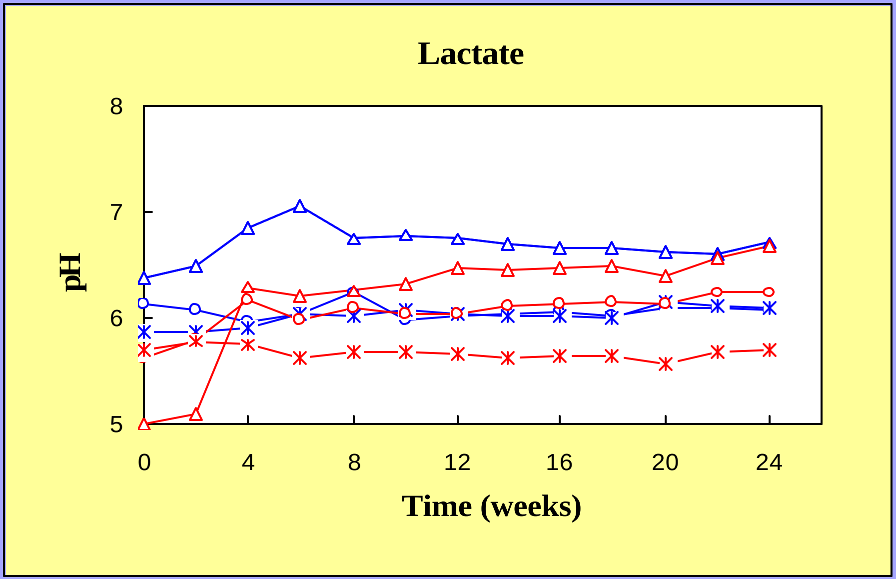
Potter: acidic

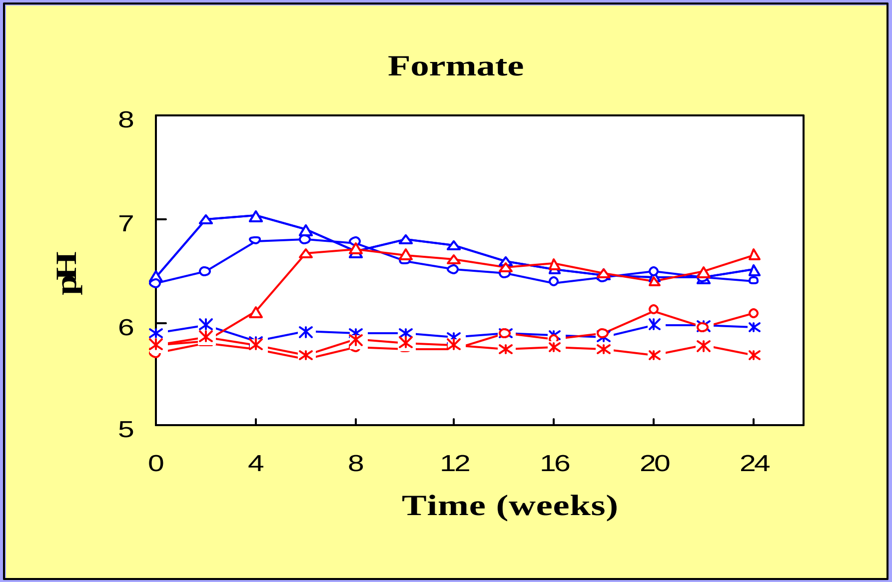


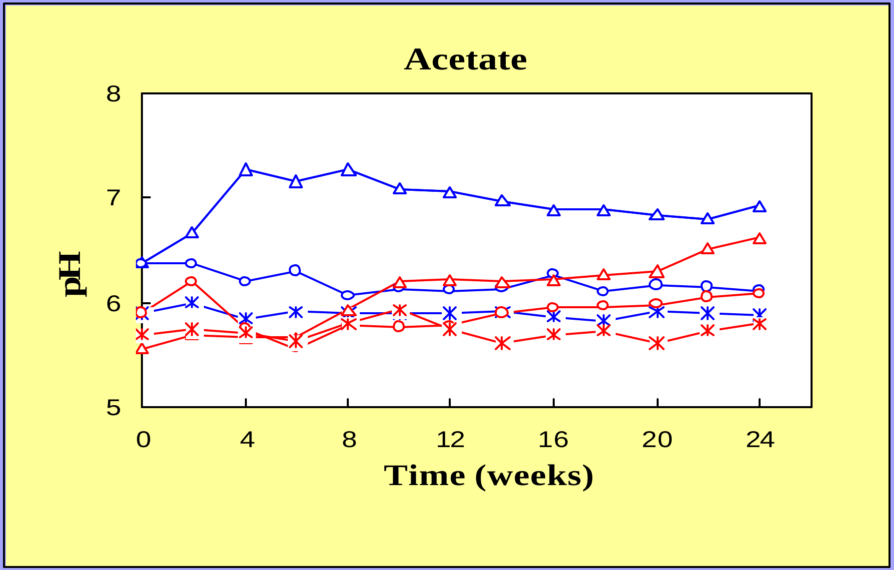
Calumet: neutral

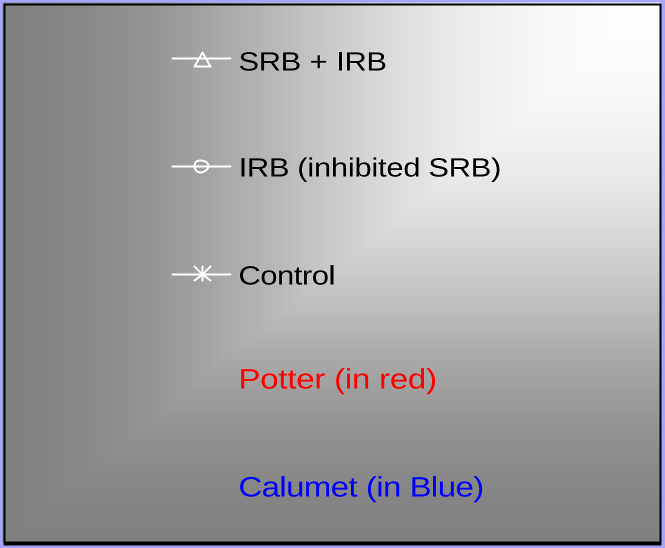


pH (Potter and Calumet)

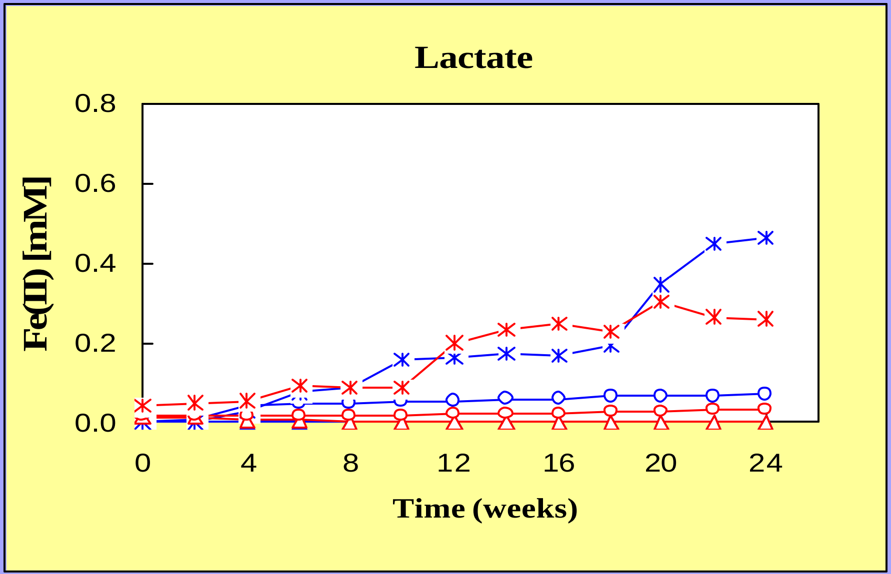


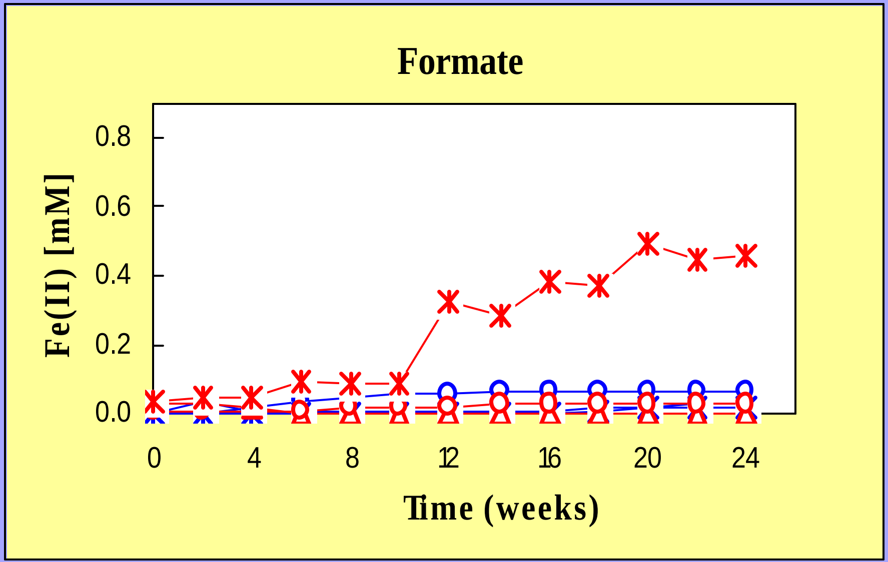


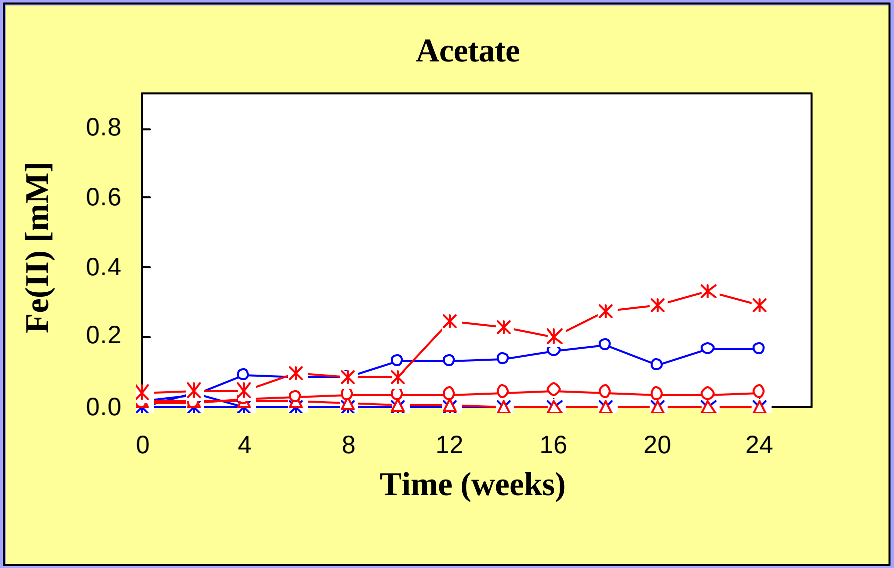




Fe(II) (Potter and Calumet)







SRB + IRB

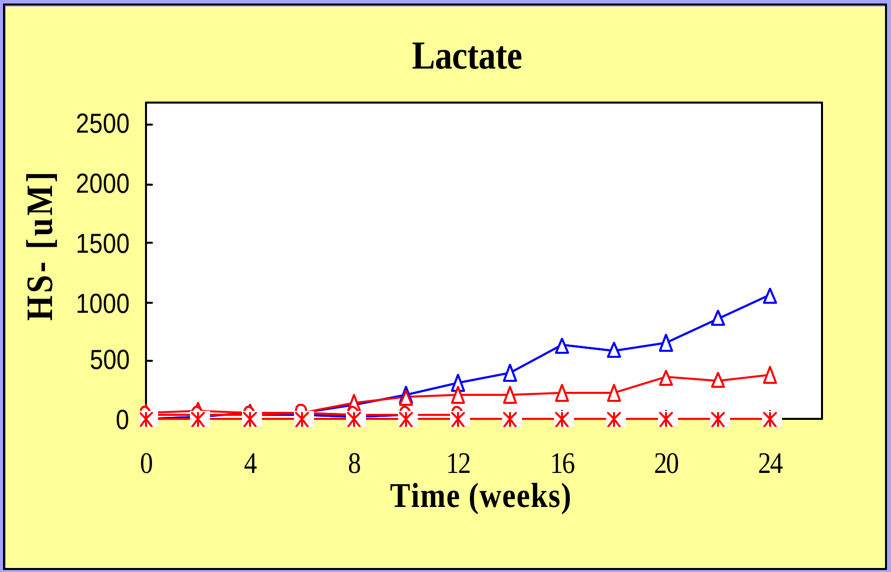
IRB (inhibited SRB)

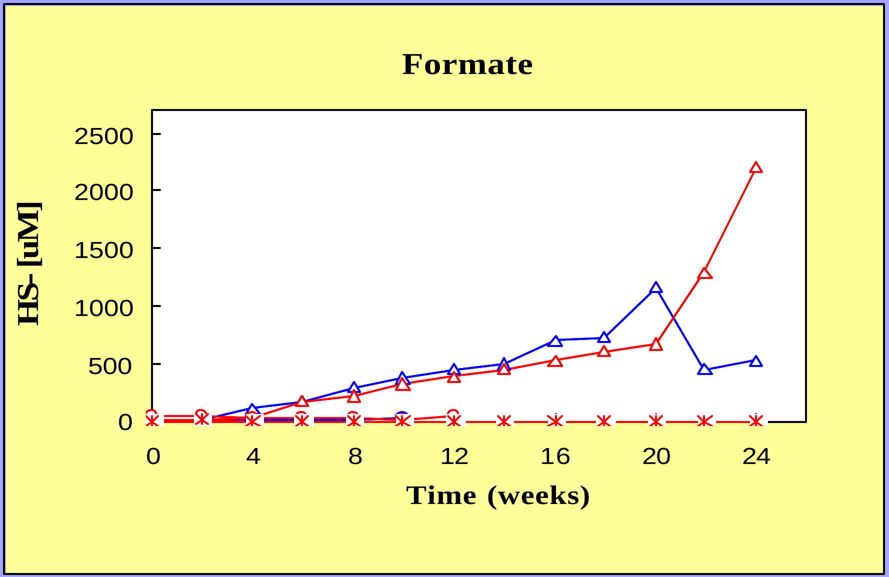
Control

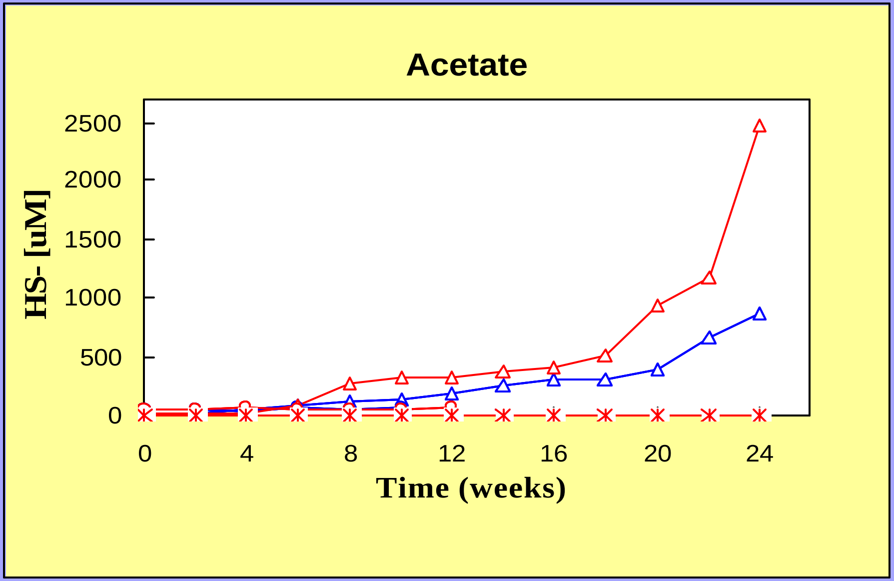
Potter (in red)

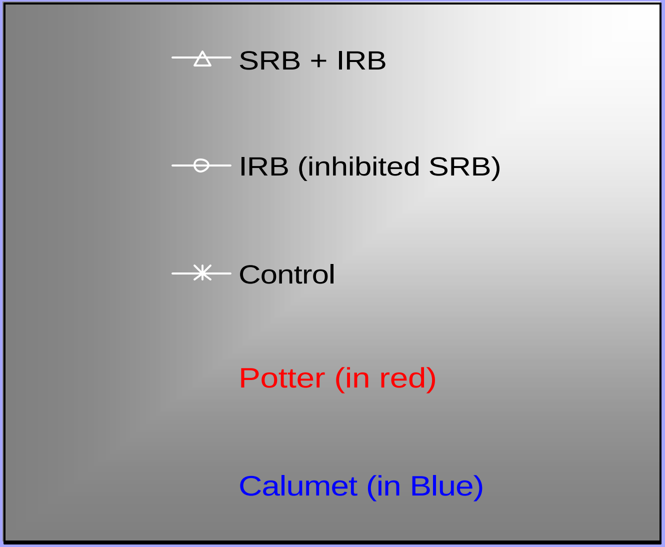
Calumet (in Blue)

HS$^-$ (Potter and Calumet)

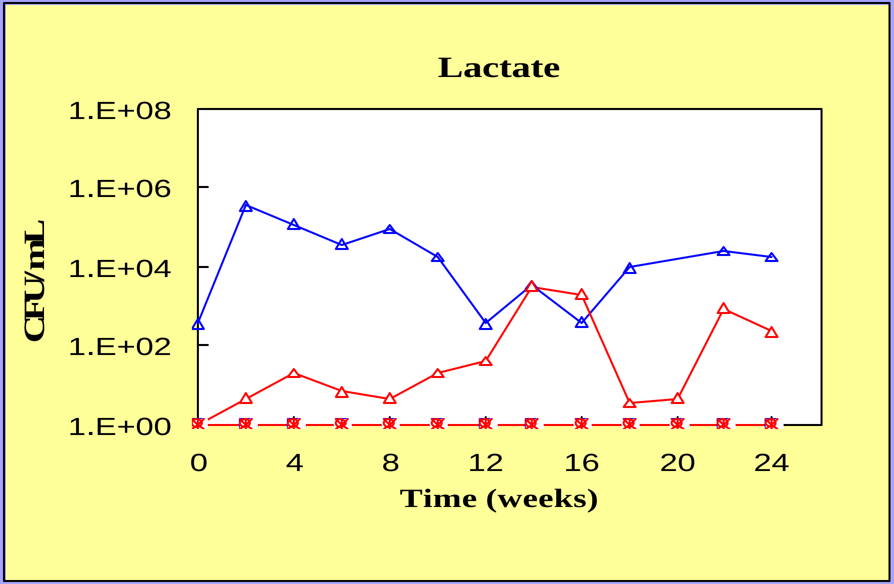


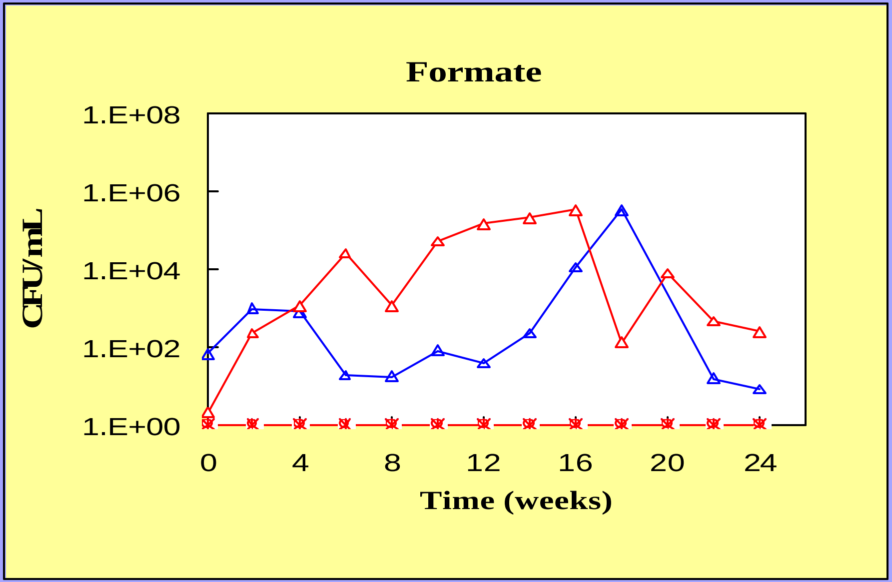


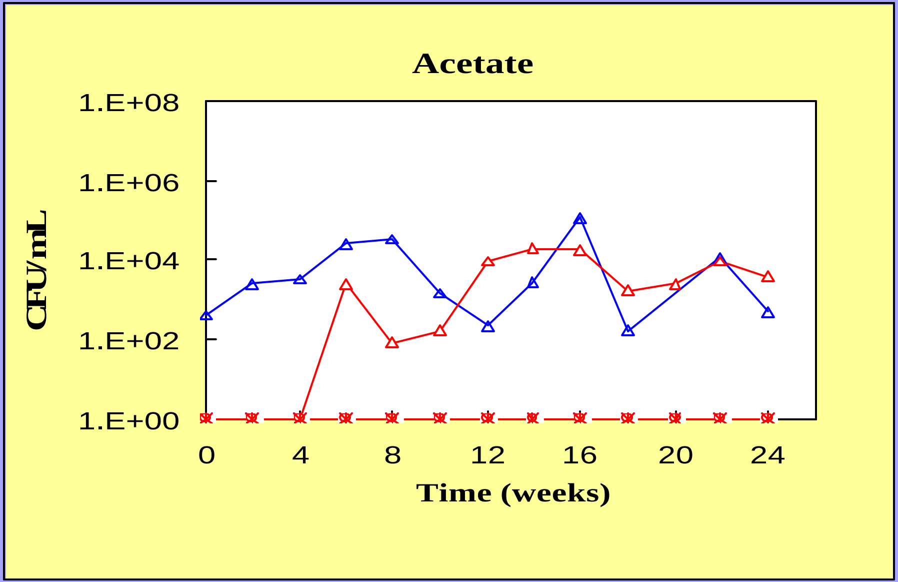


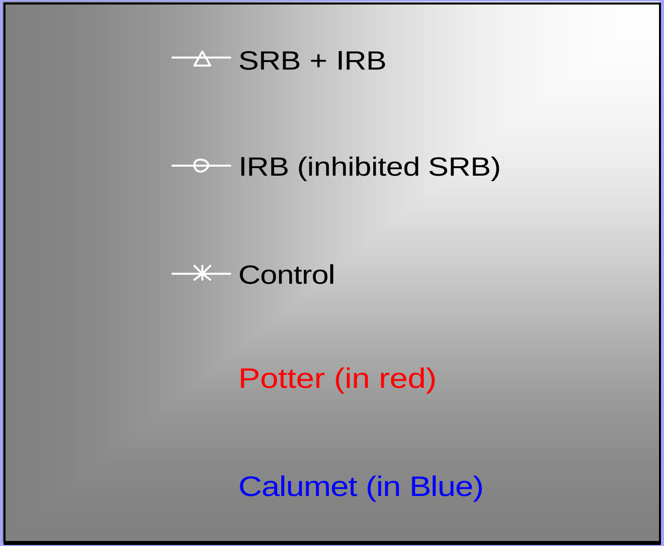


SRB (Potter and Calumet)

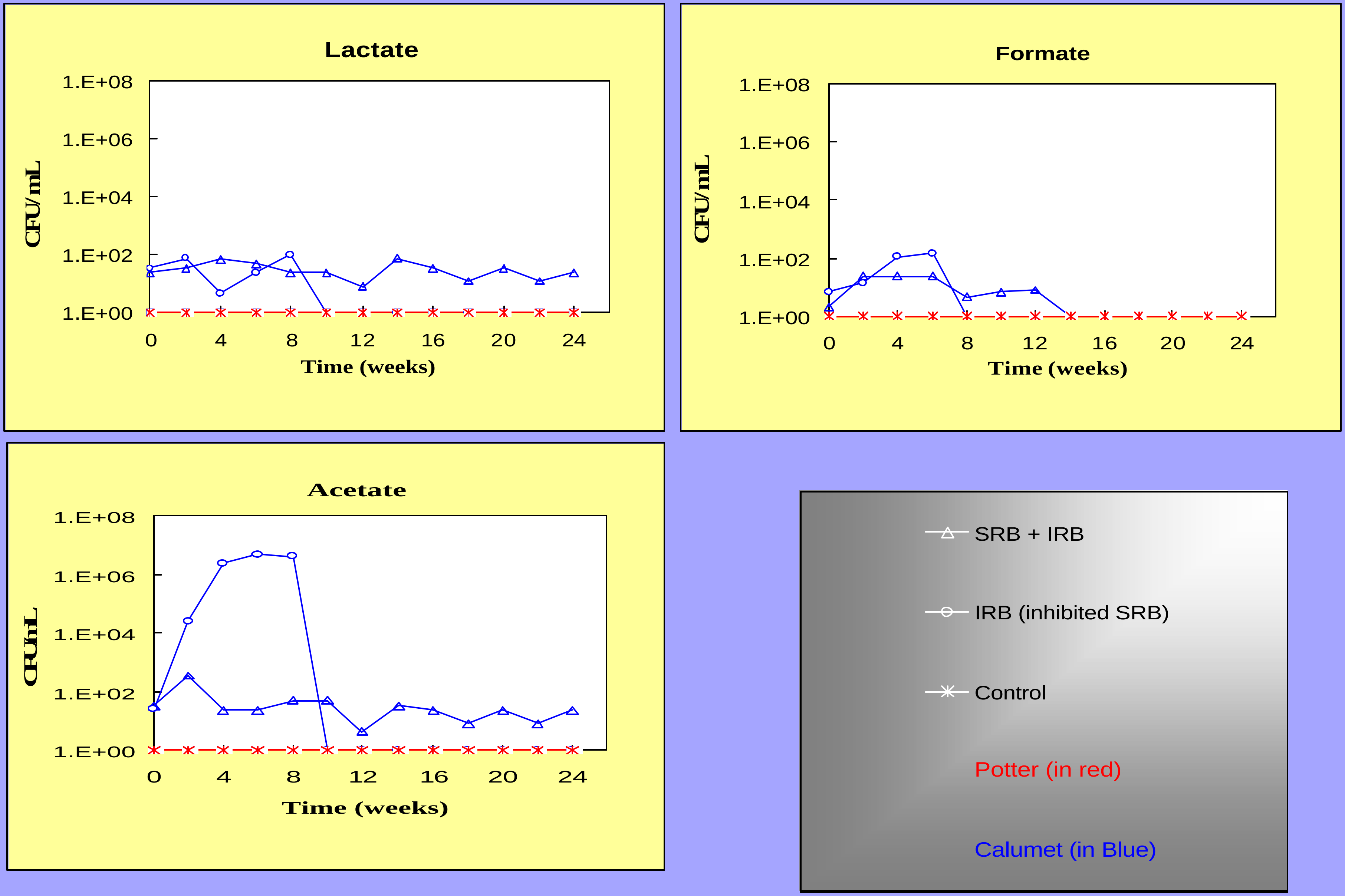








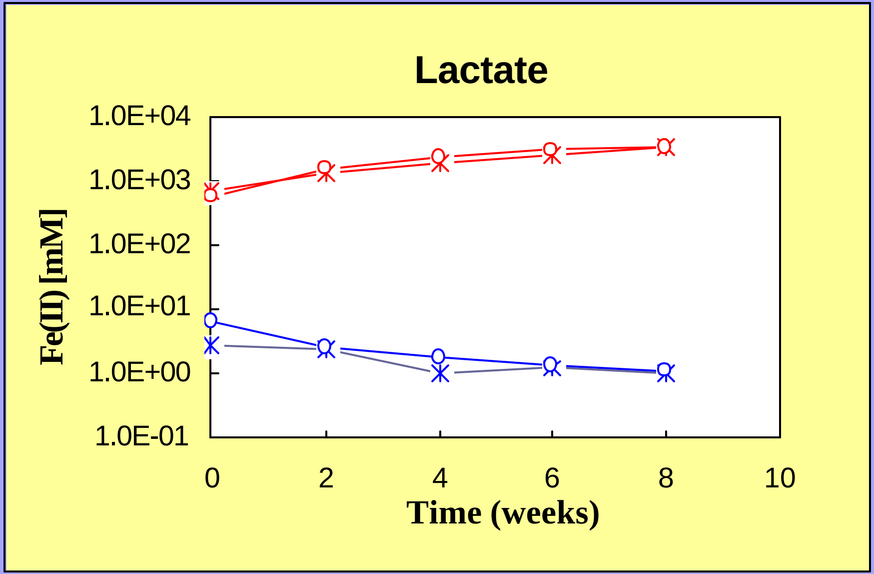
IRB (Potter and Calumet)

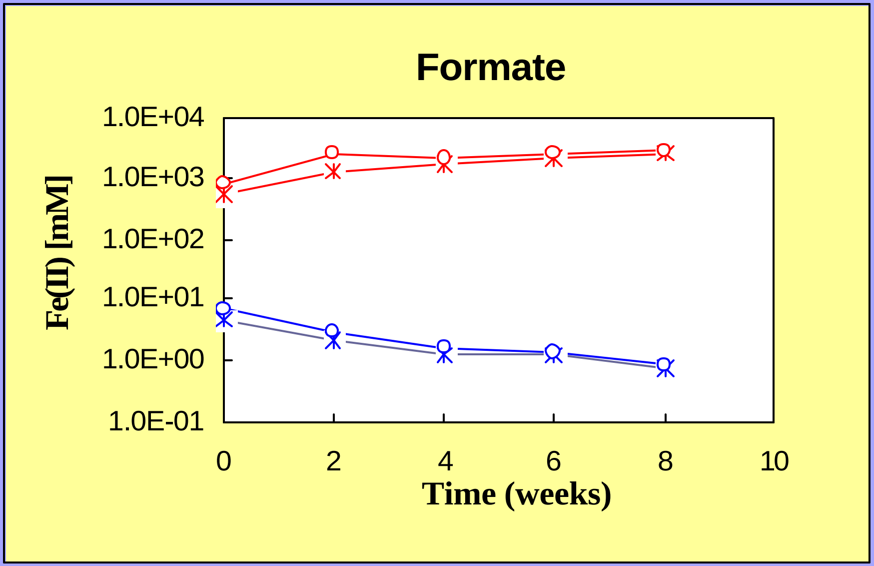


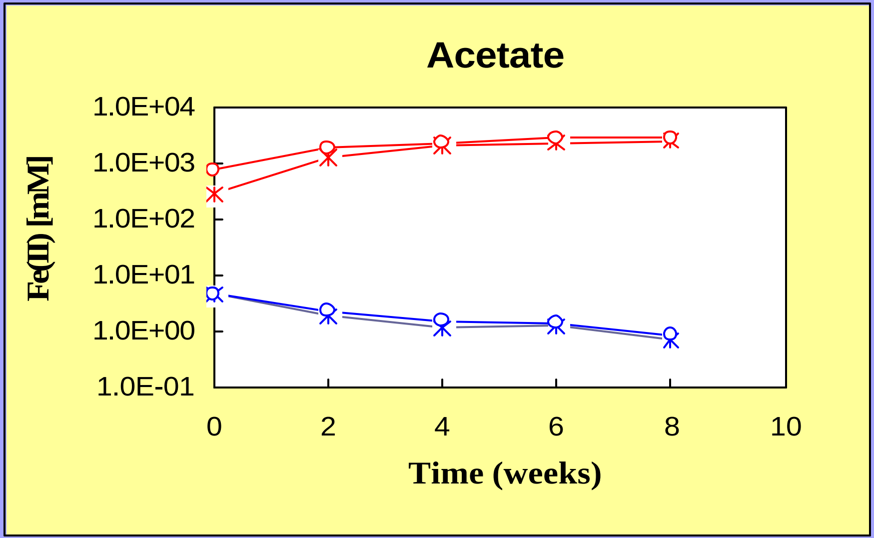
Summary systems

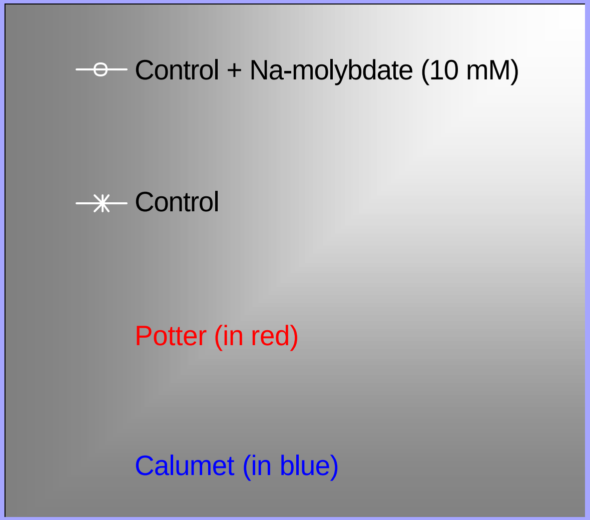
- Largest pH increase in systems containing IRB and SRB: alkalinity production.
- Reduction of Fe (III) in inhibited systems (i.e., IRB alone), no release of Fe(II) in SRB + IRB systems because of iron mono-sulfides formation, **but Fe(II) release in control systems**.
- What is reducing Fe(III)? Organic electron donors? Unknown compound in the tailings? Sulfides?
- Soluble sulfides are likely not responsible for Fe reduction because they were not produced in the control systems.

Results for abiotic Fe(III) reduction of sterile mine tailings

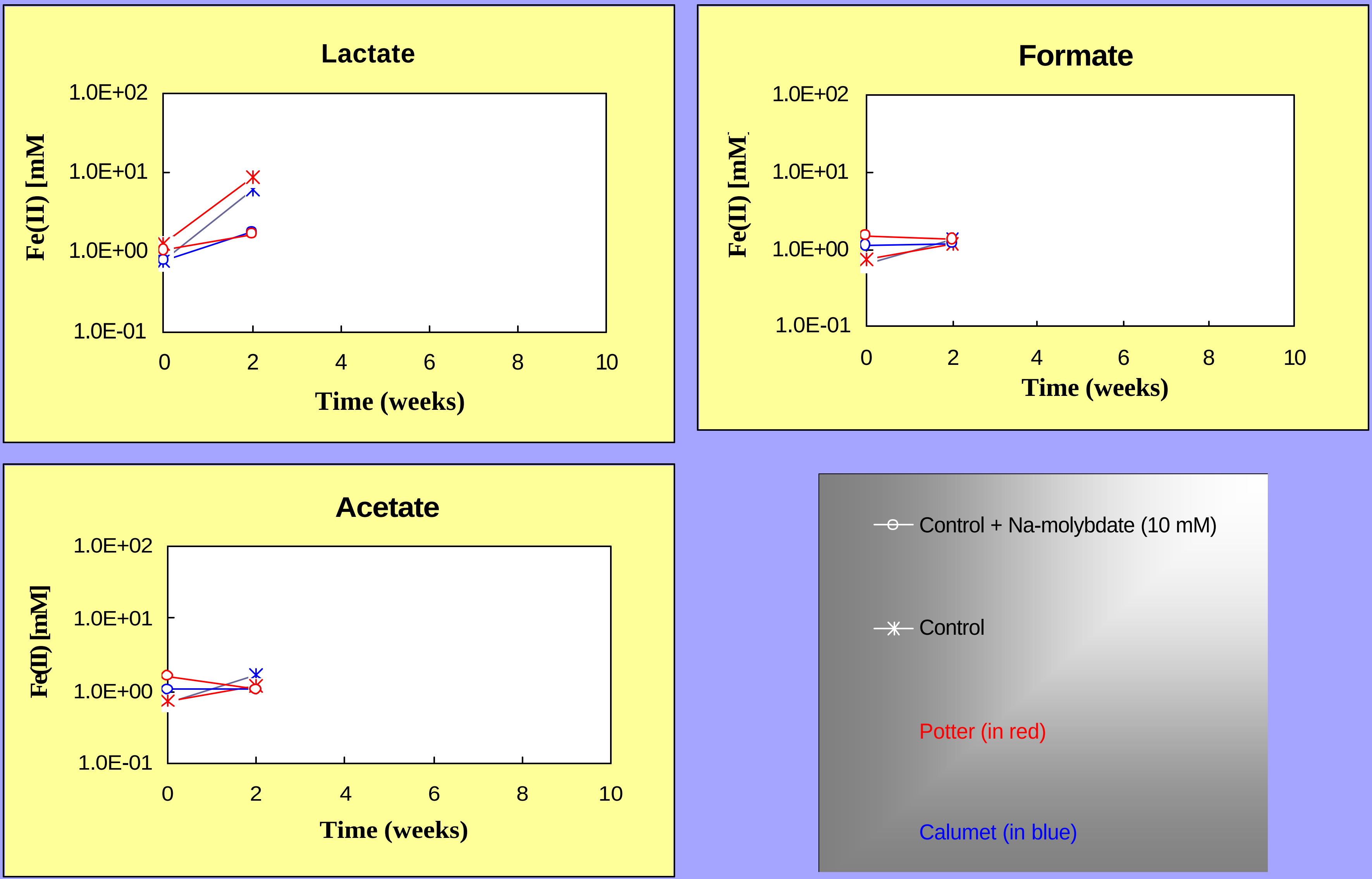








Results for abiotic Fe(III) reduction of synthetic Fe-hydroxides ($Fe(OH_3)$)



Summary abiotic Fe(III) reduction

- Evidence of abiotic Fe(III) reduction in acidic tailings (Potter), but not in alkaline mine tailings (Calumet) suggests that solid sulfides (pyrite, pyrrhotite) present in large quantities in the Potter tailings are acting as reducing agents for Fe(III). Also the possibility that an unknown organic compound is present in the Potter tailings, but not in the Calumet tailings
- Control systems with Fe-hydroxides and no tailings show some evidence of abiotic Fe(III) reduction, especially in the presence of lactate.

Summary systems (con'td)

- Soluble sulfide production in all SRB + IRB systems consistent with SRB growth.
- SRB growth in the presence of all electron donors for both types of tailings.
- No IRB growth in the Potter tailings so far, but Fe(II) produced.
- IRB growth is favored in the presence of acetate in Calumet tailings.

Conclusions

- ✓ Test each control systems for abiotic reduction of Fe^{+3} for a longer time period (4 month).
- ✓ Quantify the abundance of soluble Fe(III) in all systems.
- ✓ Analyze residual organic acids by HPLC to determine the relative abundance of all three electron donors in the systems.
- ✓ Chemical extraction of tailings after 6 months to assess Fe-reactive, Fe-silicate and Fe-pyrite.
- ✓ Analyze IRB populations by DNA sequencing (external lab).

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Thank you