Sulfate and Nitrate Removal from Mining Wastewaters using the Electro-Biochemical Reactor (EBR) Technology

By Jane Fudyma, Ola Opara, John Bowden & Jack Adams

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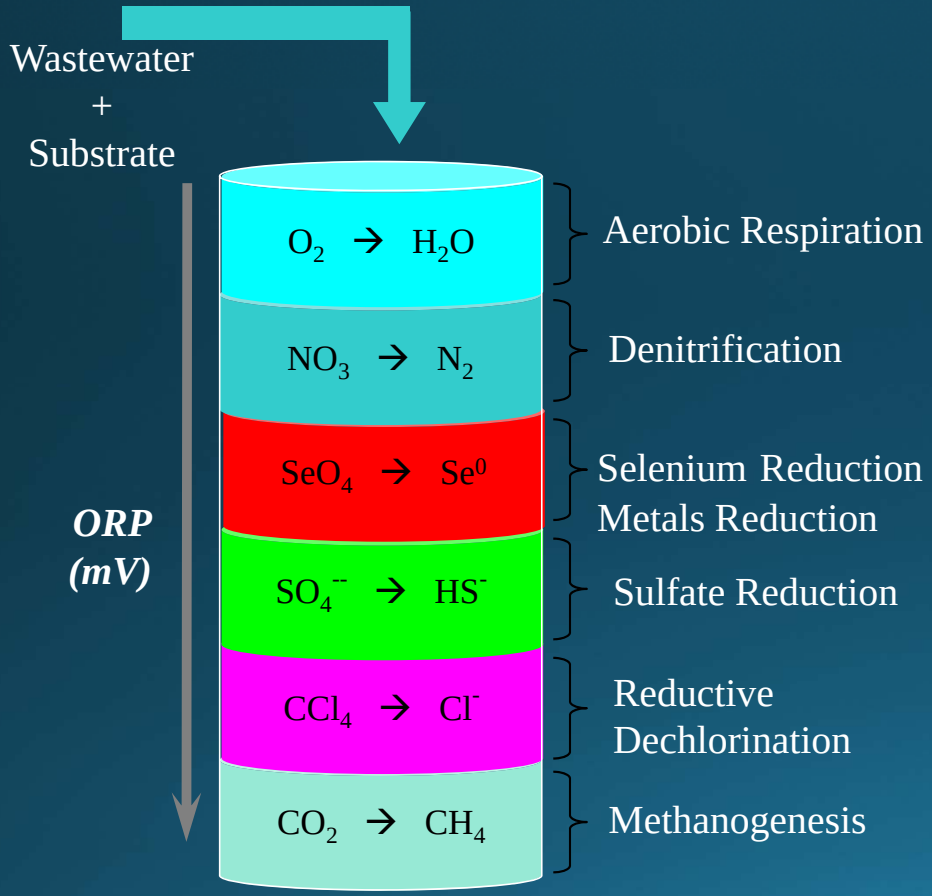
Central America Silver Mine

- Deposit is an intermediate-sulfidation silver-gold-lead-zinc vein
- Ore processed by differential flotation
- Mining impacted wastewaters are treated via chemical precipitation and coagulation/flocculation system
- Does not target Sulfate (SO_4) and Nitrate (NO_3-N)
  - SO_4 – AVG 1,000 mg/L
  - NO_3-N – AVG 3.6 mg/L
- Metals monitored during testing: As, Cd, Cr, Cu, Fe, Pb, Se, and Zn

The Electro-Biochemical Reactor



- Microbes mediate the removal of metal and inorganic contaminants through redox reactions
  - $SO_4^{2-} + 8e^- + 10H^+ \rightarrow H_2S + 4H_2O$
  - $NO_3^- + 5e^- + 6H^+ \rightarrow 1/2N_2 + 3H_2O$
- Anaerobic, reductive conditions

Conventional Bioreactor Technology

- Organic electron donors (nutrients) can provide electrons under oxidation or metabolism
  - One molecule of glucose = 24 electrons under full metabolism
  - Nutrients to control ORP environment
- Excess biomass production
  - High TSS leads to post-treatment solids management
  - Biomass carries excess metals, post-treatment management
  - High CAPEX /OPEX costs

$SO_4^{2-} + 8e^- + 10H^+ \rightarrow H_2S + 4H_2O$

$NO_3^- + 5e^- + 6H^+ \rightarrow 1/2N_2 + 3H_2O$

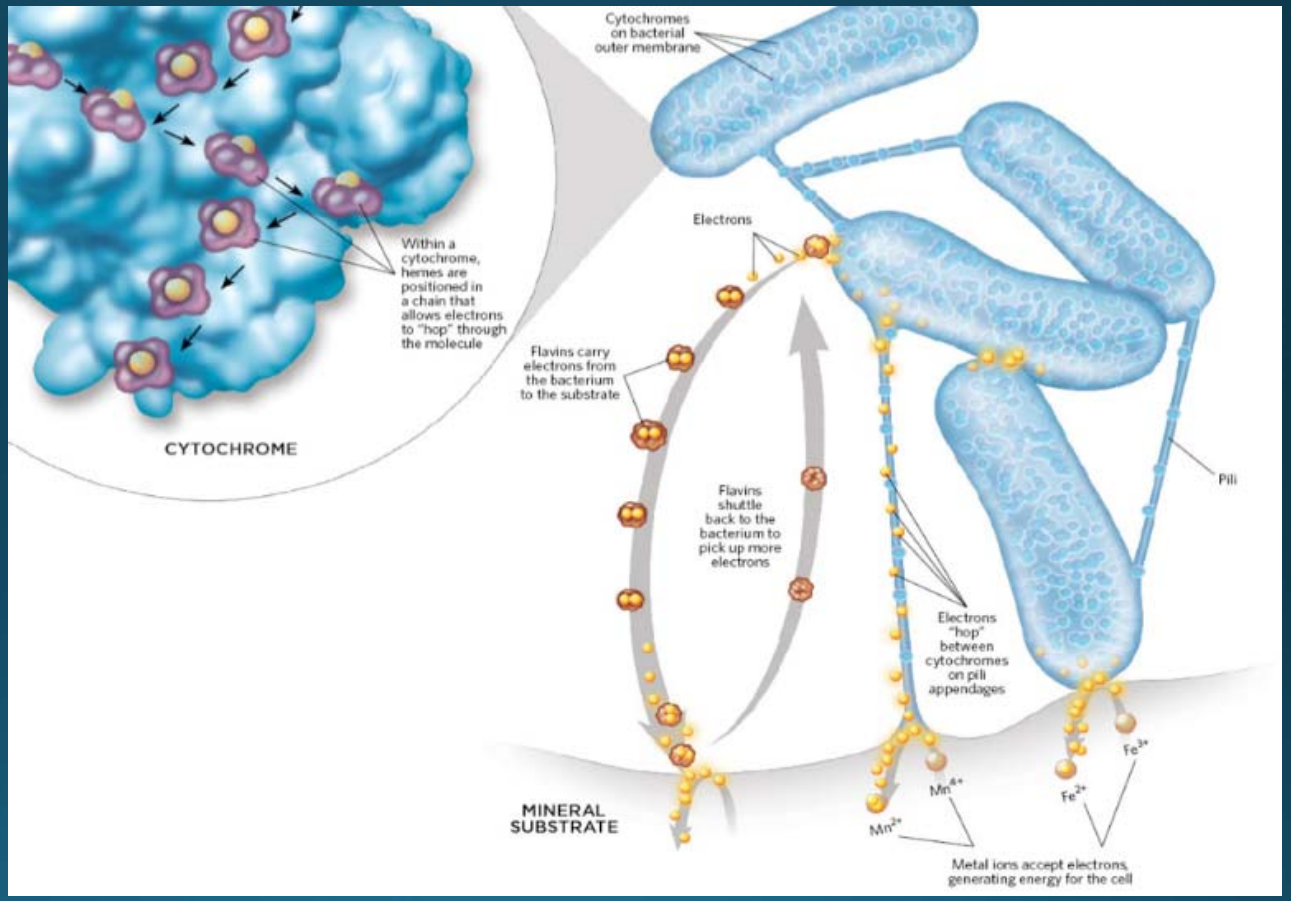
= 13 electrons total

The Electro-Biochemical Reactor

- Low voltage (1-3 Volts potential) supplied directly across bioreactor
- 1 mA provides 6.24×10^{15} electrons/second
  - Electrons and electron acceptor environments for controlled contaminant removal environment
  - Compensation for inefficient and fluctuating electron availability through nutrient metabolism
  - Replaces up to 2/3 of the nutrients/electron donors required, while producing lower contaminant concentrations
  - Produces much less TSS (bio-solids)
    - Post-treatment usually not required

Electro-microbiology

- An emerging field to understand how microbes utilize directly provided electrons



Adapted from Mohamed Y. El-Naggar & Steven E. Finkel May 2013

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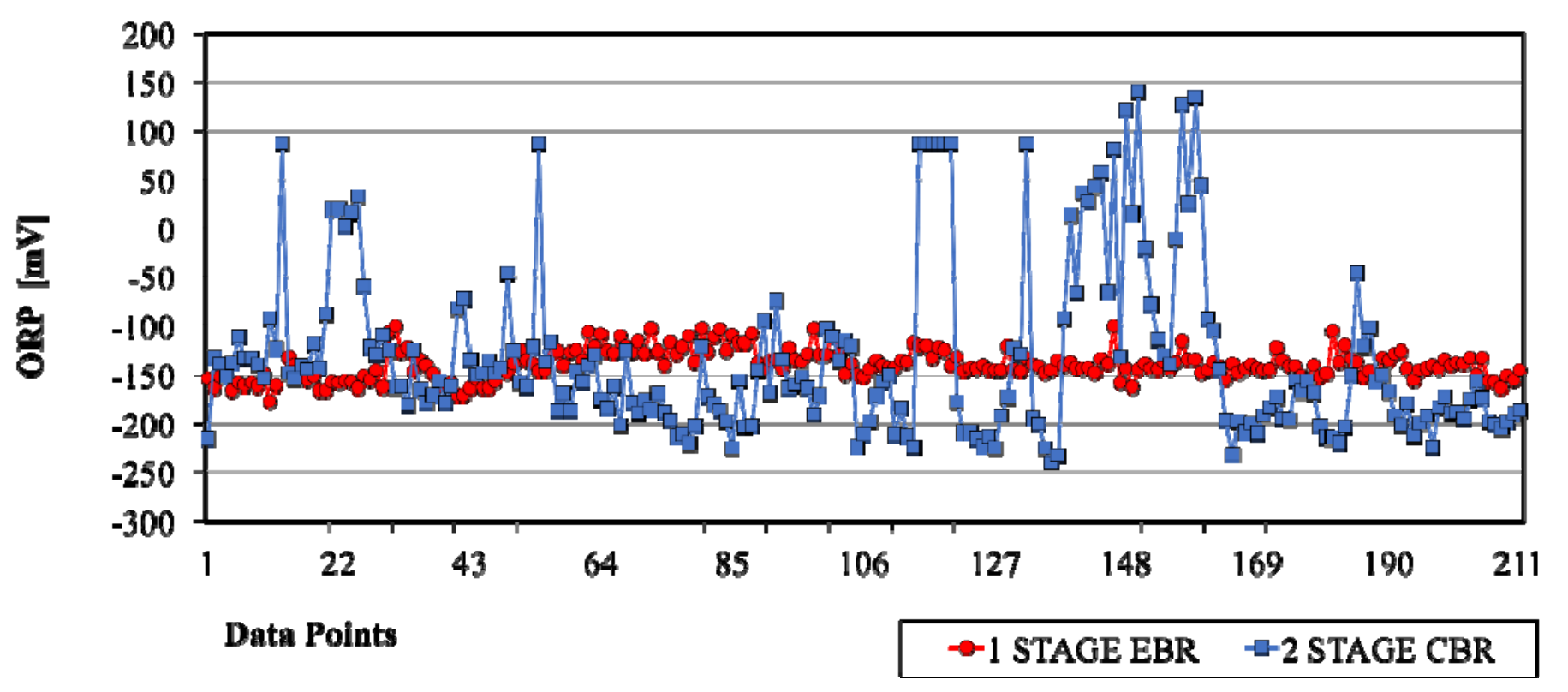
ORP control and stability



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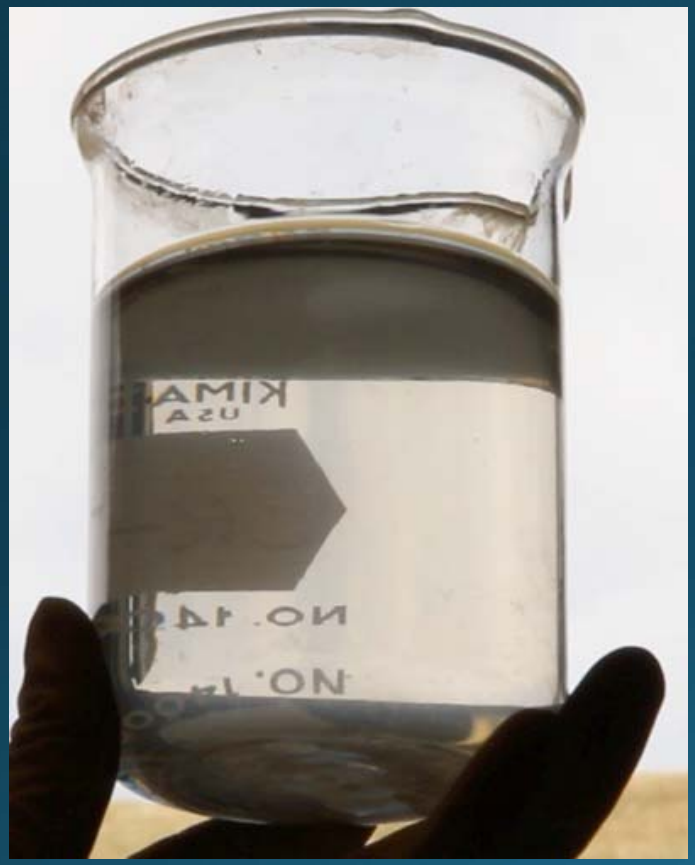
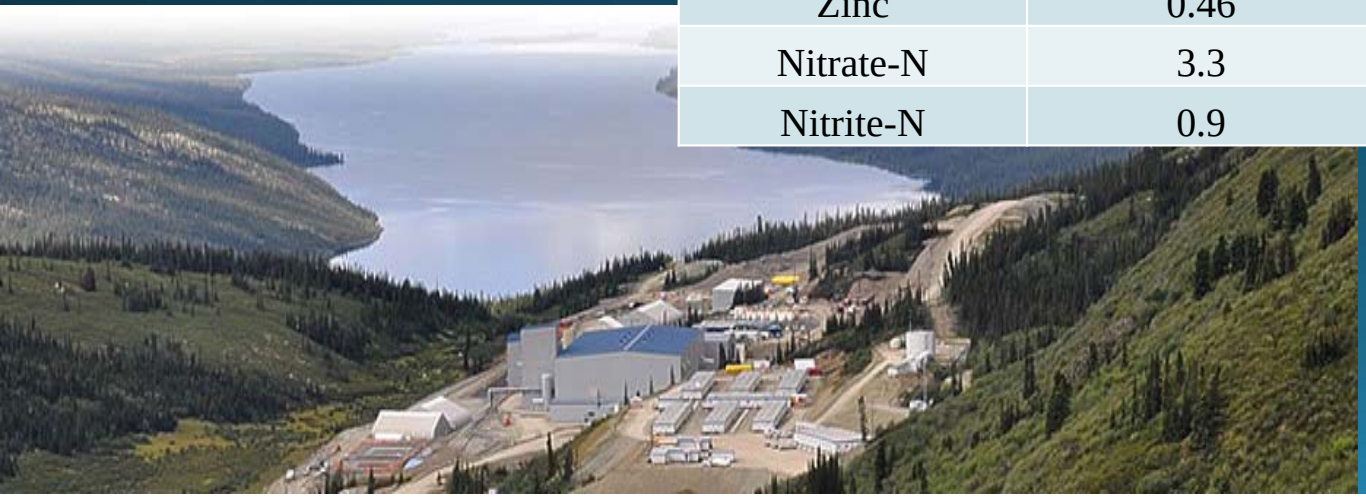


- From onsite EBR effluent, no filtration or post-treatment

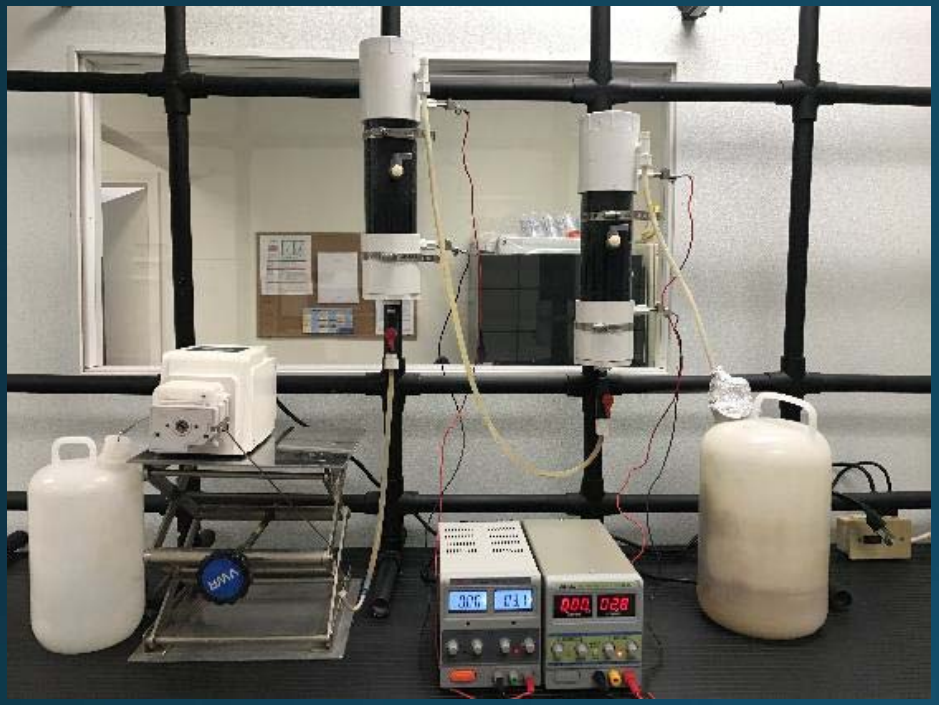
EBR Metal & Inorganic Removal – Example Pilot Results

Parameter [mg/L]	Average Influent	Average EBR Discharge	% Removal
Antimony	0.15	<0.001	>99.3%
Arsenic	1.2	<0.013	>98.7%
Cadmium	0.014	<0.0002	>98.0%
Copper	0.41	<0.005	>98.7%
Lead	0.30	0.0008	99.7%
Molybdenum	0.10	<0.0005	>99.5%
Selenium	2.73	0.002	99.9%
Silver	0.041	<0.0001	>99.8%
Zinc	0.46	<0.03	>93.5%
Nitrate-N	3.3	<0.1	>97.1%
Nitrite-N	0.9	<0.02	>97.8%



Silver Mine Target Goals for Contaminant Removal

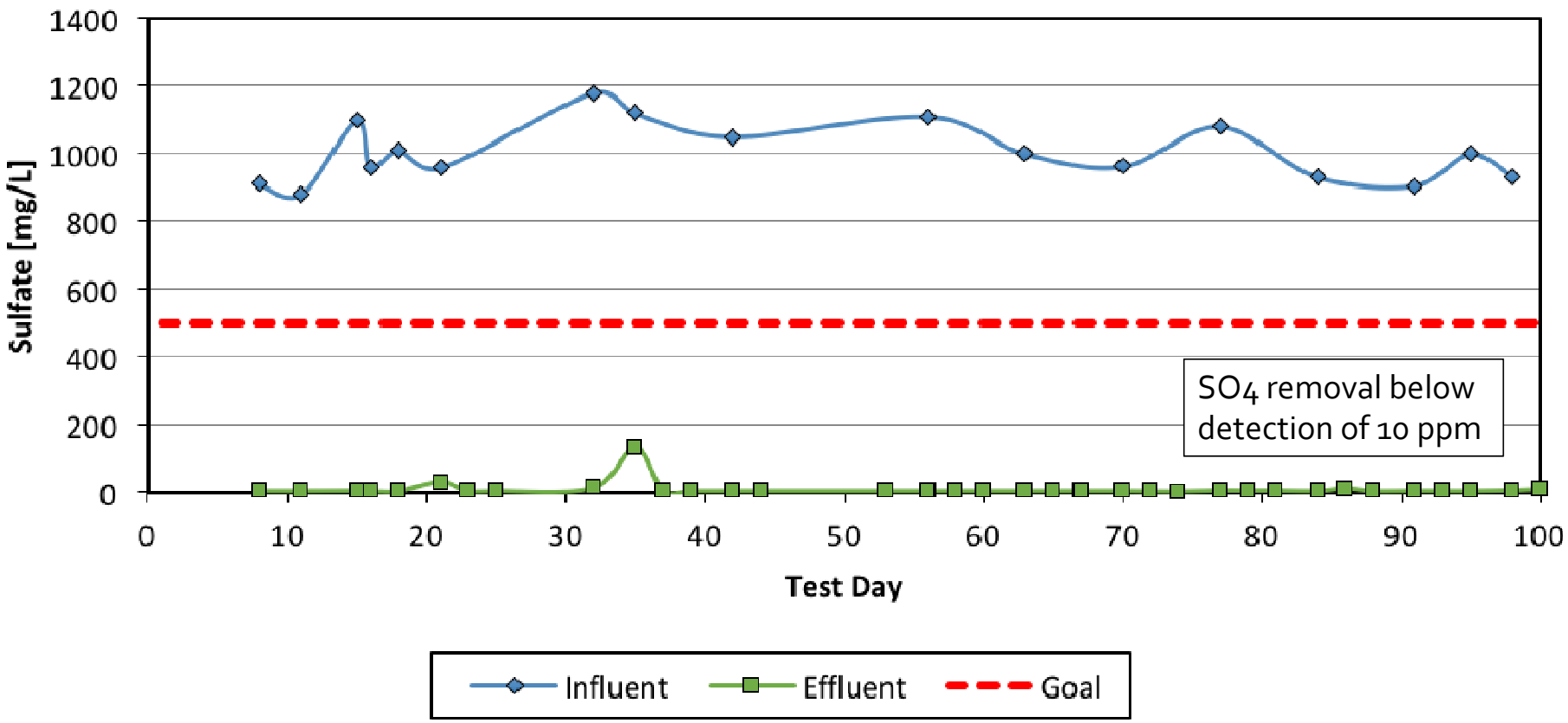
- Sulfate (SO_4)
  - Influent: ~1,000 mg/L
  - Goal: 50% removal, ~500 mg/L
- Nitrate (NO_3-N)
  - Influent: ~ 3.6 mg/L
  - Goal: complete removal
- Pilot scale- metals
  - As, Cd, Cr, Cu, Fe, Pb, Se, Zn



Laboratory Bench Testing

Parameter	Influent Average	EBR Effluent Average
Sulfate (SO_4) mg/L	1008	<10
Nitrate-N (NO_3-N) mg/L	3.6	<0.2
ORP (mV)	-99.4	-333.9
Dissolved Oxygen (mg/L)	1.7	0.9
pH	7.0	7.4
Temperature (℃)	22.8	22.9
Flowrate (mL/min)	0.96	

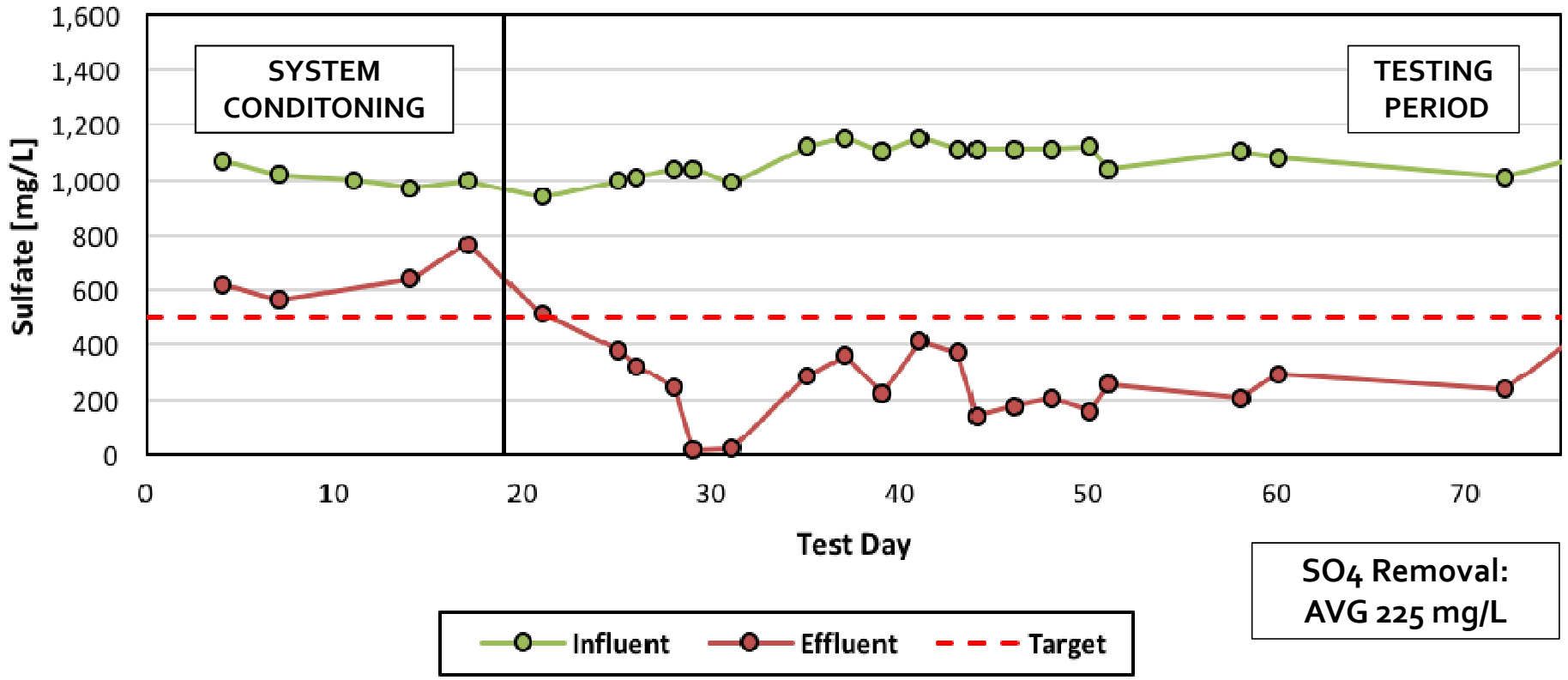
Laboratory Bench Testing



On-site Pilot-scale Testing

Parameter	Influent Average	EBR Effluent Average
Sulfate (mg/L)	1071	255
NO_3-N (mg/L)	3.6	<0.2
ORP (mV)	-35.9	-276.2
Dissolved Oxygen (mg/L)	5.9	0.3
pH	7.9	6.2
Temperature (℃)	24.4	24.8
Flowrate (L/min)	0.65	

On-site Pilot-scale Testing



Conclusions

- The EBR system was successful for sulfate and nitrate removal from silver mining effluent waters to below target goals
  - Both laboratory bench and pilot scale testing
- Full scale design is in review by the company

Thank you!

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