Shifts in Sediment pH and Redox in Response to an Electromagnetic Treatment: Implications for Metal Speciation, Mobility, and Bioavailability in Waterbodies

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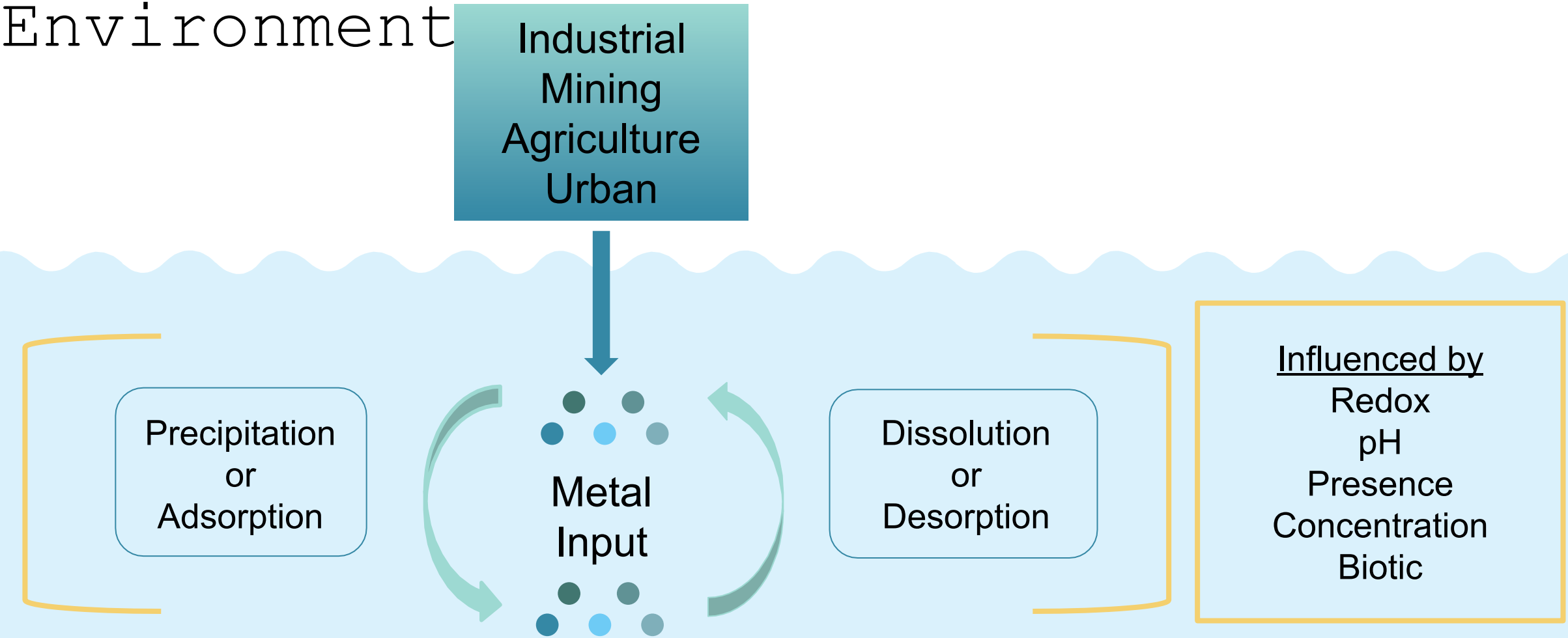
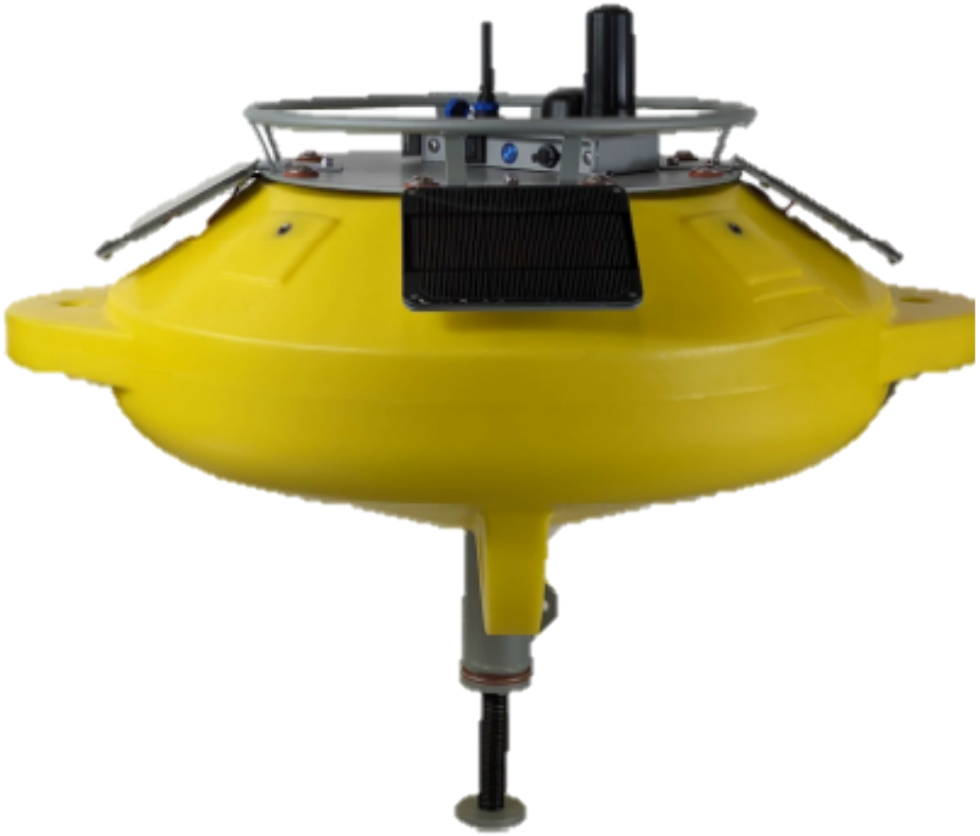
Metal Pollution in Freshwater Environment



Increased Oxygen Delivery

Using EMF-1120

- Self-contained, solar-powered electromagnetic signal generator
- Non mechanical, chemical free application
- Affects up to 20 ha (50 acres) of water SA
- Specific frequency and amplitude combinations demonstrate enhanced oxygen transfer across air-water interface (K_{600})
  - K_{600} transfer rate up 2x faster in treated bodies



Oxygen Flux Experiments 2020

Objective

Establish baseline oxygen flux under reference and EMF treatment conditions

- Oxygen exchange platforms installed at six locations → measured over 6 weeks
- EMF unit installed on an ON-OFF cycle
  - Reference (EMF-OFF), treatment (EMF-ON)
- Total = 225 usable measurements used to calculate first order gas exchange rate (K_{600})

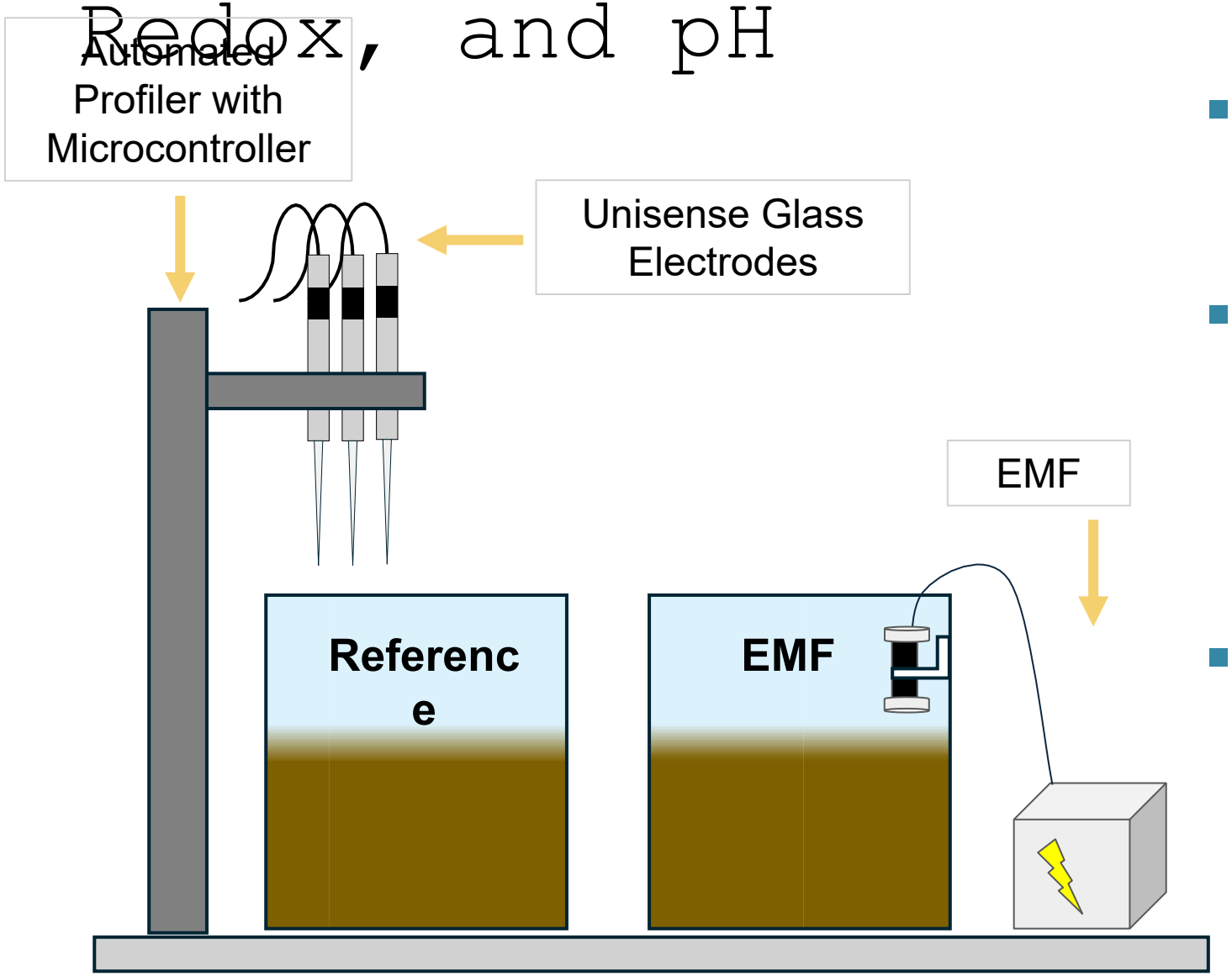
Results: Oxygen Flux Rates

Table 1. Oxygen exchange rates in Big Pond under Reference and EMF treatment conditions in the summer of 2020

Treatment	K_{600} (h^{-1})	
	Mean* (± SE)	50th Percentile (Median)
Reference (n= 140)	0.072 ± 0.018	0.020
EMF Treatment (n= 115)	0.159 ± 0.019	0.138

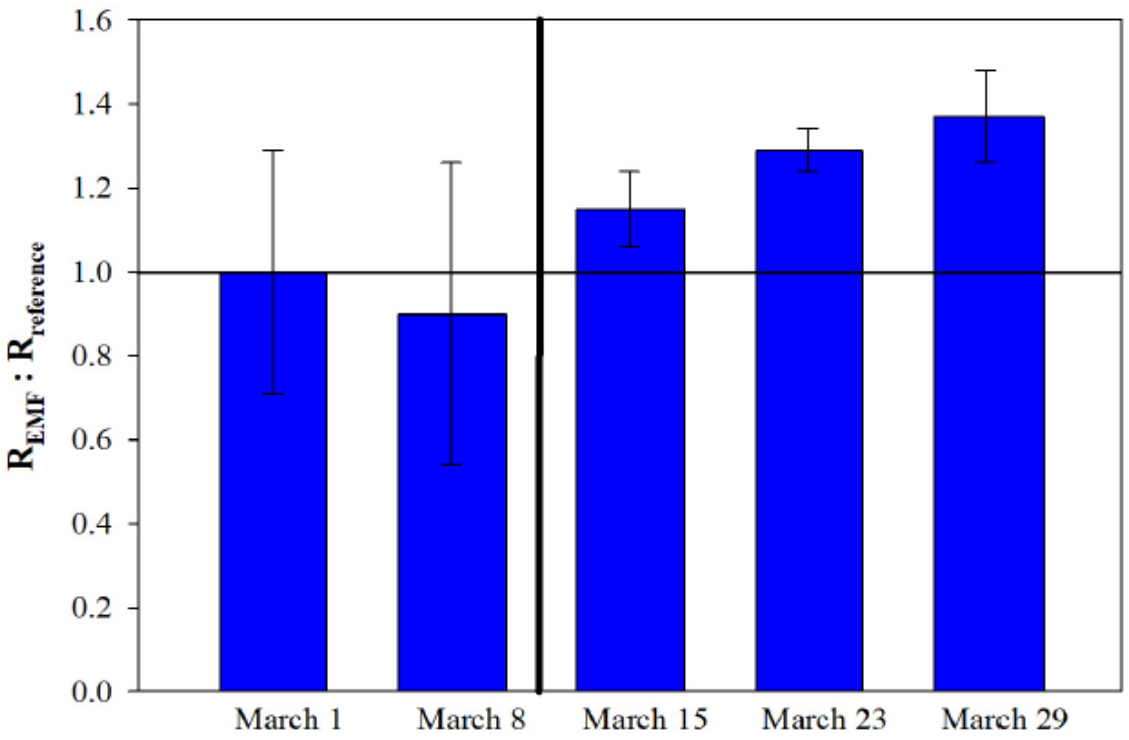
*Mean oxygen flux values were statistically significantly different ($p < 0.01$) between treatments

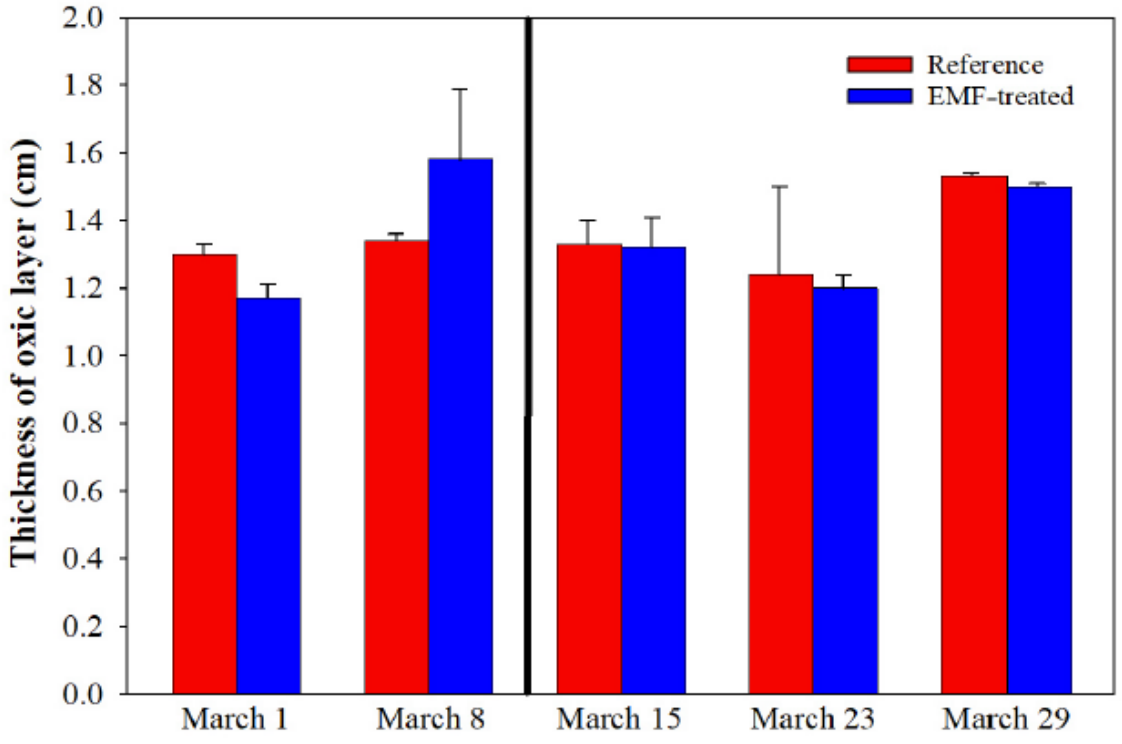
Sediment Profile: Respiration, Redox, and pH



- 4 weeks to equilibrate (no EMF)
- Experiment Run Time = ~37 days
  - Start: 2 weeks NO Treatment
  - Treatment ON: 3 weeks
- Measured Respiration Rates, Eh, and pH of soil profiles
  - 4 profile measurements in aquaria per time point

Results: Respiration Rates

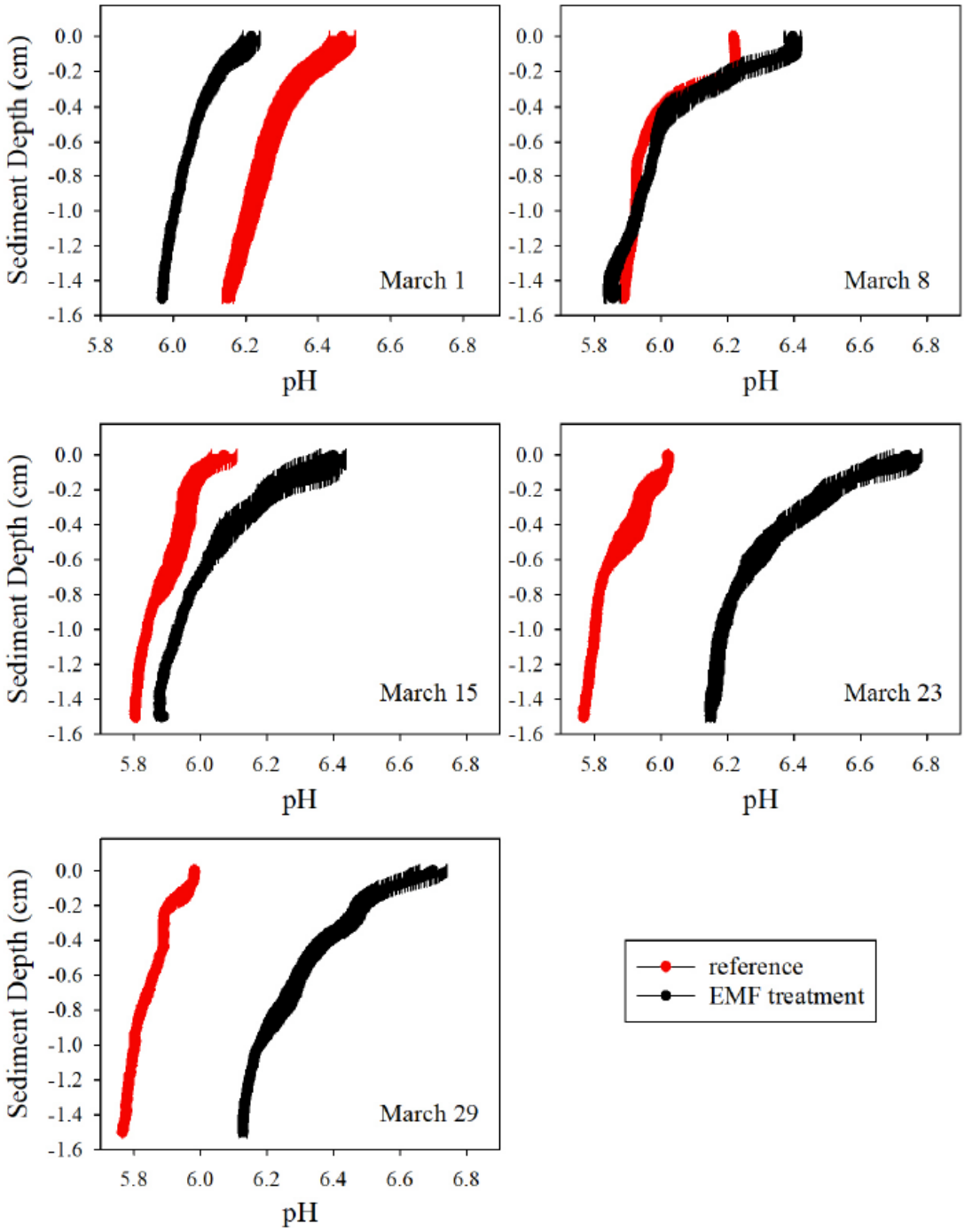




- Respiration rates increased as a function of EMF <u>without</u> a change in the thickness of the oxic zone → March 29th = 37% higher
  - Higher rate of O_2 delivery = support greater aerobic metabolism

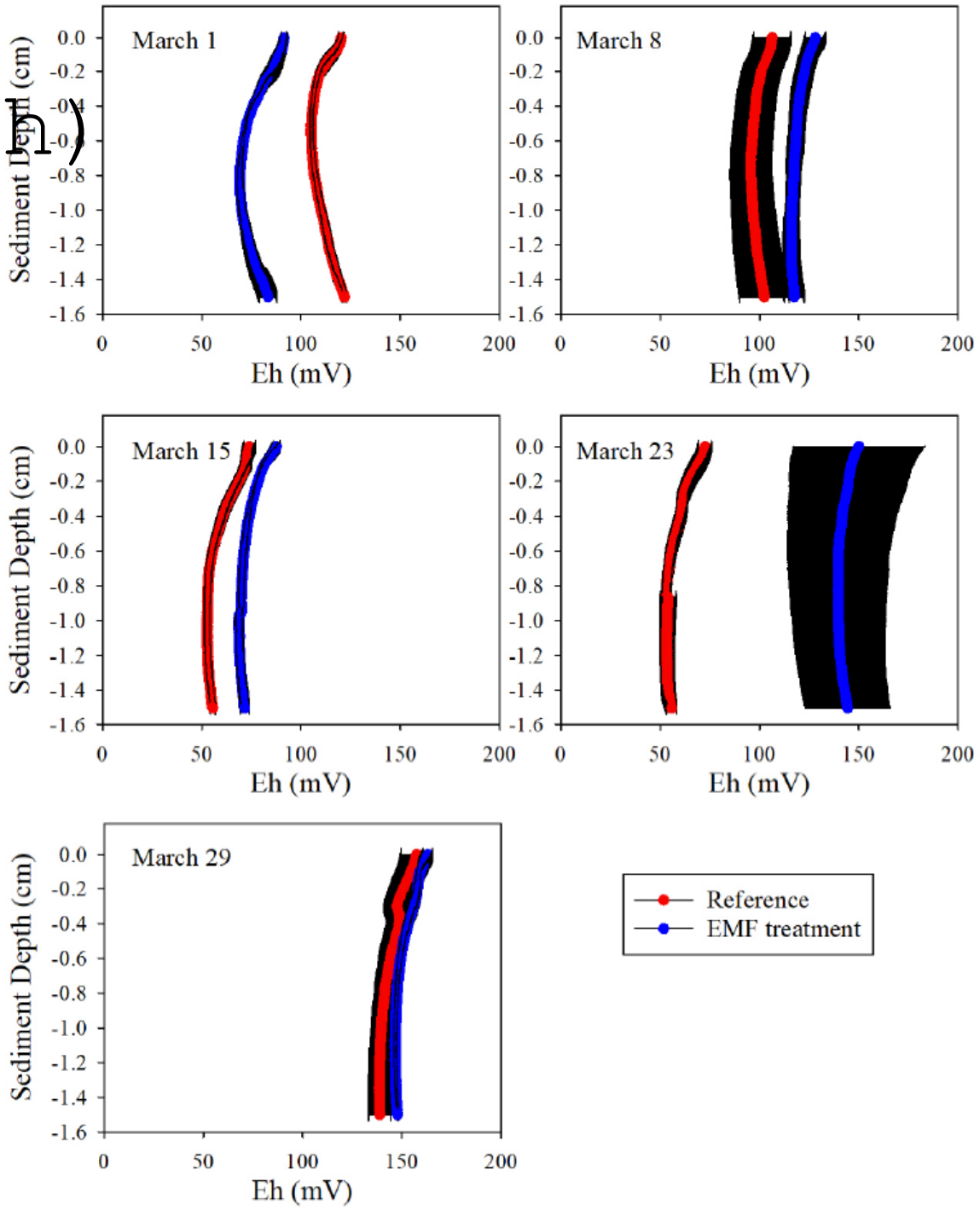
Results: pH

- EMF treatment shifted pH
- At surface
  - Shift = ~0.8 -0.9 units
- Sediment depth (1.6 cm)
  - Shift = ~0.4 units

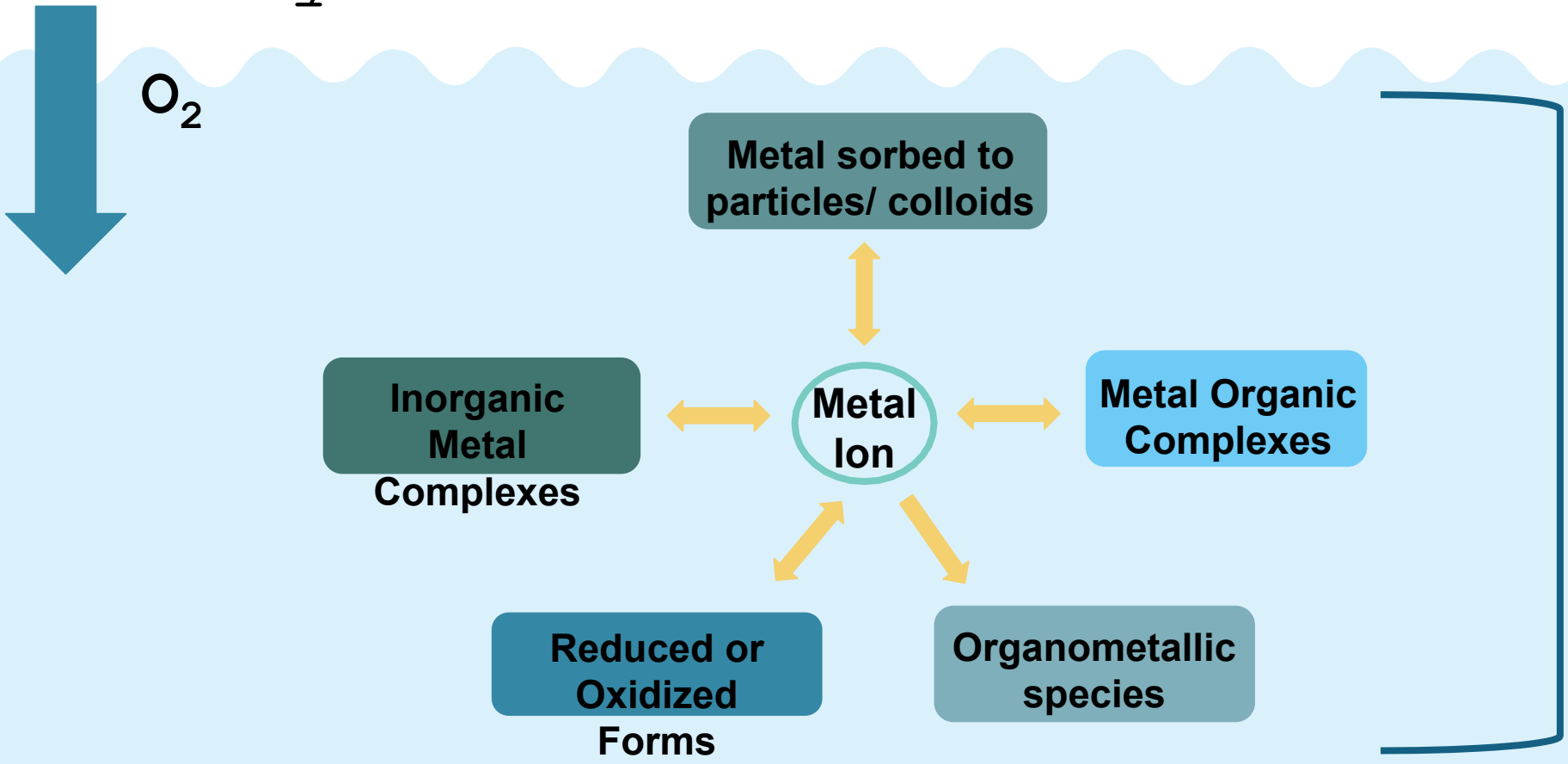


Results: Redox (Eh)

- EMF increased redox conditions (initially)
- After 3 weeks, redox was similar in Reference and Treatment conditions
- EMF accelerated shift in redox versus Reference



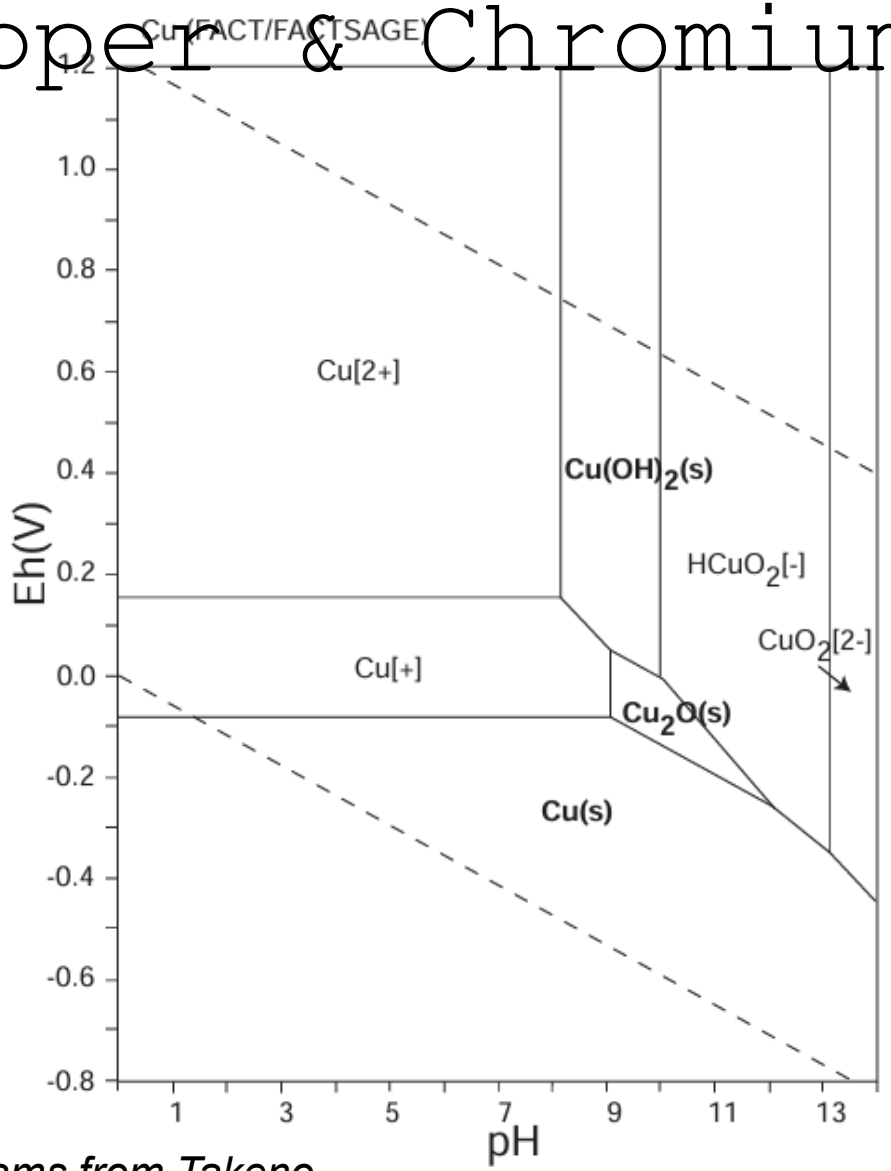
EMF & Metal Speciation and Mobility

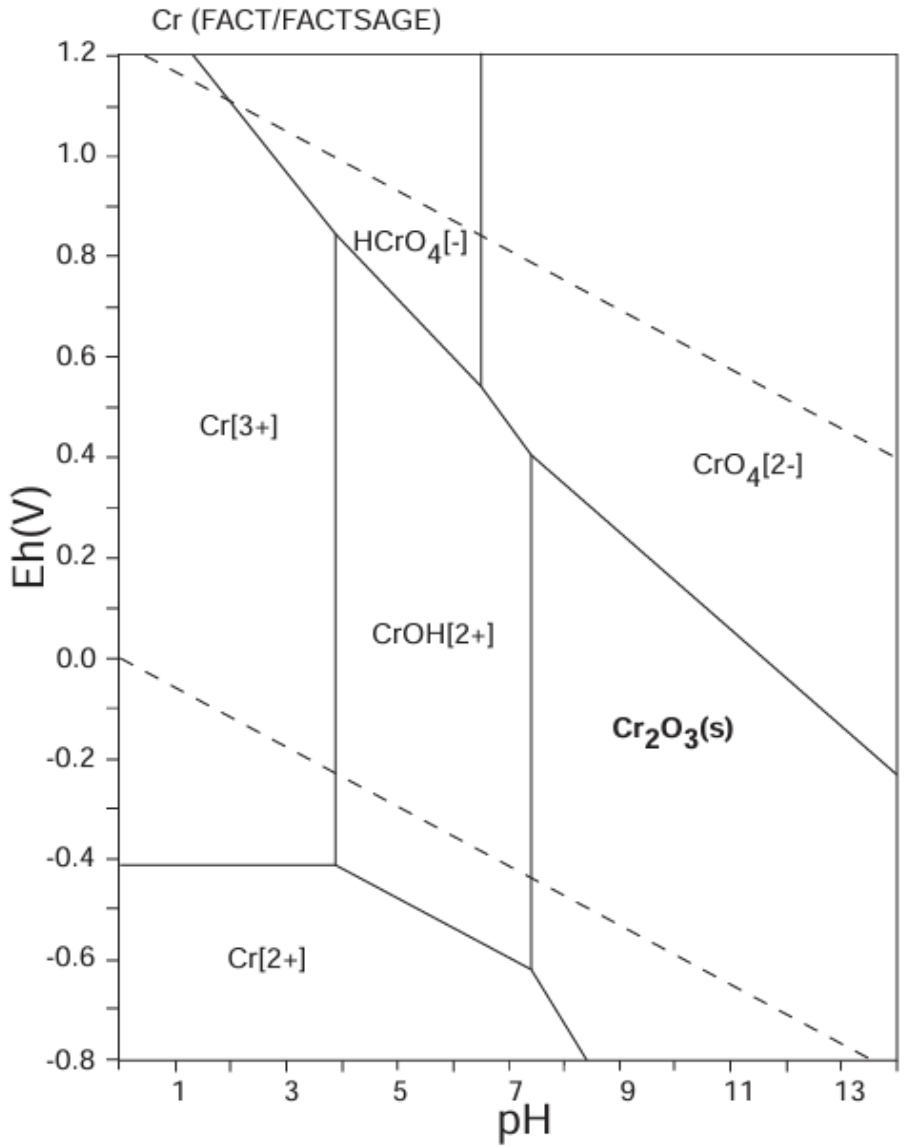


Influential Factors

Redox
pH
Presence
Concentration
Biotic

Implications of Sediment Profiles: Copper & Chromium

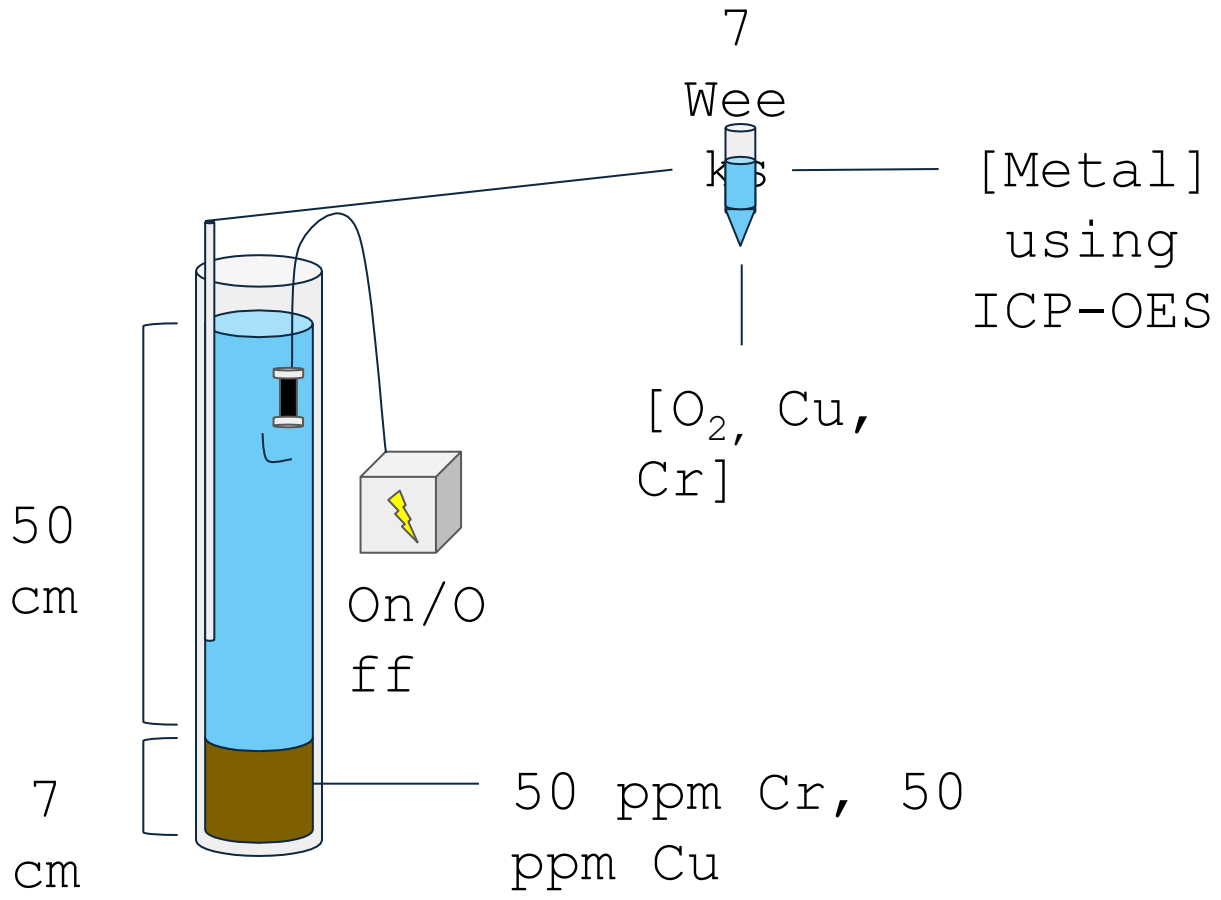




Eh-pH diagrams from Takeno

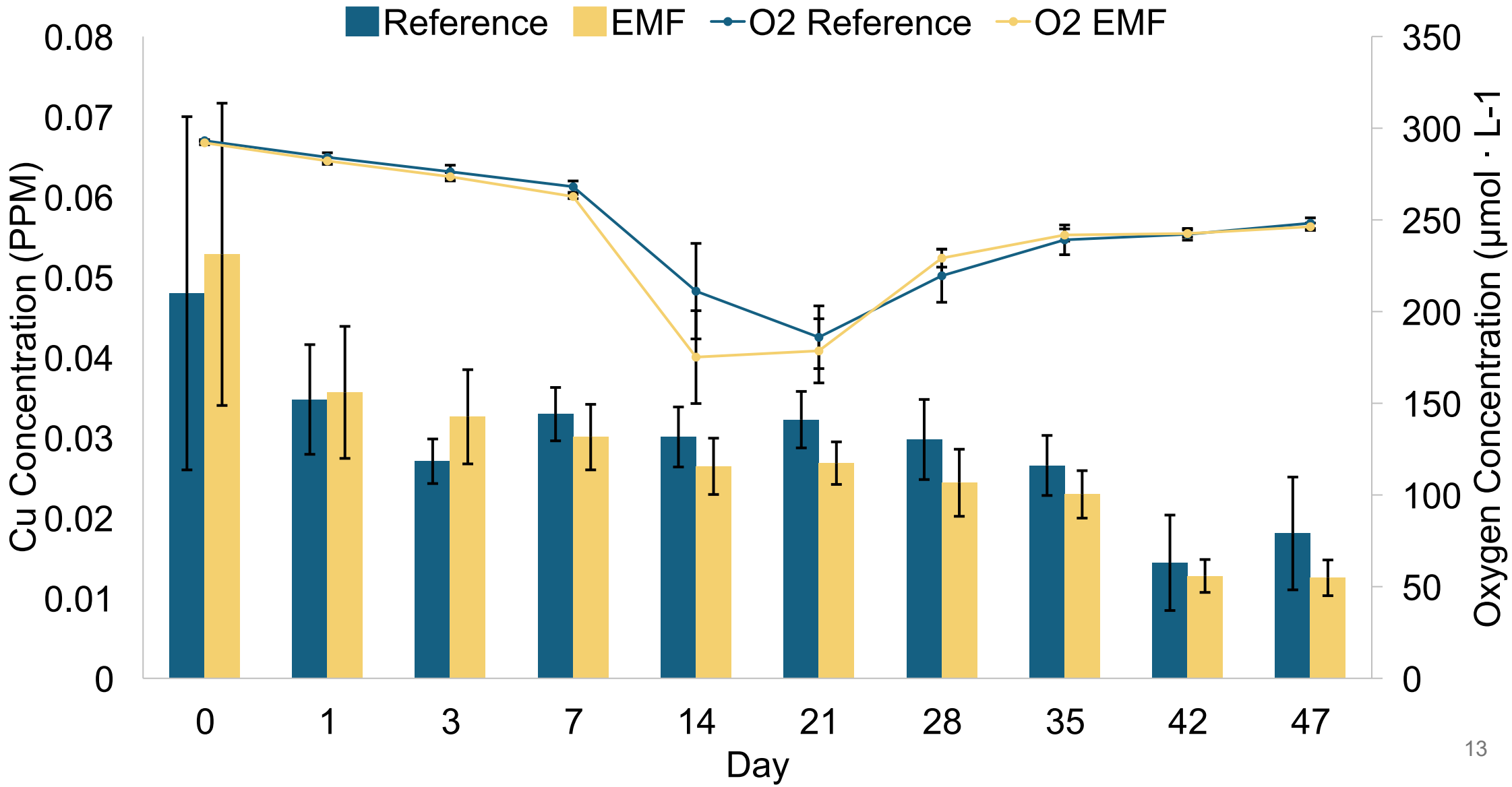
Copper and Chromium Case Study

Photo and Schematic Edited from Preveen

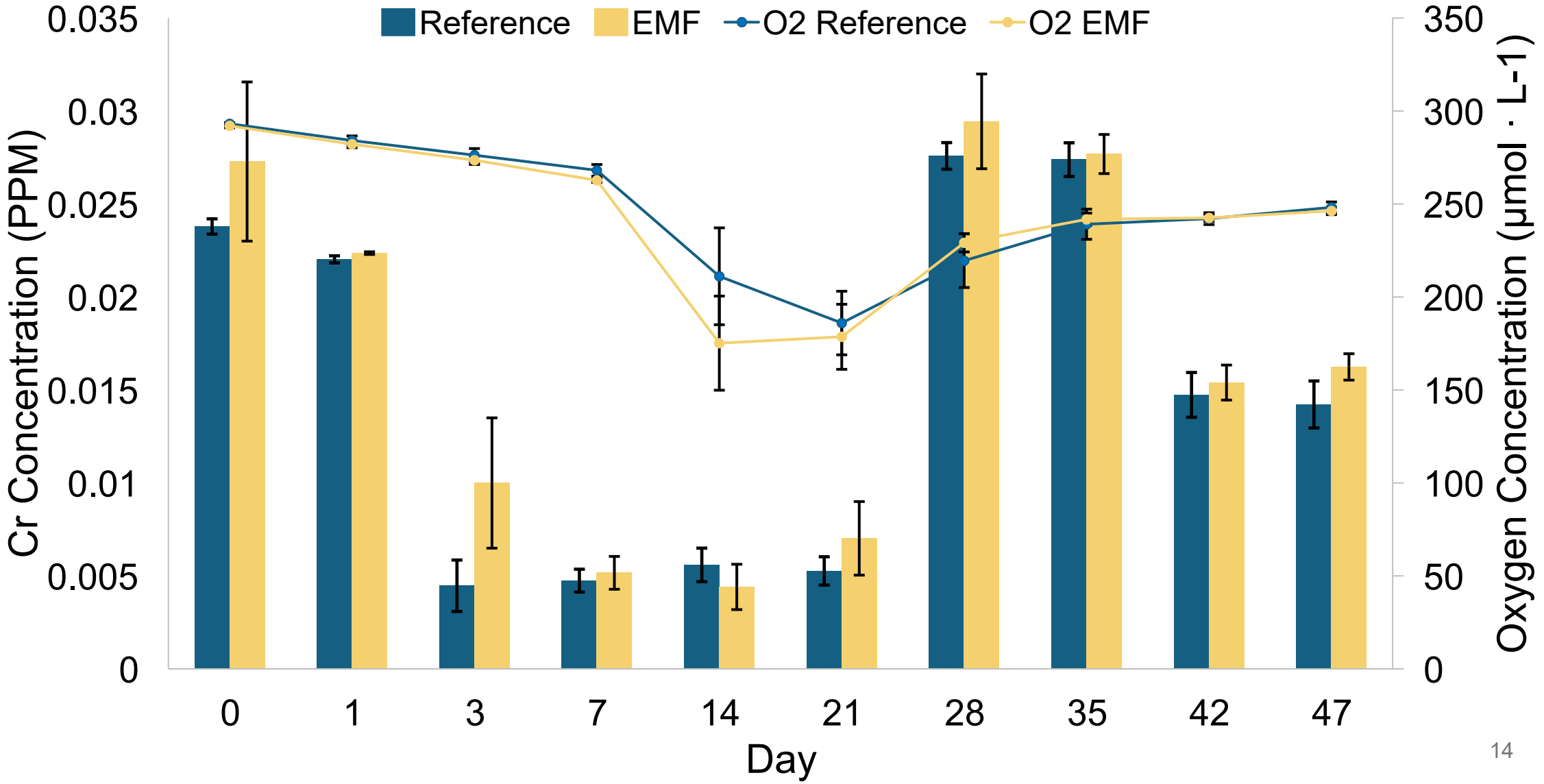


X 10 replicates (5 Reference, 5 EMF)

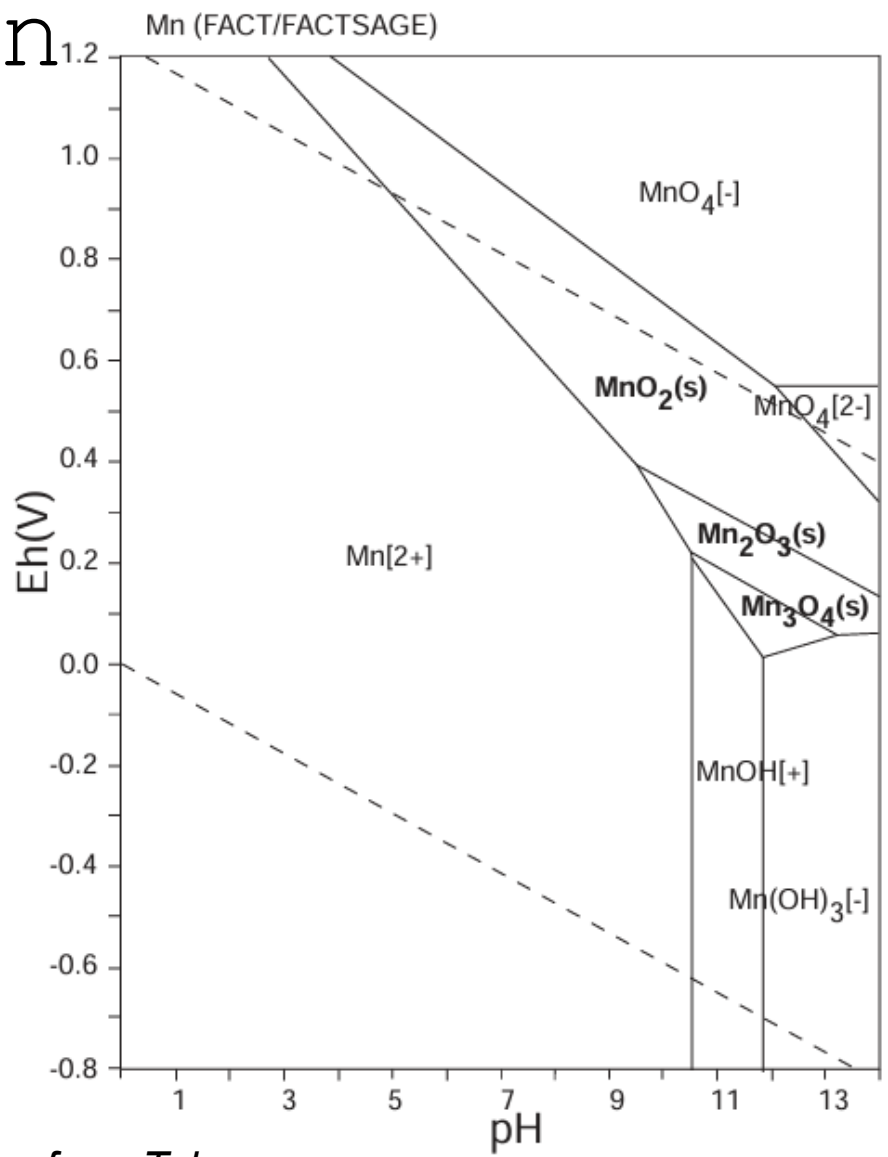
Results: Copper Mobility

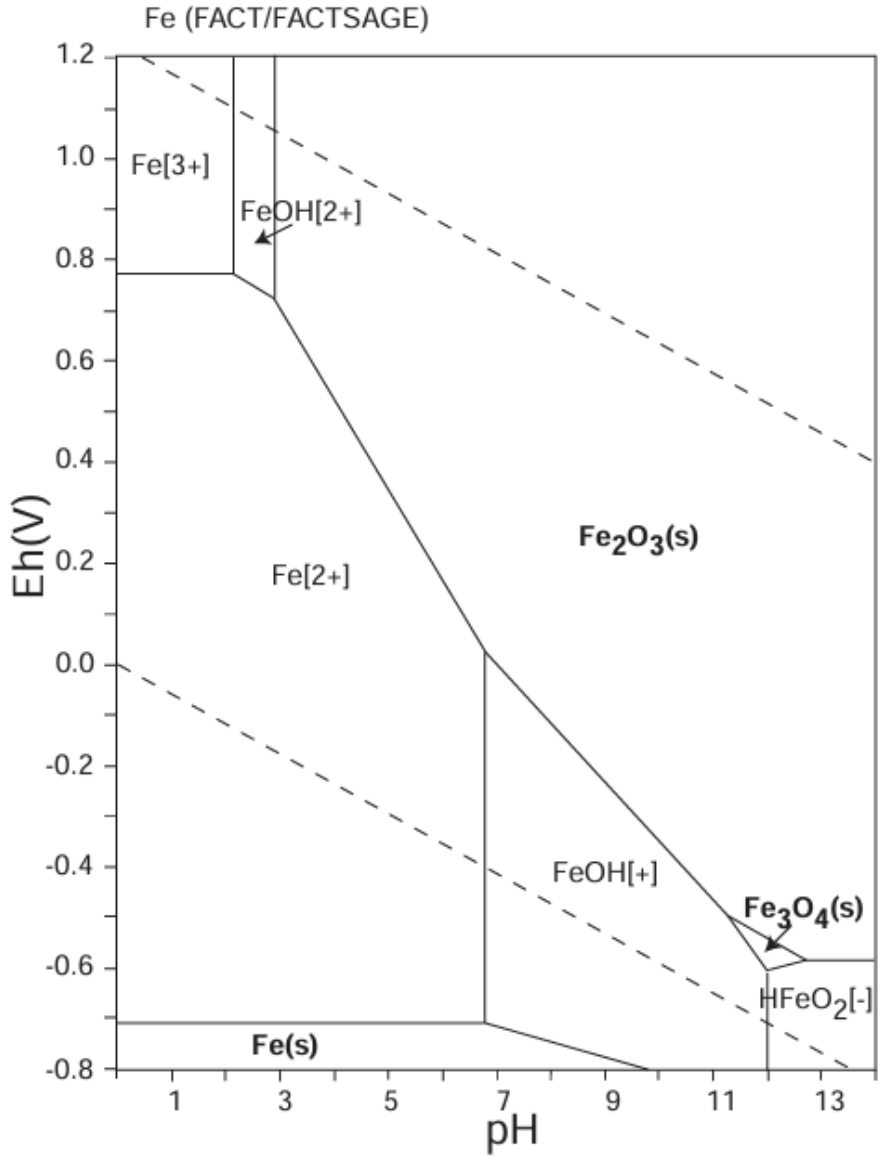


Results: Chromium Mobility



Shift in Redox : Manganese & Iron





Eh-pH diagrams from Takeno

Considerations & Moving Forward

- EMF demonstrates increase in DO
  - Can affect pH & redox conditions
- Evidence of speciation/precipitation for chromium but not conclusive
  - Irrespective of EMF treatment
  - Could not create oxygen deficit in microcosms
- Moving Forward → Replicate “real world” conditions
  - Contribute to novel remediation methods to precipitate metals
- Better candidate metals considering shift in redox conditions
  - Manganese and Iron

Acknowledgements

- Graduate Students: Preveen Varathan & Victoria Cunningham

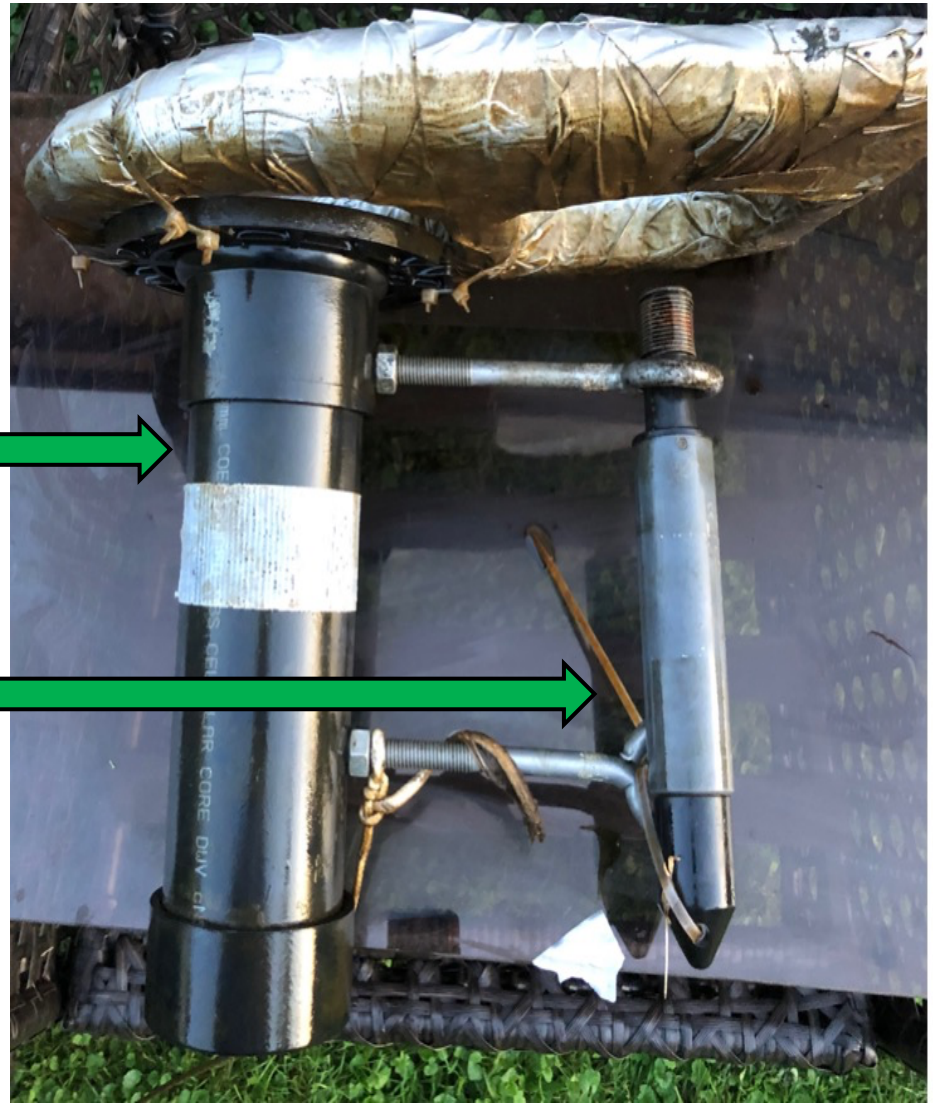
- Supervisor: Prof. Andrew Laursen

Extra Slides

Oxygen Flux Experiment – Oxygen Logger Platform

Encased Oxygen Sensor

Open Water Oxygen Sensor



Flux Equation

$$F = hK(C_{measured} - C_{equil}) \ (1)$$

$$K_x = K_{600} \ x \ (Sc_x/600)^{-n} \ (2)$$

$$K_{O2}\ (h^{-1}) = \frac{F\ (mmol\ O_2\ m^{-2} h^{-1})}{h\ (m)\ x\ (C_{measured} - C_{equilibrium})\ (mmol\ m^{-3})} \ (3)$$

$$K_{600} = K_{O2\ calculated} \times \left(\frac{600}{Sc_{O2\ calculated}}\right)^{-n} \ (4)$$

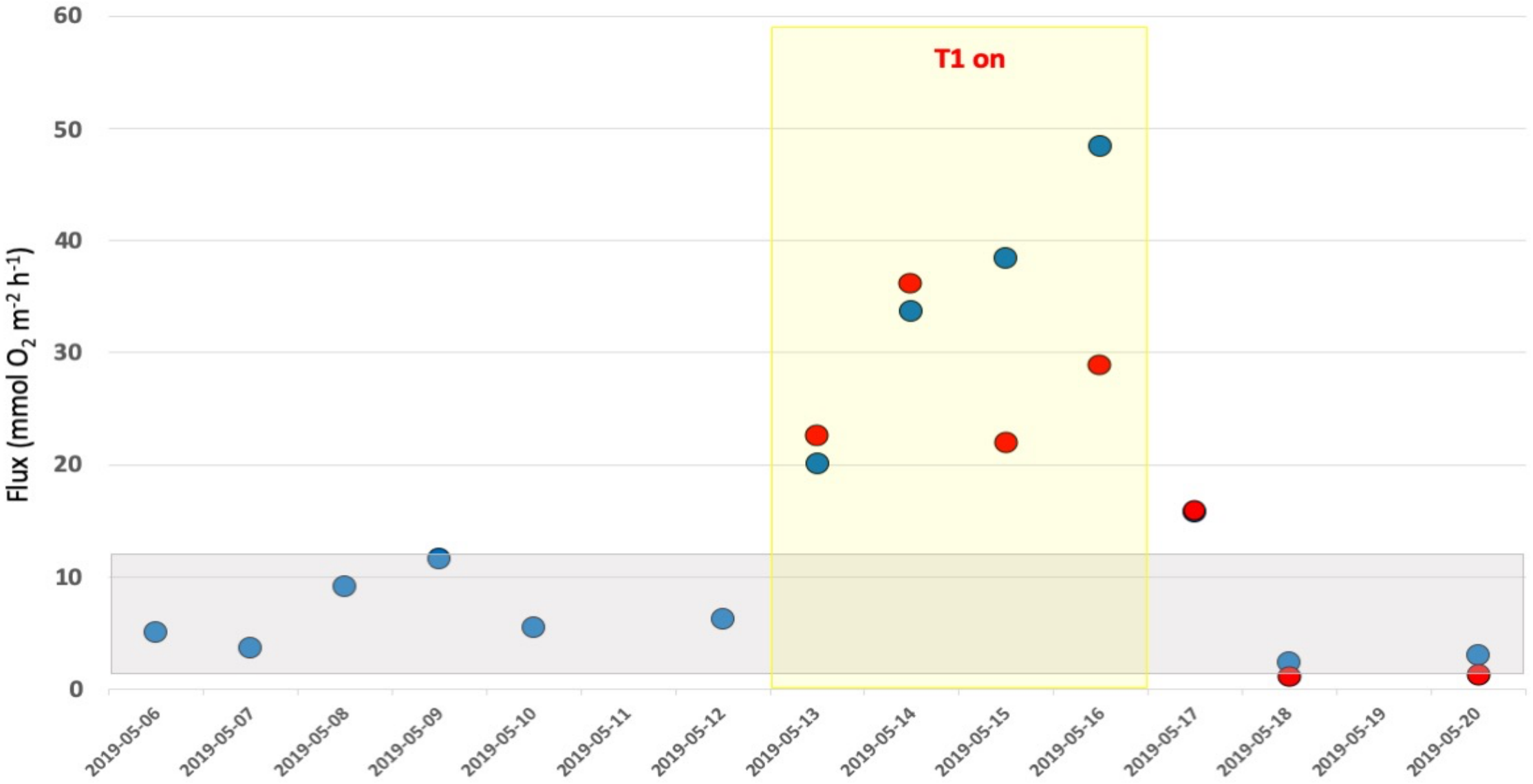
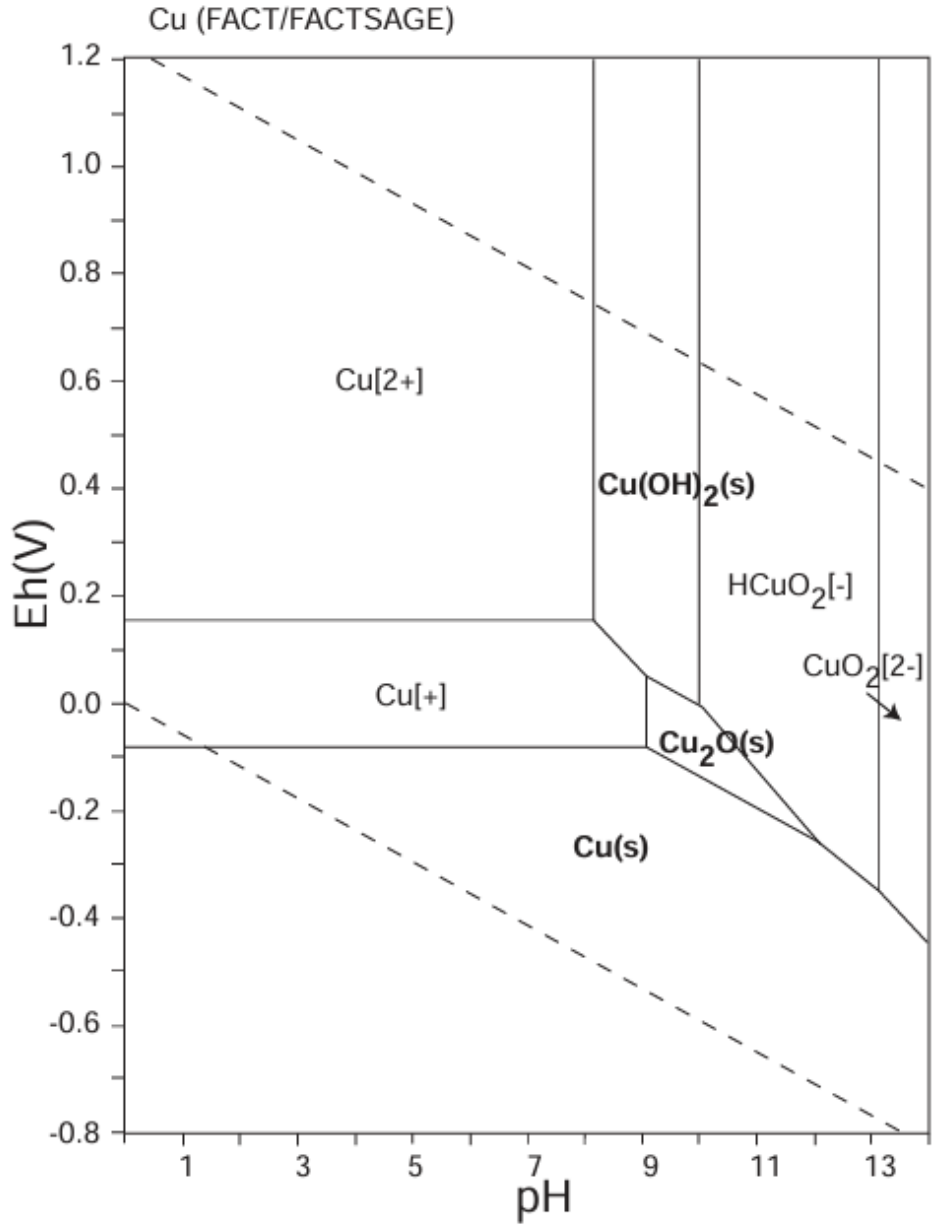
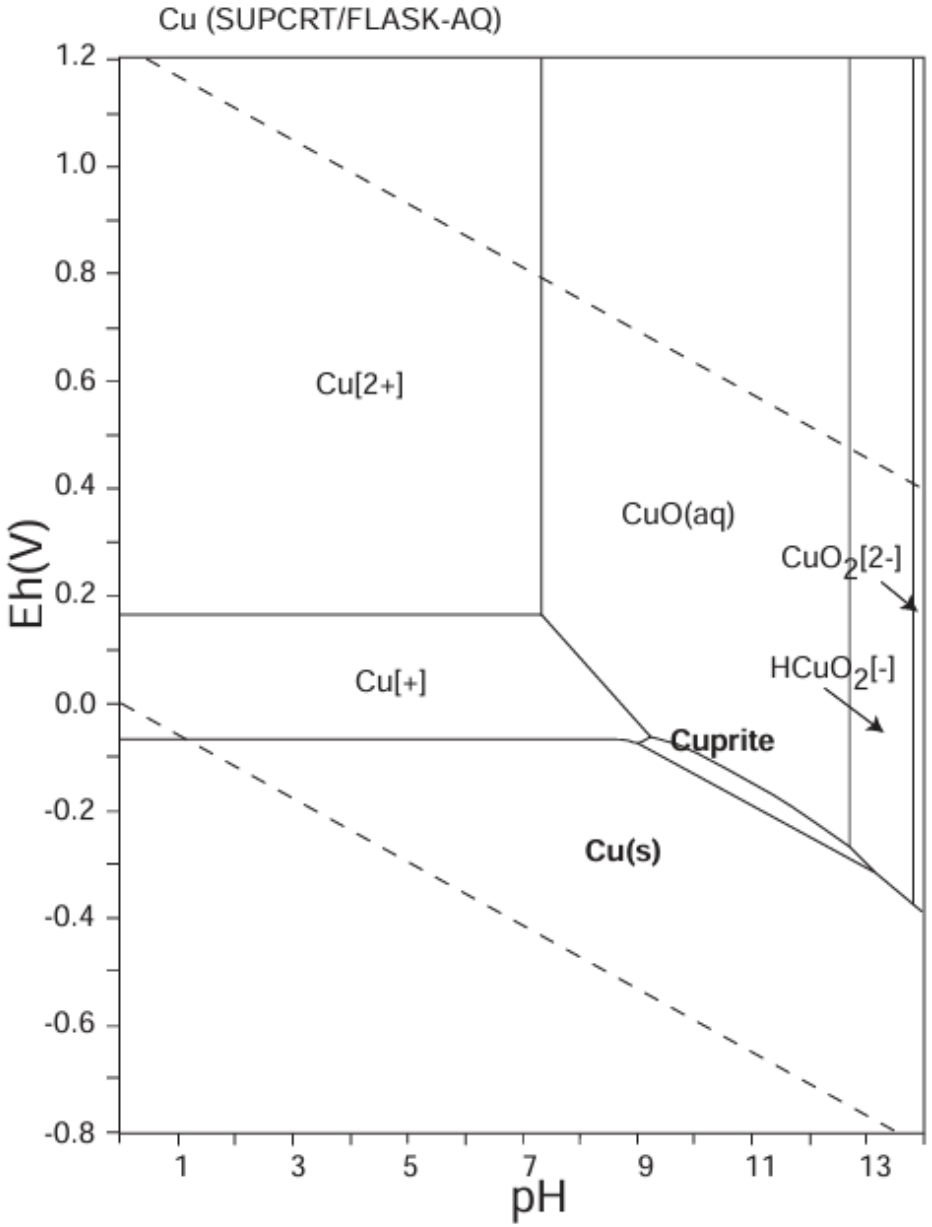


Figure 1. *Oxygen flux rates (from air to water). Yellow shaded region indicates dates EMF unit was activated. Blue dots represent flux rates measured near the EF unit (10 m distant). Red dots represent flux rates measured 110 m from EMF unit. Grey shaded region represents the expected background (reference) flux rates.*

Table 1. Oxygen exchange under reference conditions, and measured under treatment conditions at varying distances from a single active EMF device

	n	Exchange (mg O_2 L^{-1} d^{-1}) (± 95% CI)	ANOVA results (EMF to Reference)
Reference	55	2.51 ± 0.48	----
EMF device Placement (m):			
0-10	26	5.91 ± 1.12	$F_{1,79} = 41.28$, $p = 9.19 \times 10^{-9}$
1-30	22	4.44 ± 0.88	$F_{1,76} = 14.76$, $p = 2.52 \times 10^{-4}$
31-60	26	4.13 ± 0.89	$F_{1,79} = 11.85$, $p = 9.27 \times 10^{-4}$
61-90	13	4.81 ± 1.59	$F_{1,66} = 13.18$, $p = 5.53 \times 10^{-4}$
121-150	23	4.01 ± 1.29	$F_{1,76} = 6.99$, $p = 9.97 \times 10^{-3}$


Cu (FACT/FACTSAGE)
Eh(V)
pH
Cu[2+]
Cu(OH)2(s)
HCuO2[-]
CuO2[2-]
Cu[+]
Cu2O(s)
Cu(s)


Cu (SUPCRT/FLASK-AQ)
Eh(V)
pH
Cu[2+]
CuO(aq)
CuO2[2-]
HCuO2[-]
Cu[+]
Cuprite
Cu(s)