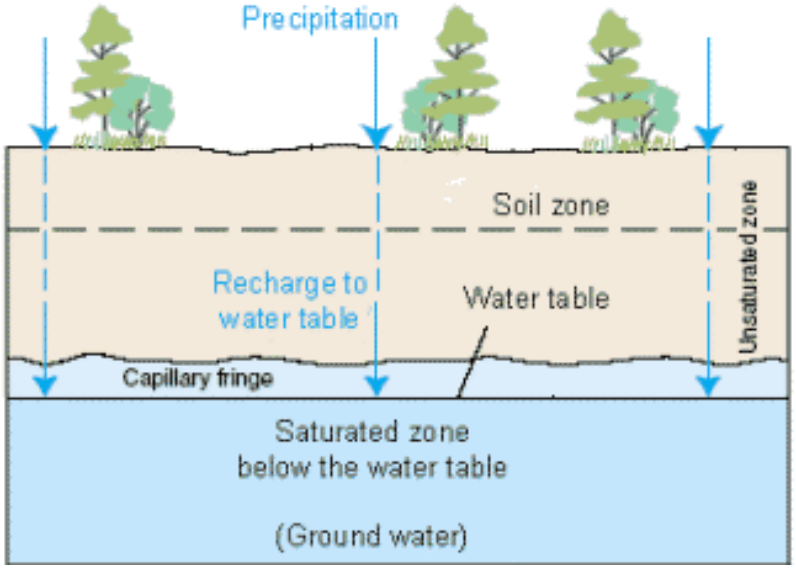
Usage of Water-Filled Trench in Improving Groundwater Quality

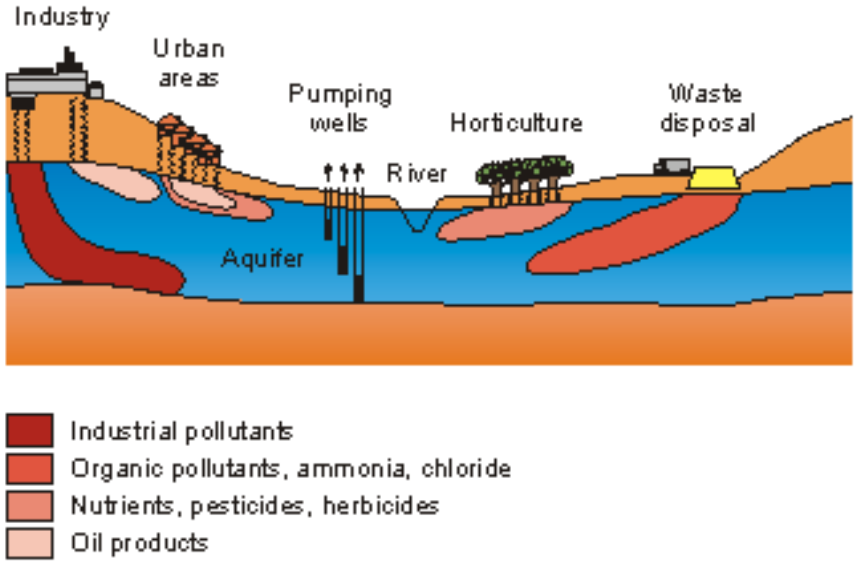
Gang Chen, Amy Chan Hilton, and Kamal Tawfiq

Department of Civil and Environmental Engineering
FAMU-FSU College of Engineering

Florida A & M University

Florida State University





Shallow Vadose Zone

BTEX, PCE, TCE and Iron Contamination

Groundwater in Florida

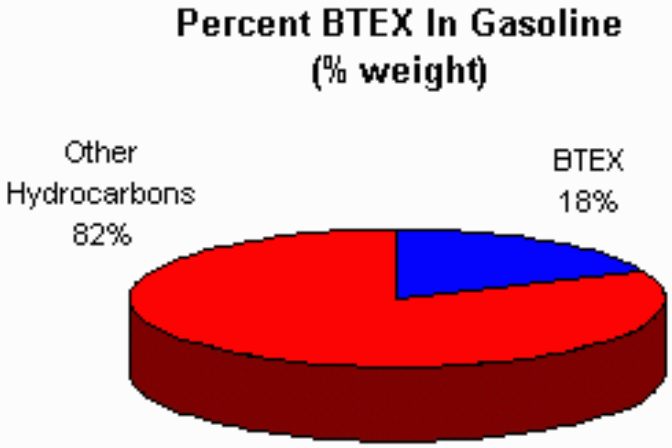
Florida A & M University

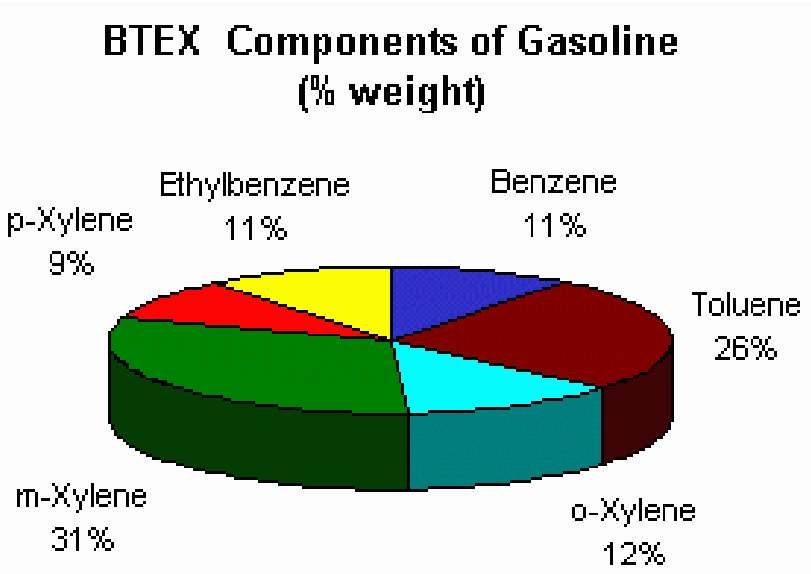
Florida State University

BTEX Contamination

Florida A & M University

Florida State University



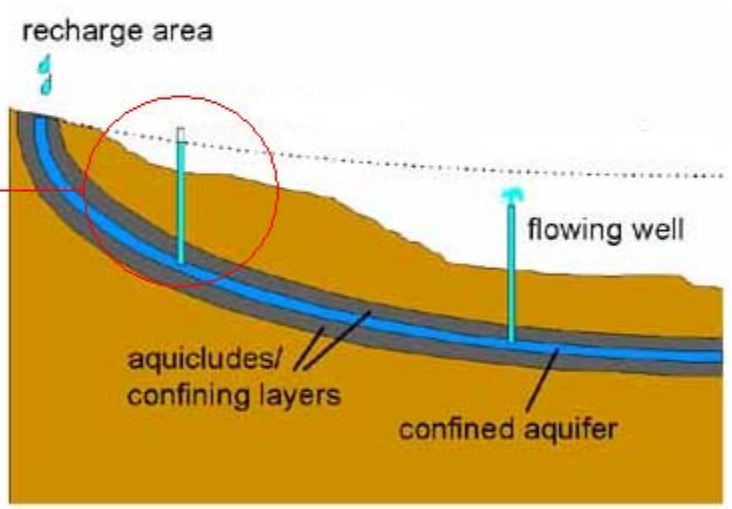


Gasoline Composition

Florida A & M University

Florida State University

- Organic compound degradation
- Volatile organic compound vaporization
- Metal oxidation and precipitation



Water-Filled Trench

Objectives

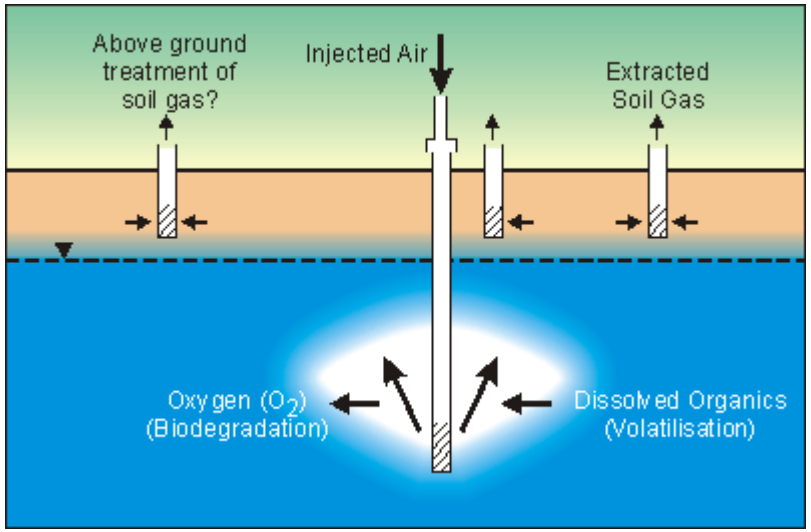
- **Explore the possibility of the usage of water-filled trench in treating contaminated groundwater**
- **Identify dominating mechanisms**
  - Organic decomposition
  - Volatile organic compound vaporization
  - Metal oxidation and precipitation
- **Investigate the effect**
  - Effect of dissolved oxygen
  - Effect of alkalinity
- **Promote field applications**
  - Quantify removal rate

Outline

- **Theoretical consideration**
  - Organic compound removal
  - Volatile organic compound removal
  - Metal removal
  - Effect of alkalinity
- **Simulated Groundwater**
- **Water-Filled Trench Experiments**
- **Water-Filled Trench with an Aerobic Filter**
- **Expected Results and Modeling**

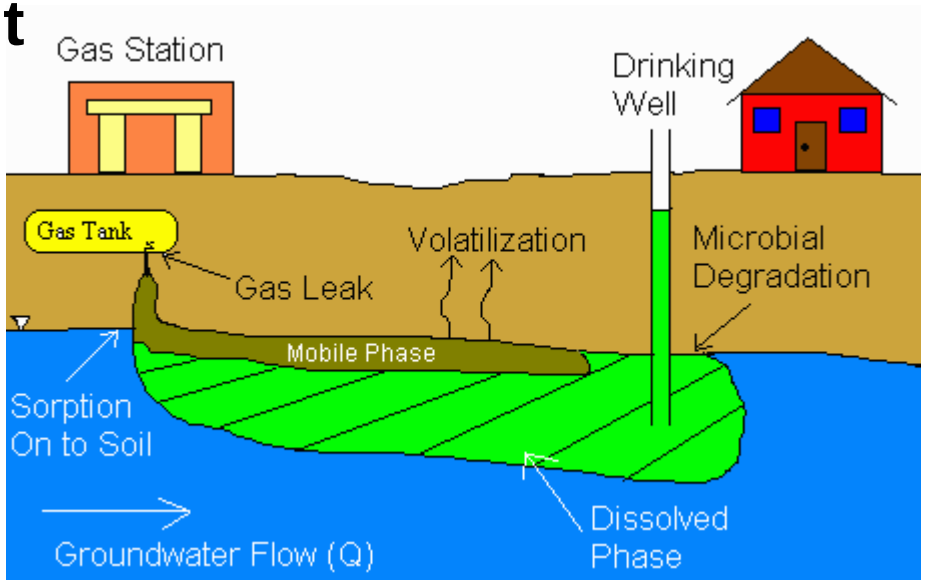
Organic Decomposition

- **BTEX, pesticides, and polycyclic aromatic hydrocarbons (PAHs)**
- **Aerobic process**
- **Nutrient requirement**
- **pH and temperature**



Volatile organic compound vaporization

- **Volatile organic contaminants**
- **High vapor pressure and low water solubility**
- **Temperature-dependent**
- **BTEX**
- **PCE and TCE**



Metal Removal

- **Heavy metals to be transformed and precipitate**
- **pH and redox conditions**
- **Alkalinity**

Dissolved Oxygen

- Organic compound degradation
- Electron acceptor
- 1.0 mg/L DO required for 0.32 mg/L BTEX
- Mass transfer between air and groundwater
- Heavy metal oxidation and precipitation

Alkalinity

- HCO_3^-, CO_3^{2-} and OH^-

- Alkalinity loss during organic degradation, CO_2 stripping and metal oxidation and precipitation

- Most important for heavy metal oxidation and precipitation

- Addition of external alkaline agents such as lime

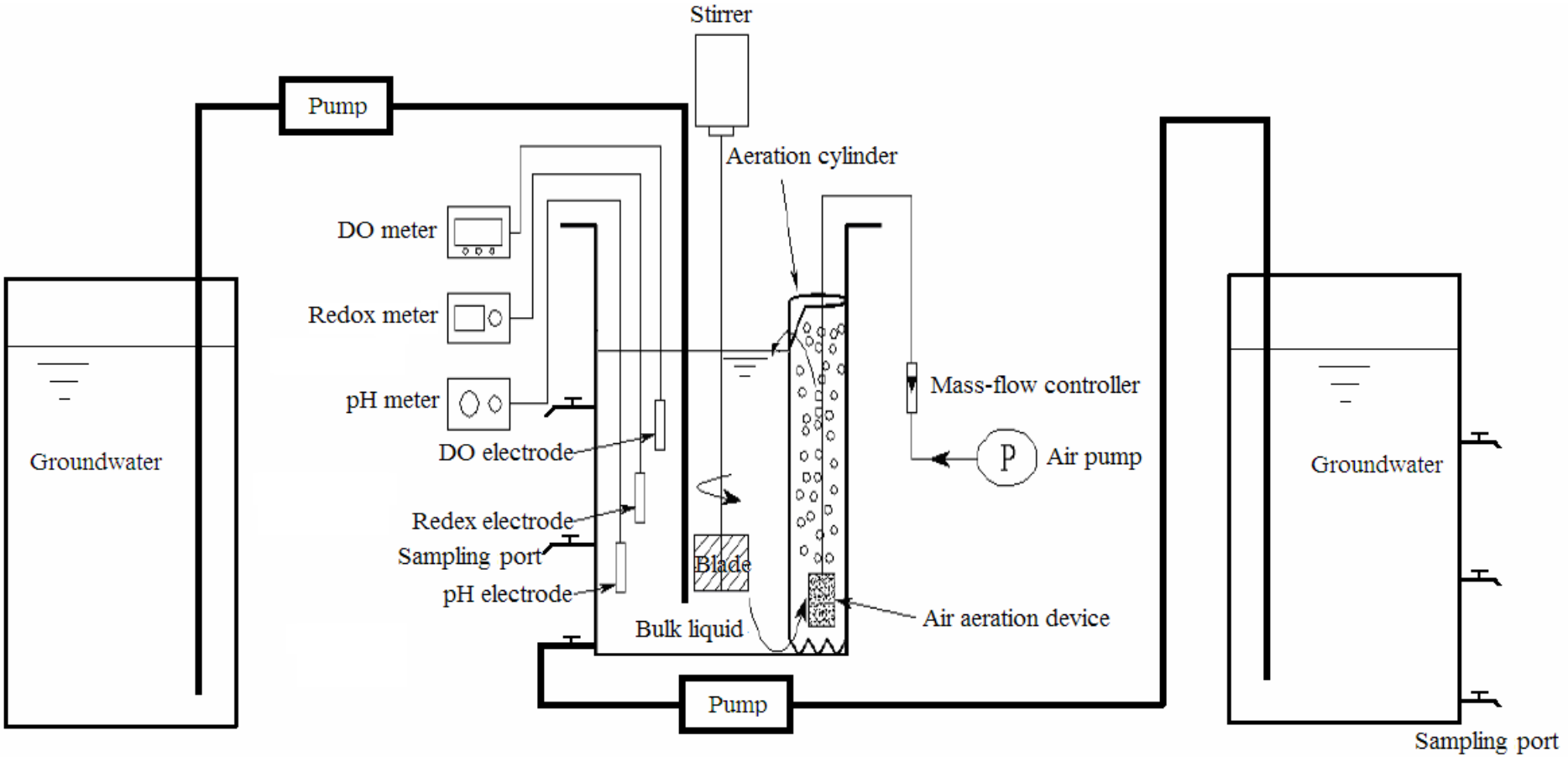
Simulated Groundwater

- Benzene, 25 mg/L
- Toluene, 25 mg/L
- Ethylbenzene, 25 mg/L
- *p*-xylene, 25 mg/L
- PCE, 20 μg/L
- TCE, 200 μg/L
- Glucose, 50 mg/L
- Ferrous iron, 10 mg/L

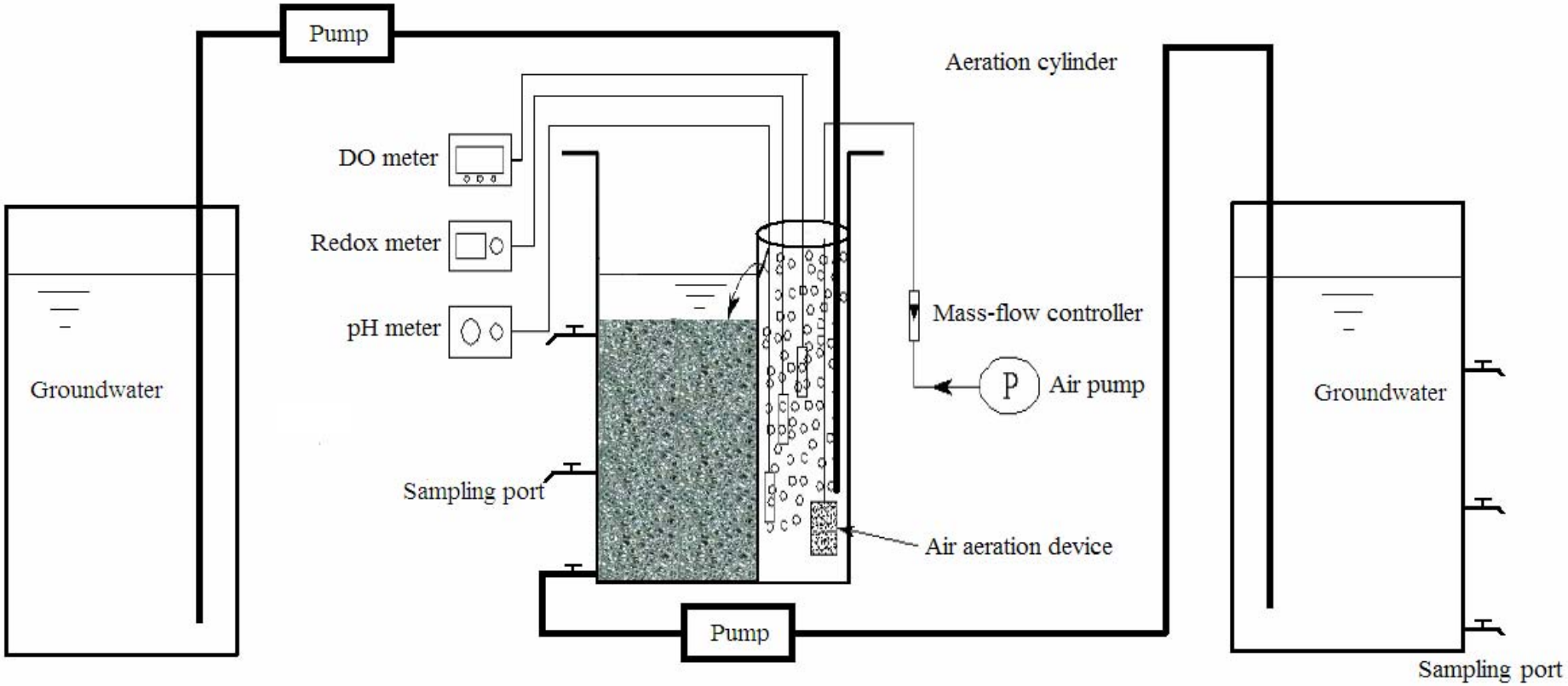
Benzene, toluene, *p*-xylene, PCE, and TCE to be monitored by a GC with a flame ionization detector and helium as the carrier gas

Glucose and iron to be quantified by HPLC and spectrophotometer

Water-Filled Trench Setup



Water-Filled Trench with a Filter



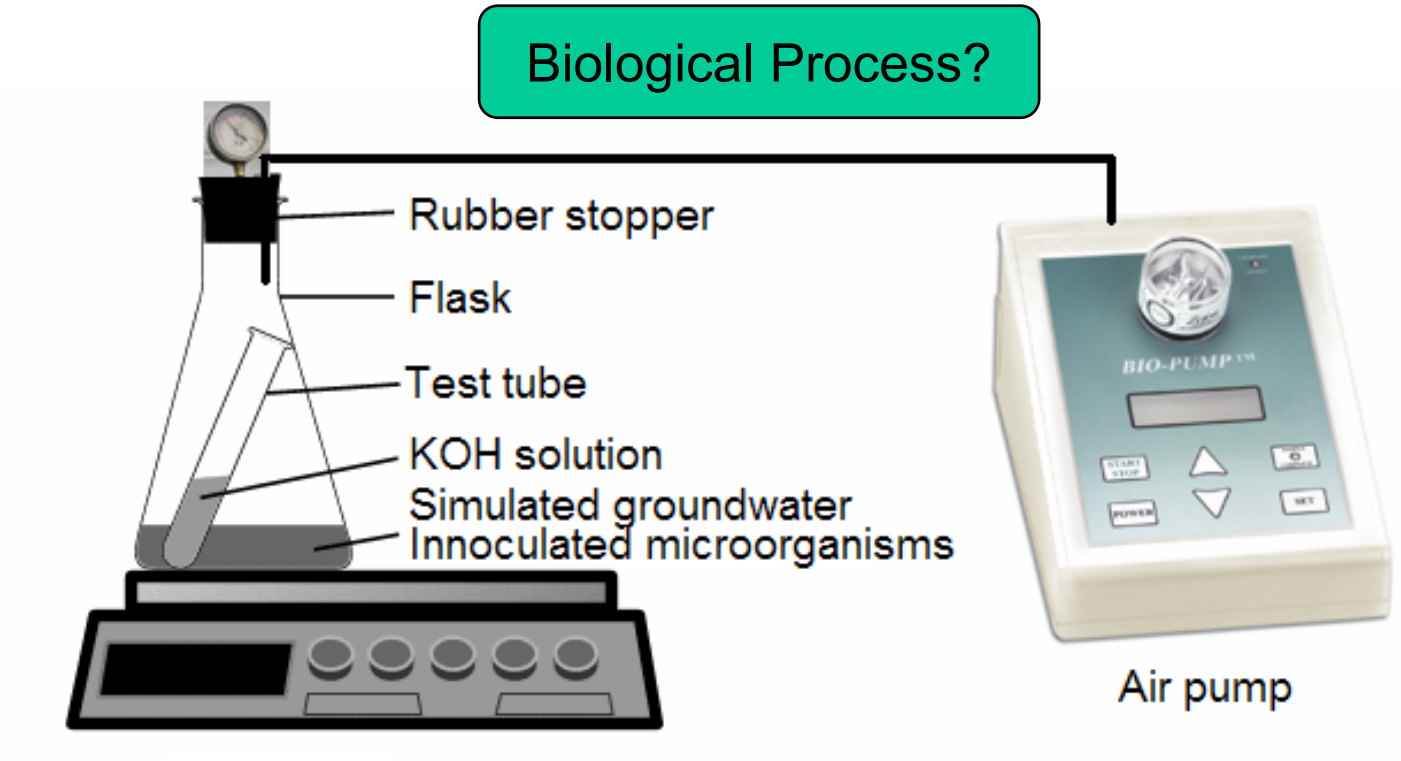
Other Parameters to Be Monitored

- **Redox Potential**
- **pH**
- **Conductivity**
- **Temperature**

Florida A & M University

Florida State University

Control Experiments

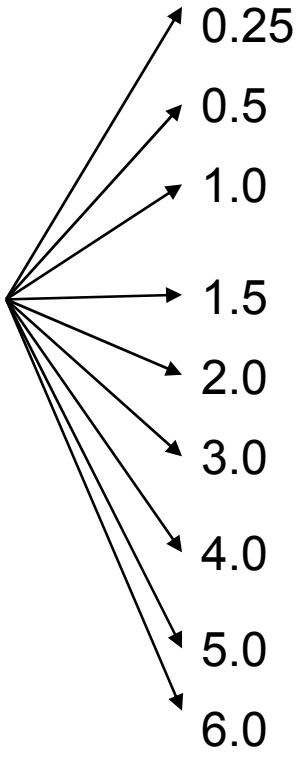


$$C_p = C^* P[\frac{(1 - P_w/p)(1 - \theta P)}{(1 - P_w)(1 - \theta)}]$$

C_p: oxygen concentration at nonstandard pressure
C^*: oxygen concentration at standard pressure
P: nonstandard pressure
P_w: partial pressure of water vapor

Expected Results — Water-Filled Trench

Benzene, 25 mg/l
Toluene, 25 mg/l
xylene, 25 mg/l
PCE, 20 μg/l
TCE, 200 μg/l
Glucose, 50 mg/l
Fe^{2+}, 10 mg/l



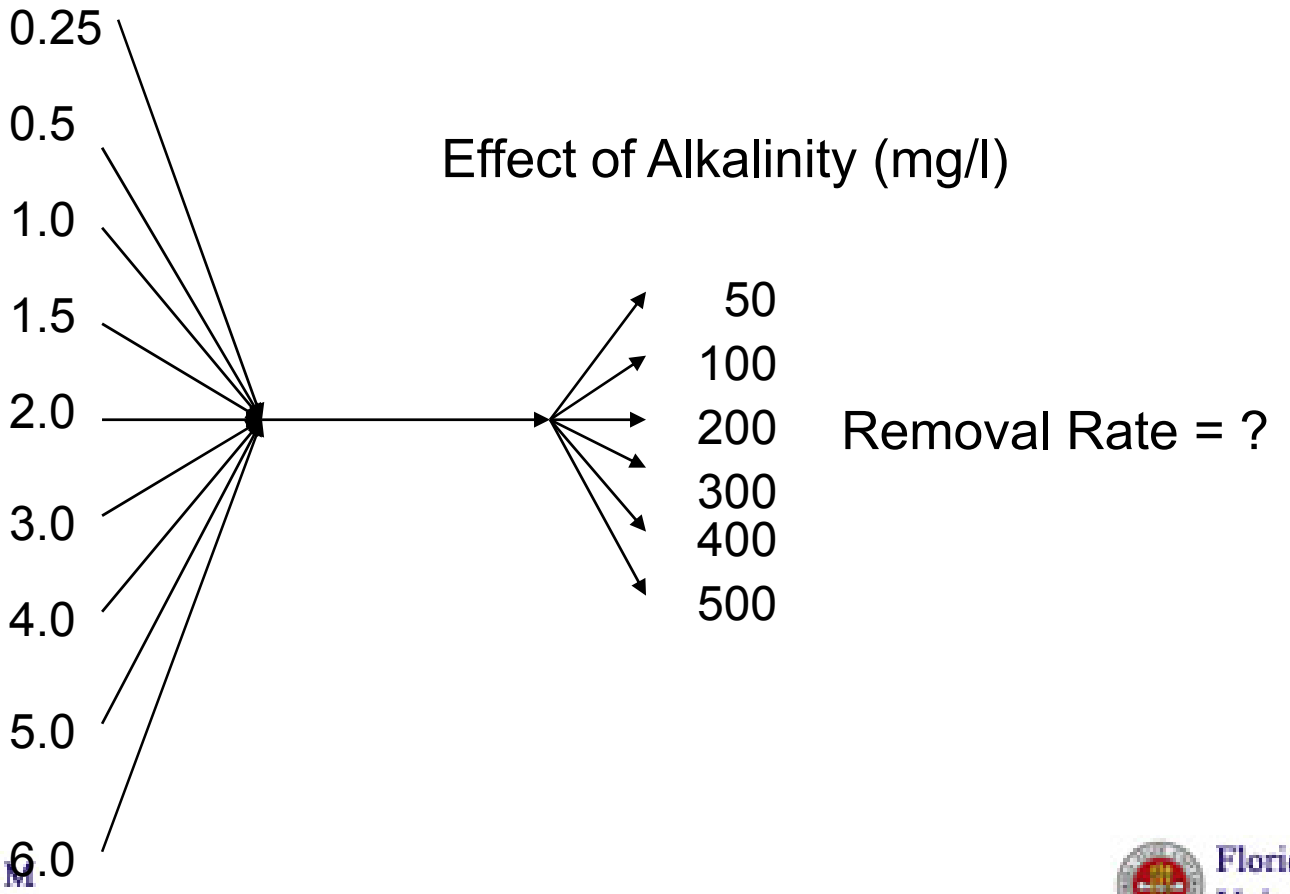
DO Value (mg/l)

Benzene=? Toluene=?
Xylene=? Glucose=?
PCE=? TCE=? Fe^{2+}=?

pH=? Redox=? Microbial activity?

Expected Results — Water-Filled Trench

Organic Removal — Biological Process?



Florida A & M University

Florida State University

Expected Results — Water-Filled Trench

BTEX, PCE & TCE Removal – Evaporation?

0.25

0.5

1.0

1.5

2.0

3.0

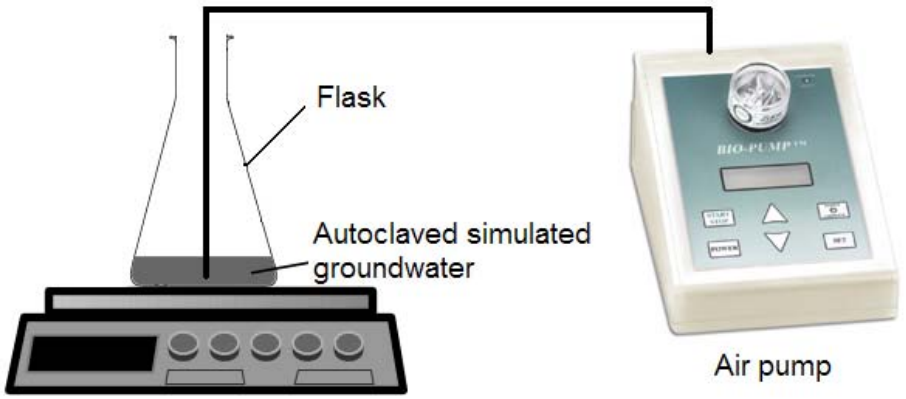
4.0

5.0

6.0

DO Value (mg/l)

Removal Rate = ?

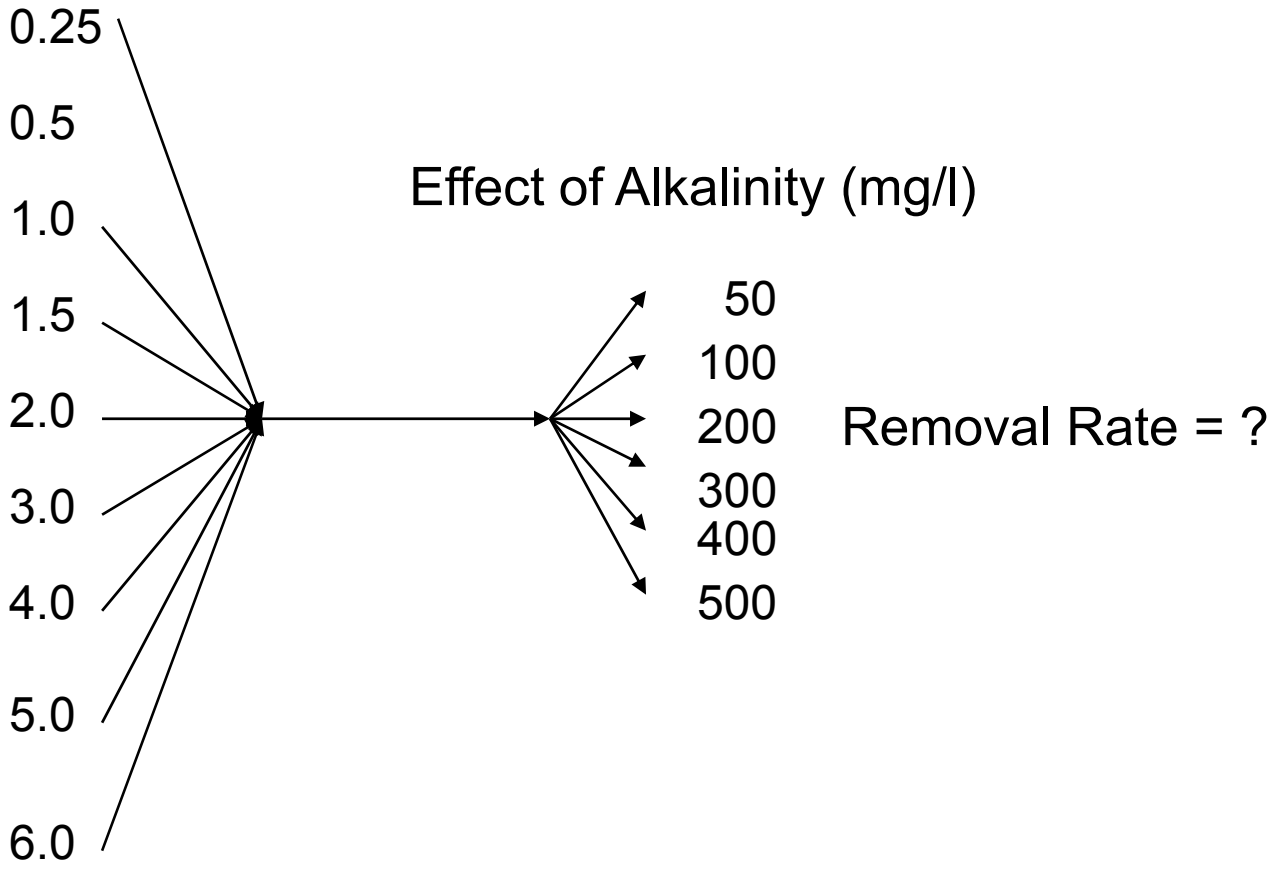


Florida A & M University

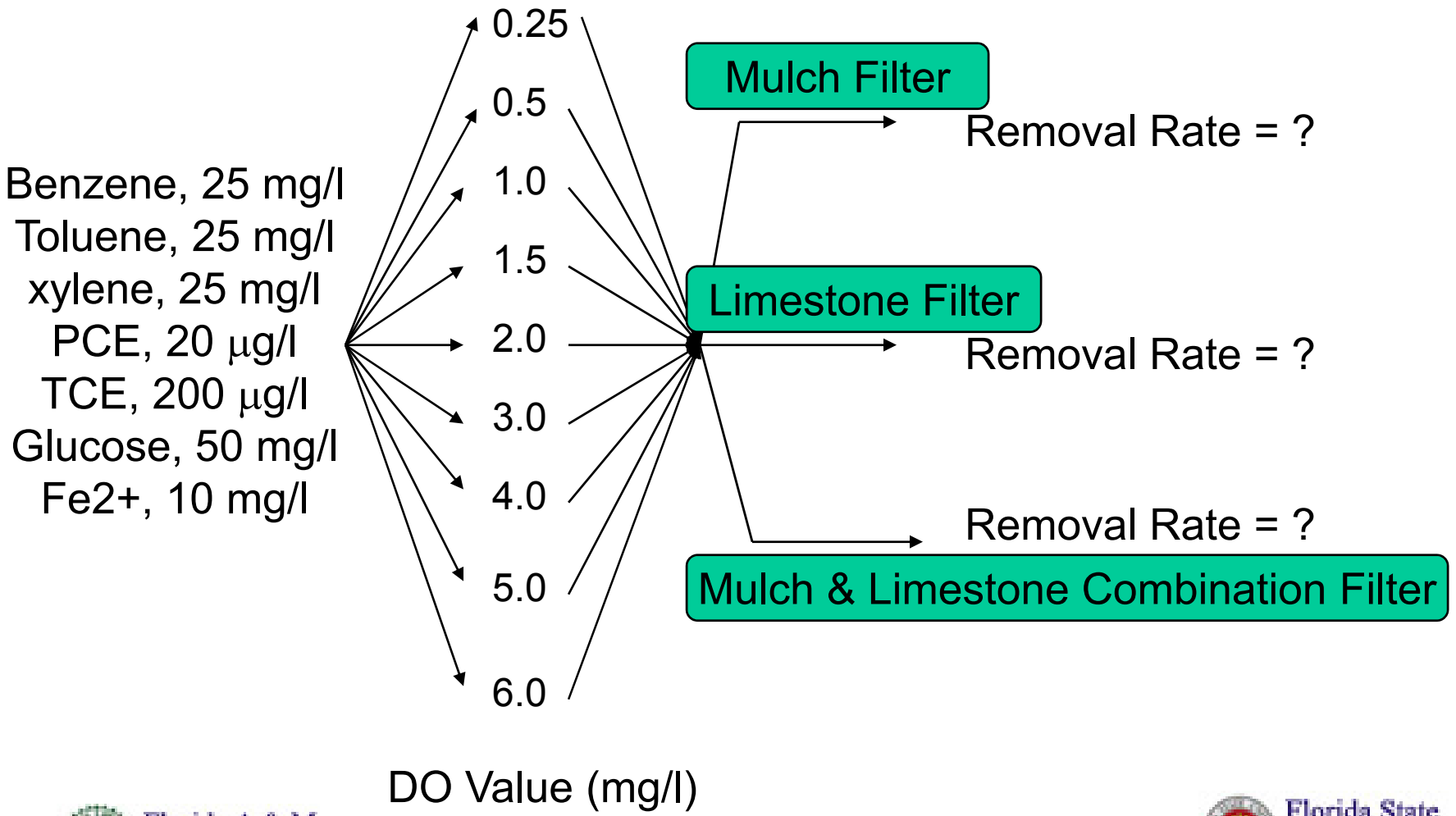
Florida State University

Expected Results — Water-Filled Trench

Fe^{2+} Removal — Biological or Chemical Oxidation and Precipitation?



Expected Results — Water-Filled Trench with Aerobic Filter



Biodegradation Simulation

Organic contaminant degradation: $$\frac{dS}{dt} = -\frac{\mu_{max} S}{K_m + S}$$

$$S = K_m W[\frac{S_0}{K_m} \exp(\frac{S_0 - \mu_{max} t}{K_m})] \qquad W(x) + \ln[W(x)] = \ln(x)$$

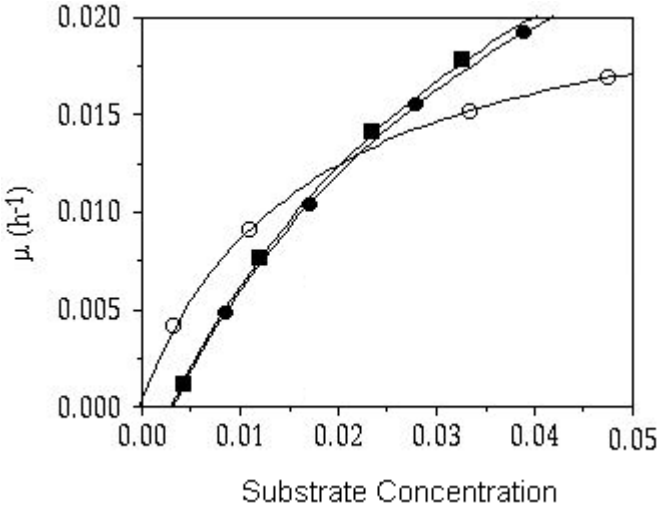
S: organic compound concentration

μ_{max}: maximum bacterial growth rate

K_m: half saturation constant

S_0: initial organic compound concentration

W: Lambert function x: argument of W



Evaporation Simulation

Volatile organic contaminants mass transfer:

$$M = K_L a(C_L^* - C_0)$$

M: mass of volatile organic contaminants transferred per unit time and volume

K_L: mass transfer coefficient

a: effective mass transfer area

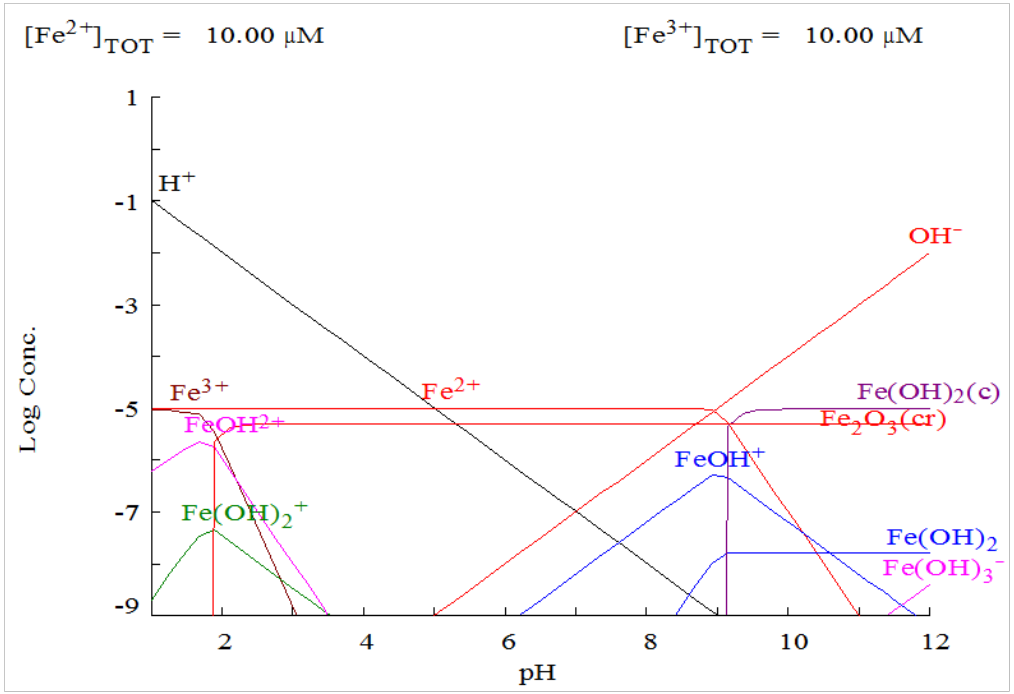
C_L^*: liquid phase concentration in equilibrium with gas phase concentration

C_0: bulk phase liquid concentration

Oxidation/Precipitation Simulation

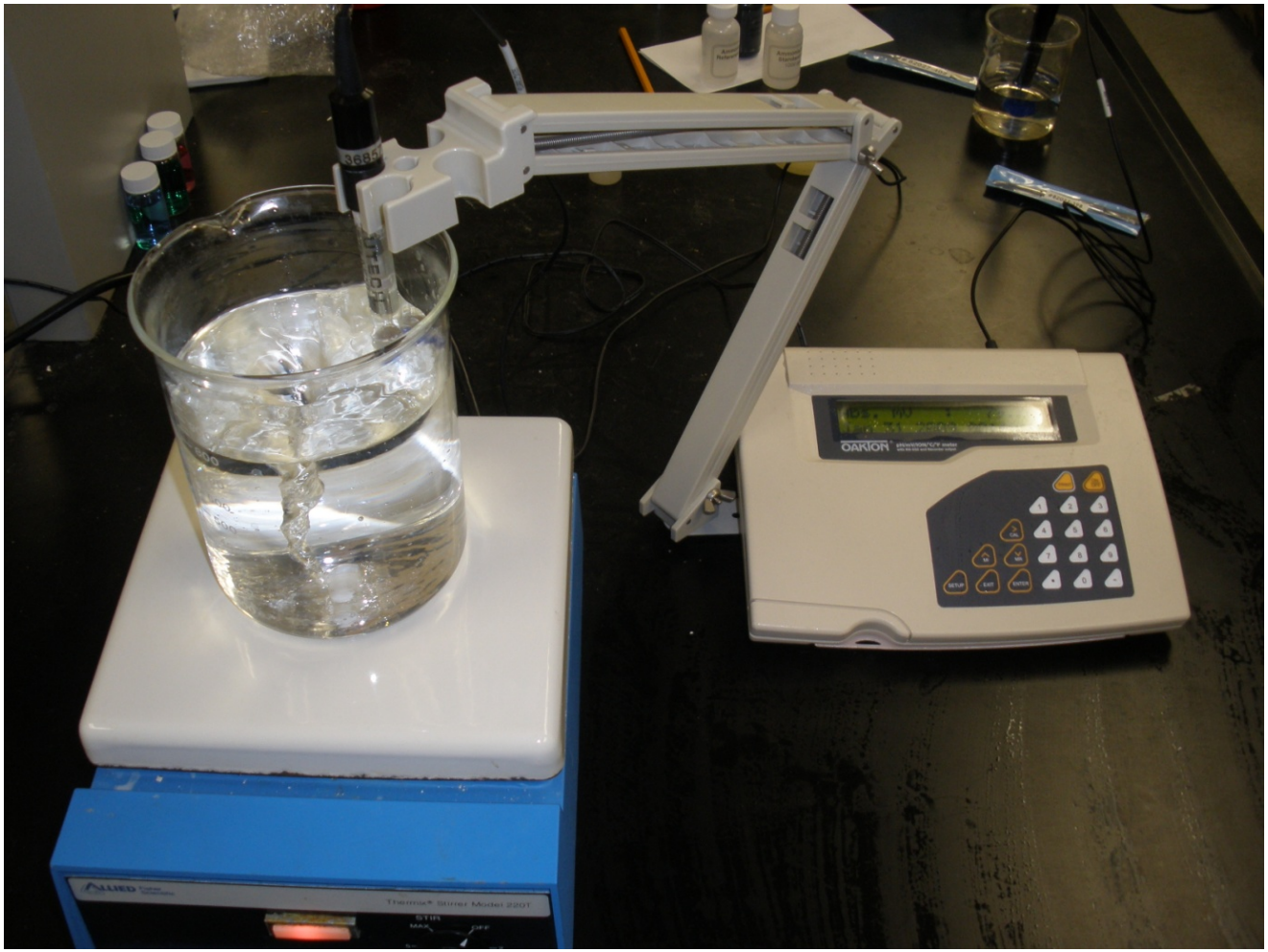
- **For microbial mediated metal transformation, Monod function to be used**

- **For chemically mediated metal transformation, a stoichiometry relationship to be established and precipitation process to be simulated by Visual MINTEQ 2.51**

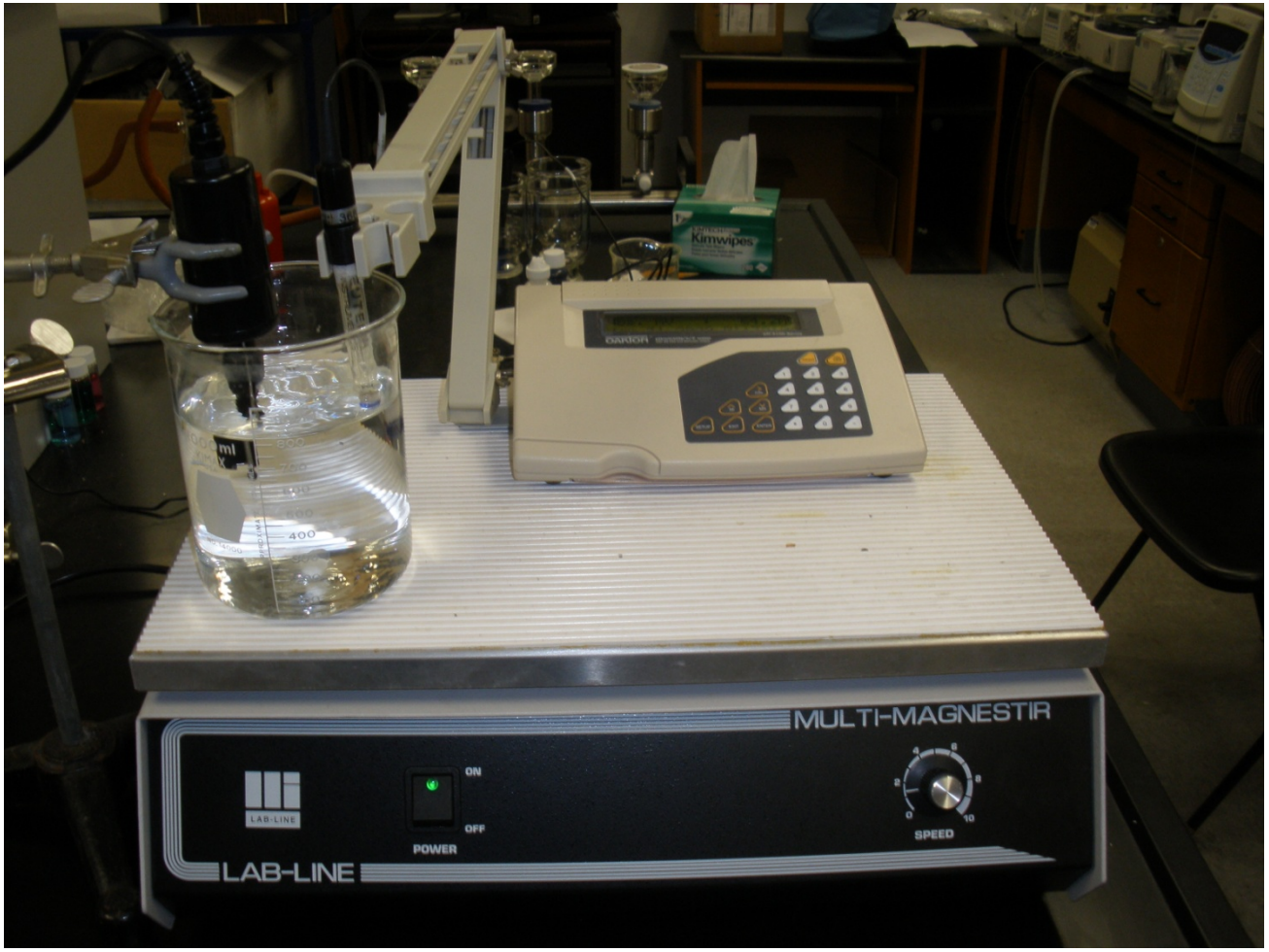


Florida A & M University

Evaporation



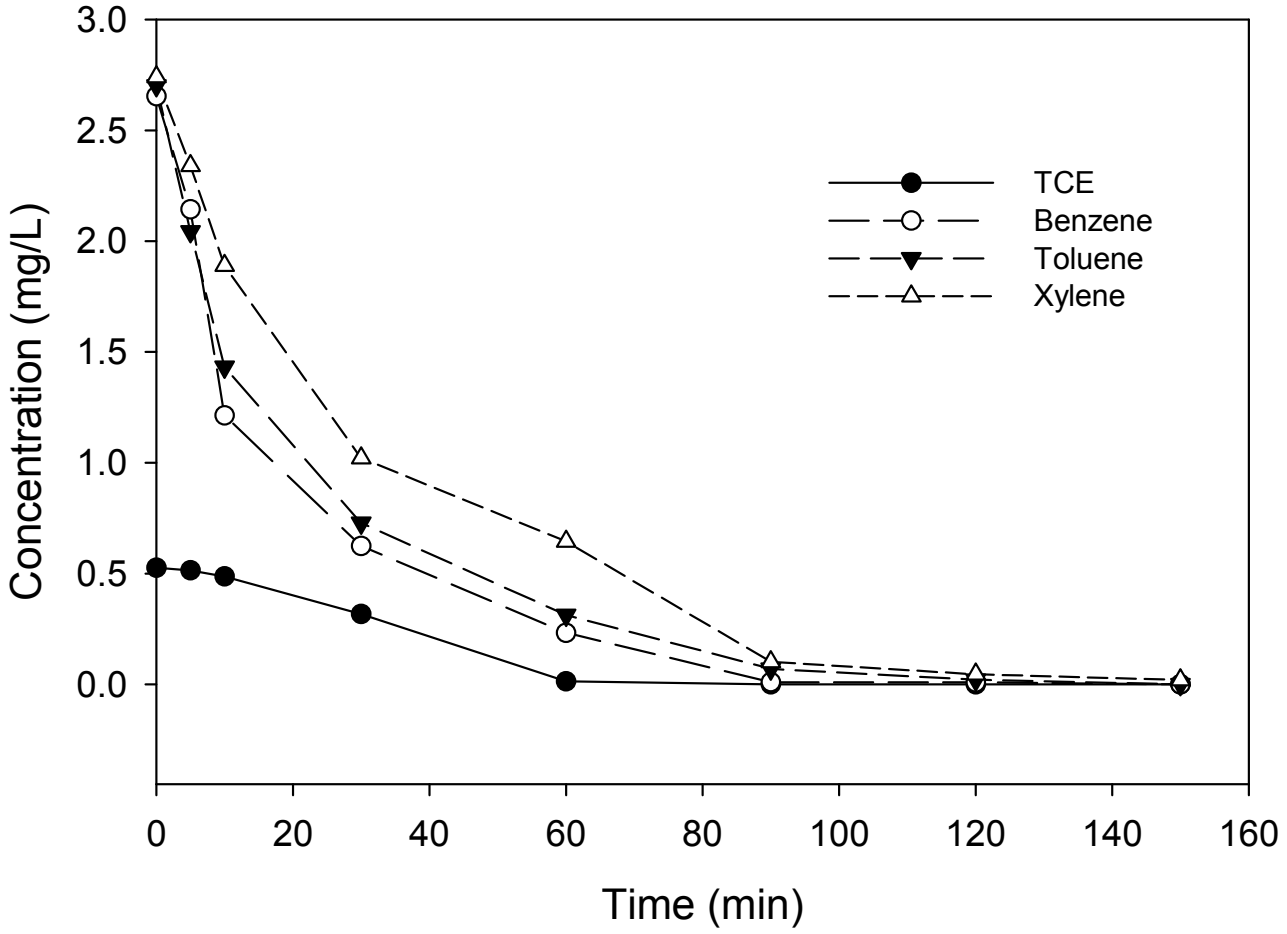
Evaporation



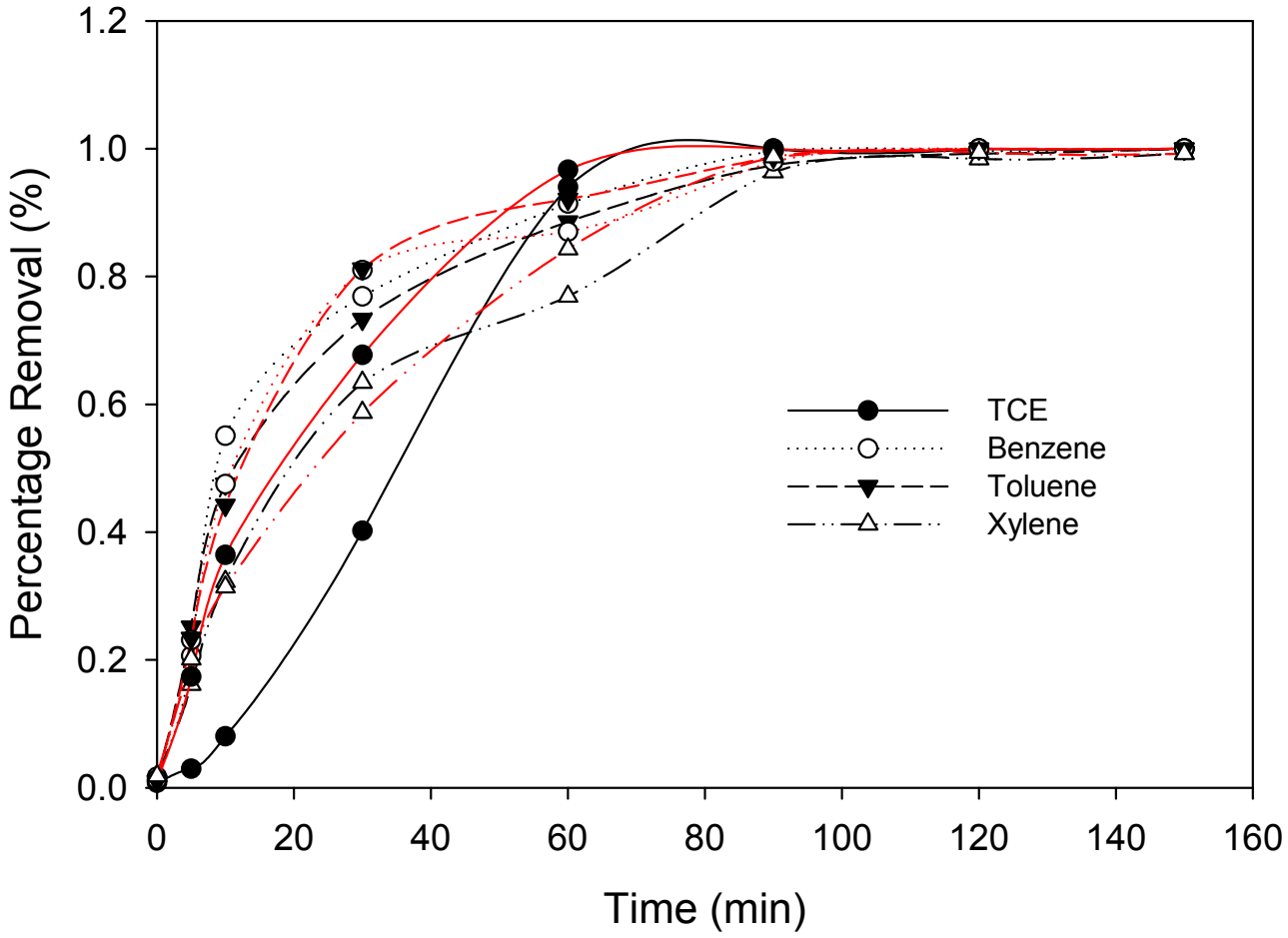
Florida A & M University

Florida State University

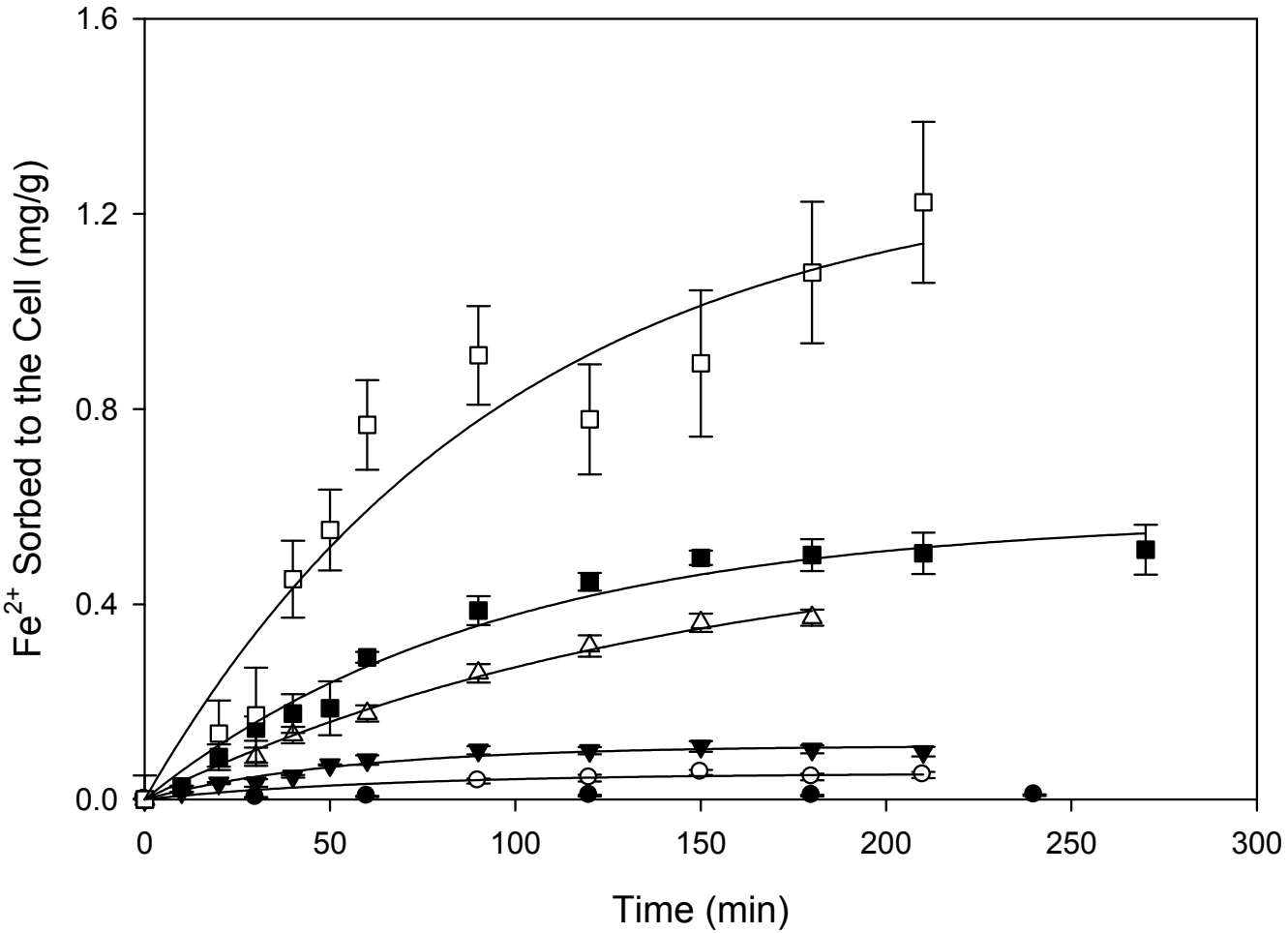
Evaporation



Evaporation



Ferrous Iron Sorption



ferrous iron concentrations investigated in this study: 0.25, 2.0, 3.5, 10.0, 15.0, and 30.0 mg/l

Florida A & M University

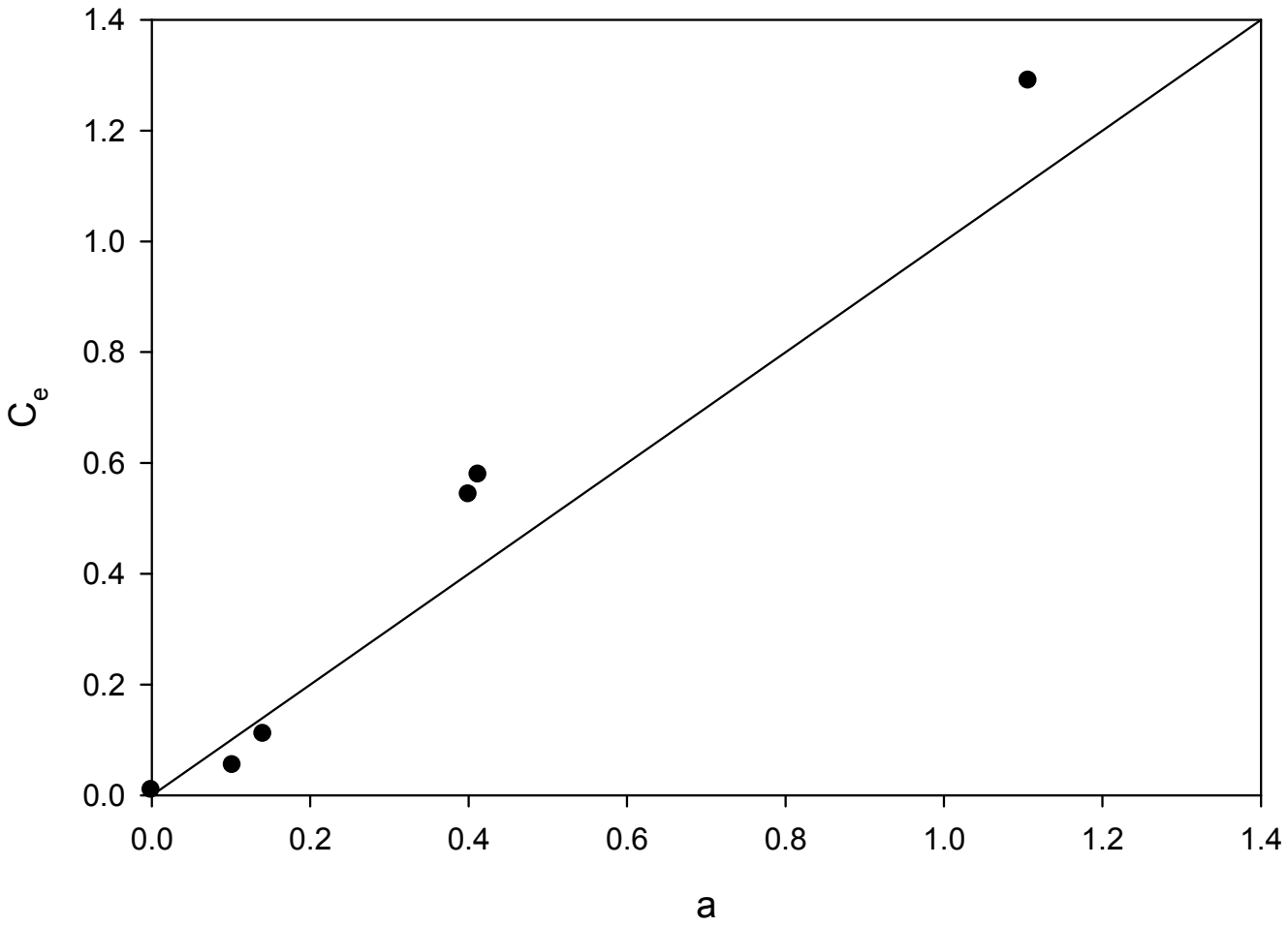
Florida State University

Ferrous Iron Sorption

$$q = a(1 - b^{c})$$

	a	b	R^2
0.25	0.0085 ± 0.0002	0.9796 ± 0.0013	0.9970
2.00	0.0533 ± 0.0058	0.9850 ± 0.0056	0.9606
3.50	0.1099 ± 0.0058	0.9818 ± 0.0025	0.9609
10.0	0.5424 ± 0.0473	0.9931 ± 0.0010	0.9945
15.0	0.5779 ± 0.0317	0.9894 ± 0.0013	0.9788
30.0	1.2890 ± 0.1837	0.9898 ± 0.0029	0.9214

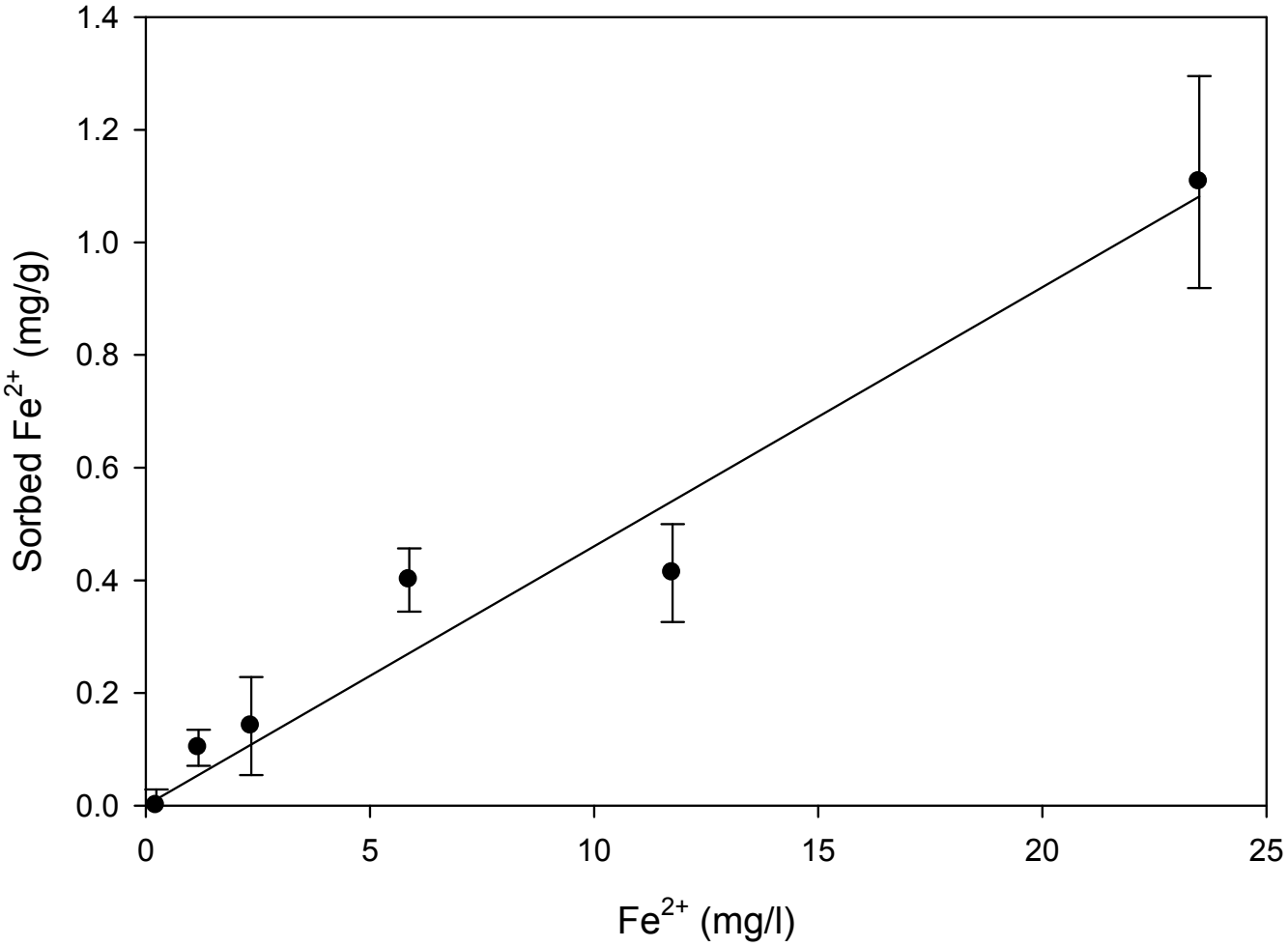
Ferrous Iron Sorption



Florida A & M University

Florida State University

Ferrous Iron Sorption



Florida A & M University

Florida State University

Questions?