

# **Preliminary Study of Multiple Heavy Metal Removal Using Waste Iron Oxide Tailings**

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**October 17, 2002**

# Background Information

- Most of heavy metals in the aquatic environment are toxic to many life forms.
- Heavy metal contamination exists in aqueous wastes of many industries.
- Removal of heavy metals from wastewater is necessary for improving water quality.
- R & D for cost-effective removal of heavy metals has been widely conducted.

# Methods for Heavy Metal Removal

- Precipitation
- Membrane filtration
- Ion exchange
- Adsorption
- Co-precipitation/adsorption
- Biological treatment

# Adsorptive Removal of Heavy Metals Using Waste materials

- Fly ash
- Waste metal hydroxides
- Blast furnace slag
- Red mud
- Biomass
- Carbonaceous materials, etc.

*The key benefit of using these wastes or by-products: cost-effectiveness.*

## Objective of This Study

To evaluate the feasibility of using a type of waste iron oxide tailings as an adsorbent for removing selenium (Se), chromium (Cr), cadmium (Cd), and lead (Pb) from aqueous solution.

# Waste Tailings Material



Tailings slurry



Dry tailings

# Major Composition of Dry Tailings

Constituent	Al	Ca	Cr	Fe	Mg	Ni	S	Si
wt%	1.76	4.12	0.97	23.05	0.89	1.60	1.85	8.70
Oxide	Al <sub>2</sub> O <sub>3</sub>	CaO	Cr <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MgO	NiO	SO <sub>4</sub>	SiO <sub>2</sub>
wt%	3.32	5.51	1.41	32.93	1.48	2.03	5.54	18.60

- *Iron is the predominant constituent in the tailings.*
- *The majority of iron oxide is magnetite (Fe<sub>2</sub>O<sub>3</sub>).*

# Some Physical Properties of the Tailings

- Median particle size (raw tailings): 4.2  $\mu\text{m}$
- BET surface area (dry tailings): 32.8  $\text{m}^2/\text{g}$
- Bulk density (dry tailings): 0.84  $\text{g}/\text{cm}^3$
- Particle density (dry tailings): 3.1  $\text{g}/\text{cm}^3$
- pH (dry tailings): 6.8



# Experimental Methods

- Batch jar adsorption tests using single metal and multiple metals at room T (20°C)
- Tested metal species: Se(VI), Se(IV), Cr(VI), Cr(III), Cd(II) and Pb (II)
- 24 hr reaction for equilibrium tests
- Initial metal concentration: 0 – 50 mg/L
- Experimental pH: 6.5 and 9.0
- Metal analyzed by ICP-MS

# Tested Heavy Metal Species

- Se(VI) -  $\text{SeO}_4^{2-}$
- Se(IV) -  $\text{SeO}_3^{2-}$
- Cr(VI) -  $\text{Cr}_2\text{O}_7^{2-}$
- Cr(III) -  $\text{Cr}^{3+}$
- Cd(II) -  $\text{Cd}^{2+}$
- Pd(II) -  $\text{Pd}^{2+}$

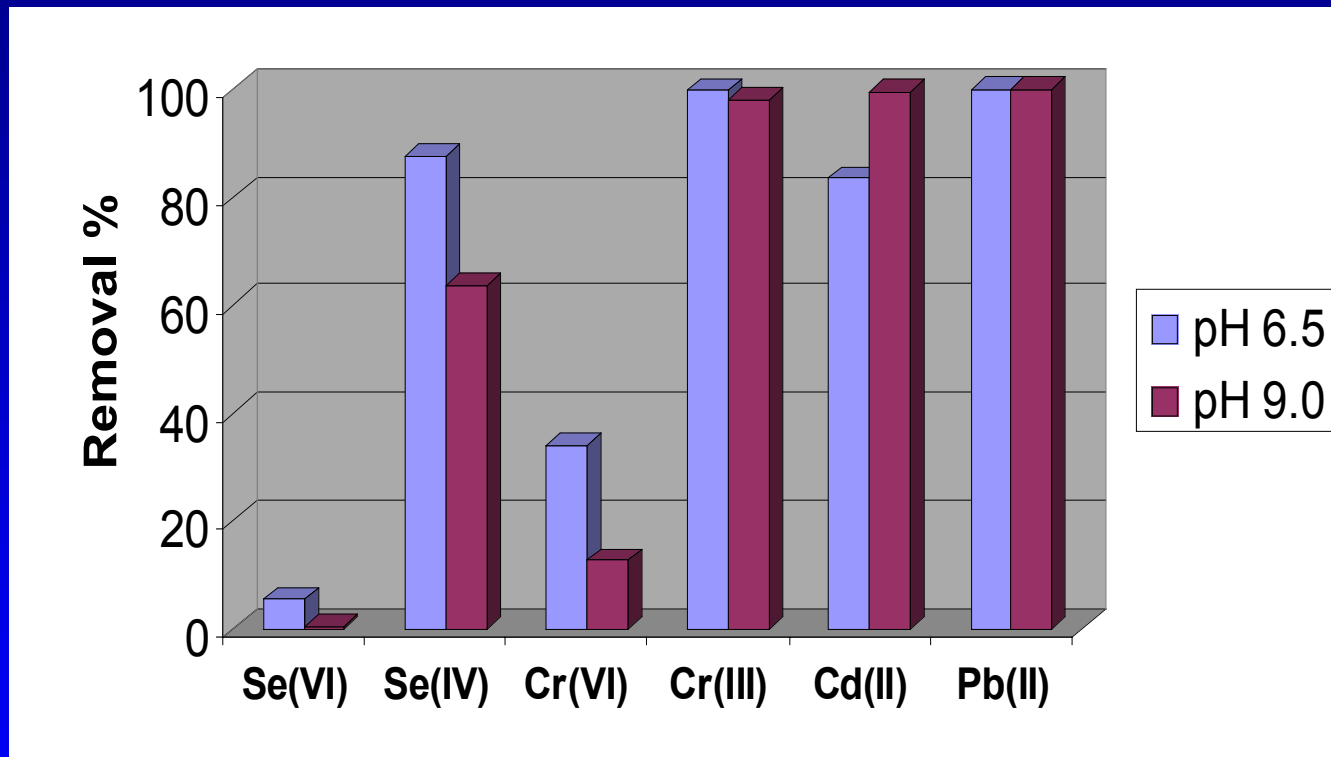
# Results and Discussion

# Leachable Metals from the Tailings

Run #	pH	Se µg/g	Cr µg/g	Cd µg/g	Pb µg/g	Fe µg/g
Blank1	6.2	0.1	1.5	0.1	0.2	6.4
Blank2	9.0	0.6	26.5	0.01	0.02	1.3

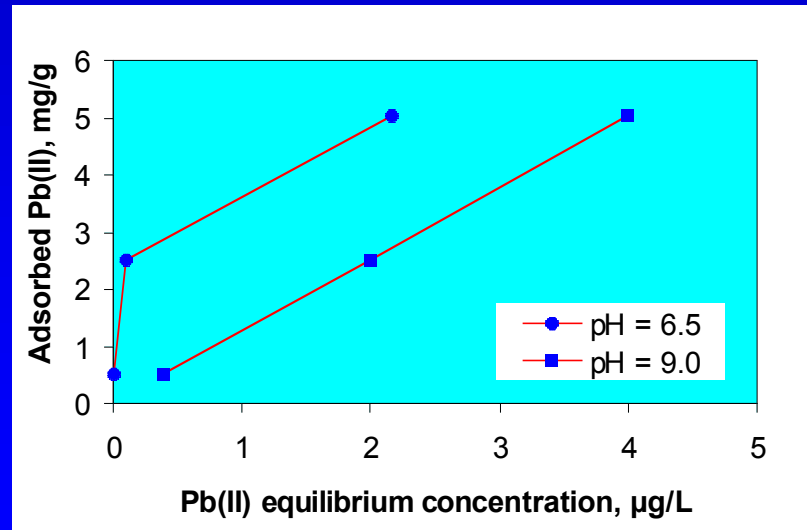
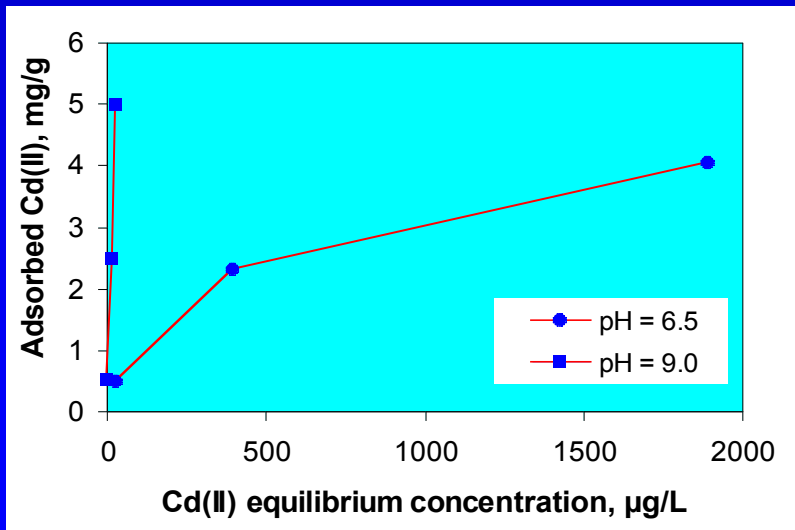
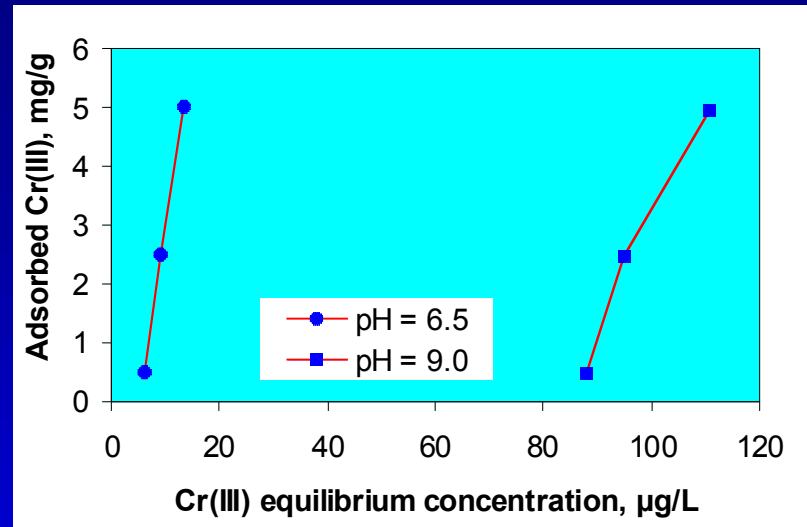
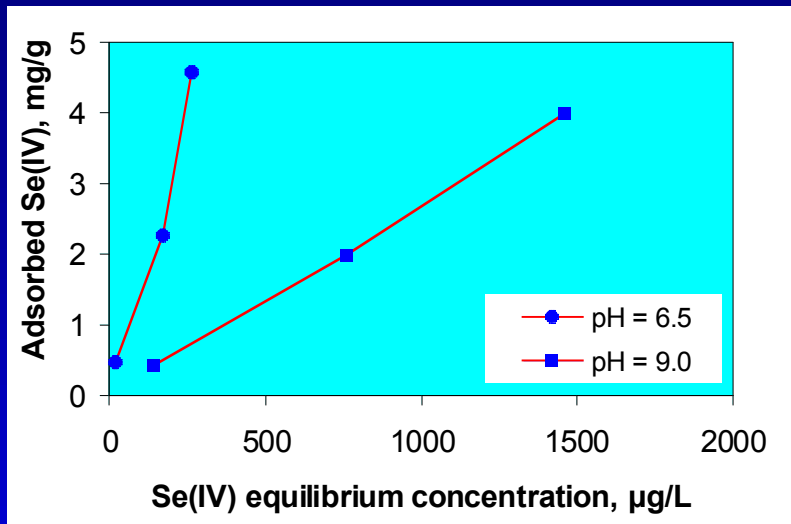
*The leached metals from the tailings are negligible.*

# Adsorption of a Single Metal

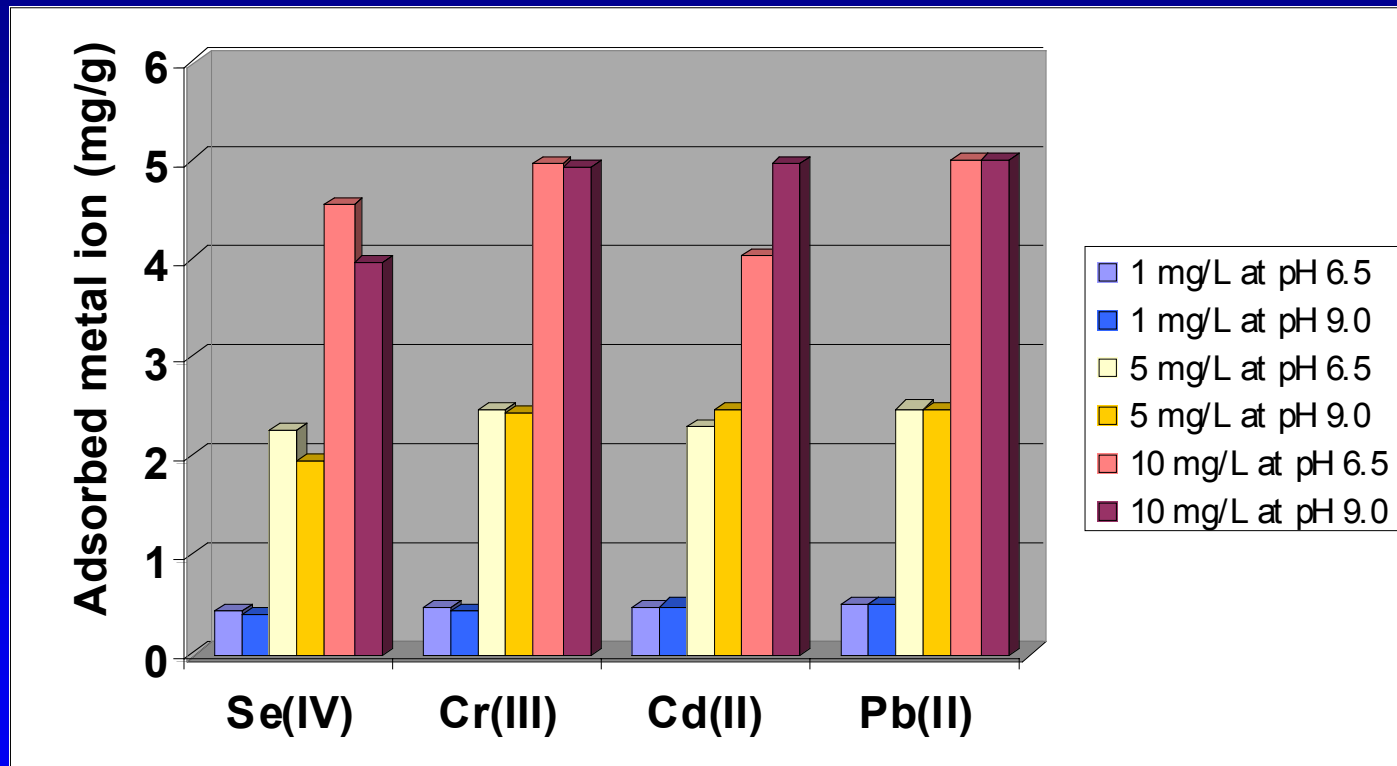


Pb(II)  $\approx$  Cr(III) > Se(IV) > Cd(II) > Cr(VI) > Se(VI) (at pH 6.5),  
Pb(II)  $\approx$  Cd(II) > Cr(III) > Se(IV) > Cr(VI) > Se(VI) (at pH 9.0).

# Adsorption of Multiple Metals

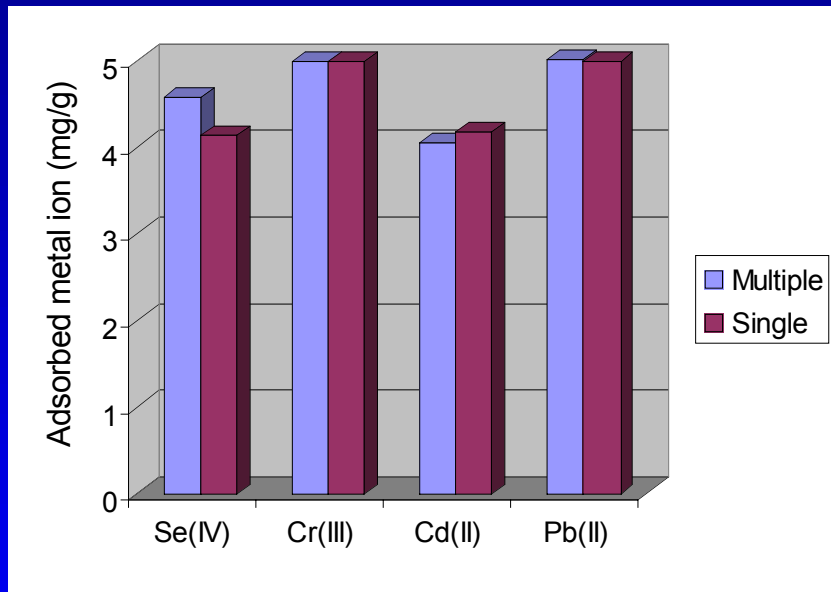


# Order of Removal Capacity in the Multiple Metal System

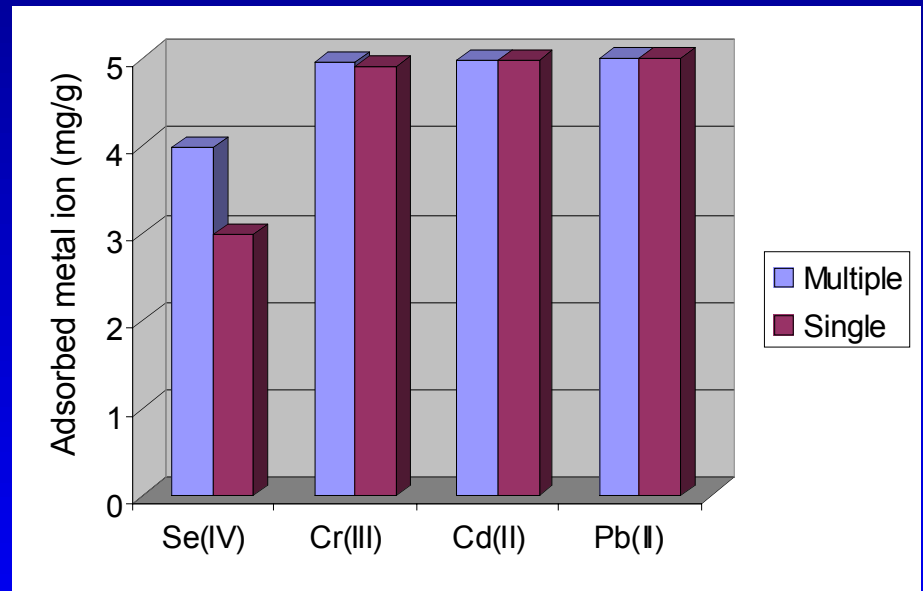


- $\text{Pb(II)} \approx \text{Cr(III)} > \text{Se(IV)} > \text{Cd(II)}$  (at pH 6.5)
- $\text{Pb(II)} \approx \text{Cd(II)} > \text{Cr(III)} > \text{Se(IV)}$  (at pH 9.0)

# Comparison of Single and multiple Metal Adsorption



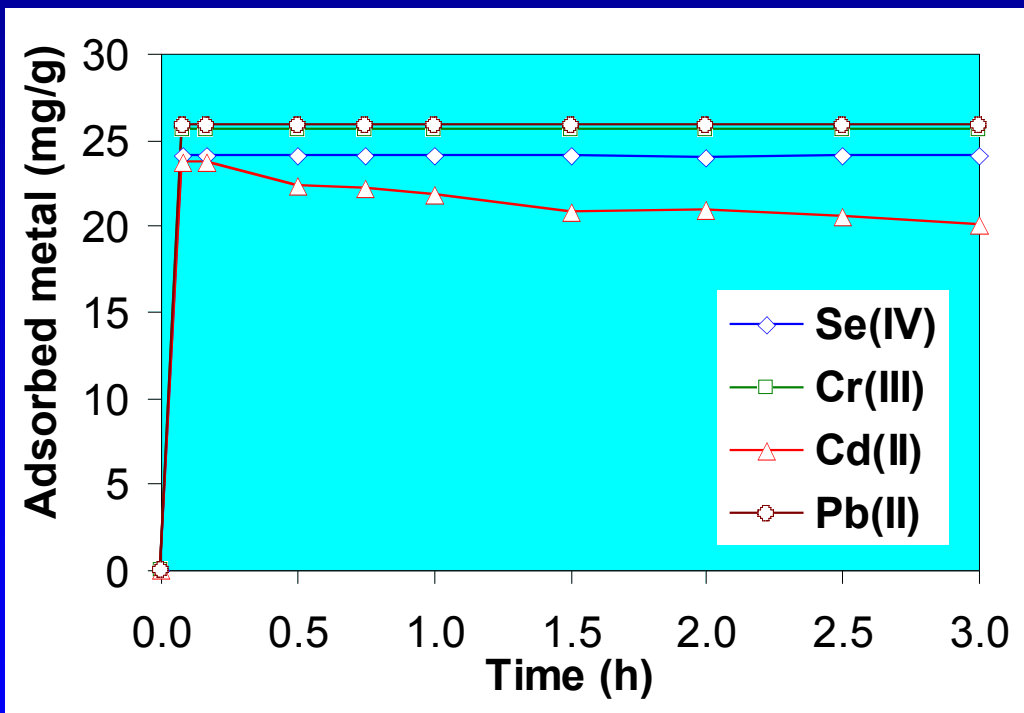
pH = 6.5 and  $C_0 = 10$  mg/L  
for each metal.



pH = 9.0 and  $C_0 = 10$  mg/L  
for each metal.

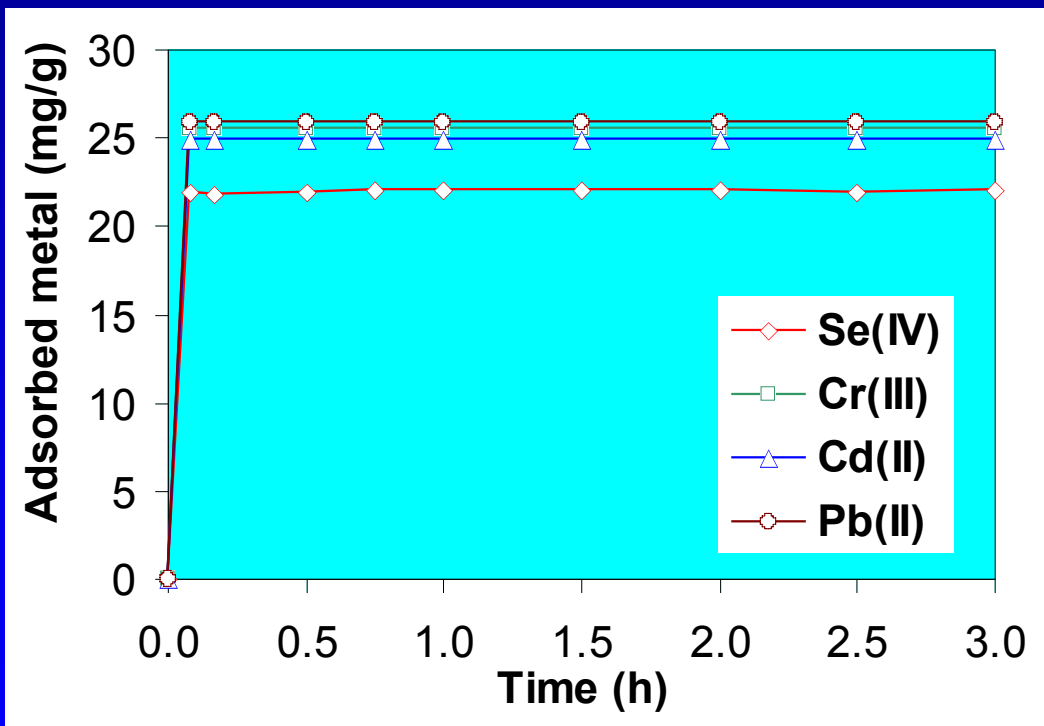


# Adsorption Kinetics in a Multiple-metal System at pH 6.5



- $C_0 \cong 50$  mg/L each metal
- pH = 6.5 and 20°C
- Most of the metal adsorption was completed in 5 min
- Cd(II) was desorbed after 10 min.

# Adsorption Kinetics in a Multiple-metal System at pH 9.0



- $C_0 \cong 50$  mg/L each metal
- pH = 9.0 and 20°C
- Most of the metal adsorption was completed in 5 min
- No Cd(II) desorption was found.

# Potential Mechanisms for Metal Removal by the Tailings

- Adsorption
- Precipitation
- Adsorption and precipitation

# Potential Applications

- As adsorbents for sewage treatment to remove heavy metals,
- As adsorbents for removal of heavy metals from landfill leachates,
- As adsorbents to treat heavy metal from industrial wastewater.

# Conclusions

- Batch experiments showed that the iron oxide tailings had a relatively large capacity and fast rate of adsorption of several heavy metals including Pb(II), Cr(III), Cd(II) and Se(IV).
- Due to its low cost and high capability, this iron oxide tailings has the potential to be utilized for cost-effective removal of heavy metals from wastewater.

**Thank you !**