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

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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_2O_3	CaO	Cr_2O_3	Fe_2O_3	MgO	NiO	SO_4	SiO_2
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_2O_3).*

Some Physical Properties of the Tailings

- Median particle size (raw tailings): 4.2 μm
- BET surface area (dry tailings): 32.8 m^2/g
- Bulk density (dry tailings): 0.84 g/cm^3
- Particle density (dry tailings): 3.1 g/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) - SeO_4^{2-}
- Se(IV) - SeO_3^{2-}
- Cr(VI) - $Cr_2O_7^{2-}$
- Cr(III) - Cr^{3+}
- Cd(II) - Cd^{2+}
- Pd(II) - Pd^{2+}

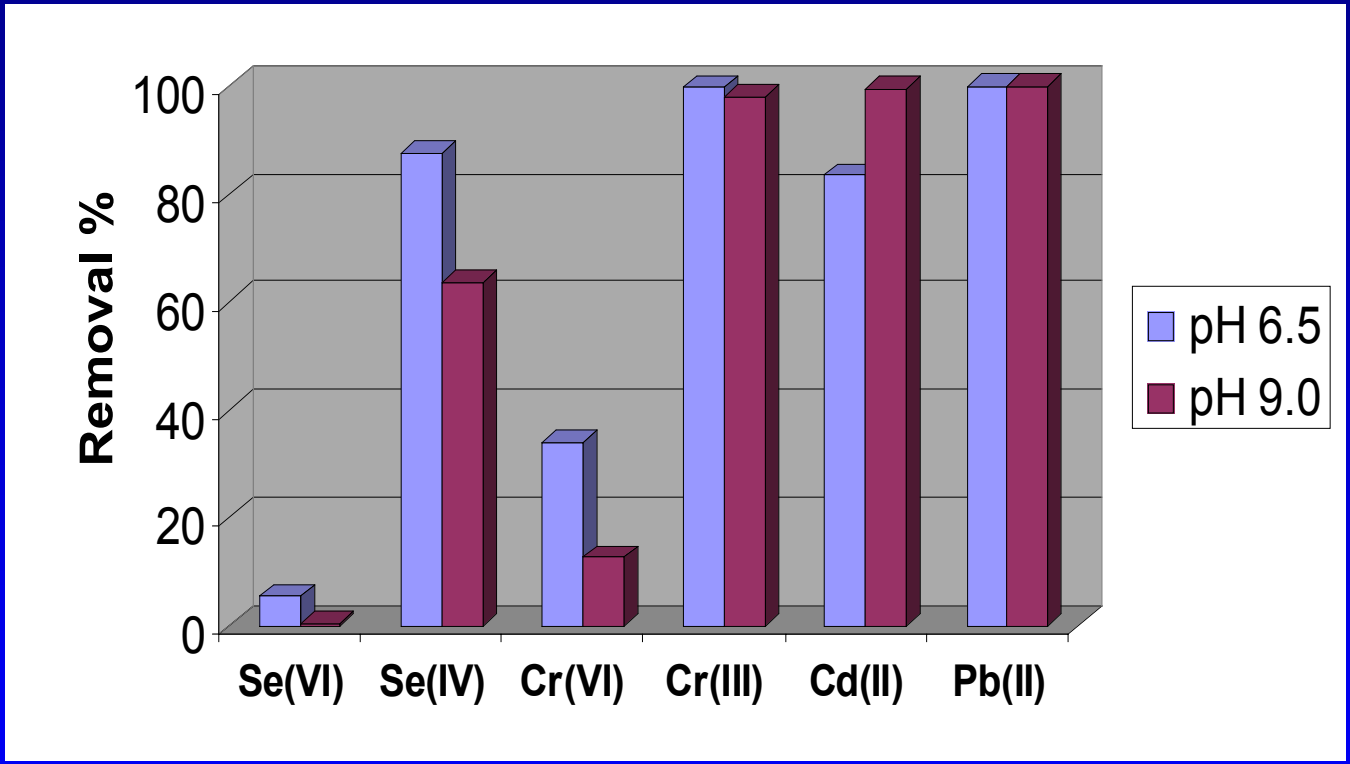
Results and Discussion

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

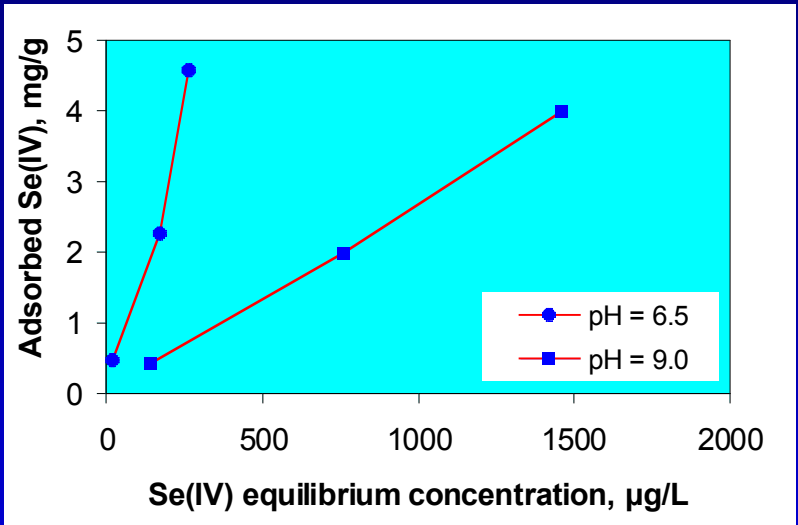
The leached metals from the tailings are negligible.

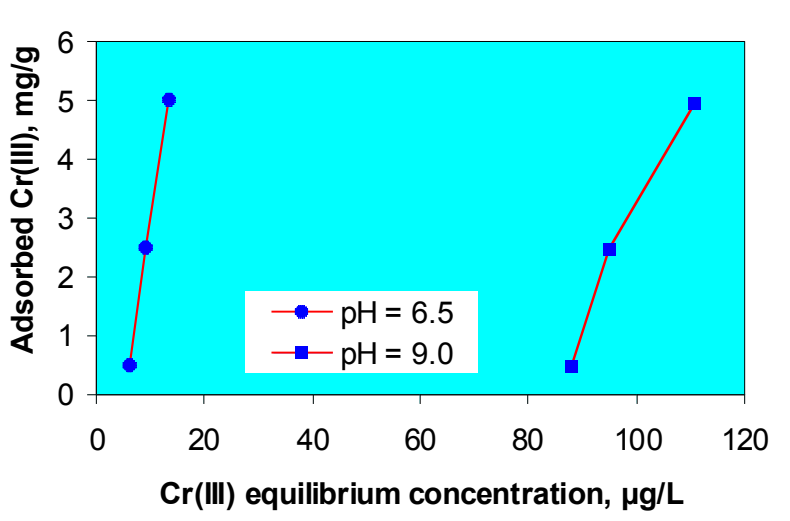
Adsorption of a Single Metal

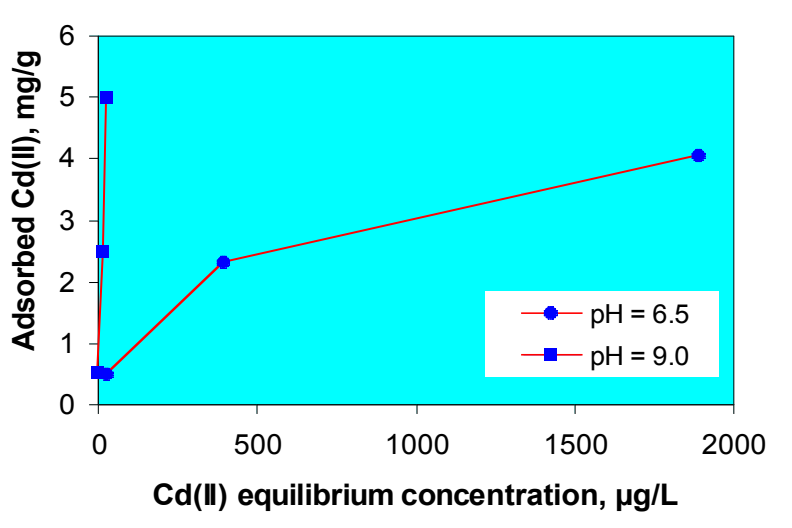


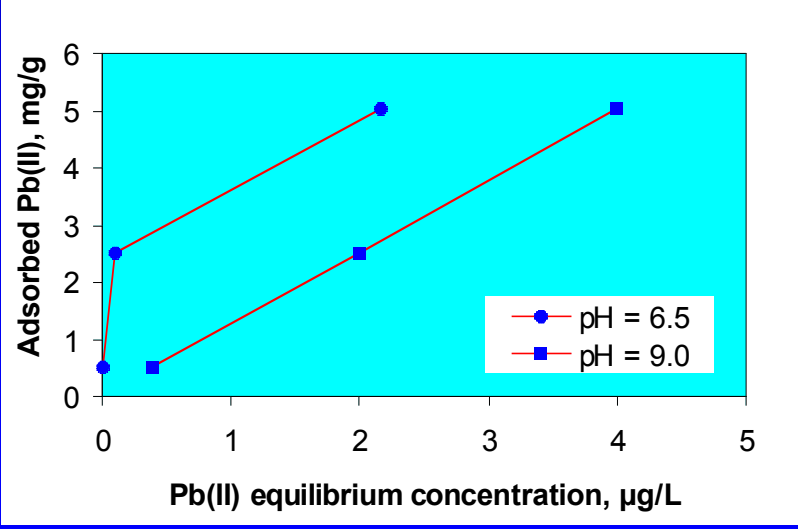
Pb(II) ≈ Cr(III) > Se(IV) > Cd(II) > Cr(VI) > Se(VI) (at pH 6.5),
Pb(II) ≈ Cd(II) > Cr(III) > Se(IV) > Cr(VI) > Se(VI) (at pH 9.0).

Adsorption of Multiple Metals

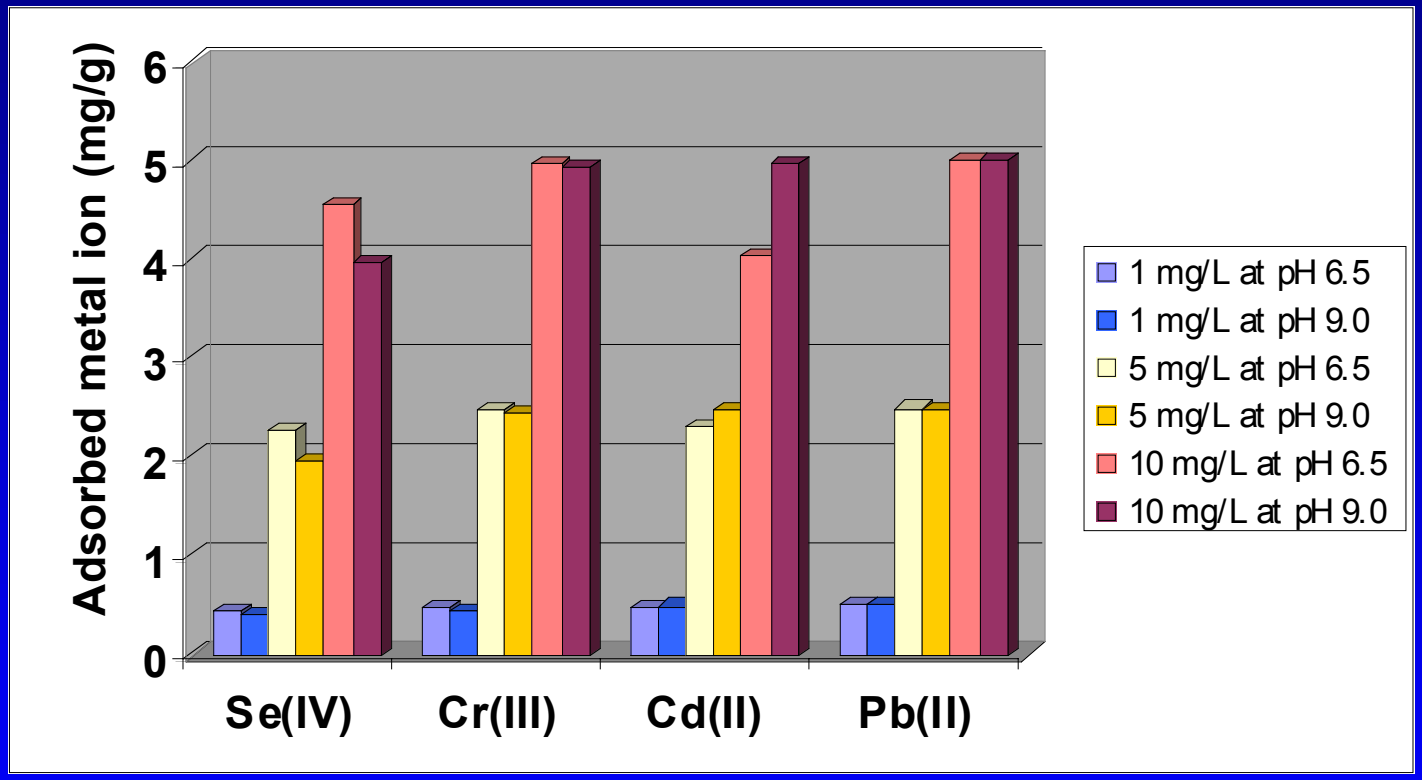






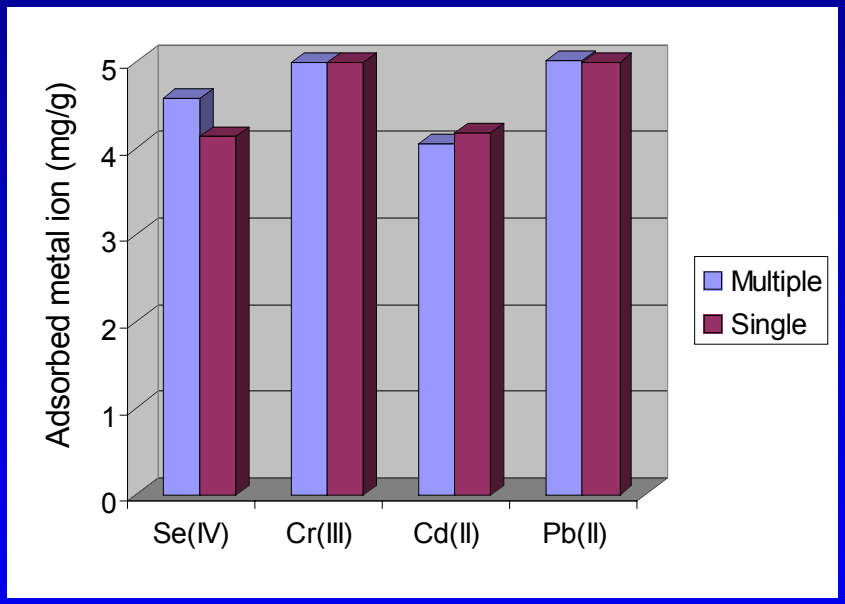


Order of Removal Capacity in the Multiple Metal System

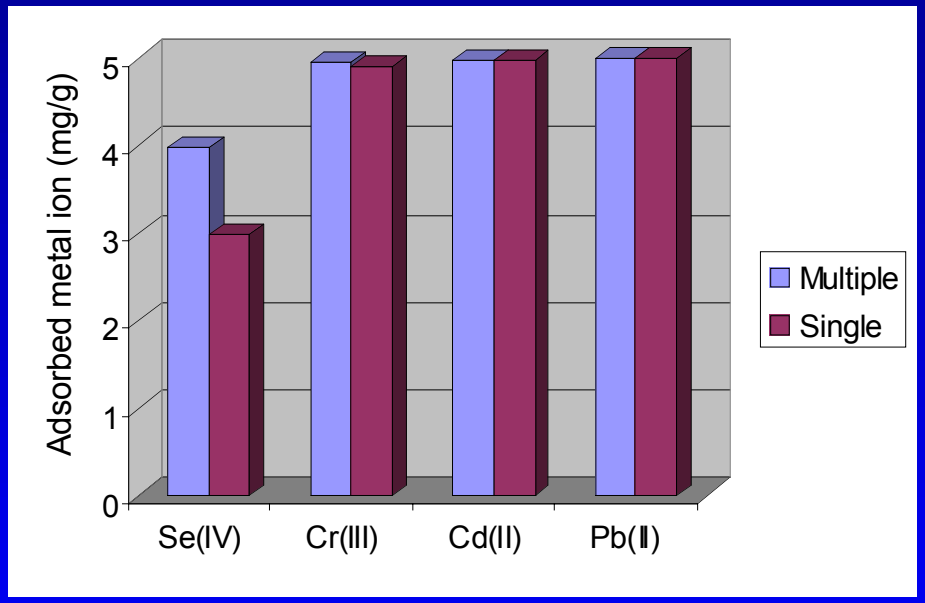


- Pb(II) ≈ Cr(III) > Se(IV) > Cd(II) (at pH 6.5)
- Pb(II) ≈ Cd(II) > Cr(III) > Se(IV) (at pH 9.0)

Comparison of Single and multiple Metal Adsorption

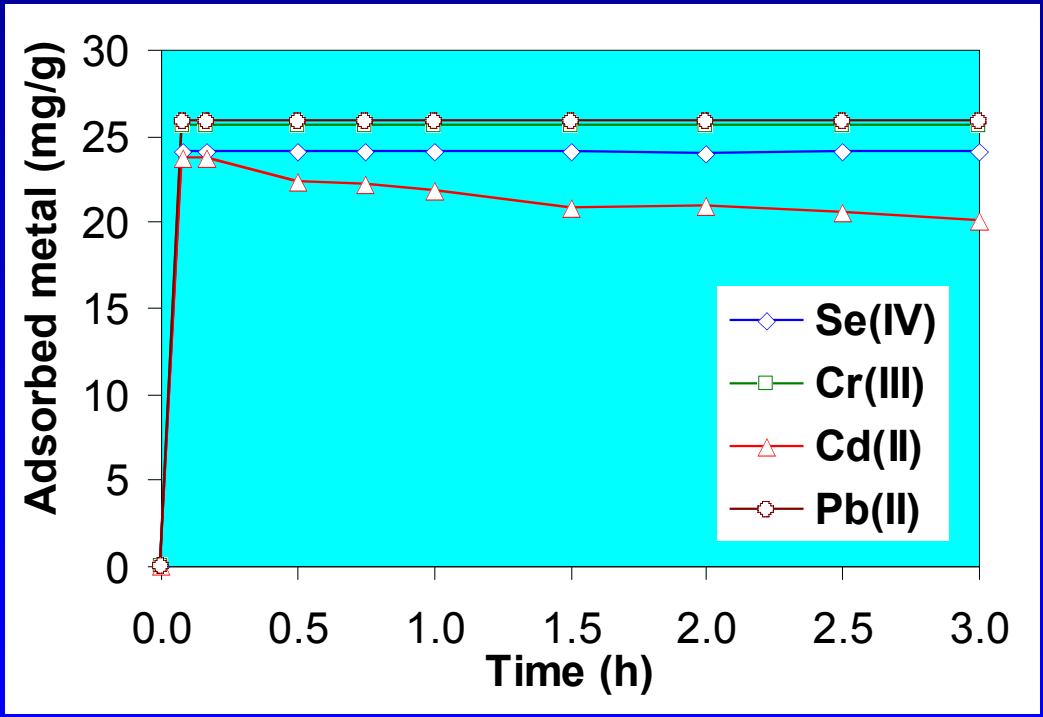


pH = 6.5 and C_o = 10 mg/L for each metal.



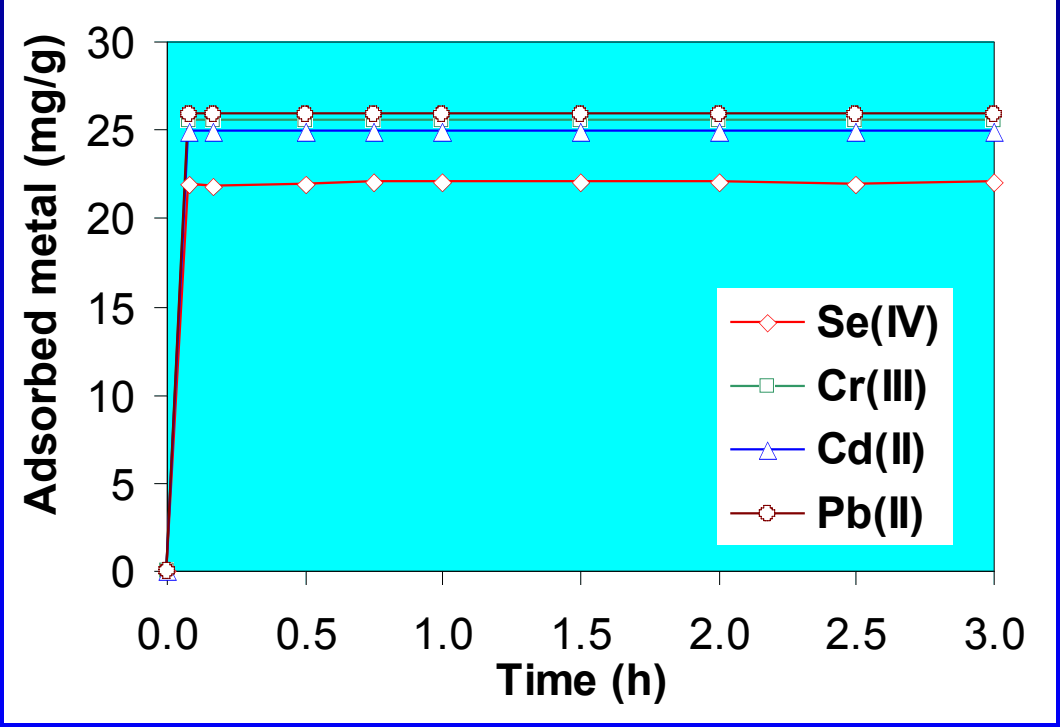
pH = 9.0 and C_o = 10 mg/L for each metal.

Adsorption Kinetics in a Multiple-metal System at pH 6.5



- $C_o \cong 50$ 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



- $C_o \cong 50$ 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.

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Thank you !