Application of silica polyamine composites for the removal of heavy metals from acid mine drainage

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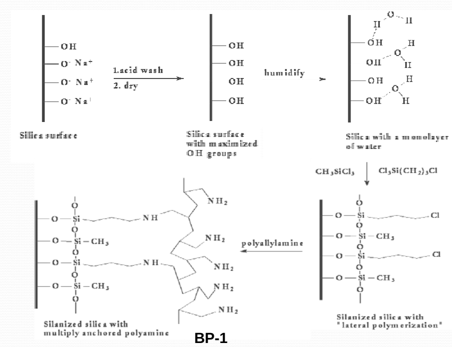
Presentation Outline

- Introduction
  - Treatment and remediation of AMD
  - Silica polyamine composites (BPAP)
- Methodology
- Results and Discussion
- Conclusion
- Outlook
- Acknowledgements

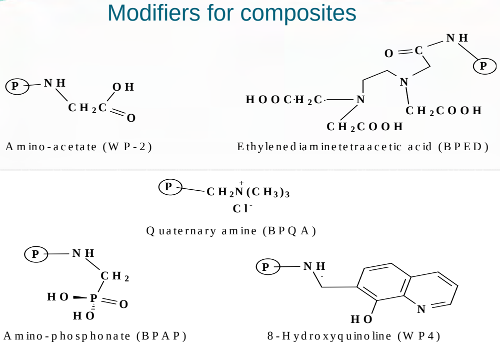
Treatment and remediation strategies

- Neutralization by lime/limestone
- Phytoremediation – phytoextraction, phytostabilisation, phytovolatilisation
- Bioremediation e.g fungal and algal biomass, bacteria
- Zeolite, activated silica, clay, activated carbon, nanomaterials
- Wood shavings, chitosan, shells, sewage sludge, peat, tea bags
- Fly ash, cement kiln dust, recycled concrete
- Ion exchange (chelator) resins
- Amorphous silica polyamines

Silica Polyamine Composites

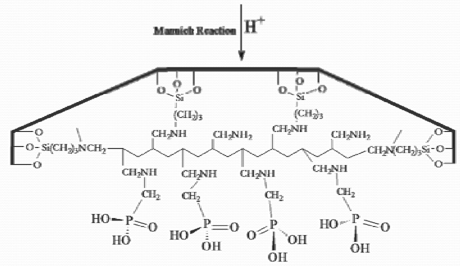


Modifiers for composites



Formation of BPAP

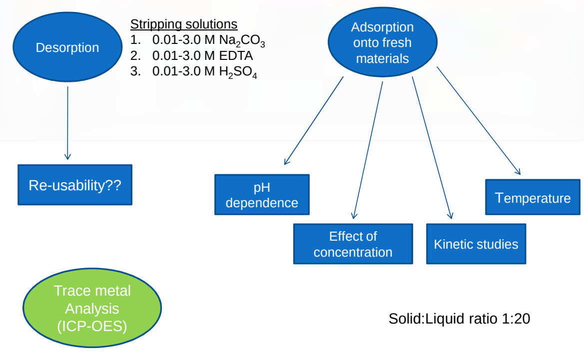
$$BP\text{-}1 + CH_2O + H_3PO_3$$



Objectives of Project

- Main objective: Assess capability of SPCs in heavy metal removal from AMD and reusability (regeneration)
- Specific tasks:
  - Desorption of heavy metals
    - Previously used BPAP material
    - Different extractant solutions
  - Batch adsorption
    - Adsorption edges/isotherms
    - Assessing effects of pH, time and concentration on adsorption
    - Adsorption energies

Methodology

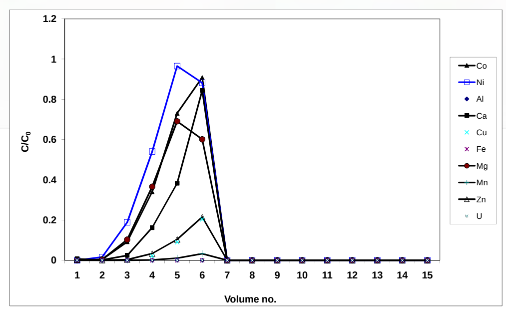


Results and Discussion

- Preceding work: involved adsorption of heavy metals in a synthetic AMD solution (pH = 2.5) onto BPAP through use of columns

Metal load in synthetic solution (mg l-1)									
Al	Ca	Co	Cu	Fe	Mg	Mn	Ni	Zn	U
383.6	340.1	17.45	12.33	66.05	144.8	57.2	52.01	130.2	70.23

Breakthrough curves in column experiments



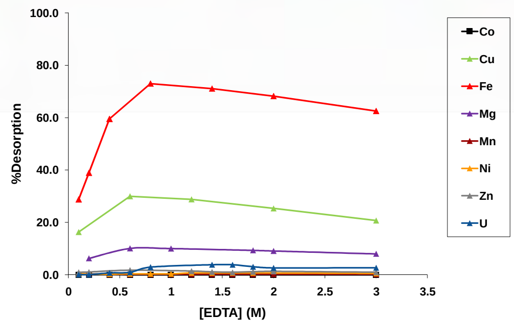
- Heavy metals adsorbed onto BPAP
- Stripping/desorption (using 0.1 M solutions)
  - NaF- only Al, Ca and a little Si removed
  - Na_3PO_4 – only Ca removed
  - EDTA- removed mainly Fe and a bit of Cu and U
  - H_2SO_4 - removed U, Fe, Ni, Zn, Co, Mg

Retained metals

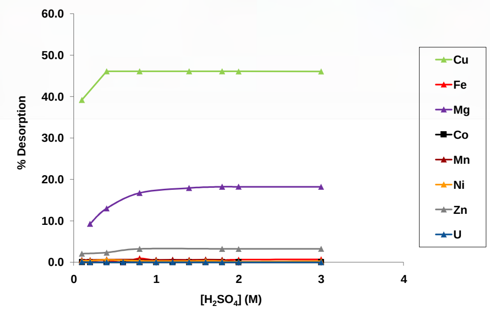
Metals adsorbed on BPAP (mg/g)							
Co	Cu	Fe	Mg	Mn	Ni	Zn	U
7.86	4.13	54.56	63.76	24.44	27.34	73.68	62.09

Batch desorption studies

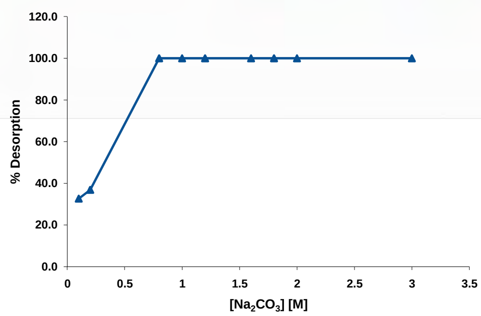
Effect of EDTA



Effect of sulphuric acid

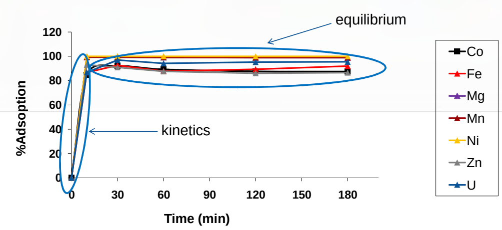


Effect of sodium carbonate on uranium



Batch adsorption studies

Effect of contact time



- Single component systems
- Adsorption based on 5 mg.l-1 solution per 1 gram of adsorbent at pH = 2.5

Pseudo first order reaction

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303} t$$

Pseudo second order reaction

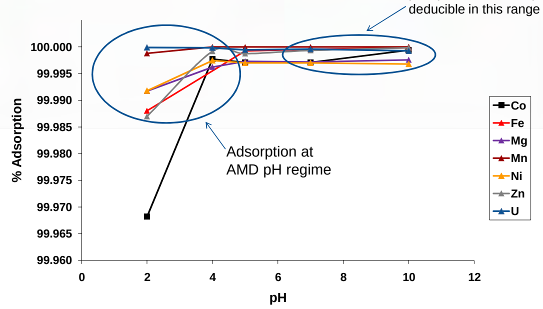
$$\frac{t}{q_t} = \frac{1}{k_2 \cdot q_e^2} + \frac{1}{q_e t}$$

q_e – adsorption at equilibrium

q_t – adsorption at time t

	Pseudo 1st order		Pseudo 2nd order	
	k	R^2	k	R^2
Co	0.145	0.691	0.105	0.970
Fe	0.220	0.541	0.141	0.984
Mg	1.903	0.401	0.862	0.754
Mn	1.182	0.0006	1.004	0.967
Ni	0.187	0.004	0.125	0.285
Zn	0.208	0.559	0.186	0.287
U	0.386	0.637	0.321	0.965

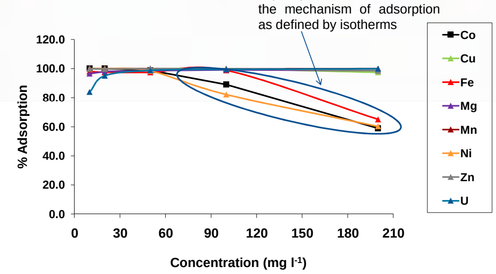
Effect of pH



- pH was adjusted using NaOH and HNO_3

Effect of concentration

The decrease in adsorption capacity could be attributed to the mechanism of adsorption as defined by isotherms



- Fe, Co and Ni defined by Langmuir isotherm- low concentrations and monolayer adsorption on homogeneous surface

Effect of temperature

Thermodynamics Parameters				
Metals	Ea	ΔG		Type of adsorption
	kJ.mol^{-1}	kJ.mol^{-1}		
		18 °C	30 °C	
Co	14.78	-13.06	-1.5	Physisorption
Cu	-2.613	-13.06	-13.42	-
Fe	-90.51	-10.14	-22.44	-
Mg	5.104	-28.65	-27.95	Physisorption
Mn	19.792	-52.48	-49.79	Physisorption
Ni	0.757	-2.98	-2.87	Diffusion
Zn	16.04	-15.39	-37.19	Physisorption
U	54.61	-66.4	-58.97	Chemisorption

- Chemisorption: Ea= 40-800 kJ. mol-
- Physisorption: Ea= 5-40 kJ.mol^{-1}

$$\Delta G = -RT \ln K_d$$

$$K_d = q_e/C_e$$

$$\ln \frac{k_1}{k_2} = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Conclusion

- SPCs have been shown to be effective in abstracting metals from AMD
- Sodium carbonate has been shown to be effective for the desorption of uranium
- The effect of concentration on adsorption is important in establishing the effective life time of the adsorbent material, e.g. in determining time for desorption
- The thermodynamic results are important in establishing the surface-metal reactions

Outlook

- Further work on kinetics
- Exploring more desorption solutions – selective desorption
- Application to the recovery of metal complexes (e.g. cyanide complexes) and metalloids (e.g. As)
- Exploring cheaper sources of silica e.g. fly ash, zeolites, liquid glass

Acknowledgements

- Friedel Sellschop Foundation
- National Research Foundation
- Carnegie Corporation