

CONTINUOUS FLOW PROCESS FOR REMOVAL AND RECOVERY OF WATER CONTAMINANTS WITH MAGNETIC NANOCOMPOSITES

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Overview

- **Introduction**
- **Experimental Methods**
 - Nanoparticle Synthesis
 - Reactor Testing
- **Results to Date**
- **Initial Conclusions**
- **Path Forward**
- **Acknowledgements**
- **References**



Introduction

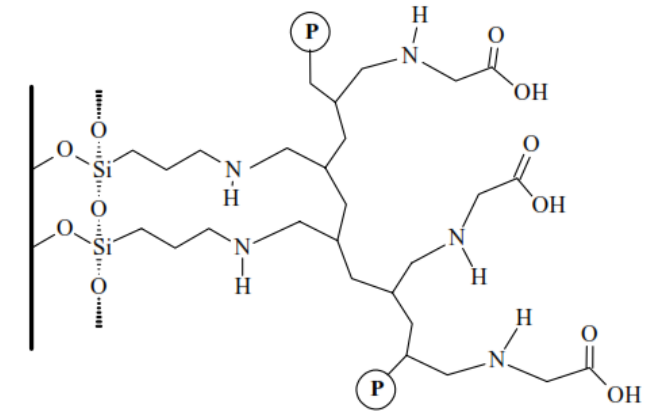
- **Magnetite Nanoparticles (Fe_3O_4 NPs)**
 - Natural
 - Synthesized
 - Si-coated
 - Chitosan coated
- **Metal Recovery System**
 - Continuous flow
 - Nanoparticle capture

Magnetite

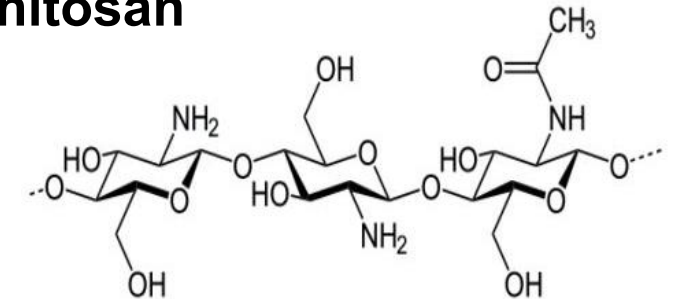


Source: National Center for Biotechnology Information. PubChem Database.

PAA acetal functionalization



Chitosan



Source: Zargar et al. (2015)

Introduction

- **Research Objectives**
 - **Modify reactor technology**
 - **Optimize synthesis**
 - **Maximize heavy metal adsorption**
 - **Minimize/Eliminate environmental concerns**



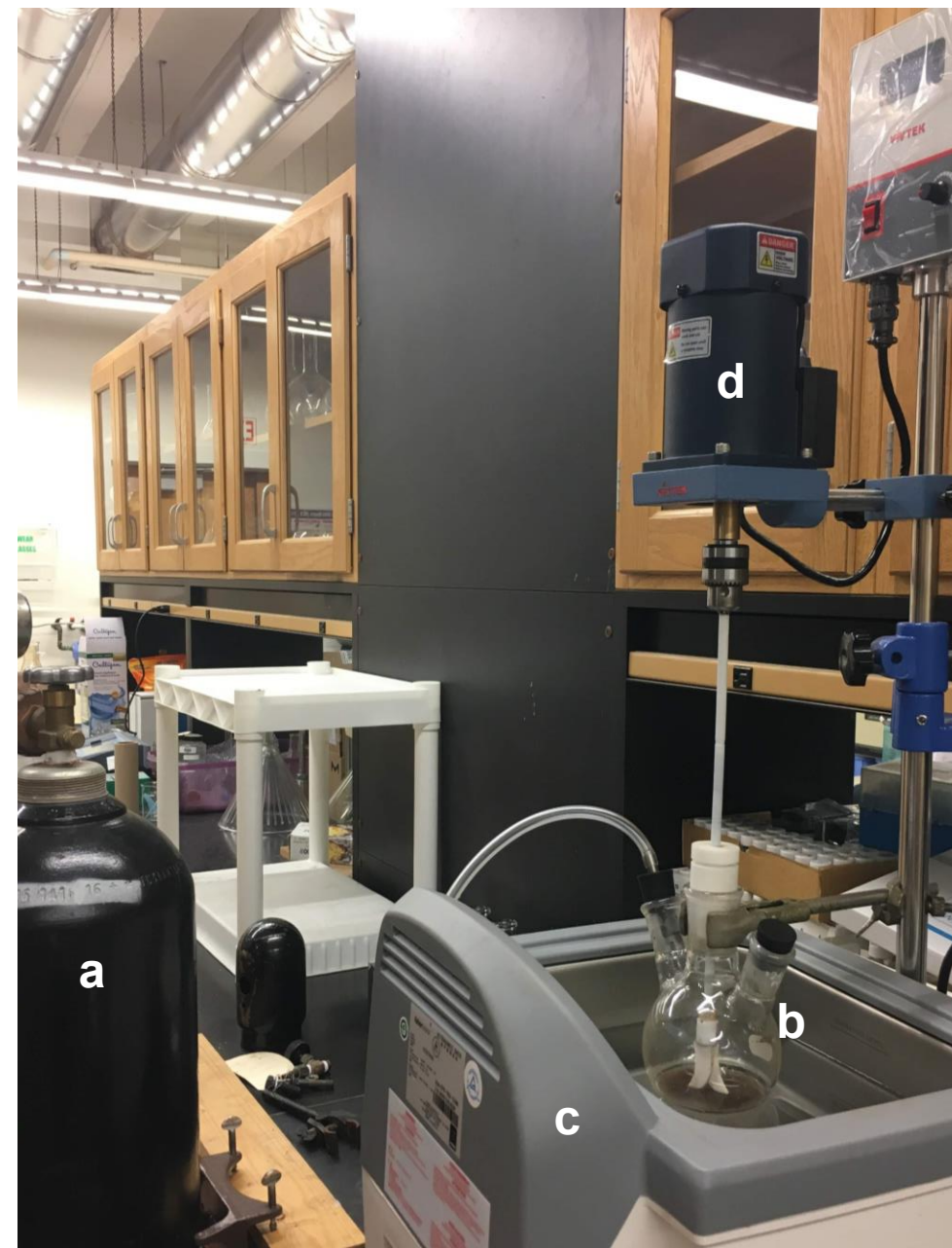
Nanoparticle Synthesis

Three Steps:

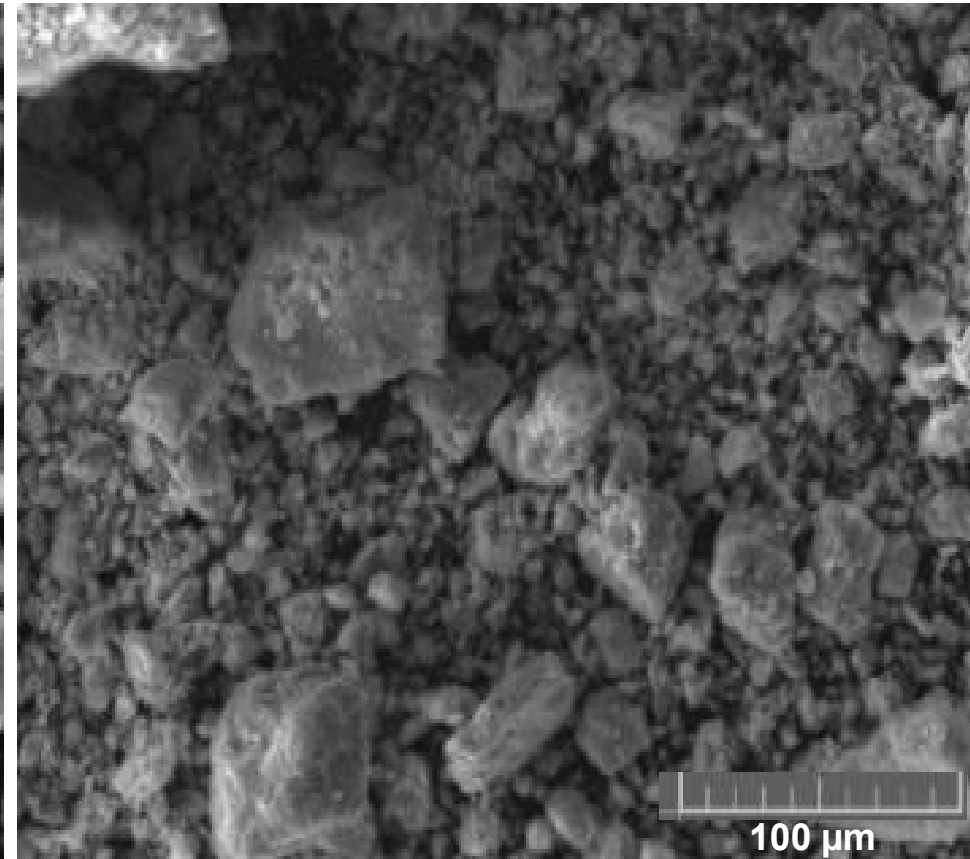
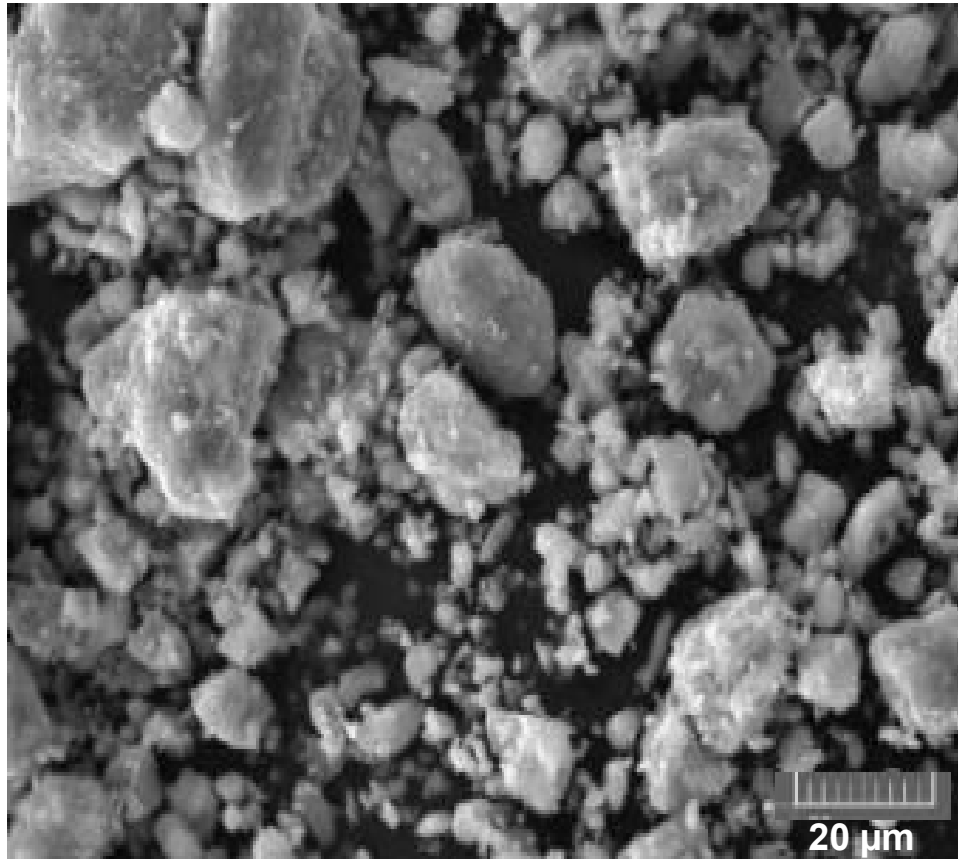
1. Silica coating

2. MTMS/CPTMS Functionalization

3. PAA Functionalization

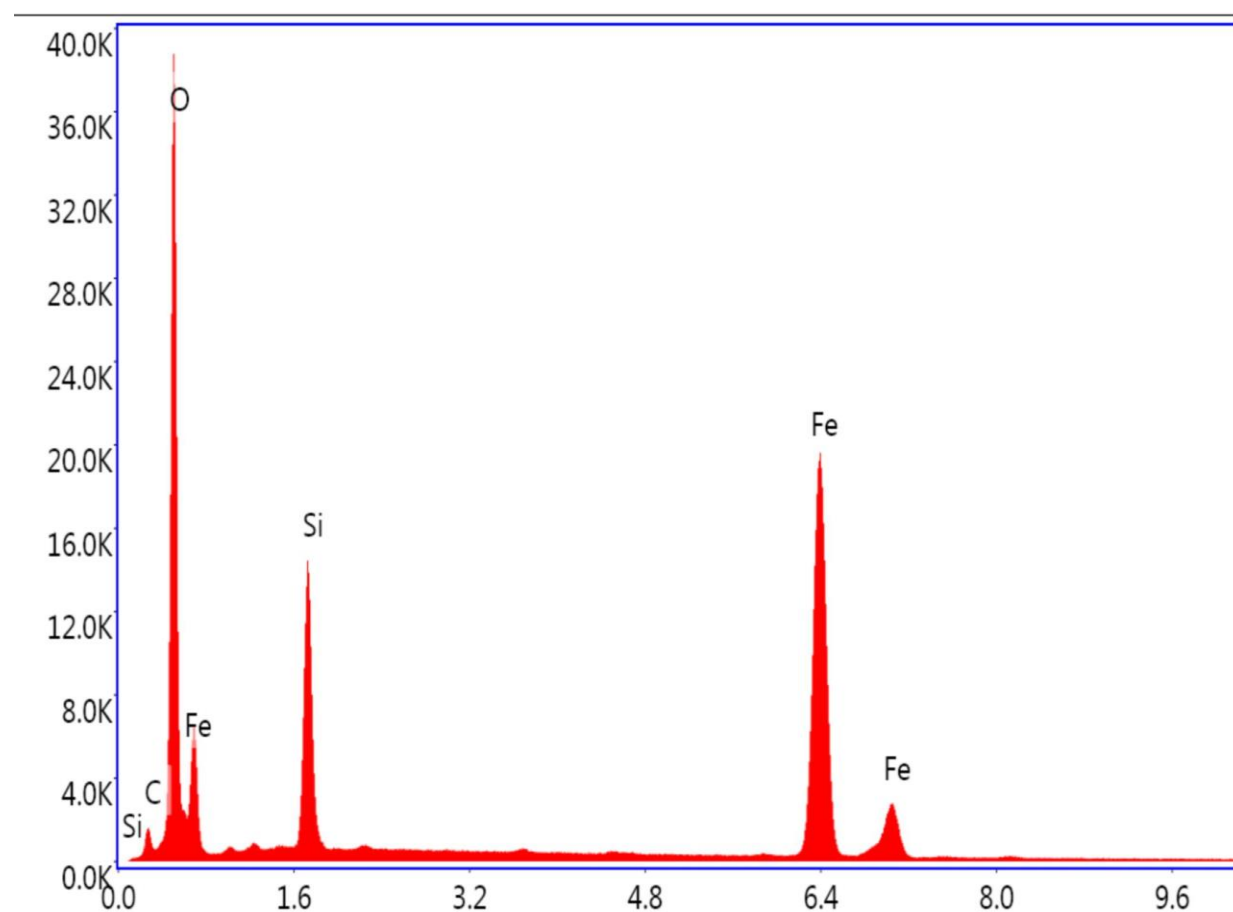
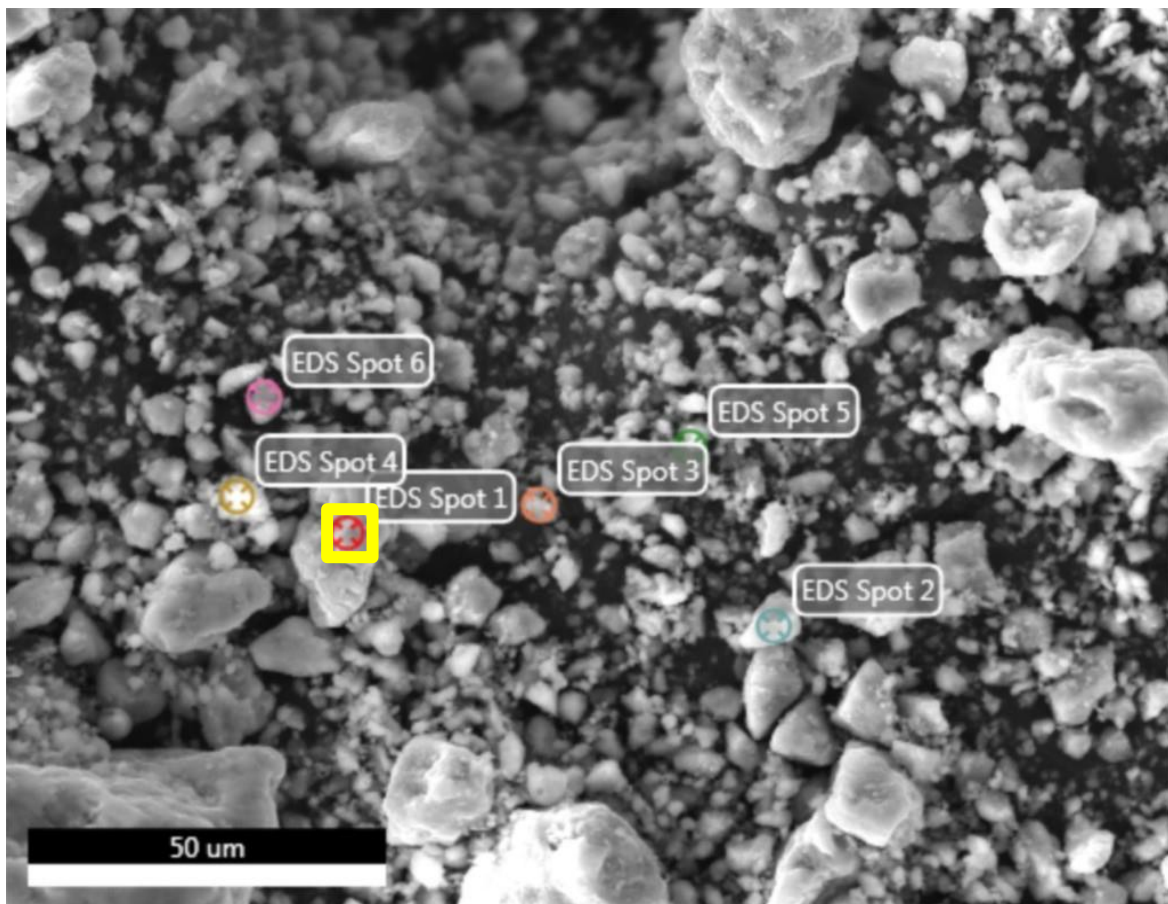


SEM Images of Fe₃O₄ Nanoparticles



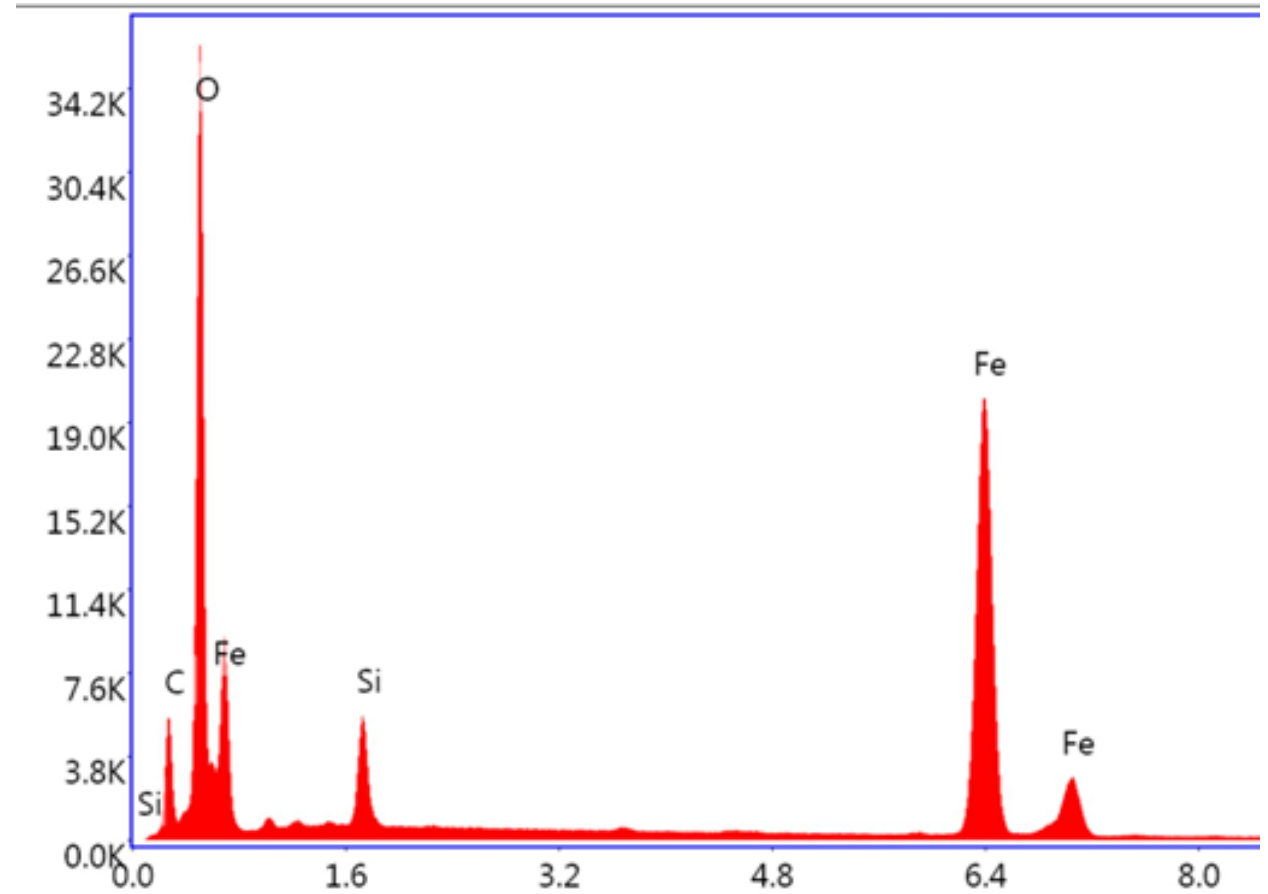
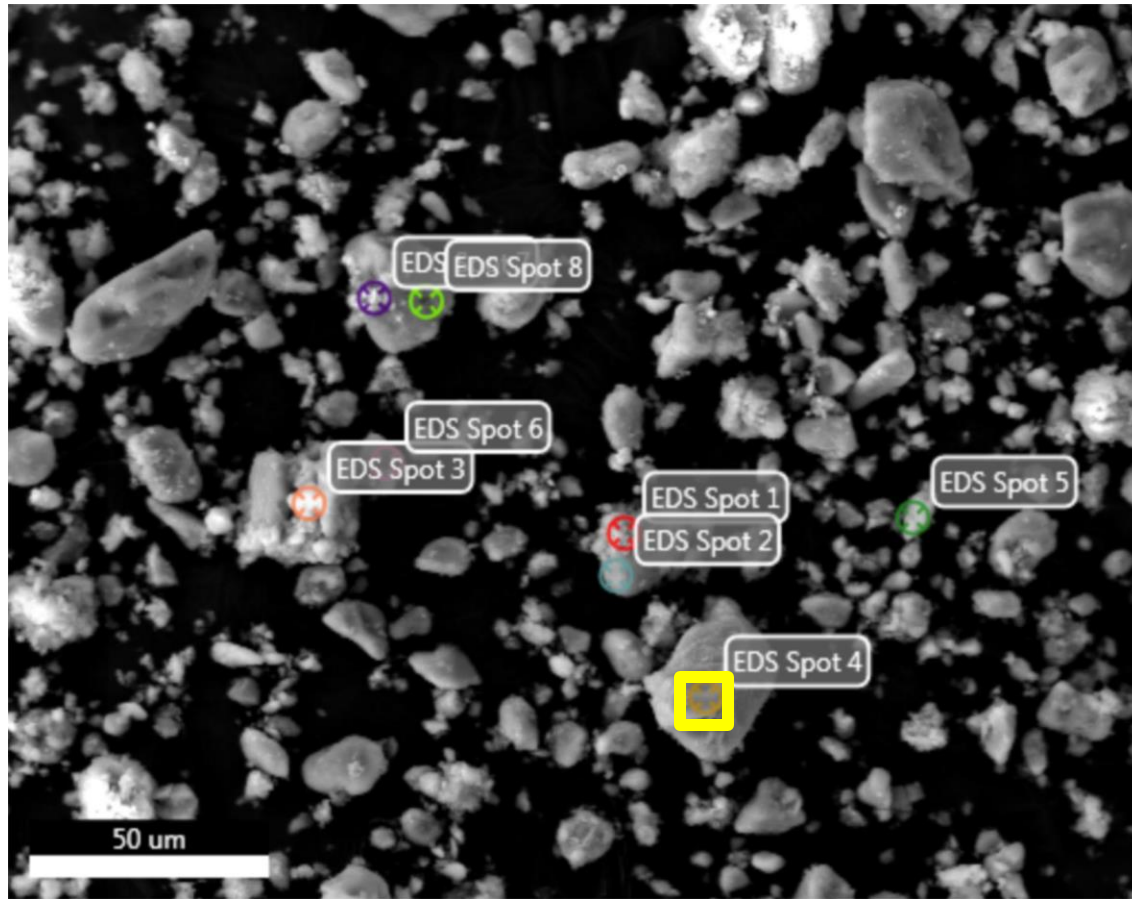
Left: Natural Fe₃O₄ from SkySpring Nanomaterials
Right: Natural Fe₃O₄ from U.S. Research Nanomaterials

SEM Image and EDAX data



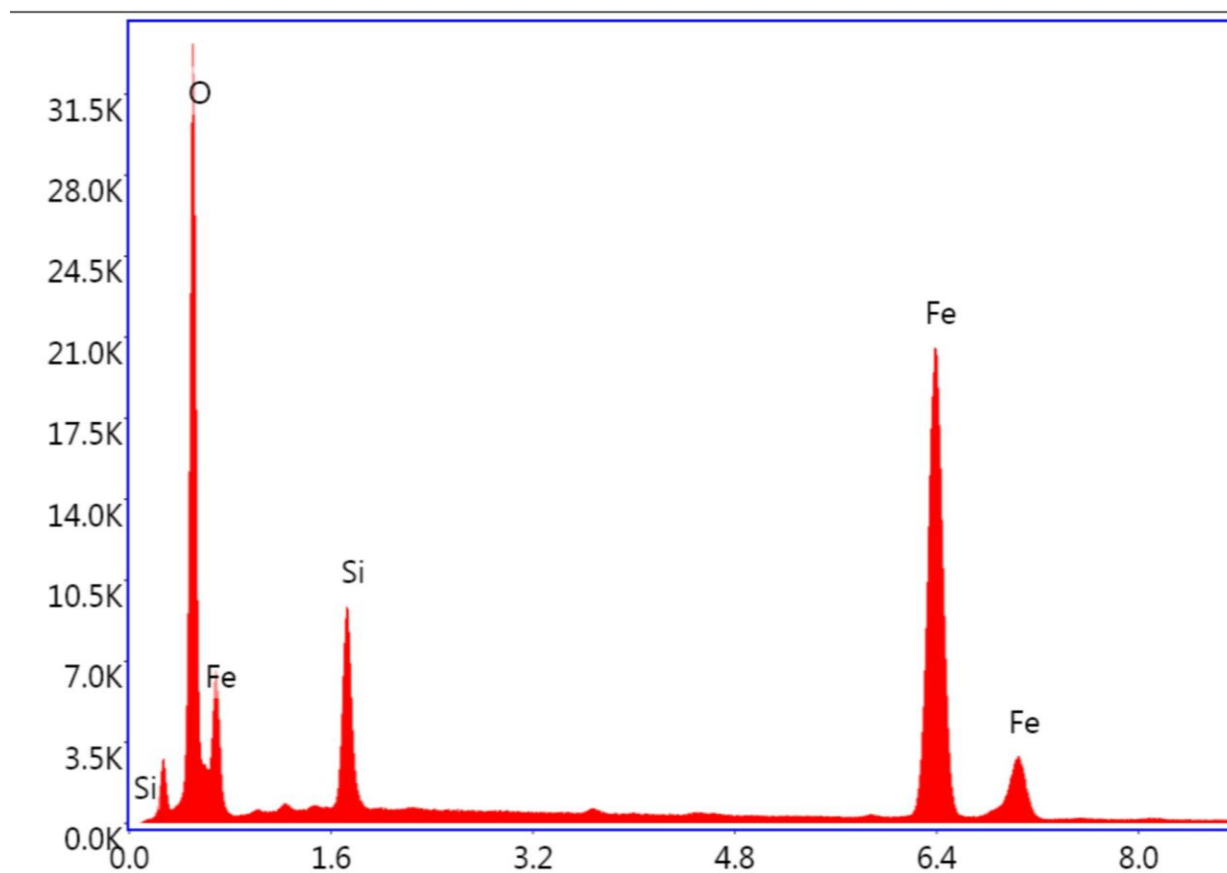
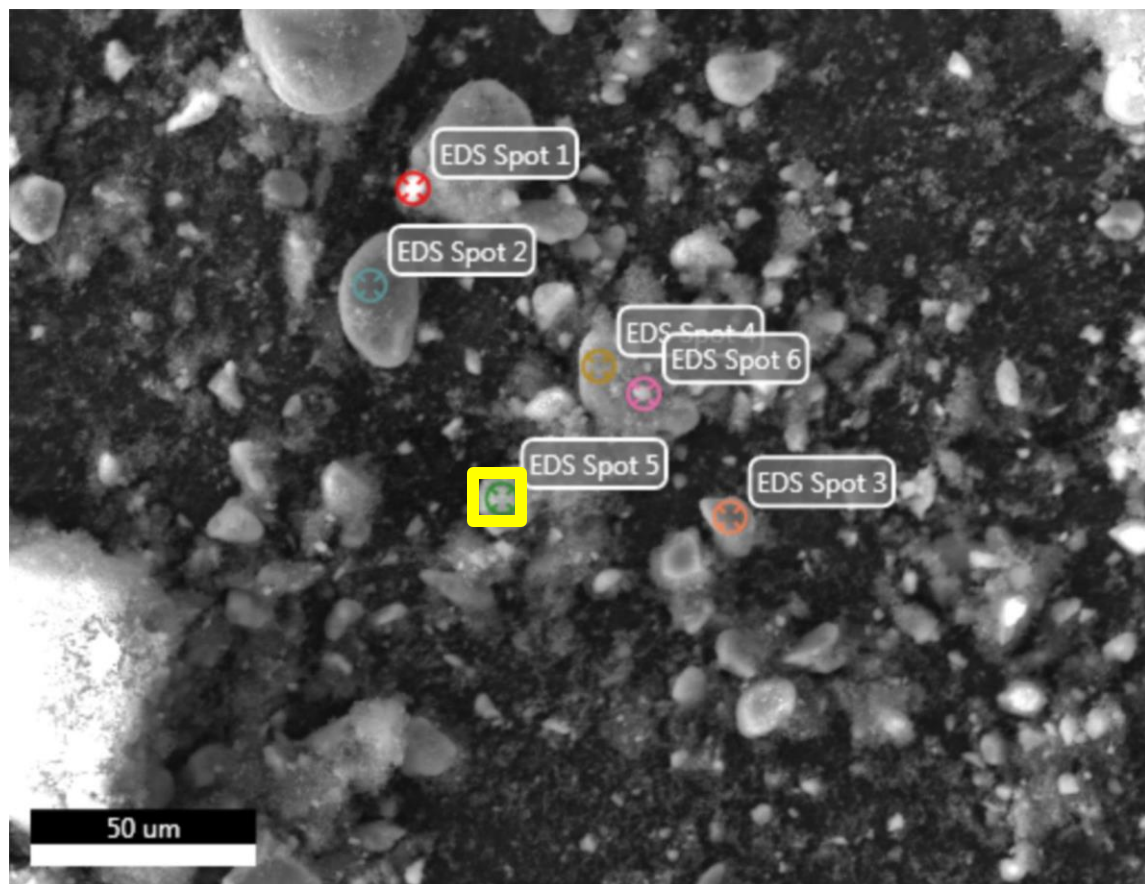
Silica-coated Fe_3O_4 from Dr. Edward Rosenberg's Lab

SEM Image and EDAX data



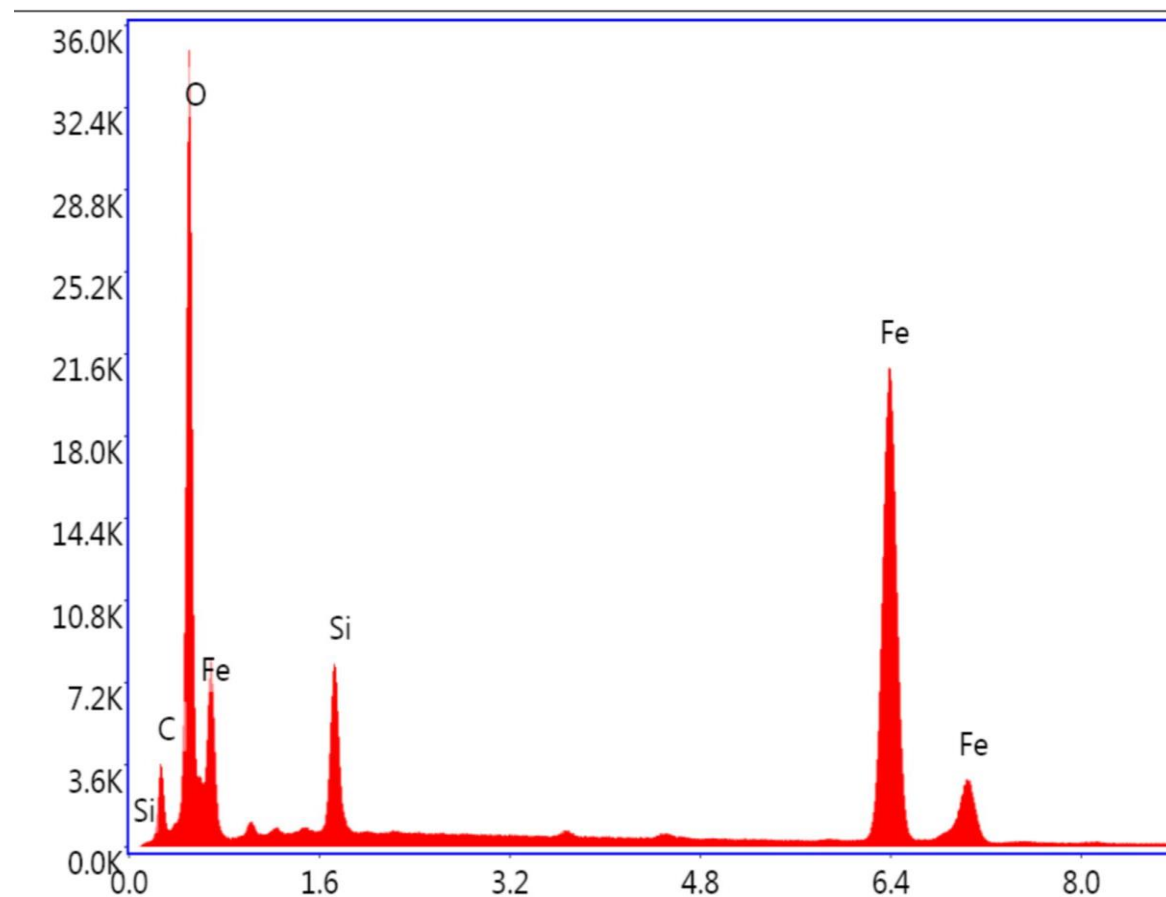
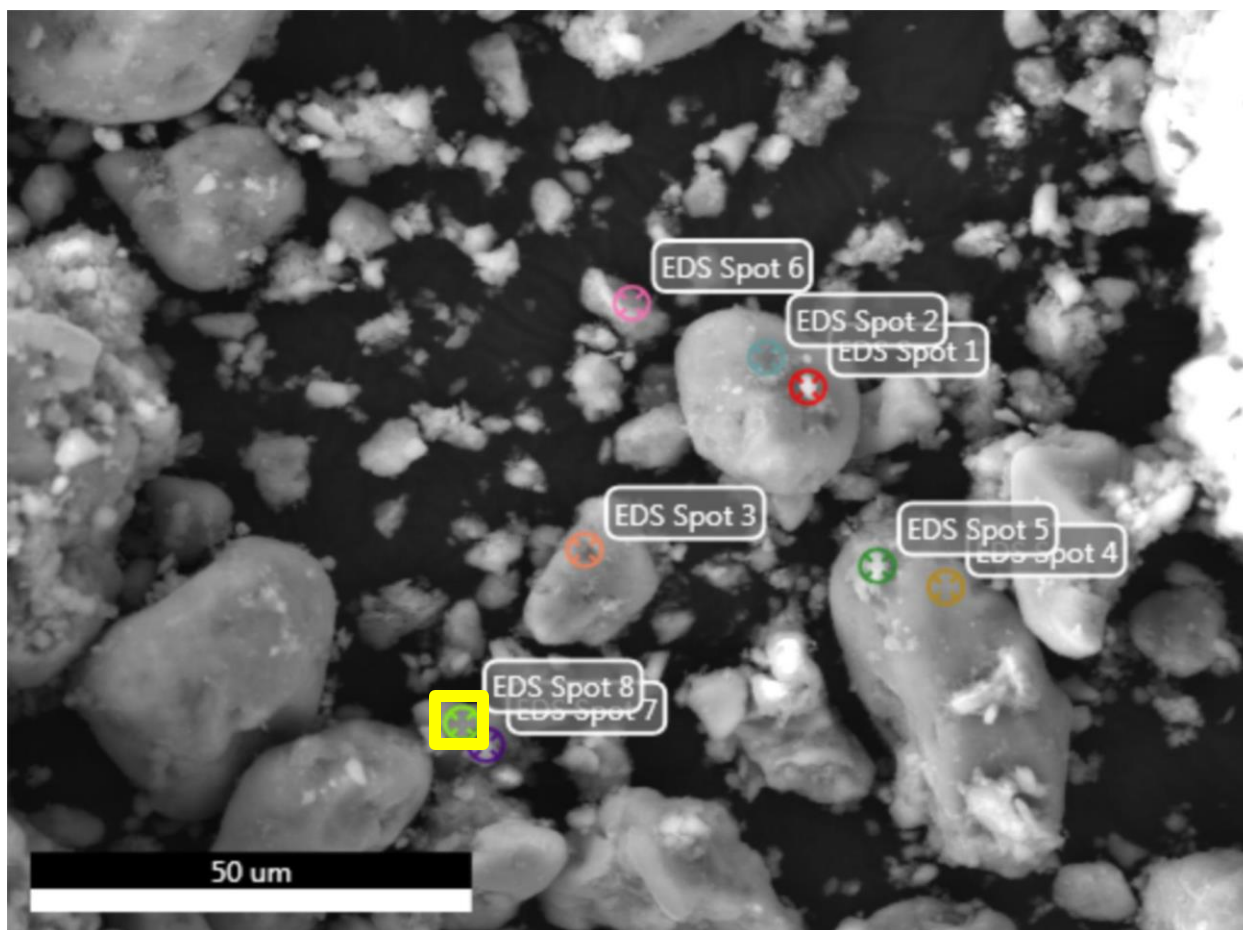
Montana Tech Synthesized Fe_3O_4 Batch 1

SEM Image and EDAX data



Montana Tech Synthesized Fe_3O_4 Batch 2

SEM Image and EDAX data



Montana Tech Synthesized Fe_3O_4 Batch 3

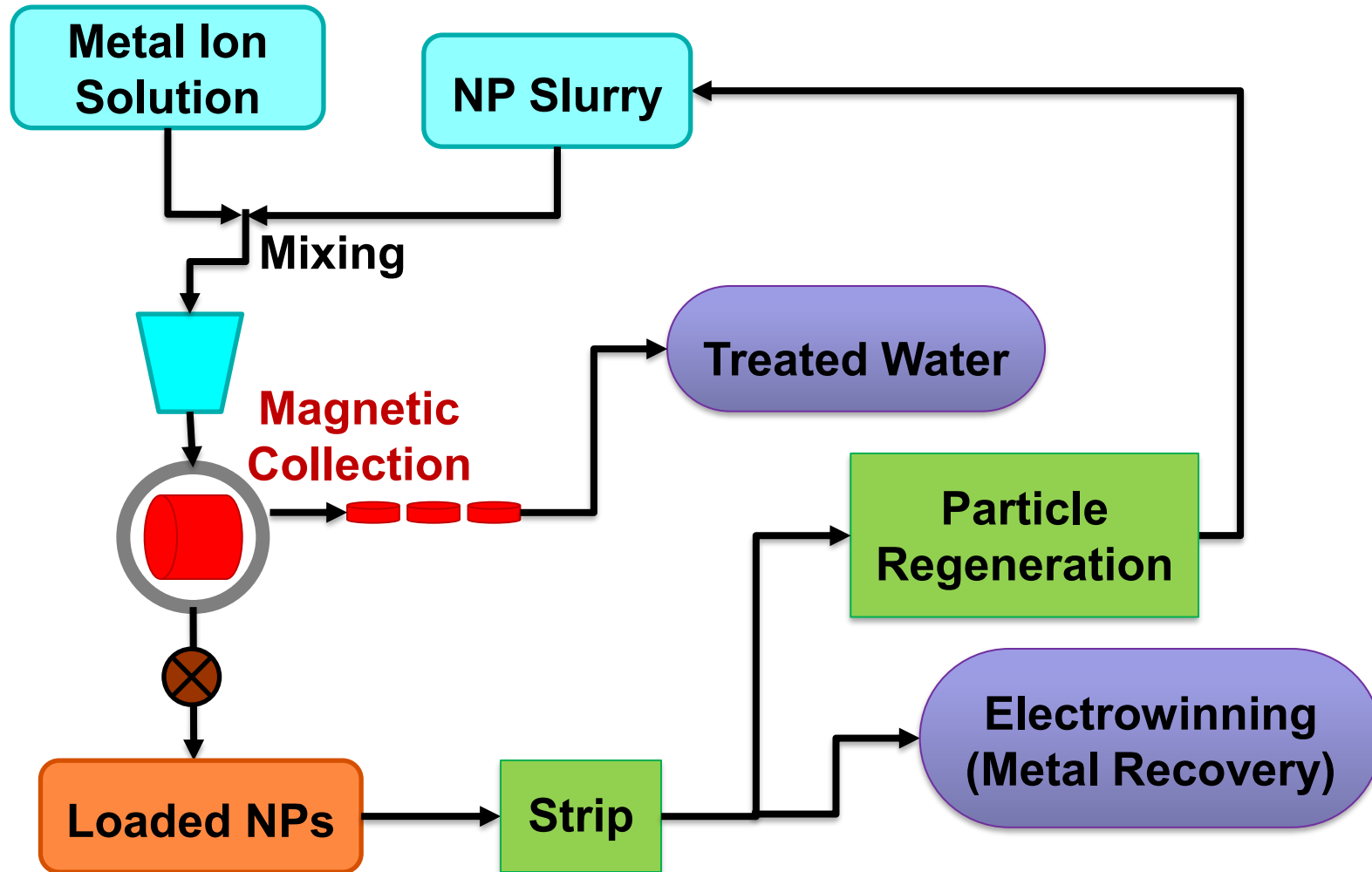
Nanoparticle Adsorption Results

Loading Capacity:

$$q = \frac{(C_i - C_f)V}{m}$$

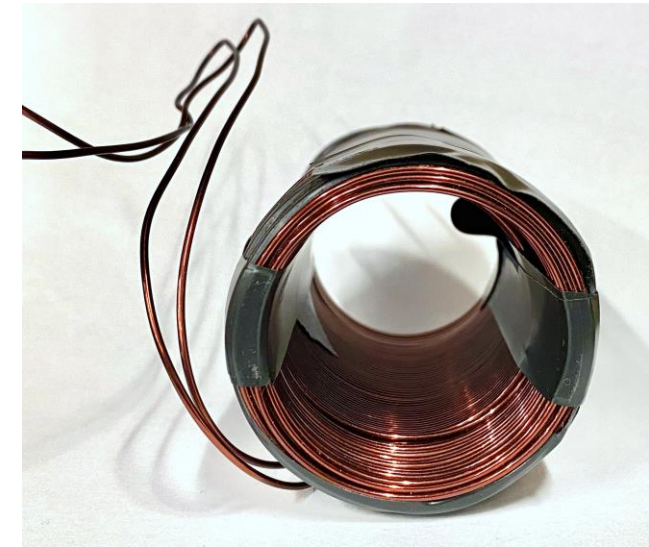
Trial	Initial Concentration $\left(\frac{\text{mg Cu}}{\text{L}}\right)$	Fe ₃ O ₄ (g)	Final Concentration $\left(\frac{\text{mg Cu}}{\text{L}}\right)$	q $\left(\frac{\text{mmol Cu}}{\text{g Fe}_3\text{O}_4}\right)$
Magnetite Nanoparticles				
1	122.47	0.5020	97.8	0.19
2	61.08	0.5006	53.6	0.06
			54.8	0.05
3	30.64	0.5005	24.6	0.05
			25.0	0.04
4	15.58	0.5061	7.0	0.07
5	7.74	0.5013	2.3	0.04
Synthesized Magnetite Nanoparticles				
6	7.53	0.5003	0.07	0.06
7	15.47	0.5055	0.05	0.12
8	30.3376	0.5053	1.36	0.23
9	46.0154	0.5029	14.44	0.25
			14.55	0.25

Continuous Flow Metal Recovery System



CFMR Coil Performance

Coil version	Current (A)	Potential (V)	Flux Density (kG)
Prototype 2	7	8.03	0.40
	9	10.37	0.50
	11	12.85	0.63
Prototype 3	7	29.2	0.87
	9	38.4	1.14
	9.66	42.5	1.20



Prototype 3

CFMR Collection Efficiencies

Fe_3O_4 (g)	I_i (A)	I_f (A)	$t_{\text{breakthrough}}$ (min)	t_{total} (min)	Fe_3O_4 Loss (g)	Flow Rate (L/min)	Efficiency (%)
15.0015	10.00	9.45	—	1.72	0.72	2.00	95.20
15.0035	10.00	9.25	1.22	3.00	0.426	1.36	97.16
30.0406	10.00	9.15	1.50	3.00	0.265	1.36	99.12
30.0421	10.00	9.04	1.37	4.05	0.220	1.36	99.27
30.0094	9.00	9.00	1.00	4.00	0.791	1.36	97.37



Initial Conclusions

- **Low copper adsorption** $\left(\bar{q} = 0.22 \frac{\text{mmol Cu}}{\text{g Fe}_3\text{O}_4}\right)$
 - Lack of full dispersion and colloidal stability
 - Agglomerations of nanoparticles
- **Highest adsorption attained with Si-coated particles**
- **Explore alternative synthesis methods**
 - Current method is expensive and time consuming
- **Particle collection efficiencies decrease at higher flow rates**

Path Forward

- **Investigate higher flow rates**
- **Test additional heavy metals**
 - Lead, Zinc
- **Expand adsorption studies to nutrients**
 - Sulphates, Nitrates
- **Automate reactor system**
 - Valve control
 - pH and temperature logging
- **Study nanoparticle toxicity**



Acknowledgements

- Dr. Jerome Downey
- Dr. David Hutchins
- Dr. Brian St. Clair
- Dr. Richard LaDouceur
- Katie Schumacher
- Grant Wallace
- Daisy Margrave



This material is based upon work supported in part by the National Science Foundation EPSCoR Cooperative Agreement *OIA-1757351*. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

- Hutchins, David. (2018) *Continuous flow process for recovery of metal contaminants from industrial wastewaters with magnetic nanocomposites*. Ph.D. Dissertation, Montana Tech.
- *National Center for Biotechnology Information. PubChem Database. Magnetite, CID=14789, <https://pubchem.ncbi.nlm.nih.gov/compound/Magnetite>*
- Zargar, Vida, et al. (2015) *A Review on Chitin and Chitosan Polymers: Structure, Chemistry, Solubility, Derivatives, and Applications*. ChemBioEng Rev, no. 3, 204-226



Questions?

