Iron Out Uranium: Using Zero Valent Iron Nanoparticles For Heavy Metal Remediation in Soil On The Navajo Nation

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Research Question

What are the sorption capacities of various nanoparticles on uranium contaminated soil from an abandoned mine site on the Navajo Nation?

Research Objectives

- Compare the application of nanoparticles for soil remediation
  - nZVI
  - Fe0@UiO-66-COOH
  - UiO-66-COOH
- Highlight the removal capacities of uranium from soil with nanoparticles
- Provide a clean-up method that removes uranium from the soil efficiently

Zero Valent Iron Nanoparticles (nZVI)

Nano sized zero-valent iron technology was created in the 1990s. Its initial use was to deteriorate toxic compounds and hazardous materials.

They are effective as reducing agents and can convert contaminants to harmless compounds by reduction reactions.[3]

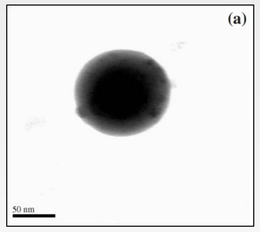

Figure (a) Micrograph of a single nZVI Particle[3]

Reduction Mechanism

$$A + B \rightarrow A^{+} + B^{-}$$

A is the oxidizing species

B is the reducing species

Metal Organic Frameworks (MOF)

3D ordered porous materials composed of inorganic clusters bridged by organic ligands. Properties include accelerated adsorption/desorption kinetics. The MOF UiO-66-COOH can be combined with zero valent iron nanoparticles to increase availability.[4]

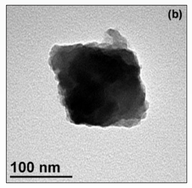

Figure (b) Micrograph of UiO-66-COOH[5]

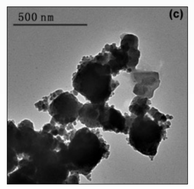

Figure (c) Micrograph of Fe0@UiO-66-COOH[5]

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Background

During the 1940s uranium was discovered in large quantities on the Navajo Nation. Uranium was in high demand due to World War II, which lead to mining for the federal Atomic Energy Commission. Uranium was mined from 1944 to 1989. Although mining ceased, mines were abandoned without proper clean up. Elevated gamma radiation levels adversely affects human health.[1]

In 2000, EPA and NNEPA identified 523 abandoned uranium mines on the Navajo Nation. From 2008 to 2019, the EPA found that 17% of the mines were priority mines. Priority mines are classified by their high levels of radiation, proximity to humans and water sources. Currently federal agencies are working with the Navajo Nation to build on previous work to remediate the contaminated uranium mine sites outlined in the Navajo Nation Ten Year Plan.[1]

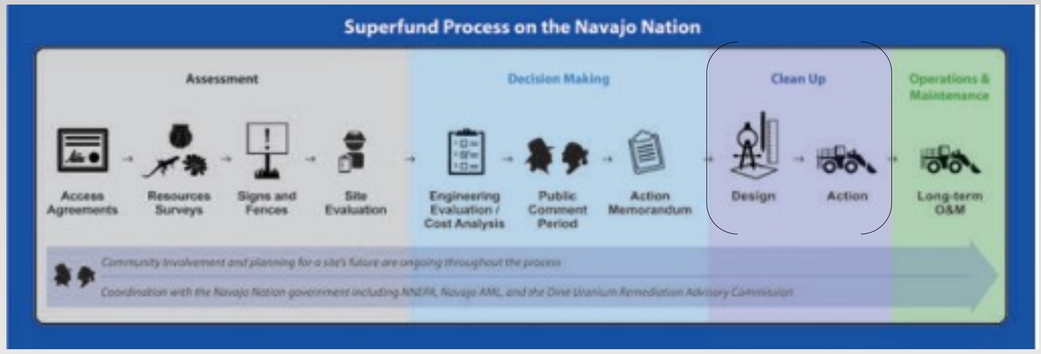

Figure (d) Superfund Process for Uranium Mine Clean Up[1]

Laboratory Methods

- Collect 4 soil plots from site and evaluate the uranium concentration in 3 plots, with 1 plot as control plot (from subsoil layer)
  - Work on plots with equal amounts of uranium contaminant
  - Each plot will have 200 grams extracted for soil sample to be used in batch experiment
- Synthesize the nanoparticles to be used as removal agents for the uranium contaminant
- To analyze the uranium removal, perform batch experiments with each nanoparticle. Leave 1 sample as a control sample
  - Batch Experiment- Add specific amount of solid into a solution containing specific concentration of contaminants with a certain solid liquid ratio. These mixtures are shaken during the reaction time. The concentration of the contaminant in solution is monitored and its change is shown as the amount of contaminant partitioned onto the solid.[5]
  - The removal percentage of U(VI) can be calculated from the initial (C_0) and final concentrations of U(VI) (C_F)
    - $\text{Removal Percentage of U(VI)} = \frac{C_0 - C_F}{C_0} \times 100\%$
- With the batch experiment results, identify the nanoparticle with highest removal percentage
- Experiments will be done in a controlled environment, does not simulate study site conditions

References

1.Environmental Protection Agency. 2020. Ten-Year Plan: Federal Actions to Address Impacts of Uranium Contamination on the Navajo Nation 2020-2029. Project Plan, Washington, D.C.: Environmental Protection Agency.
2.Liu, Ruiqiang, and Rattan Lal. 2012. "Nanoenhanced Materials for Reclamation of Mine Lands and Other Degraded Soils: A Review." Journal of Nanotechnology 1-18.
3.Sun, Yuan-Pang, Xiao-qin Li, Jiasheng Cao, Wei-xian Zhang, and H. Paul Wang. 2006. "Characterization of zero-valent iron nanoparticles." Advances in Colloid and Interface Science 47-56.
4.Wang, Shunzhi, C Michael McGuirk, Andrea d'Aquino, Jarad A Mason, and Chad A Mirkin. 2018. "Metal-Organic Framework Nanopaticles." Modular Nanomaterials 1-14.
5.Xu, Lin, Duo Zhang, Fuyin Ma, Jiarong Zhang, Afshin Khayambashi, Yawen Cai, Lanhua Chen, Chengliang Xiao, and Shuao Wang. 2019. "Nano-MOF+ Technique for Efficient Uranyl Remediation." ACS Applied Materials & Interfaces 21619-21626.
6.Zhao, Xiao, Wen Liu, Zhengqing Cai, Bing Han, Tianwei Qian, and Dongye Zhao. 2016. "An overview of preparation and applications of stabilized zero-valent iron nanoparticles for soil and groundwater remediation." Water Research 245-266.

Study Area and Soil Samples

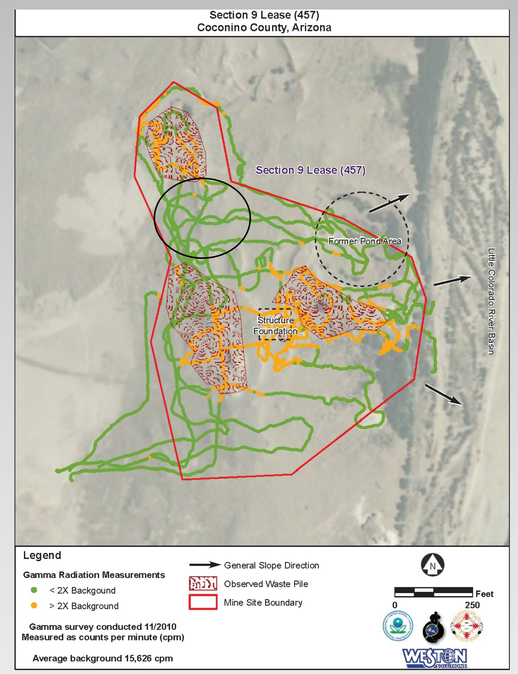

Figure (e) Gamma Radiation Map of Study Site[1]

Real World Application

The next step would be to apply the nanoparticle with the highest removal capacity on larger areas. Focusing on areas with the highest concentration of uranium, following the EPA priority list. An option for a site wide remediation would be to inject the nanoparticles into the ground water with a nanoparticle injection well.

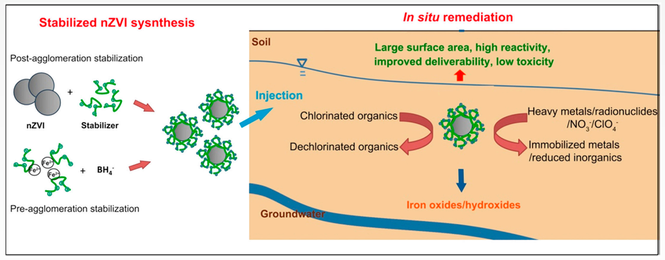

Figure (g) Nanoparticle Injection Well Diagram[6]

Acknowledgements

I would like to thank the Haskell Environmental Research Studies Institute (HERS), EPSCoR, the National Science Foundation (NSF), Haskell Indian Nations University, and the University of Kansas. I would like to acknowledge Dr. Dan Wildcat, Trina McClure, Dr. Jay Johnson, Professor Cody Marshall, and Josh Meisel. I would like to thank and acknowledge my mentor, Kari Snelding. This project was supported by KS NSF EPSCoR Award 1656006