1. Student Researcher: Rachael Apodaca
   Faculty Advisor: Dr. Kenneth C. Carroll

2. Project title: Characterizing the Effect of Salinity on PFAS Sorption to Hanford Sediment Using Column Experiments

3. Per and Polyfluoroalkyl substances (PFAS) are a class of manufactured fluorinated compounds extensively used in industrial and consumer products, with notable examples including firefighting foams. PFAS release into groundwater, documented globally and in various sites across New Mexico, poses a serious threat to human and environmental health. PFAS, marked by their high mobility and resistance to natural degradation, have been associated with bioaccumulation and various health concerns. This study addresses the pressing issue of PFAS contamination in soil and groundwater, focusing on the adsorption behaviors of specific PFAS compounds (PFOA, PFNA, PFDA, PFHxS, PFOS).The research aims to explore the intricate dynamics governing PFAS interactions within soil environments. The objectives include: **Exploring Carbon Chain Length Influence:** This objective involves a detailed investigation into how the perfluorocarbon chain length of PFAS compounds (PFOA, PFNA, PFDA, PFHxS, PFOS) influences their adsorption behaviors in soil. By systematically varying chain lengths and analyzing their respective adsorption characteristics, the research aims to establish specific trends and correlations, providing insights into the role of molecular structure in PFAS-soil interactions. **Assessing the Impact of Mass-Balance Recovery Conditions:** This objective focuses on evaluating how the adsorption system responds to different mass-balance recovery conditions, specifically examining the variability in adsorption calculations under low-recovery scenarios. By doing so, the research aims to understand how variations in recovery conditions may affect the reliability and consistency of PFAS adsorption measurements. This investigation is crucial for determining the system's responsiveness to different recovery scenarios and ensuring the robustness of the obtained data. **Systematically Examining Salt Concentration Effects, with a Focus on Sodium Sulfate and Sodium Phosphate:** The research aims to comprehensively study the effects of varying salt concentrations on PFAS adsorption, emphasizing a particular focus on sodium sulfate and sodium phosphate. By systematically altering salt concentrations and observing the resulting adsorption behaviors, the study aims to uncover nuanced effects associated with different salts under varying concentrations. This detailed examination will contribute to a more thorough understanding of how environmental salts impact PFAS interactions in soil.
Understanding these objectives is paramount for developing effective remediation strategies and advancing knowledge on PFAS behavior in soil environments.

4.
We conducted lab experiments using Hanford sediment to recreate saturated groundwater conditions. Before starting, columns were thoroughly flushed with deionized water to establish equilibrium. Maintaining a flow rate of 0.5 ml/min ensured a realistic pore water velocity. To understand sediment characteristics, we used non-reactive tracer experiments with PFBA. The study involved five scenarios, including PFAS solutions without salts, to explore the impact of different salinities on PFAS behavior.

For analysis, we utilized a modeling tool to interpret data in various modeling scenarios. Our comprehensive approach included various chemical analysis methods such as pH measurements, electrical conductivity readings, ion chromatography, UV-visible spectroscopy, and LC-MS/MS for PFAS determination. his multifaceted approach allowed us to unravel the complexities of PFAS interactions within the soil environment, including their behavior in the presence of co-contaminants.

5. Description of results; include findings, conclusions, and recommendations for further research.

1. **Mass Balance Recovery Challenges and Irreversible Sorption:**
    - Low recovery in certain experiments suggested potential irreversible sorption of PFAS to the soil.
    - This implies that some PFAS compounds might strongly adhere to soil particles, making their removal challenging.
2. **Influence of Carbon Chain Length on Sorption:**
    - Longer-chain PFAS compounds generally exhibited increased affinity for soil, impacting their persistence and mobility.
    - The introduction of sodium sulfate intensified this positive correlation between chain length and sorption.
3. **Context-Dependent Relationship with Sodium Phosphate:**
    - Sodium phosphate introduced complexity to the chain length-sorption relationship, showing a nuanced impact.
    - Under 0.01M conditions, longer chains exhibited reduced binding affinity, while 0.02M conditions displayed variations in the behavior.
4. **Sensitivity to Salt Concentrations:**
    - PFAS compounds demonstrated diverse responses to varying salt concentrations, highlighting the importance of environmental factors.
    - Sodium sulfate generally enhanced adsorption, while sodium phosphate exhibited compound-specific inhibitory effects.
5. **Consistency and Variability in Measurements:**
    - Experiments showed consistent results for PFHxS and PFOA, while PFNA, PFDA, and PFOS exhibited higher variability, especially under low-recovery scenarios.
    - The choice of solution (sodium phosphate or sulfate) influenced measurement consistency.
6. **Chain Length and Soil Adsorption Coefficient:**
    - Positive correlations were generally observed between chain length and soil adsorption coefficient emphasizing the influence of PFAS chain length on soil interactions.
7. **Complex Dynamics of PFAS in Soil:**
    - PFAS interactions with soil components were found to be complex and context-dependent, emphasizing the need for a nuanced approach in understanding their fate in the environment.

Future research includes delving into the long-term effects of PFAS contamination, including accumulation and persistence. Our ongoing research involves soil extraction experiments. These experiments aim to quantify the extent of PFAS irreversibly sorbed to the soil, providing essential insights into the lasting environmental impacts of PFAS contamination. Continuing along this avenue of study, we seek to enhance our understanding of PFAS behavior in soil environments and contribute valuable data to the assessment of sustained environmental impacts.

6. The research findings hold substantial value for a diverse array of stakeholders, encompassing environmental scientists, policymakers, regulatory bodies, and water agencies. Understanding the adsorption behaviors of PFAS compounds, such as PFOA, PFNA, PFDA, PFHxS, and PFOS, in soil is critical for the development of effective remediation and management strategies. By exploring the intricate dynamics influenced by chain length, recovery conditions, and salt concentrations, the study contributes nuanced insights into PFAS-soil interactions.
Environmental scientists stand to benefit significantly as the research enhances the current understanding of PFAS behaviors within soil environments. The nuanced exploration of chain length impact, recovery conditions, and salt concentration effects provides crucial data points for refining existing models and theories related to PFAS sorption. This deeper comprehension is instrumental in advancing the predictive accuracy of PFAS transport and retention, facilitating more accurate risk assessments in contaminated sites.
Policymakers and regulatory bodies such as the EPA, can leverage the research results to formulate and refine environmental regulations concerning PFAS contamination. The findings contribute to a more nuanced understanding of the factors influencing PFAS mobility in soil, guiding the development of targeted and effective policies. This is particularly relevant given the persistent nature of PFAS compounds and their potential threats to human health and ecosystems.
Water agencies are direct beneficiaries of the research outcomes as the study investigates the impact of varying salinities on PFAS sorption. Understanding how environmental salts influence PFAS migration potential in soil and groundwater is crucial for water resource management. The findings equip water agencies with valuable insights into the potential risks and challenges posed by PFAS contamination, aiding in the development of strategies to safeguard drinking water quality.

7. Describe how you have spent your grant funds.
The funds were used to purchase various regent chemicals including PFAS chemicals and salts. We also purchased sampling vials and other experimental supplies, and we purchased isotope labeled standards for PFAS chemical analysis and solvents for chemical analysis.

8. List Publications: (we are drafting a journal manuscript to be submitted this summer)
Carroll, K., **Apodaca, R**., Mohamed, R.,Young, RB., Impact of aqueous salinity on PFAS sorption to the Hanford soil. Soil Science Society of America Annual Meeting St. Louis, MO, Poster Presentation (October 29th, 2023)
Apodaca, R., Mohamed, R., Carroll, K., The co-transport of PFAS and anionic salts. WM Symposia, Phoenix, AZ, Poster Presentation (March 1, 2023)

9. I extend my heartfelt thanks to Sophia Fuentes for her significant contribution to the data collection process. Her meticulous approach, attention to detail, and commitment to ensuring the accuracy of the gathered information have greatly enriched the quality of this study.

I also want to acknowledge the invaluable assistance of Ruba Mohamed in the data analysis phase. Her expertise, analytical skills, and insightful perspectives have been crucial in deriving meaningful conclusions from the collected data.

10. I am on track to complete my degree in spring 2024. Concurrently, I have secured a position with the City of Las Cruces in their water quality lab, operating under the Department of Regulatory Compliance. This opportunity aligns with my academic focus and serves as a stepping stone toward contributing to water-related fields. My current career trajectory reflects a commitment to applying my education in practical contexts, with a specific focus on water-related issues, both in New Mexico and beyond.

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