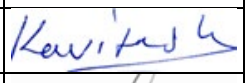
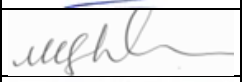
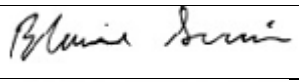
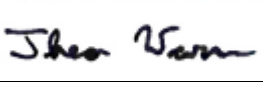
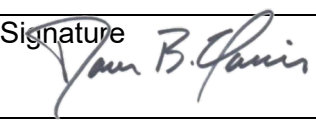
Proposal Number:	Total Amount Requested: $131,800
Proposal Track: Proof of Concept	
NSF I-Corps participation: Have you participated in, or plan to participate in the NSF I-Corps Program? We will participate in 2026.	

Title of Proposed Project: SECURE: Strategic Exploration of Critical and Unconventional Resources for Energy	
Specific Project Focus: Leveraging our industrial partnerships, we will design and deploy bio-inspired and sulfur-rich polymer platforms that enable selective, scalable, and environmentally responsible recovery of critical minerals from Idaho's industrial waste streams while creating commercialization pathways and workforce opportunities benefitting both the national supply chain and Idaho's economy.	
Project Start Date: July 1, 2026	Project End Date: June 30, 2027
Name of Institution: Idaho State University	**Department:** Department of Chemistry
Address: 921 S 8th Ave, Pocatello, ID 83209	
E-mail Address: isuaor@isu.edu	**Phone Number:** 208.282.2592

Role	Name	Title	Signature
Principal Investigators:	Courtney Jenkins, Ph.D.	Associate Professor	
	Kavita Sharma, PhD.	Assistant Professor	
Co-investigator(s):	Mustafa Mashal, Ph.D.	Professor	
	Jared Cantrell	Associate Director, Strategic Partnerships & Innovation	

Name of Partnering Company:	Company Representative Name:	Signature
Bayer, Soda Springs' Phosphate	Brock Sturm	
Perpetua Resources	Blaine Serrin	
J R Simplot Co	Theo Warner	

Authorized Organizational Representative	**Name:** Dave Harris	Signature 

1. BACKGROUND AND PROBLEM STATEMENT

The U.S. faces critical energy and national security challenges as it advances defense systems, AI data centers, and energy storage, driving demand for critical minerals far beyond domestic supply.[1,2] Import-reliant for 80% of rare earth elements (REEs) and fully dependent on foreign sources for gallium (Ga),[3] supply weaponization and price volatility have created severe vulnerabilities.[4,5] This dependence exposes the nation to significant risks, including supply chain disruptions, geopolitical leverage, and price volatility. The uneven global distribution of these resources, combined with high market concentration in a few countries, further amplifies vulnerabilities and underscores the urgency of developing domestic solutions. Fortunately, the United States, especially Idaho, possess substantial, untapped resources. Idaho's rich geological landscape, combined with its industrial activity, presents a unique opportunity to address this gap through sustainable and innovative recovery strategies. Stockpiled mine tailings, mineral processing waste, and e-waste pose an environmental threat as well as an untapped economic resource. For example, Bayer's phosphate processing plant in Soda Springs produces vast quantities of phosphogypsum (PG) waste, known to be rich in REEs and gallium. Antimony (Sb), a critical defense material, and other residual precious metals are abundant in the Stibnite District's mine tailings. Integrating a selective extraction technology directly into the processing loop could enhance total recovery, improve project economics, and strengthen the Idaho company's environmental, social, and governance performance.

To ensure national security and economic resilience President Trump has issued multiple executive orders aimed at improving access to critical minerals.[6] Finding and developing new REE deposits is both time consuming and expensive; however, mine tailings, electronic waste (e-waste), and other waste streams offer an alternative, scalable strategy to recycle available material for new products. Until recently, it was not profitable for these companies to pursue extraction strategies.[23] However, supply chain disruption has made sourcing materials within the U.S. a matter of economic resilience and national security. Idaho has a rich supply of material and the scientific expertise to develop extraction technologies that can be directly integrated into industrial partner operations, turning costly environmental liabilities into new revenue streams.

2. SIGNIFICANCE OF PROJECT AND PROJECT OBJECTIVES

Leveraging abundant, low-cost, and locally available sagebrush biomass to develop advanced polymers that mitigate industrial byproducts is both innovative and significant for its economic solution to challenging industrial and environmental problems. Transforming underutilized and often environmentally burdensome resources into high-value functional materials reduces reliance on petrochemical feedstocks, lowers production costs, and enhances sustainability. Using region-specific raw materials strengthens supply chain resilience, supports local industries, and establishes a scalable, circular material economy within Idaho. The proposed project directly addresses a critical national priority: securing a resilient domestic supply of strategic materials essential for clean energy, advanced technologies, and national defense.

The escalating demand for low-carbon energy systems (e.g., solar panels, wind turbines, nuclear energy, electric vehicles, and hydrogen fuel cells) significantly increases reliance on critical and strategic materials. In particular, there is an urgent need to secure a domestic supply of Neodymium (Nd), a critical REE essential for high-strength magnets used in electric vehicles, wind turbines, and defense technologies.[7] While Nd is primarily sourced from foreign deposits, Idaho has significant untapped resources from ores, stockpiled mine tailings, and processing waste.[8] Traditional extraction methods are often environmentally damaging and economically marginal. To address this, we propose to develop a sustainable alternative by transforming sagebrush biomass into high-performance, selective polymeric adsorbents. This bio-based

approach not only reduces environmental impact but also introduces a cost-effective and scalable pathway for domestic material recovery.

This project will also target antimony (Sb), a vital metalloid found in lead-acid batteries, and semiconductor devices.[9,10] In Idaho, Sb has historically been managed as an environmental contaminant from mine tailings.[11,12] However, the shift to mineral independence has turned waste streams into strategic assets. Using elemental sulfur, an industrial byproduct, we will synthesize high-capacity, sulfur-rich adsorbents decorated with and bio-inspired co-monomers to exploit Sb's thiophilic nature. This two-fold approach repurposes industrial sulfur waste and reclaims critical minerals.

In partnership with Bayer's, Soda Springs phosphate facility, Perpetua Resources, and J R Simplot Co, we will identify key elements in the waste stream and extract those elements using low-cost, scalable polymers designed to selectively capture and refine high-value metals. Designing bio-inspired and sulfur-rich polymeric adsorbents will permit engineering of multidentate coordination environments specifically tuned for Ga, Nd, and Sb's thiophilic nature and establish a mechanistically precise path for domestic mineral circularity. **Figure 1** illustrates SECURE's overall framework, which integrates polymer design and synthesis, material characterization, binding studies, and industrial partnerships.

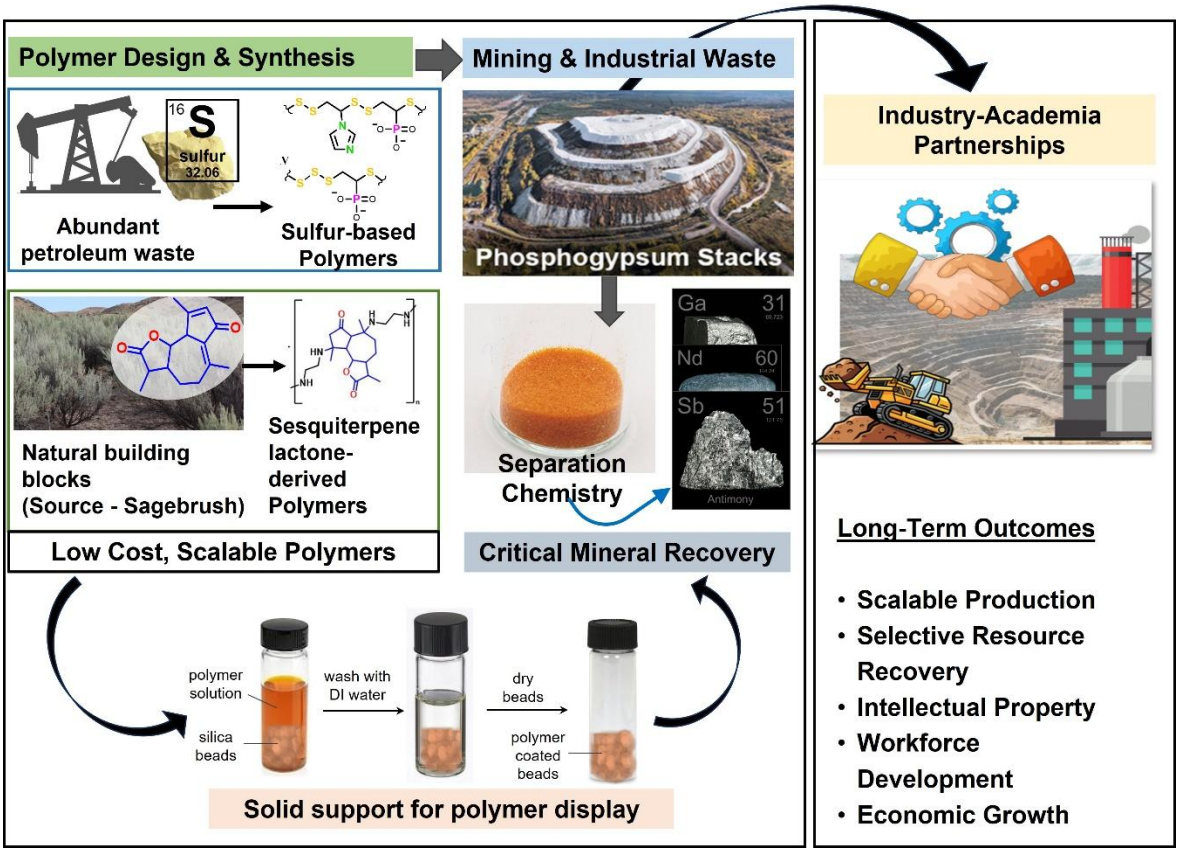


Figure 1 *Illustrates SECURE's integrated framework, encompassing polymer design, characterization, binding studies, and industrial collaboration.*

Recycling mining waste is challenging due to the complexity and variety of materials; however, the resource recovery, environmental protection, and economic growth benefits justify the investment.[13] *Partnering with state industries, our long-term goal is to establish a circular materials economy that increases Idaho's competitiveness, attracts private investment, and ensures that economic and environmental benefits stay within the state. This project will position*

Idaho as a model for sustainable resource recovery, where science, industry, and workforce development intersect to create lasting value.

The primary objectives of this project are:
Objective 1: *Synthesize sagebrush derived biopolymer frameworks for high-affinity Nd extraction (Sharma)*. Using sagebrush, we will synthesize a new class of bio-polymer derived from sesquiterpene lactones. The oxygen-rich functional groups of lactones and nitrogen-rich group of amines are ideal ligands for selectively binding hard metals, such as Ga and Nd.

Objective 2: *Synthesize sulfur-based polymers with targeted functional groups for Sb and Ga recovery (Jenkins).* Sulfur plays a key role in mobilizing Sb from minerals,[14] and sulfur-rich polymers (20 to 90% sulfur) offer promising adsorbents.[15] An array of biomolecules that combine sulfur with other nucleophilic binding sites (e.g., carboxylic acids and phosphates) have demonstrated selectivity for Sb.[16-18] Peptide and phage studies with Ga indicate a strong affinity for hydroxyl and thiol groups and improved selectivity for structures with limited flexibility.[19, 20] We will design and tailor sulfur-based polymers with targeted ligands to enhance selective Sb and Ga extraction.

Objective 3: *Employ bio-inspired and sulfur-rich polymers for critical mineral recovery (Sharma and Jenkins).* Critical mineral recovery is not only dictated by the materials used but how they are deployed. We will test these polymers as water-soluble flocculants, powders, and displayed on solid supports to optimize the extraction method. This technology will then be validated against standard laboratory solutions and industrial samples.

3. SPECIFIC PROJECT PLAN AND TIMELINE

<u>Task 1: Synthesis of sagebrush derived biopolymer frameworks targeting Nd and Ga extraction</u>
Using techniques validated from NSF grant #2004257, Jenkins's developed fully renewable polymers that combine garlic oil, and crude sagebrush extracts, to make amorphous polymers for green adhesives. Building from this discovery, Sharma will use simple purification strategies to effectively extract, purify and modify sagebrush sesquiterpene lactones (secondary metabolites).[21] The simple extraction and purification methods provide access to an inexpensive and pure natural compound from a common Idaho shrub, which can be modified by an array of synthetic techniques.[21]
Sesquiterpene lactones (SLs) were selected due to their rigid multi-cyclic backbone that can be chemically modified or derivatized[21] to create the specific rigid pockets required to selectively fit larger Nd over smaller, heavier REEs like dysprosium (Dy)**.** A hard Lewis acid with an internally shielded [Xe] $4f^3$ configuration, Nd^{3+} favors purely electrostatic bonding and requires a high coordination environment (8 to 12) for stability.[22] Sagebrush-derived SLs provide a naturally oxygen-dense, multi-cyclic backbone that acts as a

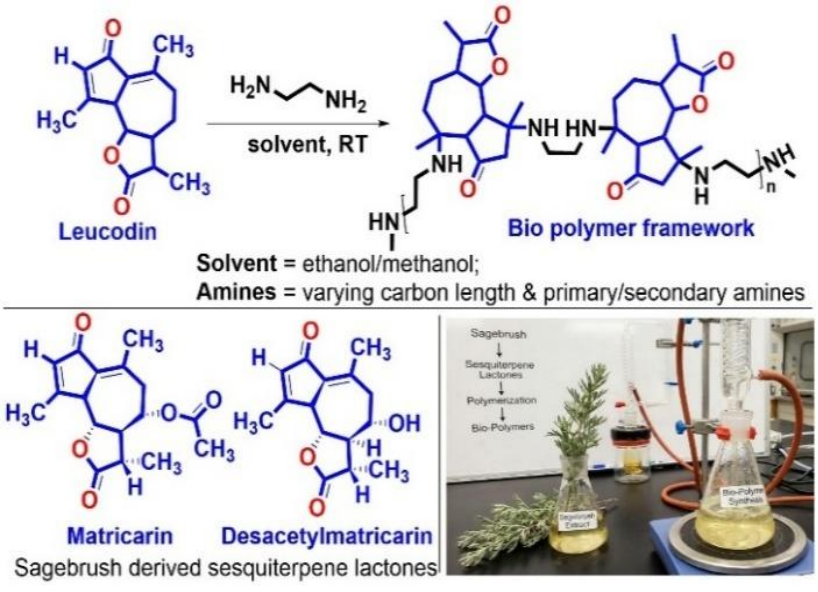


Figure 2 1. *Synthetic route for sagebrush-derived sesquiterpene lactone-amine polymers.*

primary hard-donor site. By covalently tethering these metabolites to amines via Michael addition, we create biopolymers with an integrated multidentate oxygen-nitrogen donor network. This engineered scaffold wraps around the Nd, satisfying its coordination demand, while using SLs' rigid framework to create a binding pocket sized specifically to accommodate Nd's larger ionic radius, effectively discriminating against metal contaminants that do not fit the electrostatic or geometric site profile.

Biopolymer synthesis begins with the extraction and purification of SLs from sagebrush, which serves as the primary bio-scaffold.[21,23] Metabolites are functionalized via Michael addition using diamines, such as 1,2-diaminoethane and 1,3-diaminopropane (**Figure 2**).[24] The synthesis relies on a 1,4-conjugate addition of primary or secondary amines to the lactone ring's exocyclic double bond. This reaction typically achieves high regioselectivity and high yields.

The α-methylene group is a potent Michael acceptor, allowing the reaction to proceed in polar protic solvents (e.g., methanol) in 4 to 12 hours at 25°C to 50°C.[24] Using a slight molar excess of the amine often ensures complete conversion of the natural metabolites into the desired monomeric units without the need for harsh catalysts, thereby preserving the bio-scaffold's structural integrity.

Advances in biomass modification have enabled the sustainable production of diamines.[25] Converting these small molecules into extended polymer networks allows these materials to function as multidentate ligands enhancing the metal binding affinity. ***These bio-based polymers are low cost, renewable, and Idaho-sourced***, and establish a local materials platform that aligns with the state's sustainability priorities.

Task 2. Synthesis of sulfur-based polymers targeting Sb and Ga recovery

The low cost and high abundance of sulfur extracted from crude oil has led to the development of an array of inexpensive, scalable, sulfur-based polymers using inverse vulcanization.[26-32] The Jenkins lab has nearly a decade of sulfur-based polymer expertise [33-37]and will use inverse vulcanization to synthesize sulfur-rich polymers, a method that achieves high atom economy and eliminates costly post-polymerization processing.[38,39] These polymers have been produced on the kilogram-scale in under one hour without inert gas, offering a simple, scalable technique.[15] Jenkins will develop terpolymers that unite cationic and anionic monomers, incorporating new chemical functionalities. Poly(sulfur-vinylimidazole) effectively binds gold, even in the presence of higher concentrations of other metal ions, binding nearly 2 g of gold (III) per gram of polymer, almost triple the

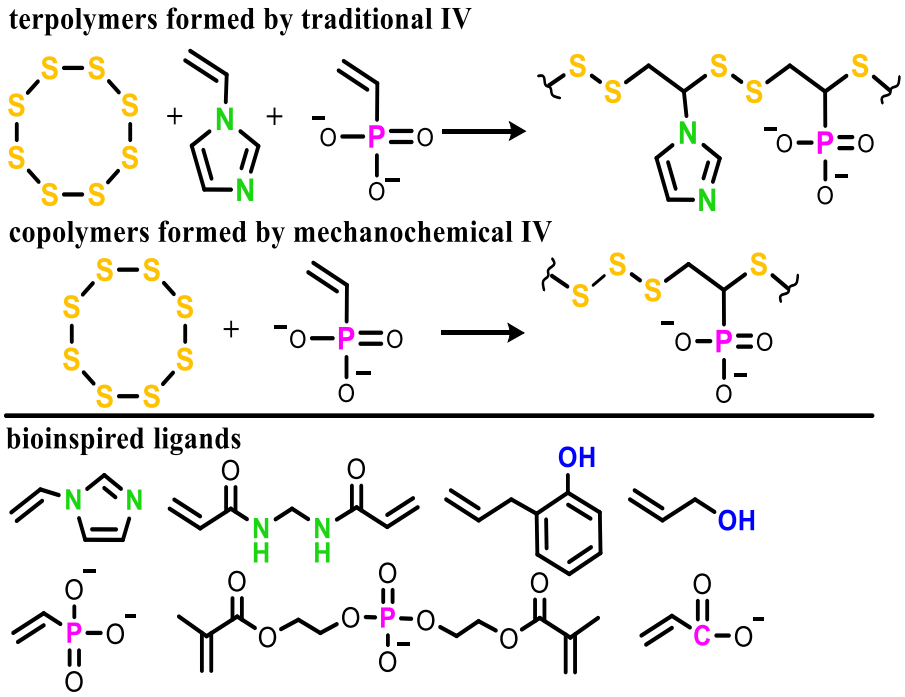


Figure 3. *Sulfur-based polymers formed by typical or mechanochemical inverse vulcanization (IV). Possible monomers containing bioinspired ligands.*

binding efficiency of similar materials.[15] A provisional patent has been filed for selective metal extraction using this polymer (Application No.: 19/302,785). Here, the sulfur content will be varied by altering the synthetic feed ratios. To improve selectivity, we will mimic biological binding sites, by incorporating monomers with targeted ligands (e.g., hydroxyl, acrylate, and phosphate) into sulfur-rich polymers (**Figure 3**). Preliminary studies indicate that altering the sulfur content, co-monomer, and synthetic method can alter the metal binding profile. Ga structural rigidity will
be enhanced by increasing the cross-link density using difunctional monomers and decreasing the sulfur rank by lowering sulfur feed ratios. A provisional patent has been granted, and a patent application has been filed for the synthesis of a subset of these cross-linked sulfur-based polymers (patent application US20260001997A1)

Despite precedent for synthetic ease and scalability, high temperatures (130-180 ˚C) are typically required, and the lack of solvents can lead to runaway reactions. However, alternate strategies may provide a more controlled, energy efficient path to material synthesis.[40] To reduce energy use, making polymer synthesis more economical, Jenkins will explore mechanochemical inverse vulcanization using ball milling,[40, 41] which has not been applied to charged or aqueous monomers, representing a significant synthetic advancement.

Task 3. Polymer characterization

Comprehensive characterization will confirm polymer composition and structure. Nuclear magnetic resonance (NMR) will verify complete monomer incorporation or the extent of polymerization. X-ray Diffraction (XRD) will determine if any crystalline sulfur remains. Gel permeation chromatography (GPC), dynamic light scattering (DLS), differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) will be used to determine polymer size and thermal properties. These techniques will increase understanding of the relationship between polymer properties and metal binding capabilities.

Task 4: Critical mineral binding studies

Each family of polymers will be evaluated for their ability to bind target metals and metalloids beginning with standard solutions to determine selectivity and capacity. Water-soluble polysulfides will be tested for flocculation behavior upon metal ion binding,[36] allowing select metals to be easily filtered from solution. Insoluble polymers, powdered or as a coating on carbon black, will be tested on packed-bed extraction systems.[35] Aqueous polymer solutions will be analyzed before and after ore contact using inductively coupled plasma, optical emission spectrometry (ICP-OES), to quantify the concentration change for key elements (e.g., Nd, Ga, Sb).

Effective polymers will be tested against practical samples from industrial partners (e.g. process waste and mine tailings). Metal-containing samples from Bayer and Perpetua will be digested using nitric acid and analyzed by ICP-OES to quantify composition. Polymers will be tested in both batch and column formats to assess selectivity and efficiency. Solid composites will be coated onto alumina or carbon black for enhanced handling and reusability. The binding performance will be evaluated under realistic acidic conditions representative of industrial waste streams, ensuring direct transferability to partner operations. High sulfur content polysulfides are acid resistant, showing no change to the polymer after one week in 1M sulfuric acid. Some systems show enhanced metal extraction at low pH.[36, 42] Access to anionic and cationic polymers may enhance extraction by adjusting the overall charge to optimize specific metal species at varied pH.

Timeline: Table 1 illustrates the overall project goals, along with the timeline, key objectives, and associated milestones for each phase.

Table 1: Timeline of Objectives and Milestones	Quarter				
Objectives	**1**	**2**	**3**	**4**	**Milestones**
Objective 1: Develop sagebrush derived biopolymers • Develop efficient workflow for polymer synthesis. • Synthesize and characterize an family of copolymers. • Adjust polymer design based on metal binding data.					• Develop new class of biopolymers. • Determine ideal structures for enhanced metal binding.
Objective 2: Synthesize sulfur-based polymers • Create a series of polymers with varied metal-binding ligands and rigidity. • Tailor functionality to enhance metal binding. • Develop mechanochemical polymer synthesis.					• Identify functionality that enhances binding capcity and selectivity • Establish a more economical and practical method for polymer production.
Objective 3: Employ polymers for critical mineral recovery • Determine best polymer extraction method • Solution, powder, solid support • Use standard solutions to find the metal binding capacity and selectivity of polymer systems. • Test best polymers against industrial samples.					• Develop strategy to display polymer frameworks for critical mineral extraction. • Prove polyner efficacy on lab samples. • Validate critical mineral recovery using industrial byproducts (e.g. mine tailings).

Intellectual Property and Industry Collaboration

This project is currently at Technology Readiness Level (TRL) 1–2. Basic chemical principles have been established (TRL 1), the concept has been formulated, and this proposal outlines the pathway for experimental proof of concept (TRL 3). The objective of this Proof-of-Concept grant is to complete laboratory-scale validation, advancing the technology to TRL 3. Both polymer systems—the sagebrush-derived biopolymers and sulfur-based polymers—represent patentable, scalable technologies for selective metal recovery. The work is expected to generate new intellectual property disclosures covering polymer composition, process optimization, and application-specific designs. A patent and provisional patent have already been filed for a subset of the sulfur-based polymers. Methodological advancements being pursued here will make future scale-up more practical enabling more efficient TRL advancement. Collaboration with Bayer and Perpetua Resources provides a direct pathway for industrial validation and commercial scale-up.

4. POTENTIAL ECONOMIC IMPACT

Project results are expected to have a substantial economic impact by transforming underutilized resources such as industrial sulfur waste and sagebrush biomass into high-value

polymer materials, which will be used for the extraction of Nd, Sb, and Ga from several waste streams. The development of low-cost, scalable, polymer-based adsorbents that can be directly integrated into existing industrial workflows, will reduce technical and financial risks for Idaho-based companies and create new revenue from waste materials. Early pilot demonstrations will facilitate technology transfer, licensing opportunities, and the adoption of sustainable extraction practices. By the end of the project, the polymer design will be adapted based on laboratory testing and will be validated against industrial waste samples. The project is expected to reach profitability as the technologies scale from lab validation to industrial deployment. Economic benefits include private investment recruitment, reduced waste management costs, and a stronger critical material domestic supply chain. Positioning Idaho's leadership in sustainable critical mineral recovery, this project ensures that both economic and environmental gains remain within the state, supporting long-term regional competitiveness and innovation. Collaboration with industrial partners will expand internship and job opportunities in advanced manufacturing, mayerials processing, and analytical sciences, preparing local graduates for Idaho's growing clean technology economy. Aligned with HERC's mission, this project combines education, research, and economic development. Strengthening critical material domestic production will reduce global market volatility and geopolitical disruptions and stabilize supply chains. This increased supply security can lower costs for downstream industries, improve manufacturing reliability, and encourage further innovation and investment within the U.S.

5. CRITERIA FOR MEASURING SUCCESS

Technical Performance: This project's technical performance will be evaluated in conjunction with the objectives described in Section 2.

- Develop a new class of sagebrush derived polymers.
- Create a family of sulfur-based polymers with functional ligands (i.e. hydroxyl, phosphate, and carboxylic acid). A subset of polymers will be formed by mechanochemical polymerization.
    - Successful polymerization will be assessed by NMR and GPC analysis showing complete monomer incorporation. (≥90% polymer design and characterization by the end of the project).
- Effective critical mineral recovery from standard solutions. Polymers will be testing against pure metal solutions, complex mixed metal solutions, and industrial samples.
    - Successful metal binding will be quantified by ICP-OES. (≥50% of the binding studies of Nd, Sb, Ga, Section 2).

Industrial Partnerships*:* At the early stages of technological development, the exchange of information exchange between partners is essential for success. Non-disclosure agreements with Bayer and Perpetua Resources will enhance communication and data sharing and provide a better understanding of existing waste stream composition and limitations. We will meet with partners 2-4 times over the year to evaluate their waste streams and test polymer performance on at least 1–2 industrial samples by the end of the project.

Commercialization and Economic Impact Metrics: A minimum of one invention disclosure or provisional patent will be submitted during the year. The research scientist and undergraduate students will develop technical expertise and strengthen Idaho's skilled workforce pipeline. Preliminary data will be used for federal grant applications to support continued technology development and commercialization.

6. DEVELOPMENT CHALLENGES AND MITIGATION STRATEGIES

Despite careful design strategies, it is possible that the polymers described in tasks 1 and 2 will lack the selectivity or binding capacity necessary for industrial use. Ion-imprinted polymers formed by initial complexation and polymerization with the metal of interest, have demonstrated enhanced selectivity and adsorption capacity.[41,44-46] Combining targeted functionality with perfectly sized recognition sites enhances polymer function and encourages a cyclic lifecycle of elemental recovery and polymer reuse. Several strategies have been used to create these polymers.[41,44-46] Polymers from tasks 1 and 2 that demonstrate successful extraction will be investigated as ion-imprinted polymers. Ligand-containing monomers (e.g., aminated sesquiterpene lactones, vinylimidazole) will be dissolved and stirred in the presence of the target metal ions. Precipitated complexes will be washed and combined with additional co-monomers (e.g., amines and sulfur) and polymerized. Metal ions will be removed using an acidic wash leaving the final templated polymer. The low and variable concentration of critical minerals in industrial waste streams may limit adsorption efficiency and economic feasibility. To address this, we will (i) optimize polymer functional groups to enhance selectivity and binding affinity, (ii) prioritize higher-grade ores and enriched waste streams when necessary, and (iii) develop pre-concentration strategies to increase target metal availability prior to polymer treatment. The complex chemical composition of industrial waste, including competing ions that may interfere with selective metal capture, presents another challenge. Mitigation strategies include the design of multidentate and tunable polymer ligands tailored for specific metals such as Nd, Sb, and Ga, along with systematic testing in both controlled and real-world sample matrices. A further concern is the potential presence of radioactive elements (e.g., uranium and thorium) in mining waste streams, as identified during industry engagement. To mitigate this risk, we will incorporate selective separation strategies, including the use of ion-selective materials such as advanced ionic-liquid-based systems, to isolate and remove radioactive species prior to or alongside target metal recovery. [47] Finally, as this project progresses toward industrial translation, scalability and process integration may present challenges. We will address this through early-stage collaboration with industry partners, enabling iterative testing, feedback, and material adaptation under realistic operating conditions.

7. BUDGET and BUDGET JUSTIFICATION

ISU Personnel - Total Request $106,900 (Salaries: $86,300 Fringe Benefits: $20,600)

- PI Courtney Jenkins, PhD, 1 month summer salary, $9739
- PI Kavita Sharma, PhD, 1 month summer salary, $10,575
- Co-PI Mustafa Mashal, PhD, .03 month's summer salary, $400
- Co-PI Jared Cantrell, PhD, .12 calendar months' (.01% effort), $1009
- Research scientist, Samjana Pradhan, PhD, 7 months' unclassified salary (58.33 % effort, $37,273)
- Three TBD Undergraduate students, (2 part time in the Jenkins's lab during the academic year and fulltime summer. One part time in the Sharma lab) at $15/hour.

Fringe Benefits - 15.1.% faculty summer, 43.5% non-classified employees, 2.9% students

Equipment Total Request $16,900

Verdor MM400 Ball Mill to develop more energy efficient and economical polymer synthesis strategies via mechanochemistry. It will enable the delivery of more practical, scalable polymers with continued use for polymer synthesis and material processing beyond the project timeline.

Materials and Supplies Total request $8,000

- Sharma lab: $4,000 for general laboratory supplies and associated laboratory analysis and polymer characterization expenses (e.g. NMR, LC-MS, ICP-MS, and GC-MS).

- Jenkins's lab: $4,000 for essential chemicals, materials, and lab supplies (e.g., monomers, general reagents, supplies, and consumables). Computer graphics such as ChemDraw and computer related supplies (e.g., USB drives for data transfer, storage).

Total Direct Costs: $131,800

8. PROJECT MANAGEMENT

Working in parallel to develop sagebrush derived biopolymers and sulfur-based polymers, PIs Sharma and Jenkins will be responsible for objectives 1 and 2 respectively. Monthly meetings will ensure regular communication of successful outcomes and setbacks and provide an opportunity for collaborative troubleshooting. Both PIs have capable undergraduates working on related projects, which will limit training time. Undergraduates will be working full time when funding begins. *We anticipate a series of polymers to be fully synthesized and characterized by the end of the first quarter*. Although modification of polymer design and synthesis will continue throughout the project, this initial set will enable *metal binding analysis beginning at the start of the second quarter* (**Table 1**). The immediate purchase of a ball mill will enable implementation of mechanochemical synthetic methods beginning in the second quarter. ISU research scientist Samjhana Pradhan, PhD will join the project in December. Her fresh material design perspective will help ensure continued progress. Co-PIs Marshal and Cantrell will help facilitate industrial partnerships and assist the technology's transition from the research to development phase.

9. ADDITIONAL INSTITUTIONAL AND OTHER SECTOR SUPPORT

Idaho's Strategic Position: Idaho State University (ISU) is strongly positioned to develop the tools required for urban mining and the valorization of existing waste streams. The university has signed a comprehensive, collaborative agreement with its long-term partner, the Idaho National Laboratories, (INL), which includes a focus area on Critical and Strategic Materials and Minerals.[48] Spanning upstream, midstream, and downstream processes, Idaho's resource ecosystem is one of four joint research and development priorities outlined in the ISU-INL SUPER Agreement's, Focus Area 1.[49] ISU recently established the Critical Materials and Energy Systems Innovation Center (CMESIC) at the Idaho Falls campus, underscoring the university's partnership with INL and signalling its commitment to advancing critical materials research.[50]

10. FUTURE FUNDING

Data from this work will support future applications to the National Science Foundation (NSF), Department of Energy (DOE), and Department of Defense (DOD) programs focused on domestic critical materials supply and green manufacturing. The technology's modular design will likely be attractive to private sector investment and potential startup formation within Idaho's growing clean-tech sector. Additional collaborations are anticipated with MP Materials, USA Rare Earths, U.S. Critical Materials Corp, Wastewater Resources, and Nth Cycle. Following successful completion of this *proof-of-concept* award, we will apply for initial startup or innovation-track funding. Dr. Jenkins has a strong record of securing NSF funding for her sulfur-based polymer research including an *NSF CAREER DMR-2337376* and *NSF-2004257*. These awards have led to one provisional patent and another provisional patent application focused on metal extraction, which provides the foundation for this proposal. She also has Department of Energy funding for collaborative polymer degradation (DE SC0023413O). Drs. Jenkins and Sharma have submitted an NSF- ICREW grant to create an undergraduate VIP course (RISE: Recovery of Idaho's Strategic Elements). ISU is the lead institution on their $6 million NSF EPSCoR Track 2 (NSF 24-573) proposal in collaboration with South Dakota School of Mines and the University of Nebraska-Lincoln.

References:

1) Vivoda, V.; Matthews, R.; Andresen, J. Securing Defense Critical Minerals: Challenges and U.S. Strategic Responses in an Evolving Geopolitical Landscape. *Comp. Strategy* **2025**, 44 (2), 281–315.
2) Kalantzakos, S. The Race for Critical Minerals in an Era of Geopolitical Realignments. *Int. Spect.* **2020**, 55 (3), 1–16.
3) Critical mineral resources: the U.S. geological survey (USGS) role in research and analysis. https://www.congress.gov/crs-product/R48005 (accessed 2026-01-04).
4) How the US can mine its own critical minerals — without digging new holes. https://www.gatech.edu/news/2025/05/06/how-us-can-mine-its-own-critical-minerals-without-digging-new-holes (accessed 2026-01-04).
5) What is a critical mineral? | U.S. geological survey. https://www.usgs.gov/faqs/what-a-critical-mineral (accessed 2026-01-04).
6) https://www.whitehouse.gov/fact-sheets/2025/04/fact-sheet-president-donald-j-trump-ensures-national-security-and-economic-resilience-through-section-232-actions-on-processed-critical-minerals-and-derivative-products/#:~:text=BOLSTERING%20AMERICA'S%20CRITICAL%20MINERALS%20FUTURE,President%20Trump's%20April%202%20order.)
7) https://www.llnl.gov/article/53696/energy-efficient-process-delivers-rare-earth-element-magnets
8) Gillerman, V.S.; Jercinovic, M.J.; and Schmitz, M.D. Neodymium-Rich Monazite of the Lemhi Pass District, Idaho and Montana: Chemistry and Geochronology. *Minerals*, **2025**, 15(11),1156.
9) https://www.usitc.gov/publications/332/executive_briefings/ebot_a_critical_material_probably_never_heard_of.pdf
10) He, Z.L.; Pu, C.; Zhou, W.F. Effect of antimony on the semiconducting properties of the anodic plumbous oxide film formed in sulfuric acid solution I. Studies with alternating-current (ac) impedance. *J. Power Sources* **1992**, 39(2), 225-232.
11) https://perpetuaresources.com/project/
12) https://www.spokesman.com/stories/2025/oct/12/mine-baby-mine-us-governments-critical-mineral-cru/
13) Jäger-Roschko, M.; Herremans, E.; Petersen, M., Umans, L.; Dons, G. Challenges and Best Practices in Recycling Supply Chains: A Qualitative Analysis of Five Major Waste Streams. **2020**, Available at SSRN 3715565.
14) Ye, L.; Zhong, W.; Zhang, M.; Jing, C. New Mobilization Pathway of Antimonite: Thiolation and Oxidation by Dissimilatory Metal-Reducing Bacteria via Elemental Sulfur Respiration. *Environ. Sci. Technol.* **2022**, 56 (1), 652–659.
15) Dodd, L. J. Inverse Vulcanisation: A New Starter's Guide to an Emerging Field. *RSC Appl. Polym.* **2025**, 3 (1), 10–42.
16) Ge, R.; Sun, H. Bioinorganic Chemistry of Bismuth and Antimony: Target Sites of Metallodrugs. *Acc. Chem. Res.* **2007**, 40 (4), 267–274.
17) Tella, M.; Pokrovski, G. S. Antimony (III) Complexing with O-Bearing Organic Ligands in Aqueous Solution: An X-Ray Absorption Fine Structure Spectroscopy and Solubility Study. *Geochim. Cosmochim. Acta* **2009**, 73 (2), 268–290.
18) Zhong, W.; Yin, Z.; Wang, L.; Yan, L.; Jing, C. Structural and Mechanistic Study of Antimonite Complexation with Organic Ligands at the Goethite-Water Interface. *Chemosphere* **2022**, 301, 134682.
19) Schönberger, N.; Taylor, C.; Schrader, M.; Drobot, B.; Matys, S.; Lederer, F.L.; Pollmann, K. Gallium-binding peptides as a tool for the sustainable treatment of industrial waste streams. *J. Hazard. Mater.* **2021**, 414, 125366.

20) Schönberger, N.; Zeitler, C.; Braun, R.; Lederer, F.L.; Matys, S.; Pollmann, K. Directed Evolution and Engineering of Gallium-Binding Phage Clones—A Preliminary Study. *Biomimetics* **2019**, 4(2), 35.
21) Paucar, N.E.; Leuven, S.V.; Jesus, K.D.; Pashikanti, S.; Mateen, S.; Pradhan, S.; Sharma, K. Synthesis and Biological Evaluation of Desacetylmatricarin Derivatives Isolated from Basin Big Sagebrush. *Separations* **2024**,11(7), 217.
22) Jiménez, J.A.; Amesimenu, R.; Thomas, M. Impact of lanthanide (Nd3+, Gd3+, and Yb3+) ionic field strength on the structure and thermal expansion of phosphate glasses. *J. Phys. Chem. B* **2024**, 128(12), 2995-3003.
23) Anibogwu, R.; Jesus, K.D.; Pradhan, S.; Leuven, S.V.; Sharma, K. Sesquiterpene lactones and flavonoid from the leaves of basin big sagebrush (Artemisia tridentata subsp. tridentata): Isolation, Characterization and Biological Activities. *Molecules* **2024**, 29(4), 802.
24) Woods, J. R.; Mo, H.; Bieberich, A. A.; Alavanja, T.; Colby, D. A. Amino-Derivatives of the Sesquiterpene Lactone Class of Natural Products as Prodrugs. *MedChemComm* **2012**, 4 (1), 27–33.
25) Wang, X.; Gao, S.; Wang, J.; Xu, S.; Li, H.; Chen, K.; Ouyang, P. The production of biobased diamines from renewable carbon sources: Current advances and perspectives. *Chin. J. Chem. Eng.* **2021**, 30, pp.4-13.
26) Chalker, J.M., Mann, M., Worthington, M.J. and Esdaile, L.J., Polymers made by inverse vulcanization for use as mercury sorbents. *Organic Materials*, **2021**, *3*(02), pp.362-373.
27) Lee, T.; Dirlam, P.T.; Njardarson, J.T.; Glass, R.S.; Pyun, J. Polymerizations with elemental sulfur: from petroleum refining to polymeric materials. *J. Am. Chem. Soc.* **2021**, *144*(1), pp.5-22.
28) Chung, W.J.; Griebel, J.J.; Kim, E.T.; Yoon, H.; Simmonds, A.G.; Ji, H.J.; Dirlam, P.T.; Glass, R.S.; Wie, J.J.; Nguyen, N.A.; Guralnick, B.W. The use of elemental sulfur as an alternative feedstock for polymeric materials. *Nat. Chem.* **2013**, *5*(6), pp.518-524.
29) Rollins, J., Call, C. B., Herera, D., **Jenkins, C.L**., 2025, Gold Binding and Removal by Sulfur-Based Cationic Polymers. *ACS Appl. Polym. Mater*. 7, 13, 8529–8537
30) Griebel, J.J.; Glass, R.S.; Char, K.; Pyun, J., Polymerizations with elemental sulfur: A novel route to high sulfur content polymers for sustainability, energy and defense. *Prog. Polym. Sci.* **2016**, *58*, pp.90-125.
31) Chalker, J.M.; Worthington, M.J.; Lundquist, N.A.; Esdaile, L.J. Synthesis and applications of polymers made by inverse vulcanization. *Sulfur Chem.* **2019**, pp.125-151.
32) Crockett, M.P.; Evans, A.M.; Worthington, M.J.; Albuquerque, I.S.; Slattery, A.D.; Gibson, C.T.; Campbell, J.A.; Lewis, D.A.; Bernardes, G.J.; Chalker, J.M. Sulfur-Limonene Polysulfide: a material synthesized entirely from industrial by-products and its use in removing toxic metals from water and soil. *Angew. Chem. Int. Ed* **2016**, *55*(5), pp.1714-1718.
33) Davis, A. E.; Sayer, K. B.; Jenkins, C. L. A Comparison of Adhesive Polysulfides Initiated by Garlic Essential Oil and Elemental Sulfur to Create Recyclable Adhesives. *Polym. Chem*. **2022**, 13 (32), 4634–4640.
34) Sayer, K. B.; Miller, V. L.; Merrill, Z.; Davis, A. E.; Jenkins, C. L. Allyl Sulfides in Garlic Oil Initiate the Formation of Renewable Adhesives. *Polym. Chem.* **2023,** 14 (26), 3091–3098.
35) Eder, M. L.; Call, C. B.; Jenkins, C. L. Utilizing Reclaimed Petroleum Waste to Synthesize Water-Soluble Polysulfides for Selective Heavy Metal Binding and Detection. *ACS Appl. Polym. Mater.* **2022**, 4 (2), 1110–1116.
36) Rollins, J.; Call, C. B.; Herrera, D.; Jenkins, C. L. Gold Binding and Removal by Sulfur-Based Cationic Polymers. *ACS Appl. Polym. Mater.* **2025**, 7 (13), 8529–8537.

37) Smith, J. A.; Mulhall, R.; Goodman, S.; Fleming, G.; Allison, H.; Raval, R.; Hasell, T. Investigating the Antibacterial Properties of Inverse Vulcanized Sulfur Polymers. *ACS Omega* **2020**, 5 (10), 5229–5234.
38) Griebel, J. J.; Glass, R. S.; Char, K.; Pyun, J. Polymerizations with Elemental Sulfur: A Novel Route to High Sulfur Content Polymers for Sustainability, Energy and Defense. *Prog. Polym. Sci.* **2016**, 58, 90–125.
39) Schmitt, C. W.; Dodd, L. J.; Walz, J. K.; Deterding, L.; Lott, P.; Grimm, A. P.; Shaver, M. P.; Hasell, T.; Théato, P. A Critical Review on the Sustainability of Inverse Vulcanised Polymers. *RSC Sustain*. **2025**, 3 (10), 4190–4227.
40) Yan, P.; Zhao, W.; McBride, F.; Cai, D.; Dale, J.; Hanna, V.; Hasell, T. Mechanochemical Synthesis of Inverse Vulcanized Polymers. *Nat. Commun*. **2022**, 13 (1), 4824.
41) Dolak, I.; Keçili, R.; Hür, D.; Ersöz, A; Say, R. Ion-imprinted polymers for selective recognition of neodymium (III) in environmental samples. *Ind. Eng. Chem. Res*. **2015**, 54(19), 5328-5335.
42) Lu, F.; Xiao, T.; Lin, J.; Ning, Z.; Long, Q.; Xiao, L.; Huang, F.; Wang, W.; Xiao, Q.; Lan, X.; Chen, H. Resources and extraction of gallium: A review. *Hydrometallurgy* **2017**, 174,105-115.
43) Radková, A.B.; Jamieson, H.E.; Campbell, K.M.; Hudson-Edwards, K.A. Antimony in mine wastes: geochemistry, mineralogy, and microbiology. *Econ. Geol.* **2023**, 118(3), 621-637
44) Jakavula, S.; Biata, N.R.; Dimpe, K.M.; Pakade, V.E.; and Nomngongo, P.N. Magnetic ion imprinted polymers (MIIPs) for selective extraction and preconcentration of Sb (III) from environmental matrices. *Polym.* **2021**,14(1), 21.
45) Zheng, B.; Wang, X.; Lin, P.; Chen, K.; Chen, J.; Lin, X.; Shen, H.; Zhang, H. Inverse Vulcanization-Induced Self-assembly of Polysulfide into Responsive Micelles and their Templated Hydrogel Adsorbent for Sr2+ Removal. *Langmuir* **2025**, 41(18), 1614-11629.
46) Teng, D.; Liu, C.; Ma, L.; Jin, P.; Fan, G.; Li, P.; Cao, Y.; Wang, W. Selective adsorption of Ga (III) from aqueous solutions using magnetic chitosan-based ion-imprinted polymers: Synthesis optimization and mechanistic insights. *Int. J. Biol. Macromol*. **2025**, 298, 139957.
47) De Jesus K.; Rodriguez R.; Baek D.L.; Fox R.V.; Pashikanti S.; Sharma K. Extraction of lanthanides and actinides present in spent nuclear fuel and in electronic waste. *J. Mol. Liq.* **2021** Aug 15; 336:116006.
48) https://www.isu.edu/news/2025-fall/university-laboratory-dedicate-idaho-falls-facility-for-critical-materials-research-to-secure-domestic-supply-of-critical-materials-for-energy-and-defense.html
49) https://www.isu.edu/research/industry/super-agreement
50) https://localnews8.com/news/2025/08/26/isu-inl-partner-to-strengthen-domestic-critical-materials-supply-chain/?fbclid=IwdGRzaAMcZq9jbGNrAxxmAWV4dG4DYWVtAjExAAEepgqOcDaqVdgpzEaJ1fDsp7kROpvzAlawvJHEEvasxHFVlYw2AefYgr5bcuk_aem_FQfiS6MLx3eOzmxsWIefpw&sfnsn=mo

APPENDIX A: FACILITIES and RESOURCES

Introduction
Idaho State University's (ISU) mission is to engage students through learning and research opportunities that improve the intellectual vigor, cultural vitality, and health of our communities. ISU actively recruits and admits a wide range of students, including a large population of first-generation students, students from economically disadvantaged backgrounds, and those with lower participation rates in biomedical research. ISU is a Carnegie classified Doctoral University – high research activity (R2) and offers over 250 academic programs, comprehensive research and scholarship support, from securing funding to navigating complex regulatory requirements. Administrative support for grant preparation and pre-and post-award grant management is provided at the department, college, and division levels. The University maintains 275,000 ft^2 of research space and its investment in research infrastructure has paid off with increased grant dollars. FY 25 research expenditures totaled $42.5 million dollars. The proposed project will provide opportunities for these students to participate in cutting-edge, multidisciplinary work.

Department of Biomedical and Pharmaceutical Sciences
Dr. Sharma's laboratory is ~300 ft^2 and is outfitted with safety hoods, a dedicated working table, rotatory-evaporator, centrifuge, shakers, incubators, CO_2 incubators, autoclaves, glassware and other items necessary to perform general microbiological, molecular, and biochemical experiments. The BD FACSMelodyTM flow cytometer, used for immunophenotyping studies, is housed in ISU's Molecular Research Core Facility. Dr. Sharma's office and laboratory are located in Lenoard Hall, which reopened in September 2025 after a complete $20 million renovation. The renovations also include updated or renovated office space for faculty and about 2000 ft^2 of collaborative and study space for students.

Analytical Laboratory – major equipment list
- Focus-XCI Peptide Synthesizer
- Shimadzu Prominence Semi-preparative HPLC system with DAD
- Agilent HPLC with DAD and FLD
- SCIEX QTRAP 5500 LC-MS/MS
- IShin BioBase Freeze Dryer
- Precision NanoSystems NanoAssemblr
- Cellink BioX and an INKREDIBLE+ 3D bioprinters
- ImageXpress Pico Digital Confocal Imaging system
- DOT Liquid Handling instrument

Hot Laboratory – major equipment list
- Mettler analytical scale
- Eppendorf centrifuge
- LKB Wallac 1277 Gammamaster Automatic Gamma Counter.
- -20^C degree freezer
- refrigerator

Dr. Jenkins has 1200 $ft^2$of laboratory space including four, 6-foot fume hoods and ample bench space that is dedicated for sole use by her research group. The Jenkins lab is equipped with an Instron Universal Testing System, gel permeation chromatography system with a refractive index detector, two analytical balances, a chemical refrigerator/freezer, and an oven. The laboratory includes attached student desk space and shared computers. The PI has dedicated office space including a computer and printer.

Analytical Core Laboratory, Department of Chemistry, College of Science and Engineering
The Department of Chemistry provides a wide range of instruments for chemical, optical, physical, and electrical characterization. Relevant instrumentation includes FTIR/NIR with microscope attachment, one pulsed and two CW-laser-based Raman spectrophotometers with microscope attachment, UV-Vis,

powder X-ray diffraction, an Agilent 5800 inductively coupled plasma optical emission spectroscopy, and atomic absorption spectrometer, as well as a Bruker 400 MHz NMR spectrometer, differential scanning calorimetry, and thermogravimetric analysis.

Chemical waste removal services are provided by the department. Staff within the department provide support for ordering supplies and coordinating travel. Additionally, there is a technical staff member who helps facilitate instrument repairs with outside vendors, and provides basic repairs for laboratory equipment.

University Facilities and Resources
Microscopy and Microanalysis Laboratory (MML)
The Microscopy and Microanalysis Laboratory is located at the Eames Complex at ISU. Operated by the Office for Research, MML is designed to facilitate materials research across many disciplines. With a full analytical lab and a newly renovated microscopy lab, MML is a powerful tool for researchers.

- Major equipment at Eames Research available for use includes:
- Agilent 8900 ICP-QQQMS with Element 193nm Laser Ablation System
- Thermo iCAP Qc ICP-MS with autosampler
- Perkin Elmer STA-MS (STA-800/Clarus SQ8 MS)
- 200-kV Jeol 2000FX Transmission Electron Microscope
- FEI DualBeam 835 with Omniprobe manipulator and EDS
- Various Optical microscopes

Information Technology Services (ITS)
The Information Security (ISEC) team is responsible for ensuring the security and integrity of ISU's computer systems, networks and electronic data. This includes managing intrusion detection systems, monitoring data flows, initiating system vulnerability audits and risk assessments, securing data transmissions (using encryption when needed), providing incident response including mitigation and forensic analysis, and maintaining identity management and access control systems. The team also conducts ongoing security research and security awareness training and works with campus governance bodies to recommend and implement appropriate security policies and procedures.

Research Data Center (RDC)
The RDC provides secure data storage for research projects. The laboratory uses a 40 Gbps core with 10 Gbps switches connecting each server to the core at 10 Gbps with minimal network bottleneck issues. Back-up power supply is designed to allow RDC servers to run continuously on DC battery backup for approximately 30-minutes allowing sufficient time for automated system shutdown in the event of a long-term power outage. The facility is cooled by two 10-ton roof mounted air-conditioning units and a third backup unit forcing cold air through the floor to the front of each rack. The RDC contains space for approximately 17 full-height server racks and accompanying UPS units. Racks one and two will have sufficient expansion space to add numerous additional servers as needed.

Printing Services
Printing services for research posters are readily available through the Idaho Center for Health Research.

Office for Research
ISU, like all universities, has a specific structure in place to ensure that all externally funded programs are accountable, in line with their contracts, and meet A-133 audit requirements. Detailed processes ensure controls are in place to administer grants and that personnel working on projects are aware of relevant policies and regulations. ISU additionally offers information technology services, legal counsel review and risk management assessments.

Office of Sponsored Programs (OSP)
Within the Office of Research, Sponsored Programs supports pre and post-award research efforts at the university by promoting the development, implementation, and coordination of sponsored research. OSP

staff members assist faculty members by identifying potential funding sources, developing and submitting applications to funding agencies. OSP personnel ensure that research is compliant with sponsor guidelines and university policies. OSP additionally negotiates the terms, conditions of awards, contracts, and amendments, and develops subawards/subcontracts for collaborative arrangements with non-ISU agencies and non-ISU consultants. The OSP assists with extensions or changes of PIs. ISU Grants and Contracts Accounting staff assist with purchasing, travel, accounts payable, project payroll, sponsor billing, and financial reporting.

Marketing and Communications
ISU's Office of Marketing and Communications (MarCom) is the primary resource for promoting the University's mission and communicating its successes. MarCom uses a strategic combination of owned, earned, and paid media to support outreach and communication goals. Regular internal communication is accomplished through *ROAR Weekly,* a student newsletter that shares information about campus events, provides important academic updates, and recognizes student accomplishments; *ISU News*, daily posts and searchable curated content organized by division or college; *Idaho State Today,* a twice-weekly employee newsletter that shares University successes, provides important campus updates, and recognizes the accomplishments of our faculty and staff; a University calendar that coordinates and promotes more than 5,000 on-campus events. The calendar can be filtered by event-type and audience categories. The online calendar platform also allows users to easily email or share event posts on social media.

Educational Facilities
Eli M. Oboler Libraries
ISU Libraries, including Idaho Health Sciences Library, serve the university community by providing collections and services in support of the university's teaching and research missions. As the largest state-supported library in eastern Idaho, the Libraries also play a role in the development of university cooperative programs and in the provision of library services to the people of Idaho. The Libraries have holdings of over 1,000,000 books, subscriptions to access of 60,592 journals, including both print and electronic versions. The Libraries have 12,463 journal titles in medicine and life science and over 20 medical and health sciences databases. Health Sciences Library is Idaho's NN/LM Resource Library that provides health library and information services to ISU faculty, students, community and healthcare professionals in Idaho

Distance Learning (DL)
Distance delivery classrooms and several conference rooms with video telecommunication systems are available for graduate courses, faculty, and department meetings. This complex system is managed by a full time IT team that is available to develop new technologies and manage all DL connections. This IT team is part of a larger IT team that supports computer systems across campus. Faculty and students can access this system from their offices, homes, and classrooms, making it a versatile and highly dependable system. An internal IT team assists with computer installation, maintenance and troubleshooting on demand and is a great strength of the division.

Instructional Technology Resource Center (ITRC)
The Instructional Technology Resource Center (ITRC) assists faculty with using instructional technology for effective, learner-centered instruction. ITRC offers guidance and support for teaching strategies, instructional design, and technology integration, whether developing a new course or enhancing an existing course.

Student Resources
ISU Undergraduate Research and Outreach Office
The ISU Undergraduate Research and Outreach Office works to increase students' participation in research, scholarship, and creative inquiry, emphasizing increasing access and opportunity for students in Science, Technology, Engineering, and Mathematics (STEM). We foster collaborative partnerships with industry stakeholders and national support groups and engage with the local and regional community in

strategic initiatives that benefit society. We mentor, advocate for, and connect students to undergraduate research opportunities on campus, off campus, and with industry partners. This office provides funding opportunities for faculty to support undergraduate student research assistants and for students to attend scientific conferences to present their research successes.

Student Research Opportunities

Student Research Opportunities, Resources, and Services

- ***Idaho INBRE***: To further student involvement in biomedical research, ISU participates in the statewide, NIH-funded Idaho IDeA Program of Biomedical Research Excellence (INBRE) whose mission includes strengthening Idaho's capacity for biomedical research and education. ISU receives an annual $100-150K institutional sub-award that supports student summer research (stipend and supplies), program leader and graduate assistant summer salaries, the ISU INBRE seminar series, travel to the annual INBRE summer conference, and awards one graduate student research assistantship, typically to a student in a doctoral program in Biological Sciences, Psychology, or Pharmaceutical and Biomedical Sciences. Other funds to support student research, faculty assisting with the summer program, and to maintain and expand core facilities are provided by the ISU Office of Research. The summer INBRE fellowship program provides professional development and financial resources for faculty, graduate and undergraduate students to pursue publishable biomedical research, thus increasing their capability to successfully compete for NIH funding. ISU's dedicated INBRE website posts opportunities for students and mentors.
- I**SU's Research and Creative Works Symposium:** Both undergraduate and graduate students are encouraged to participate in ISU's annual Research and Creative Works Symposium, an opportunity for students of all disciplines to showcase and present their scholarly and creative works. Students may present their in-progress or completed research from literature reviews, research projects, capstone projects, case studies, grant proposals, humanitarian trips, class papers, and other related scholarly or creative work.
- **Biological Sciences Research Roundup and SPARK a FIRE Annual Symposium:** This offers a low-stakes opportunity for communication and networking for graduate students, undergraduate students and faculty.
- ***American Chemical Society's SEED Program:*** This program gives high school students from low-income families and underrepresented groups the chance to obtain hands-on research experience during an 8-week summer program.
- **Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) at ISU** is the only Idaho student chapter recognized by the National SACNAS Organization. It is co-advised by Dr. Martin (Bio Sci faculty) and Ms. Sonia Martinez (Director of Undergraduate Research and Outreach) in providing guidance to the chapter officers in maintaining the SACNAS mission to foster success of Chicanos/Hispanics and Native American in attaining advanced degrees, career, and positions of leadership in STEM. As such this organization has grown into a critical support network for minoritized students majoring in STEM. It promotes cultural awareness, leadership development, research opportunities, and establishes networks among the ISU, Pocatello, and surrounding communities.
- **Chemistry Club:** Students lead community outreach efforts through programs like the Chemistry Magic Show, a community event where students conduct a variety of chemistry demonstrations followed by hands-on activities. Students also visit elementary schools to do hands-on activities to help them understand basic chemical concepts. The engagement of Chemistry Club has led to financial support from the community and the university as well as grants from ACS. These funds pay for lunch for students every Friday. These informal meetings create a very cohesive and supportive student body.
- **Microbiology Club:** Membership in the microbiology club is open to all students with an interest in microbiology. Activities typically integrate microbiology principles in everyday life such as sour dough bread baking and brewery tours. The club invites guest speakers to discuss their research interests. Many faculty members attend and are available for mentoring.

- ISU provides general student support such as large format color printing for posters, student travel and research grants, and a writing center which can assist students with writing resumes and personal statements for applications.

Career Path Internships (CPI)
The university-wide CPI program provides meaningful job experience to ISU students through internship opportunities. CPI facilitates student exposure to authentic research experiences, while providing faculty with funds for student salaries.

Student Services
Office of Equal Opportunity and Title IX
The Office of Equal Opportunity ensures compliance with federal regulations and state laws related to discrimination and harassment based on protected classes. The office manages discrimination and harassment complaints, conducts necessary investigations, prepares recommendations, and issues written reports. handle complaints of discrimination and harassment, conduct necessary investigations, prepare recommendations, and issue written reports. The office also offers bystander intervention and violence prevention programs for the university community.

Bengal Success Center
The Bengal Success Center supports academic success for all ISU students by providing enhanced resources and opportunities to meet the needs of the entire student body. Programs within the Bengal Success Center include: The Center for Teaching and Learning and Instructional Excellence, focuses on promoting excellence in both student learning and faculty teaching and several programs aimed at undergraduate success. The TRIO programs are also housed under the Bengal Success umbrella.

TRIO Access and Opportunity Programs
A set of seven federally-funded college opportunity programs that motivate and support students, TRIO provides direct support services including academic tutoring, personal counseling, mentoring, financial guidance, and other support necessary for educational access and retention. Funded by the U.S. Department of Education, these programs offer free services to qualifying ISU students. Programs that may specifically benefit S-STEM scholars who transfer to ISU include:

- Student Support Services – offers advising/scheduling assistance, counseling (academic, personal, financial, and career), orientation to campus, advocacy, mentoring, and tutoring for students who are first-generation college students, meet low-income guidelines or have a physical, psychological, or learning disability.
- TRIO McNair Scholars – assists with the academic and professional development of first-generation, low-income, or underrepresented undergraduate students who are interested in research and want to pursue graduate school. The program provides paid summer research internships, funding for participants to attend a scientific conference, GRE test preparation, tutoring, assistance with identifying and applying to graduate school, and fee waivers for graduate school applications. All participants are paired with a faculty research mentor.
- TRIO Veterans Program – supports undergraduate students who are veterans with any aspect of their educational attainment. Services include academic and tutoring support, preparation for placement testing, career exploration and counseling, finding financial support.
- Educational Opportunity Center Student Support Services – supports adults who want to enter or continue a postsecondary education. Services include college admission waivers, career exploration, finding financial support, financial literacy, transfer guidance, and help with the transition to college life.

Hispanic Awareness Leadership Organization (HALO)
(HALO) is an organization dedicated to broadening students' perspectives and promoting cultural awareness. The organization hosts inclusive cultural events such as baile night, providing opportunities for students to learn about different cultures and participate in cultural activities.

Native American Student Services Center
This office offers a gathering place for students with a computer lab and lounge. This center assists students with academic guidance and finding financial support, and serves as a connection to other campus resources. Students lead and implement NASS activities such as leadership and professional development workshops, and sponsorship of inclusive cultural events.

ISU Veteran Student Services Center
This service provides a safe, social study environment with trained on-site staff, including Hero, an emotional support dog. The center also provides professional development and employment preparation through ISU's Career Closet. ISU is recognized as a top ten Military Friendly School (2024-2025).

Disability Services
Disability Services (DS) strives to increase equal access and opportunities to all programs and services sponsored or funded by Idaho State University and is dedicated to creating an accessible environment for students, employees, and community members with disabilities. In achieving this, DS:

- Works collaboratively with University Partners to foster a welcoming, diverse, and inclusive University community.
- Collaborates with and empowers individuals who have documented disabilities by working together proactively to determine reasonable accommodation(s).
- Promotes a culture of self-advocacy, responsibility, and agency.
- Ensures compliance with the Americans with Disabilities Act Amendments Act (ADAAA) and other current legislation.
- Readily responds to grievances and advances inclusion through the removal of identified informational, physical, and/or attitudinal barriers.
- Advocates for Universal Design (UD) as a crucial framework to support the diverse needs of students, faculty, staff, and community members.
- Develops partnerships with external community members/groups to support the advancement of equity and inclusion at the local, state, and national levels.
- Provides institution-wide advisement, consultation, and training on disability-related topics, including but not limited to: legal and regulatory compliance and universal design.

Support services available to the ISU community include: access to American sign language and English interpreters, multimedia captioning services, academic coaching, website accessibility, document digital accessibility, instructional technology resource center, and universal design for learning, an approach to curriculum design that can help teachers customize curriculum to serve all learners, regardless of ability, disability, age, gender, or cultural and linguistic background. Students may also request accommodations (e.g. readers/scribes; occasional flexibility in attendance, assignments, testing; allowable disability materials in the classroom and during testing).

Center for Learning and Instructional Excellence
The Center for Learning and Instructional Excellence fosters a culture of student success and teaching excellence by promoting evidence-based and innovative instructional practices that are responsive to identified student needs, providing collaborative and structured support for faculty development, and aligning teaching methods with institutional goals. Through these efforts, the Center aims to enhance student success and create equitable opportunities for learning across the academic community and will advance ISU as a premier regional institution of higher education, distinguished by its commitment to student success, innovation, and academic excellence.

Annual Student Events

ISU Research and Scholarship Symposium. This single, expansive event encompasses all undergraduate and graduate academic work.

On Common Ground is a recent University initiative that celebrates identity and community through artistic expression. This annual event is a platform for students to communicate their unique perspectives about finding belonging in the Bengal Community through creative works.

Three Minute Thesis is an academic competition that cultivates students' presentation and science communication skills. The competition challenges them to describe their research within three minutes to a general audience.

Effective 05/20/2024 NSF BIOGRAPHICAL SKETCH OMB-3145-0279

IDENTIFYING INFORMATION:

NAME: Jenkins, Courtney

ORCID iD: https://orcid.org/0000-0002-5499-0711

POSITION TITLE: Associate Professor

PRIMARY ORGANIZATION AND LOCATION: Idaho State University, Pocatello, Idaho, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
California Institute of Technology, Pasadena, California, United States	Postdoctoral Fellow	08/2015 - 07/2016	Chemical Biology
Purdue University, West Lafayette, Indiana, United States	PHD	08/2010 - 07/2015	Chemistry
Saint Louis University, St. Louis, Missouri, United States	BS	08/2006 - 05/2010	Biochemistry

Appointments and Positions

2023 - present Associate Professor, Idaho State University, Pocatello, Idaho, United States
2026 - present Joint Appointment, Idaho National Laboratory , Idaho Falls, Idaho, United States
2019 - 2023 Assistant Professor, Idaho State University, Pocatello, ID, United States
2016 - 2019 Assistant Professor, Ball State University, Muncie, IN, United States

Products

Products Most Closely Related to the Proposed Project

1. Juliette Rollins, Cameron B. Call, Daniel Herrera, Courtney L. Jenkins. Gold Binding and Removal by Sulfur-Based Cationic Polymers. ACS Applied Polymer Materials. 2025 July. DOI: 10.1021/acsapm.5c00958
2. Eder M, Call C, Jenkins C. Utilizing Reclaimed Petroleum Waste to Synthesize Water-Soluble Polysulfides for Selective Heavy Metal Binding and Detection. ACS Applied Polymer Materials. 2022 January 15; 4(2):1110-1116. Available from: https://pubs.acs.org/doi/10.1021/acsapm.1c01536 DOI: 10.1021/acsapm.1c01536
3. Westerman C, Jenkins C. Dynamic Sulfur Bonds Initiate Polymerization of Vinyl and Allyl Ethers at Mild Temperatures. Macromolecules. 2018 September 11; 51(18):7233-7238. Available from: https://pubs.acs.org/doi/10.1021/acs.macromol.8b01555 DOI: 10.1021/acs.macromol.8b01555
4. Orme K, Fistrovich A, Jenkins C. Tailoring Polysulfide Properties through Variations of Inverse Vulcanization. Macromolecules. 2020 October 25; 53(21):9353-9361. Available from: https://pubs.acs.org/doi/10.1021/acs.macromol.0c01932 DOI: 10.1021/acs.macromol.0c01932

5. Kyler B. Sayer, Veronica L. Miller, Zackry Merrill, Anthony E. Davis, Courtney L. Jenkins. Allyl sulfides in garlic oil initiate the formation of renewable adhesives. Polymer Chemistry. 2023. DOI: 10.1039/D3PY00390F

Other Significant Products, Whether or Not Related to the Proposed Project

1. Davis A, Sayer K, Jenkins C. A comparison of adhesive polysulfides initiated by garlic essential oil and elemental sulfur to create recyclable adhesives. Polymer Chemistry. 2022; 13(32):4634-4640. Available from: https://xlink.rsc.org/?DOI=D2PY00418F DOI: 10.1039/D2PY00418F
2. Westerman CR, Walker PM, Jenkins CL. Synthesis of Terpolymers at Mild Temperatures Using Dynamic Sulfur Bonds in Poly(S-Divinylbenzene). J Vis Exp. 2019 May 20; PubMed PMID: 31157781.
3. Jenkins, C. L.; Wilker, J. J. Integrating Mussel Chemistry into a Bio-Based Polymer to Create Degradable Adhesives. Macromolecules. 2017 January.
4. Herrera C, Ysinga KJ, Jenkins CL. Polysulfides Synthesized from Renewable Garlic Components and Repurposed Sulfur Form Environmentally Friendly Adhesives. ACS Appl Mater Interfaces. 2019 Sep 25;11(38):35312-35318. PubMed PMID: 31448895.
5. Griffin ME, Jensen EH, Mason DE, Jenkins CL, Stone SE, Peters EC, Hsieh-Wilson LC. Comprehensive mapping of O-GlcNAc modification sites using a chemically cleavable tag. Mol Biosyst. 2016 May 24;12(6):1756-9. PubMed Central PMCID: PMC4905554.

Certification:

I certify that the information provided is current, accurate, and complete. This includes, but is not limited to, information related to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

In accordance with Section 10632 of the CHIPS and Science Act of 2022 (42 U.S.C. § 19232), each individual identified as a senior/key person must certify that they are not a party to a malign foreign talent recruitment program.

Research Security Training Requirement for Federal Award Personnel: In accordance with Section 10634 of the CHIPS and Science Act of 2022 (42 U.S.C. § 19234), each individual identified as a senior/key person must certify that they have completed the requisite research security training that meets the requirements specified in Item 2 of Important Notice No. 149 within 12 months prior to proposal submission.

Certified by Jenkins, Courtney in SciENcv on 2026-02-25 09:08:08

IDENTIFYING INFORMATION:

NAME: Sharma, Kavita

POSITION TITLE: Assistant Professor

PRIMARY ORGANIZATION AND LOCATION: Department of Biomedical and Pharmaceutical Sciences, Idaho State University, Pocatello, Idaho, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
Konkuk University, Seoul, Gyeonggi , South Korea	PHD	10/2010 - 02/2015	Molecular Biotechnology
University of Pune, Pune, Maharashtra, India	MS	06/2007	Analytical Chemistry
University of Pune, Pune, Maharashtra, India	BS	06/2005	Chemistry

Appointments and Positions

2024 - present Assistant Professor, Department of Biomedical and Pharmaceutical Sciences, Idaho State University, Pocatello, Idaho, United States

2022 - 2024 Research Assistant Professor, Department of Biomedical and Pharmaceutical Sciences, Idaho State University, Pocatello, Idaho, United States

2021 - 2022 Postdoctoral Researcher, Dept. of Biomedical and Pharmaceutical Sciences, Idaho State University, Pocatello, Idaho, United States

2017 - 2020 Research Assistant Professor, Department of Chemistry, Idaho State University/Idaho National Laboratory, Pocatello, Idaho, United States

2015 - 2017 Assistant Professor, Yeungnam University, Gyeongsan, Gyeongsang, South Korea

2007 - 2010 Research Chemist, CHEMBIOTEK Research International Pvt. Ltd., Pune, Maharashtra, India

Products

Products Most Closely Related to the Proposed Project

1. Anibogwu R, Jesus K, Pradhan S, Leuven SV, Sharma K. Sesquiterpene Lactones and Flavonoid from the Leaves of Basin Big Sagebrush (Artemisia tridentata subsp. tridentata): Isolation, Characterization and Biological Activities. Molecules. 2024 Feb 9;29(4) PubMed Central PMCID: PMC10892904.
2. Paucar N, Kiggins K, Blad B, De Jesus K, Pashikanti S. Ionic liquids for the removal of sulfur and nitrogen compounds in fuels: a review. Environmental Chemistry Letters. 2021 January 11; 19:1205. Available from: https://link.springer.com/article/10.1007/s10311-020-01135-1
3. De Jesus K, Rodriguez R, Baek D, Fox R, Sharma K. Extraction of lanthanides and actinides

present in spent nuclear fuel partitioning and in electronic waste. Journal of Molecular Liquids. 2022; 336(13):116006.

4. Anibogwu R, Jesus K, Pradhan S, Pashikanti S, Mateen S, Sharma K. Extraction, Isolation and Characterization of Bioactive Compounds from Artemisia and Their Biological Significance: A Review. Molecules. 2021 Nov 19;26(22) PubMed Central PMCID: PMC8618776.
5. Paucar N, Pradhan S, De Jesus K, Mateen S, Pashikanti S. Synthesis and biological evaluation of desacetylmatricarin derivatives isolated from basin big sagebrush. Separation. 2024 January 16; 26(22):6995. Available from: https://www.mdpi.com/2297-8739/11/7/217

Other Significant Products, Whether or Not Related to the Proposed Project

1. Sharma K, Mahato N, Lee YR. Systematic study on active compounds as antibacterial and antibiofilm agent in aging onions. J Food Drug Anal. 2018 Apr;26(2):518-528. PubMed Central PMCID: PMC9322202.
2. Nile SH, Nile AS, Keum YS, Sharma K. Utilization of quercetin and quercetin glycosides from onion (Allium cepa L.) solid waste as an antioxidant, urease and xanthine oxidase inhibitors. Food Chem. 2017 Nov 15;235:119-126. PubMed PMID: 28554615.
3. Mahato N, Sinha M, Sharma K, Koteswararao R, Cho MH. Modern Extraction and Purification Techniques for Obtaining High Purity Food-Grade Bioactive Compounds and Value-Added Co-Products from Citrus Wastes. Foods. 2019 Oct 23;8(11) PubMed Central PMCID: PMC6915388.
4. Saini RK, Ranjit A, Sharma K, Prasad P, Shang X, Gowda KGM, Keum YS. Bioactive Compounds of Citrus Fruits: A Review of Composition and Health Benefits of Carotenoids, Flavonoids, Limonoids, and Terpenes. Antioxidants (Basel). 2022 Jan 26;11(2) PubMed Central PMCID: PMC8868476.
5. Struhs E, Hansen S, Mirkouei A, Ramirez-Corredores MM, Sharma K, Spiers R, Kalivas JH. Ultrasonic-assisted catalytic transfer hydrogenation for upgrading pyrolysis-oil. Ultrason Sonochem. 2021 May;73:105502. PubMed Central PMCID: PMC7921008.

Certification:

I certify that the information provided is current, accurate, and complete. This includes, but is not limited to, information related to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

In accordance with Section 10632 of the CHIPS and Science Act of 2022 (42 U.S.C. § 19232), each individual identified as a senior/key person must certify that they are not a party to a malign foreign talent recruitment program.

Research Security Training Requirement for Federal Award Personnel: In accordance with Section 10634 of the CHIPS and Science Act of 2022 (42 U.S.C. § 19234), each individual identified as a senior/key person must certify that they have completed the requisite research security training that meets the requirements specified in Item 2 of Important Notice No. 149 within 12 months prior to proposal submission.

Certified by Sharma, Kavita in SciENcv on 2026-02-26 12:58:47

IDENTIFYING INFORMATION:

NAME: Mashal, Mustafa

ORCID iD: https://orcid.org/0000-0003-4654-0531

POSITION TITLE: Associate Vice President for Research, Innovation Partnerships

PRIMARY ORGANIZATION AND LOCATION: Idaho State University, Pocatello, Idaho, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of Canterbury, Christchurch, Not Applicable, N/A, New Zealand	PHD	06/2011 - 12/2015	Civil Engineering
The State University of New York at Buffalo, Buffalo, New York, United States	MS	08/2009 - 06/2011	Civil Engineering
Kabul University, Kabul, Not Applicable, N/A, Afghanistan	BS	03/2003 - 01/2009	Civil Engineering

Appointments and Positions

2025 - present Associate Vice President for Research, Innovation Partnerships, Idaho State University, Pocatello, Idaho, United States
2024 - present Professor, Idaho State University, Pocatello, Idaho, United States
2023 - present Joint Appointee, Idaho National Laboratory, Idaho Falls, Idaho, United States
2024 - 2025 Special Advisor to the Idaho State University Vice President for Research and Economic Development, Idaho State University, Pocatello, Idaho, United States
2023 - 2025 Associate Director, Center for Advanced Energy Studies, Idaho Falls, Idaho, United States
2022 - 2023 Fulbright U.S. Scholar, Qatar University, Doha, Not Applicable, N/A, Qatar
2022 - 2022 Visiting Erskine Fellow, University of Canterbury, Christchurch, Not Applicable, N/A, New Zealand
2020 - 2024 Associate Professor, Idaho State University, Pocatello, Idaho, United States
2017 - 2020 Assistant Professor, Idaho State University, Pocatello, Idaho, United States
2016 - 2017 Visiting Assistant Professor, Idaho State University, Pocatello, Idaho, United States

Products

Products Most Closely Related to the Proposed Project

1. Hogarth K, Cantrell J, Savage B, Khadka R, Mashal M. A Disaster Response Complex for training of emergency responders in the Northwest United States. J Emerg Manag. 2024 Jul-Aug;22(4):439-449. PubMed PMID: 39205601.

2. Phuyal K, Sharma U, Mahar J, Mondal K, Mashal M. Soil Stabilization Using Precipitated Calcium Carbonate (PCC) Derived from Sugar Beet Waste. Sustainability. 2024 February 26; 16(5):1909-. Available from: https://www.mdpi.com/2071-1050/16/5/1909 DOI: 10.3390/su16051909
3. Phuyal K, Sharma U, Mahar J, Mondal K, Mashal M. A Sustainable and Environmentally Friendly Concrete for Structural Applications. Sustainability. 2023 October 10; 15(20):14694-. Available from: https://www.mdpi.com/2071-1050/15/20/14694 DOI: 10.3390/su152014694
4. Mashal M, Palermo A. Emulative seismic resistant technology for Accelerated Bridge Construction. Soil Dynamics and Earthquake Engineering. 2019 September; 124:197-211. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0267726118304573 DOI: 10.1016/j.soildyn.2018.12.016
5. Mashal M., Gurung K., Acharya M.. Full-scale experimental testing of Structural Concrete Insulated Panels (SCIPs). IABSE Congress, Christchurch 2020: Resilient Technologies for Sustainable Infrastructure - Proceedings. IABSE Congress, Christchurch 2020: Resilient Technologies for Sustainable Infrastructure - Proceedings; 2020; c2020. eid: 2-s2.0-85104815351

Other Significant Products, Whether or Not Related to the Proposed Project

1. Acharya M, Duran J, Ebrahimpour A, Cantrell J, Mashal M. A Fully Precast Pier System for Accelerated Bridge Construction in Seismic Regions. Journal of Bridge Engineering. 2023 October; 28(10):-. Available from: https://ascelibrary.org/doi/10.1061/JBENF2.BEENG-6154 DOI: 10.1061/JBENF2.BEENG-6154
2. Acharya M, Cantrell J, Maharjan S, Mashal M. Metallic Dissipaters Made of Conventional and Advanced Materials for Seismic Protection of Structures. Lecture Notes in Civil Engineering [Internet] Cham: Springer Nature Switzerland; 2023. Chapter Chapter 324-33p. Available from: https://link.springer.com/10.1007/978-3-031-32511-3_3 DOI: 10.1007/978-3-031-32511-3_3
3. Marshall C, Cantrell J, Mashal M, Ebrahimpour A. A Precast Pier System for ABC in Seismic Regions. Structures Congress 2020. Structures Congress 2020; Apri 8,; St. Louis, Missouri (Conference Cancelled). Reston, VA: American Society of Civil Engineers; c2020. Available from: https://ascelibrary.org/doi/10.1061/9780784482896.018 DOI: 10.1061/9780784482896.018
4. Thapa A., Mashal M., Acharya M.. Large-Scale Flexural Testing of Concrete Beams Reinforced with Conventional Steel and Titanium Alloy Bars. IABSE Symposium Prague, 2022: Challenges for Existing and Oncoming Structures - Report. IABSE Symposium Prague, 2022: Challenges for Existing and Oncoming Structures - Report; 2022; c2022. eid: 2-s2.0-85133517690
5. Chen Y, Palermo A, Mashal M. Full-scale cyclic testing of an innovative energy dissipating device for seismic resiliency. Soil Dynamics and Earthquake Engineering. 2023 November; 174:108193-. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0267726123004384 DOI: 10.1016/j.soildyn.2023.108193

Certification:

I certify that the information provided is current, accurate, and complete. This includes, but is not

limited to, information related to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

In accordance with Section 10632 of the CHIPS and Science Act of 2022 (42 U.S.C. § 19232), each individual identified as a senior/key person must certify that they are not a party to a malign foreign talent recruitment program.

Research Security Training Requirement for Federal Award Personnel: In accordance with Section 10634 of the CHIPS and Science Act of 2022 (42 U.S.C. § 19234), each individual identified as a senior/key person must certify that they have completed the requisite research security training that meets the requirements specified in Item 2 of Important Notice No. 149 within 12 months prior to proposal submission.

Certified by Mashal, Mustafa in SciENcv on 2026-02-26 15:03:02

IDENTIFYING INFORMATION:

NAME: Cantrell, Jared

ORCID iD: https://orcid.org/0000-0002-0689-6288

POSITION TITLE: Research Engineer

PRIMARY ORGANIZATION AND LOCATION: Idaho State University, Pocatello, Idaho, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
Idaho State University, Idaho, United States	PHD	12/2026	Structural Engineering
Idaho State University, Idaho, United States	MS	05/2021	Structural Engineering
Idaho State University, Idaho, United States	BCE	05/2018	Civil Engineering

Appointments and Positions

2025 - present Associate Director of Strategic Partnerships & Innovation, Office for Research, Idaho State University, Pocatello, Idaho, United States

2017 - 2025 Research Engineer, Idaho State University, Pocatello, Idaho, United States

2022 - 2024 Structural Engineer, A&E Engineering, Inc., Pocatello, Idaho, United States

Products

Products Most Closely Related to the Proposed Project

1. Cantrell J, Duran J, Mashal M. Experimental Investigation on the Use of Mechanical Fasteners to Anchor FRP Composite Strips. 18th World Conference on Earthquake Engineering; 2024; Milan, Italy.
2. Acharya M, Bedrinana L, Cantrell J, Mashal M. Prediction of Ultimate Bond Strength Between UHPC and Titanium Alloy Bars Using a Machine Learning Approach. The Second International Conference on Maintenance and Rehabilitation of Infrastructure Facilities (MAIREINFRA2); 2023; Honolulu, HI, United States.
3. Cantrell J, Mashal M, Ebrahimpour A. Large-Scale Testing of a Precast Bent System for Accelerated Bridge Construction: Seismic Performance and Comparison with Cast-In-Place. PCI Convention; 2021; New Orleans, ID, United States.
4. Cantrell J, Mashal M, Ebrahimpour A. An Earthquake Resistant Precast Pier System for Accelerated Bridge Construction International. Association for Bridge and Structural Engineering (IABSE) Congress; 2021; Christchurch, New Zealand.
5. Cantrell J, Khadka R, Mashal M. Experimental Investigation on Mechanical Properties of Titanium Alloy Bars: Comparison with High-Strength Steel. ACI Symposium Publication. 2020; 341(8):160.

Other Significant Products, Whether or Not Related to the Proposed Project

1. Hogarth K, Cantrell J, Mashal M, Savage B, Khadka R. A Disaster Response Complex for Training Emergency Responders in the Northwest United States. Journal of Emergency

Management. 2024; 21.

2. Acharya M, Duran J, Cantrell J, Mashal M. A Seismic Resilient Concrete Pier System Incorporating Titanium Alloy Bars and Comparison with Conventional Reinforced Concrete. American Concrete Institute Special Publication. 2023; (358):206-229.
3. Acharya M, Cantrell J, Bedrinana L, Mashal M. Experimental Research on Durable and Seismic-Resilient Concrete Bridges with Use of Novel Materials. 18th World Conference on Earthquake Engineering, Milan, Italy. 2024.

Certification:

I certify that the information provided is current, accurate, and complete. This includes but is not limited to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

I also certify that, at the time of submission, I am not a party to a malign foreign talent recruitment program.

Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Cantrell, Jared in SciENcv on 2025-01-07 18:38:01

IDENTIFYING INFORMATION:

NAME: Pradhan, Samjhana

ORCID iD: https://orcid.org/0000-0002-3934-9248

POSITION TITLE: Research Scientist

PRIMARY ORGANIZATION AND LOCATION: Idaho State University, Pocatello, Idaho, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
Yeungnam University, Gyeongsan, Not Applicable, N/A, Korea South	PHD	03/2016 - 02/2020	Chemical Engineering
Tribhuvan University, Kathmandu, Not Applicable, N/A, Nepal	MS	03/2007 - 02/2009	Chemistry
Tribhuvan University, Kathmandu, Not Applicable, N/A, Nepal	BS	03/2004 - 01/2007	Chemistry

Appointments and Positions

2025 - present Research Scientist, Idaho State University, Pocatello, Idaho, United States

2023 - 2025 Postdoctoral Researcher, Idaho State University, Pocatello, Idaho, United States

Products

Products Most Closely Related to the Proposed Project

1. Pradhan S, Blanton C, Reparaz JOchoa, Bhattarai N, Sharma K. Herbs and Spices: Modulation of Gut Microbiota for Healthy Aging. Gastroenterology insights. 2024 May 22. Available from: https://www.mdpi.com/2036-7422/15/2/32
2. Anibogwu R, Jesus K, Pradhan S, Leuven SV, Sharma K. Sesquiterpene Lactones and Flavonoid from the Leaves of Basin Big Sagebrush (Artemisia tridentata subsp. tridentata): Isolation, Characterization and Biological Activities. Molecules. 2024 Feb 9;29(4) PubMed Central PMCID: PMC10892904.
3. Pradhan S, Paudel HRaj, Maharjan R, Sharma K. Essential Oils from Six Aromatic Plants of Langtang National Park: Insights on Their Chemical Constituents via GC-MS Analysis. Separations. 2023 January 13. Available from: https://doi.org/10.3390/separations10010052
4. Sharma K, Pradhan S, Duffy LK, Yeasmin S, Bhattarai N, Schulte MK. Role of Receptors in Relation to Plaques and Tangles in Alzheimer's Disease Pathology. Int J Mol Sci. 2021 Nov 30;22(23) PubMed Central PMCID: PMC8657621.
5. Anibogwu R, Jesus K, Pradhan S, Pashikanti S, Mateen S, Sharma K. Extraction, Isolation and Characterization of Bioactive Compounds from Artemisia and Their Biological Significance: A Review. Molecules. 2021 Nov 19;26(22) PubMed Central PMCID: PMC8618776.

Other Significant Products, Whether or Not Related to the Proposed Project

1. Sultana S, González-Montiel GA., Pradhan S, Khanal HDatta, Nale SD., Cheong PHa-Yeon, Lee YRok. In(III)-Catalyzed Direct Regioselective Syntheses of 1-Naphthaldehyde Derivatives via a Hidden Aldehyde 1,3-Translocation and Disjointed CO2 Extrusion. ACS Catalysis. 2021 May 18. Available from: https://pubs.acs.org/doi/full/10.1021/acscatal.1c00629
2. Mishra K, Pradhan S, Akhtar MSaeed, Yang , Kim SHong, Lee YRok. Catalytic synergy of Au@CeO2–rGO nanohybrids for the reductive transformation of antibiotics and dyes. New Journal of Chemistry. 2021 March 27. Available from: https://pubs.rsc.org/en/content/articlehtml/2021/nj/d1nj00180a
3. Pradhan S, Mishra K, Lee YR. Support-Free Pd(3) Co NCs as an Efficient Heterogeneous Nanocatalyst for New Organic Transformations of C-C Coupling Reactions. Chemistry. 2019 Aug 14;25(46):10886-10894. PubMed PMID: 31215087.
4. Pradhan S, Pokhrel MRaj. Spectrophotometric Determination of Phophate in Sugarcane Juice, Fertilizer, Detergent and Water Sample by Molybdenum Blue Method. Scientific World. 2013 July 11; 11(11):58-62. Available from: https://aulasvirtuales.udistrital.edu.co/pluginfile.php/503375/mod_resource/content/1/4653e1eb0e1d3eed862c8c81e0aac7cb5a29.pdf

Certification:

I certify that the information provided is current, accurate, and complete. This includes, but is not limited to, information related to current, pending, and other support (both foreign and domestic) as defined in 42 U.S.C. § 6605.

In accordance with Section 10632 of the CHIPS and Science Act of 2022 (42 U.S.C. § 19232), each individual identified as a senior/key person must certify that they are not a party to a malign foreign talent recruitment program.

Research Security Training Requirement for Federal Award Personnel: In accordance with Section 10634 of the CHIPS and Science Act of 2022 (42 U.S.C. § 19234), each individual identified as a senior/key person must certify that they have completed the requisite research security training that meets the requirements specified in Item 2 of Important Notice No. 149 within 12 months prior to proposal submission.

Certified by Pradhan, Samjhana in SciENcv on 2026-02-26 17:14:38

APPENDIX C: SENIOR PERSONNEL
ISU Senior Project Personnel and Expertise

Principal Investigator, Dr. Courtney Jenkins, PhD, is a polymer scientist with expertise in designing sulfur-based polymers derived from industrial waste streams as well as advanced co-polymers. Her research focuses on creating functional materials for applications in environmental remediation and resource recovery. Dr. Jenkins will serve as a co-lead on this project, working closely with Dr. Sharma to oversee overall research direction, coordinate project activities, and ensure effective integration of polymer design with downstream analytical and application-driven efforts. Dr. Jenkins will engage with industrial partners to coordinate site visits and other collaborative activities.

Principal Investigator, Kavita Sharma, PhD, is an analytical scientist with expertise in natural product purification and advanced chemical analysis. Her work focuses on the identification, separation, and characterization of complex molecular systems using state-of-the-art analytical techniques. Dr. Sharma will co-lead the overall research and project coordination alongside Dr. Jenkins, ensuring effective integration of analytical workflows with material design and application-driven objectives.

Co-Investigator, Mustafa Mashal, PhD, is a structural and materials engineering expert. He serves as Associate Vice President for Research: Innovation Partnerships at Idaho State University, with a joint appointment at Idaho National Laboratory. Dr. Mashal leads strategic industry engagement, technology transfer, and commercialization efforts, aligning research capabilities with market needs. He is also the primary liaison for the ISU–INL SUPER Agreement, advancing collaborative research and translational partnerships in critical and strategic materials and energy-environmental security.

Co-Investigator Jared Cantrell is a research engineer and Associate Director for Strategic Partnerships and Innovation in the Office for Research at Idaho State University. He leads external collaborations and innovation initiatives that strengthen industry, academia, and national laboratory partnerships. He continues to oversee large-scale experimental facilities and laboratory operations at ISU, supporting applied research and workforce development. Cantrell also holds a joint appointment with Idaho National Laboratory, advancing translational research and strategic technology partnerships.

Research Scientist Samjhana Pradhan, PhD is chemist with extensive experience in polymer synthesis. Her expertise in analytical chemistry will play a key role in this project. Her skills will support the detailed characterization of designed polymers and enable precise evaluation of metal binding, selectivity, and extraction efficiency. By applying advanced analytical techniques, she will help elucidate the mechanisms underlying polymer–metal interactions, thereby strengthening ongoing research in Dr. Jenkins’s and Dr. Sharma’s laboratories focused on targeted metal recovery and separation.

APPENDIX D: OTHER

Idaho State University

February 23rd, 2026

Dear Dr. Sharma and Dr. Jenkins,

Idaho State University's (ISU) Office for Research strongly supports your Proof-of-Concept application to the IGEM-HERC program, *SECURE: Strategic Exploration of Critical and Unconventional Resources for Energy*. I am fully committed to providing the institutional resources, infrastructure, and coordination necessary to ensure its long-term success. SECURE is ideally positioned to advance Idaho's Higher Education Research Strategic Plan and IGEM's mission. Research completed as part of the SECURE project will turn potential environmental threats into new economic opportunities. The SECURE research proposal expertly outlines how you will continue development of technologies that safely remove critical minerals such as Gallium, Antimony, and Neodymium from mining waste, introducing new areas for economic and academic growth. SECURE is very well timed, given ongoing supply-chain disruptions, coupled with an increased demand for critical minerals; this project addresses the national need for critical minerals, which has enormous potential to boost Idaho's economy.

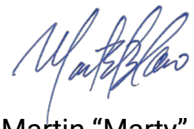
The applied research described in SECURE closely aligns with Idaho's Higher Education Research Strategic Plan, addressing three of the plan's five priority areas: Energy, Sustainability, and Resilience; Natural Resource and Agricultural Utilization and Conservation, and Novel Materials. Proposed research activities support the four goals detailed in the Higher Education Research Strategic Plan. First, SECURE will increase research collaboration among Idaho's institutions by leveraging ISU's SUPER Agreement with the Idaho National Laboratory (INL) to grow strategically important joint research ventures at both institutions. SECURE will advance progress towards Goal 2 by strengthening the research relationship between Idaho's institutions and the private sector. Your collaborations with Bayer and Perpetua Resources introduce these new industrial partners into Idaho's research ecosystem. Furthermore, by leveraging relationships with the Idaho National Lab, Bayer, Perpetua Resources, and Simplot, SECURE is well-positioned to translate research innovation to practice, supporting Goal 3. Commercializing this research, ISU will continue to carve out new opportunities for economic development throughout the state. By helping to drive economic activity, SECURE is also well-positioned to develop highly trained students who will be retained in Idaho beyond graduation (Goal 4).

The Office for Research at ISU will coordinate institutional resources to advance the high-quality research needed to establish a circular materials economy that enhances Idaho's competitiveness, attracts private investment, and ensures that economic and environmental benefits stay within the state. The Office for Research will ensure that the research team has full institutional support by facilitating access to compliance guidance, administrative coordination, and research infrastructure needed for successful project execution. Through active engagement and ongoing oversight, the Office for Research will help remove barriers, strengthen collaboration, and position SECURE for sustained impact.

Beyond immediate project needs, ISU is committed to sustaining the capabilities developed through this work. In particular, the Office of Technology Transfer will guide the commercialization of the intellectual property resulting from SECURE. ISU will also support ongoing cross-disciplinary collaboration through its Office of Research Development. This Office will help coordinate interactions among investigators, support applications for external

funding, and ensure that your research, developing scalable, novel polymers designed to selectively capture and refine high-value metals, is able to achieve long-term funding. In addition, as Idaho's only member of the Oak Ridge Association of Universities, ISU also benefits from increased access to government and industry partnerships, including those associated with technology, advanced manufacturing, and the deployment of engineering technology.

This is an innovative, exciting project. Please do not hesitate to contact me with any questions.
Sincerely,



Martin "Marty" Blair, PhD
Vice President for Research and Economic Development
Idaho State University

Perpetua Resources

February 26, 2026

Dr. Courtney Jenkins and Dr. Kavita Sharma
Idaho State University
921 South 8th Avenue
Pocatello, ID 83209

Dear Drs. Jenkins and Sharma:

I am excited to offer my support and that of Perpetua Resources to *Project SECURE: Strategic Exploration of Critical and Unconventional Resources for Energy* that will be submitted to the Idaho Global Entrepreneurial Mission Initiative sponsored by the Higher Education Research Council. Your Track 1 application has the potential to revolutionize critical mineral extraction, creating business and environmental opportunities that align with Perpetua Resources' vision to restore an abandoned gold mine site in the Stibnite District and responsibly develop the critical resources needed for a secure and sustainable future.

Perpetua Resources holds the nation's only domestic reserve of antimony (Sb), a critical mineral used in clean energy storage, flame retardant and other manufacturing, and the development of defense and/or military products including infrared sensors, night vision devices, and explosive formulations. While we have a significant quantity of Sb, selectivity and other complex metallurgical challenges have thwarted development of recovery technologies, making investment prohibitive. Precision separation, for example, is essential for maximizing antimony and gold recovery from complex sulfide ores and legacy tailings.

We are pleased to partner with you to address these challenges, first in the laboratory and then with our samples, which will ensure your research remains grounded by real-world operational constraints and the Stibnite District's unique geological characteristics. SECURE's integrated approach linking new design concepts and sustainable separation directly aligns with our commitment to modern, responsible mining and the restoration of legacy mine sites.

The proposed project has the potential to create and expand business operations, while ensuring environmental safety. Together we can revolutionize critical mineral recovery in service to Idaho's economic development, better stabilize the United States's Sb supply chain, and demonstrate Idaho's critical mineral extraction solution-focused expertise.

Perpetua Resources commits to supporting the project team in the following ways:

1. *Information Sharing with Industry Professionals*
Upon satisfaction of appropriate protocols and disclosure controls including an NDA, Perpetua Resources metallurgists and environmental engineers will share information regarding the chemical and mineralogical complexity of our stibnite (antimony sulfide) and gold-bearing ores. Our team can provide data on the mineralogical variability of the Stibnite District, helping researchers understand the

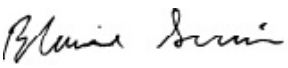
competitive binding environments between antimony and associated elements like arsenic and iron.

2. Mining Drainage Water and/or Brine Sample Access
Upon satisfaction of appropriate protocols and disclosure controls including an NDA, Perpetua may be able to support the research team with representative samples from our Idaho-based site if lab experiments are successful. These materials may include stibnite-rich ore samples, flotation concentrates, and legacy tailings. Technically, these feedstocks offer a high-complexity matrix for validating the selectivity of AI-optimized ligand networks, specifically in the separation of antimony from gold and other sulfide-bound minerals in varied pH and redox environments. .

3. Translation Support:
Our team will provide guidance on the scalability of the research outcomes. This includes advising on how the proposed ligand-based extraction systems might integrate with industrial-scale comminution and hydrometallurgical circuits, ensuring that the developed technologies consider commercial-scale flow rates and environmental regulatory standards.

4. Participation in Site Visits for future readiness
We will host site visits to our project locations for project personnel and students, providing a firsthand look at a modern mining project designed with environmental restoration at its core. We are also committed to participating in career panels and mentoring activities to help prepare the next generation of the STEM workforce for roles in extractive metallurgy, environmental science, and sustainable resource management.

Perpetua Resources looks forward to working closely with your team to secure a robust domestic supply chain for antimony and other essential minerals. We believe that Project SECURE has the potential to transform the recovery of critical minerals through science-driven, environmentally responsible innovation that will position Idaho as a leader in critical mineral recovery and waste stream mitigation.



Blaine Serrin

Geologist and Local Engagement Coordinator

Simplot

2/25/2026

To:

Dr. Courtney Jenkins and Dr. Kavita Sharma
Idaho State University
921 South 8th Avenue
Pocatello, ID 83209

Dear Dr. Jenkins and Dr. Sharma:

Simplot was founded in southern Idaho in the late 1920s. Now, nearly 100 years later, Simplot is an international agribusiness company operating in 60 countries and employing over 18,000 people worldwide. We are solution driven and pride ourselves on being a company where new ideas have a chance to grow and flourish. The fertilizer plant in Pocatello, built in response to World War II shortages, is but one example of challenge spurring success.

The proposed project, *SECURE: Strategic Exploration of Critical and Unconventional Resources for Energy,* aligns closely with our commitment to responsible resource stewardship and process innovation. In our wet-process phosphoric acid operations, the production of phospho-gypsum is an inherent byproduct, and mine tailings are generated during phosphate ore beneficiation. Exploring new pathways, such as using regionally abundant materials and sulfur-based polymers, to stabilize, repurpose, or otherwise mitigate these byproduct streams presents a meaningful opportunity. We would welcome the chance to partner with you in evaluating this innovative approach.

We will support the project as follows:
Sharing Industrial Insights: With a nondisclosure agreement in place, we will provide information on the key challenges associated with waste materials, including compositional data and processing constraints.

Site Visits and Collaboration: The research team will have the opportunity to visit our facilities and meet with our chemistry and research & development scientists to discuss practical considerations and potential applications.

Radioactive Element Mitigation: We will collaborate on strategies to address the presence of radioactive elements (e.g., uranium, thorium, radium) in waste streams, providing guidance on safe handling and potential separation methods.

We have a similar way of looking at things: imagining a better future and setting goals to reach it. I look forward to our collaboration.

Theo Warner

Theo Warner
Director of Engineering
AgriBusiness – Mining & Manufacturing Division
1130 West Highway 30
Pocatello, ID 83204

February 27, 2026

Dear Dr. Jenkins and Dr. Sharma,

On behalf of Bayer, I am pleased to express our interest in and general support for your proposed project, “SECURE: Strategic Exploration of Critical and Unconventional Resources for Energy” that you will submit to the Higher Education Research Council’s Idaho Global Entrepreneurial Mission (HERC-IGEM) Initiative.

As the sole producer of yellow phosphorus (P4) in the western hemisphere at our Soda Springs, Idaho facility, Bayer recognizes the national importance of advancing sustainable and domestic approaches for the recovery of critical minerals. We are particularly interested in research exploring the potential recovery of high-value elements such as gallium from mining overburden and industrial process by-products. Your project opens a wide-range of environmentally sound opportunities from product and service development that may result in the expansion of existing businesses or the creation of new ones. The project’s approach to selective separation and sustainable separation technologies aligns well with broader industry interests in improving resource efficiency and enabling circular mineral economy concepts.

This letter is intended to express Bayer’s general interest in and willingness to explore collaboration in connection with the proposed project. This letter does not create, and shall not be construed to create any legally binding obligations, financial commitments, partnership, joint venture, or agency relationship between Bayer and any project participant.

Subject to Bayer’s internal policies, business priorities, safety requirements, and availability of personnel and materials, Bayer may, at its discretion, participate in the following collaborative activities:

- **Industry Networking and Technical Context**

Bayer may facilitate interactions with selected personnel to provide high-level, non-confidential perspectives on phosphorus processing operations and associated by-products, subject to availability and internal approval.

- **Representative Samples**

Subject to successful laboratory outcomes, execution of mutually acceptable non-disclosure and material transfer agreements, compliance with Bayer’s safety and handling requirements, and receipt of all necessary internal approvals, Bayer may provide representative samples of electrostatic precipitator dust for research purposes. Any such provision would be governed by separate written agreements addressing permitted use, safety, confidentiality, and liability.

- **Advisory Input on Techno-Economic Analysis**

Bayer may, upon request, provide high-level, non-confidential input regarding general cost drivers, scalability considerations, and operational factors relevant to techno-economic analysis. Any such input would be

February 27, 2026

Brock Sturm

Bayer U.S. – Crop Science
P4 Production

Postal address:
P.O. Box 816
Soda Springs, ID 83276

Tel. +208-251-9528
brock.sturm@bayer.com

www.bayer.com

advisory in nature only and should not be relied upon as definitive engineering, financial, or investment guidance.

- **Site Visits and Career Engagement**

Bayer may host site visits to its Soda Springs operations for project personnel and students. Bayer may also participate in mentoring activities, as mutually agreed, to support workforce development in extractive metallurgy and industrial chemistry.

Bayer shall not be responsible for any project costs, expenses, or other financial obligations associated with the proposed collaboration unless expressly agreed to in advance in writing by Bayer.

The project team may provide periodic progress updates to Bayer for informational purposes, as mutually agreed.

Bayer assumes no responsibility or liability for the conduct of the research, project outcomes, or compliance with applicable laws, regulations, or funding requirements by Idaho State University.

All research activities remain under the sole responsibility of the institution performing the work.

Bayer may withdraw participation in this collaboration at any time, for any reason, upon providing written notice to the project participants. Such withdrawal shall not give rise to any liability or ongoing obligation on Bayer's part.

We appreciate the opportunity to learn more about the "SECURE: Strategic Exploration of Critical and Unconventional Resources for Energy" initiative and wish you success in your proposal efforts. Please feel free to contact me if additional coordination or documentation is required.

Sincerely,

Brock Sturm
Technology Lead
Bayer U.S. – Crop Science