UNM Community-Partnered Metals Research Program

Multi-generational environmental, health, & intervention research with Indigenous communities impacted by abandoned uranium mine waste

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Navajo Birth Cohort Study/Environmental influences on Child Health Outcomes
Center for Native Environmental Health Research Equity
UNM METALS Superfund Research and Training Center

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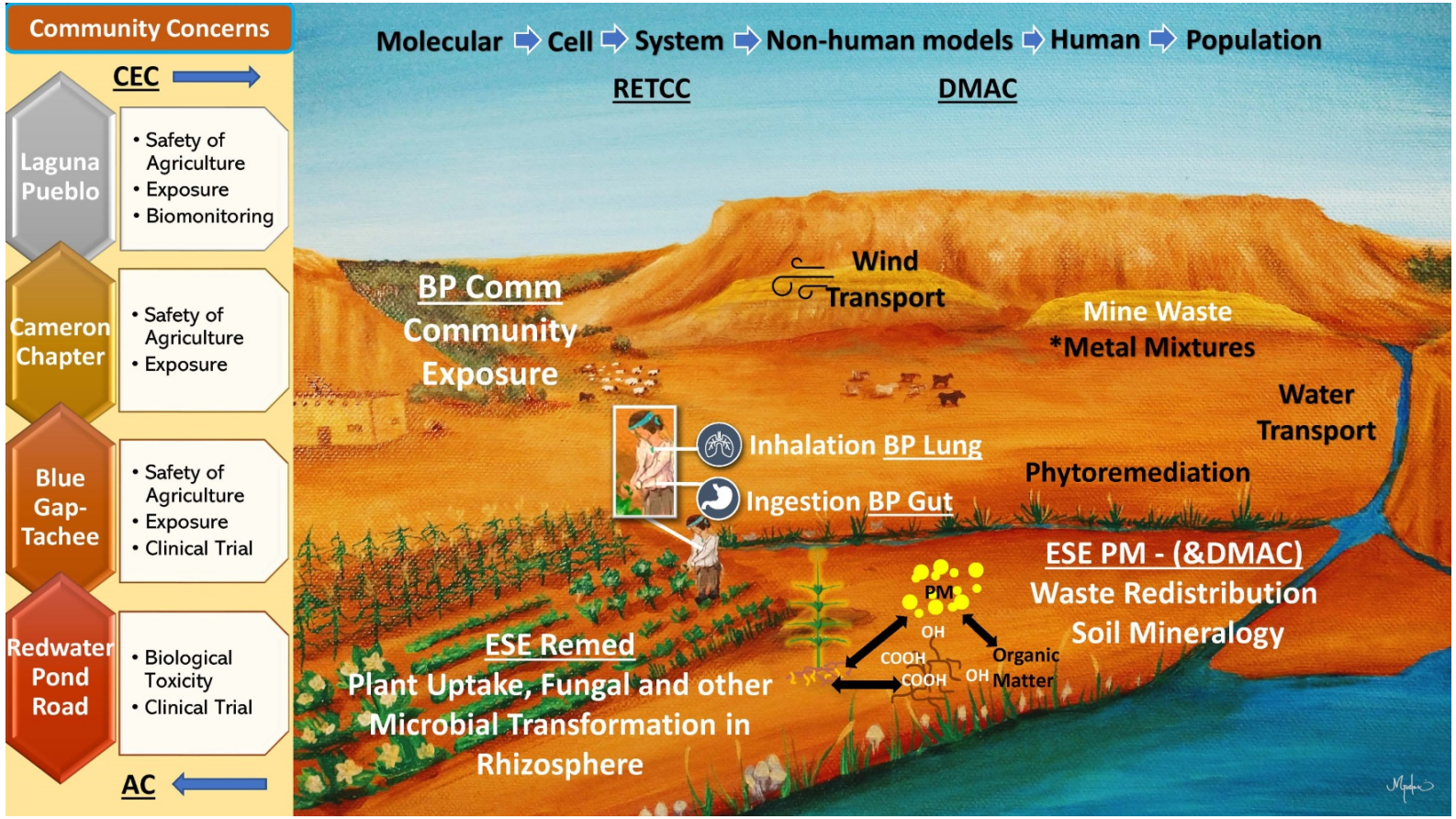
Research summarized in this slide set reflects work conducted collaboratively in partnership with communities and tribal partners from Navajo Nation and the Pueblo of Laguna in response to community concerns about the health and environmental impacts of living in proximity to abandoned uranium mines.

Work reported here began in 2005 and is ongoing through the Centers described below. Dr. Lewis could not attend this hearing due to COVID concerns, and intends this solely as a summary of available information which she is happy to provide to the committee in more detail or to discuss in depth in a future briefing to address questions raised.

DiNEH Project (RO1) **2005 - 2013**	First research to examine community impacts on health in partnership with request from 20 chapters in and adjacent to Eastern Agency of Navajo Nation (NIEHS)
NBCS & NBCS/ECHO **2010 - ongoing**	Responsive to congressional mandate to community concerns from DiNEH Project: "What is exposure doing to the health of future generations?" (CDC, NIH-OD)
Center for Native Environmental Health Research Equity **2015 - ongoing**	Comparative community partnered study with Navajo, Sioux, and Apsaloóke to examine ecosystem and health effects in tribes from distinct language groups and cultures impacted by mine waste, combined effects of microplastics and organic emissions from waste combustion. (NIEHS, USEPA, NIMHD)
UNM METALS Superfund Research and Training Center (2017-2022)	Multidisciplinary and transdisciplinary team science research partnership with Navajo and Pueblo communities to examine environmental and health risks from mine waste to communities and design interventions to reduce and reverse impacts (NIEHS)

Model underlying the body of research summarized here

- Research began with community questions on exposure and toxicity
- Results reflect a transdisciplinary team of toxicologists, engineers, mineralogists, geographers, modelers, social scientists, immunologists, statisticians, community members, data scientists, indigenous leaders, and others
- Health studies incorporate population exposure-outcome associations, validated in controlled laboratory studies
- Results are summarized in groups relating to the major outcomes to date for this ongoing partnered research
- Key publications with links are included

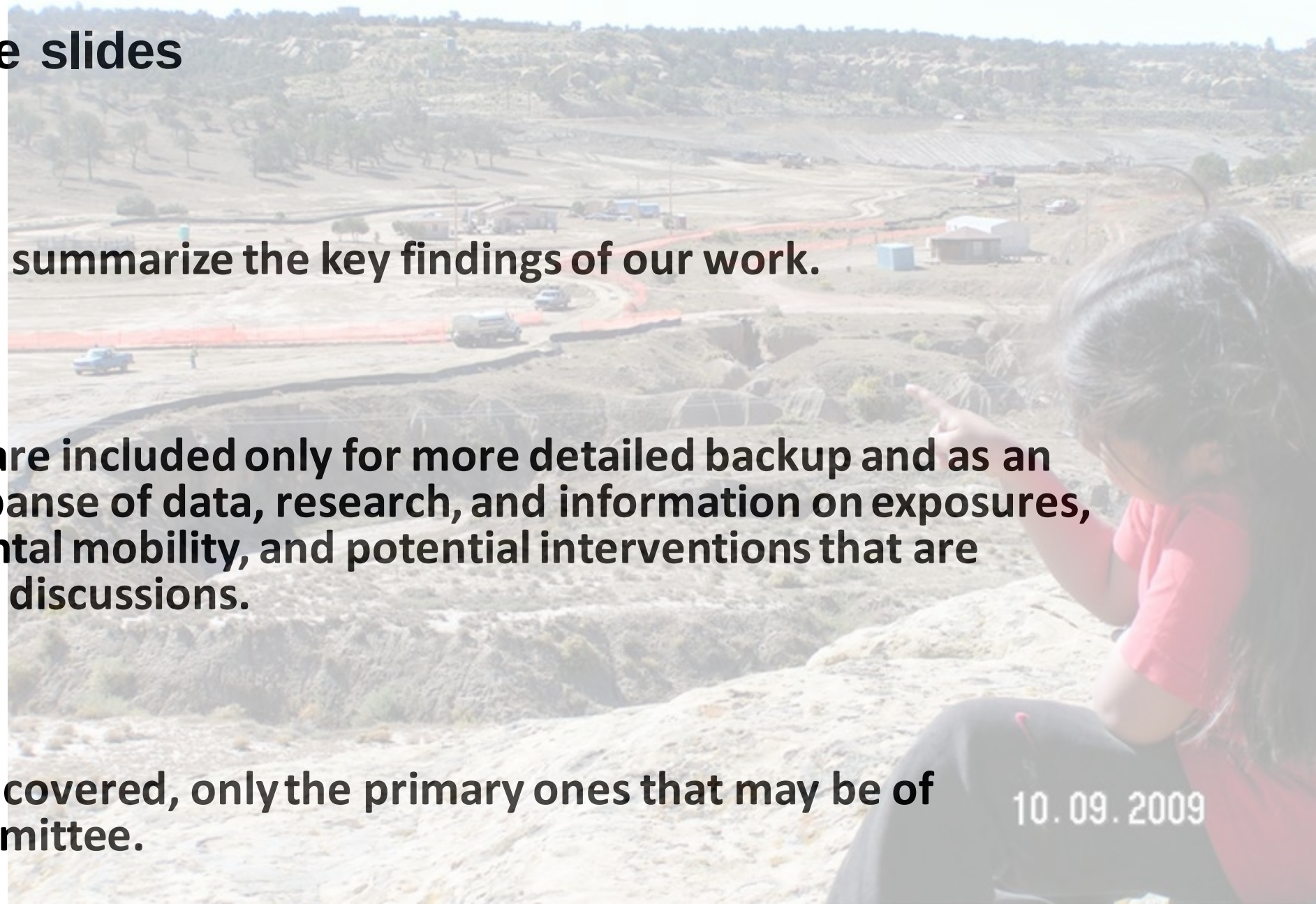


BP (Biological Projects)
ESE (Environmental Science and Engineering
DMAC (Data Management and Analysis Core)
RETCC (Research Experience and Training Core to support the next generation of researchers)
CEC (Community Engagement Core). AC (Administrative Core)
Artwork developed by staff artist-in-residence Mallery Quetawki – Zuni Pueblo

Lewis J, Hoover J, MacKenzie D. Mining and Environmental Health Disparities in Native American Communities. Curr Environ Health Rep. 2017 Jun;4(2):130-141. doi: 10.1007/s40572-017-0140-5. Review. PubMed PMID: 28447316; PubMed Central PMCID: PMC5429369. https://www.ncbi.nlm.nih.gov/pubmed/28447316/

Structure of these slides

- The next two slides summarize the key findings of our work.
- Subsequent slides are included only for more detailed backup and as an indicator of the expanse of data, research, and information on exposures, health, environmental mobility, and potential interventions that are available for future discussions.
- Not all findings are covered, only the primary ones that may be of interest to the committee.



Summary of exposure and health results

- **Exposures** – based on urine and other metals in urine and blood & surveys
  - Significantly higher than in US population with 3-5 times the number of individuals measured who exceed national population comparison values for uranium
  - Some children born with uranium greater than those adult comparison values, and children show increasing exposures over first 5 years of life
  - Evidence for exposures from multiple environmental sources including air and water

- **Health outcomes** of increased likelihood with exposure
  - Cardiovascular disease and hypertension
  - Increased likelihood of having multiple chronic diseases including cardiovascular & kidney disease, diabetes
  - 2-3 fold increase in preterm birth in mothers exposed to metal mixtures in community exposures
  - Increased immune dysfunction, chronic inflammation, and markers associated with autoimmune disease

Summary of environmental mobility investigations

- **Air**
  - Much of waste now weathered over decades to nano-sized particles, readily moved in wind and readily reaching deep lung if inhaled. Mineralogy varies by site
  - Evidence of redistribution by wind, although models suffer from lack of local meteorological data in rural regions of the state. When evaluated against federal NURE data and local soil samples, predictability increases significantly as local met station data incorporated. Major data gap currently
- **Water**
  - Mobility in water influenced significantly by pH as well as Ca and Bicarbonate concentrations with mixtures of Uranium and arsenic
  - Microbial communities, including fungi can influence mobility

- **Plant uptake**
  - Uranium movement from soil into roots and subsequent transport to shoots and intracellular localization have been visualized by our team
  - Calcium concentrations are a major factor in both uptake to roots, and root to shoot translocation which increase as calcium concentrations increase
  - Fungi in the root-soil interface greatly influence uptake as well, with interaction with calcium currently being investigated

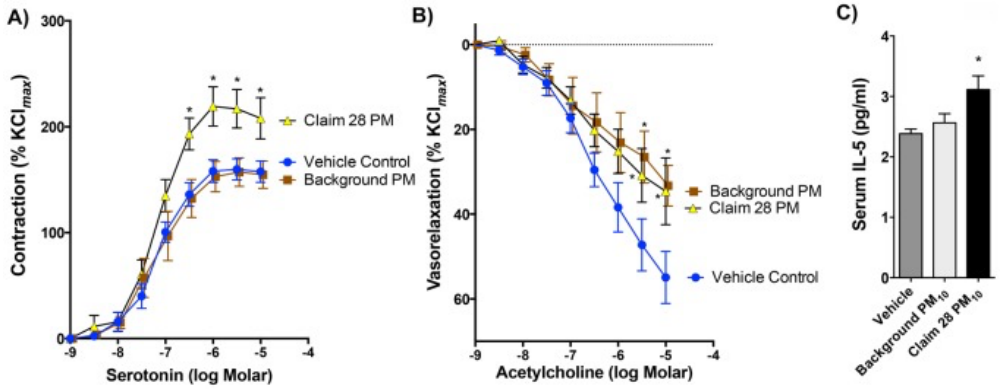
Diseases and adverse health outcomes at increased likelihood with exposures to metal mixtures from abandoned uranium mine wastes (key references noted)

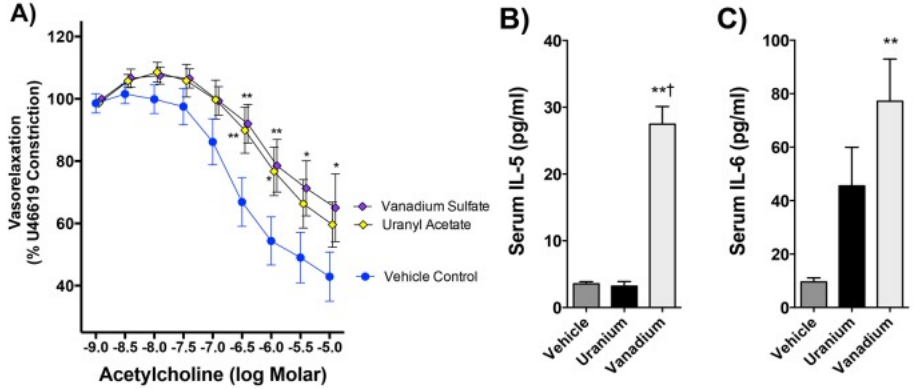
- **Cardiovascular disease**. (Example 1 following)
- **Multiple chronic diseases** when looking at cardiovascular disease, kidney disease and diabetes as a group
  - Hund L, Bedrick E, Miller C, Huerta G, Nez T, Ramone S, Shuey C, Cajero M, Lewis J. A Bayesian framework for estimating disease risk due to exposure to uranium mine and mill waste on the Navajo Nation. The Journal of the Royal Statistical Society, Series A. 2015 January. NIHMSID: NIHMS1011769.doi: 10.1111/rssa.12099
- **Immune dysfunction** including increased presence of autoantibodies
  - Erdei E, Shuey C, Pacheco B, Cajero M, Lewis J, Rubin RL. Elevated autoimmunity in residents living near abandoned uranium mine sites on the Navajo Nation. J Autoimmun. 2019 May;99:15-23. doi: 10.1016/j.jaut.2019.01.006. Epub 2019 Mar 14. PubMed PMID: 30878168; PubMed Central PMCID: PMC6489502
  - Medina S, Lauer FT, Castillo EF, Bolt AM, Ali AS, Liu KJ, Burchiel SW. Exposures to uranium and arsenic alter intraepithelial and innate immune cells in the small intestine of male and female mice. Toxicol Appl Pharmacol. 2020 Sep 15;403:115155. doi: 10.1016/j.taap.2020.115155. Epub 2020 Jul 22. PubMed PMID: 32710956; PubMed Central PMCID: PMC7490749
- Elevated **urine uranium in babies at birth** and **increasing exposure** from birth through age 5, at which time children show exposures similar to those of adults
  - Hoover JH, Erdei E, Begay D, Gonzales M, Jarrett JM, Cheng PY, Lewis J. Exposure to uranium and co-occurring metals among pregnant Navajo women. Environ Res. 2020 Nov;190:109943. doi: 10.1016/j.envres.2020.109943. Epub 2020 Jul 17. PubMed PMID: 32750552; PubMed Central PMCID: PMC7530024
- 2-3 fold increase in the likelihood of **preterm birth** with community exposures to metal mixtures (publication submitted)
- Adult **urine uranium** is greater than found in 95% of US adult population in 25-50% of those exposed in communities
- Increased **damage to DNA** and increased **oxidative stress. (clinical trial in progress to reverse)**
  - Dashner-Titus EJ, Hoover J, Li L, Lee JH, Du R, Liu KJ, Traber MG, Ho E, Lewis J, Hudson LG. Metal exposure and oxidative stress markers in pregnant Navajo Birth Cohort Study participants. Free Radic Biol Med. 2018 Aug 20;124:484-492. doi: 10.1016/j.freeradbiomed.2018.04.579. Epub 2018 Apr 30. PubMed PMID: 29723666; PubMed Central PMCID: PMC6381929

Only two detailed examples will be provided in subsequent slides. Only key highlights are presented. Full bibliography at https://www.ncbi.nlm.nih.gov/sites/myncbi/johnnye.lewis.1/bibliography/41138716/public

Example 1: Cardiovascular Disease -- Hypertension

- Increased likelihood of hypertension for those living in proximity to waste and coming in contact with waste in ongoing activities
  - Hund L, Bedrick E, Miller C, Huerta G, Nez T, Ramone S, Shuey C, Cajero M, Lewis J. A Bayesian framework for estimating disease risk due to exposure to uranium mine and mill waste on the Navajo Nation. The Journal of the Royal Statistical Society, Series A. 2015 January. NIHMSID: NIHMS1011769.doi: 10.1111/rssa.12099.
- Serum from those exposed increases the production of inflammatory markers linked to hypertension when incubated with vessel tissue
  - Harmon ME, Lewis J, Miller C, Hoover J, Ali AS, Shuey C, Cajero M, Lucas S, Zychowski K, Pacheco B, Erdei E, Ramone S, Nez T, Gonzales M, Campen MJ. Residential proximity to abandoned uranium mines and serum inflammatory potential in chronically exposed Navajo communities. J Expo Sci Environ Epidemiol. 2017 Jul;27(4):365-371. doi: 10.1038/jes.2016.79. Epub 2017 Jan 25. PubMed PMID: 28120833; PubMed Central PMCID: PMC5781233.
- Exposures to mine dust produce increase contraction and decreased relaxation of vessels in rodent model systems, and the same responses result from controlled exposures to either uranium or vanadium
  - Zychowski KE, Kodali V, Harmon M, Tyler CR, Sanchez B, Ordonez Suarez Y, Herbert G, Wheeler A, Avasarala S, Cerrato JM, Kunda NK, Muttil P, Shuey C, Brearley A, Ali AM, Lin Y, Shoeb M, Erdely A, Campen MJ. Respirable Uranyl-Vanadate-Containing Particulate Matter Derived From a Legacy Uranium Mine Site Exhibits Potentiated Cardiopulmonary Toxicity. Toxicol Sci. 2018 Jul 1;164(1):101-114. doi: 10.1093/toxsci/kfy064. PubMed PMID: 29660078; PubMed Central PMCID: PMC6016706.





PM (particulate matter); Claim 28 PM (Particulate matter from an abandoned uranium mine). Seratonin causes blood vessels to contract, exposure causes significantly MORE contraction than physiologically expected; Acetylcholine causes vessels to relax, but exposures cause a decreased relaxation to this stimulus. Both excessive responses are indicative of a enhanced contraction of the vessels, or hypertension as seem in exposed populations

Example 2: Understanding mechanisms of community health effects informs potential intervention (ongoing)

- Uranium and other metals linked to increased DNA damage through increased oxidative stress and inhibition of the processes that repair the damage
  - Dashner-Titus EJ, Hoover J, Li L, Lee JH, Du R, Liu KJ, Traber MG, Ho E, Lewis J, Hudson LG. Metal exposure and oxidative stress markers in pregnant Navajo Birth Cohort Study participants. Free Radic Biol Med. 2018 Aug 20;124:484-492. doi: 10.1016/j.freeradbiomed.2018.04.579. Epub 2018 Apr 30. PubMed PMID: 29723666; PubMed Central PMCID: PMC6381929
  - Cooper KL, Dashner EJ, Tsosie R, Cho YM, Lewis J, Hudson LG. Inhibition of poly(ADP-ribose)polymerase-1 and DNA repair by uranium. Toxicol Appl Pharmacol. 2016 Jan 15;291:13-20. doi: 10.1016/j.taap.2015.11.017. Epub 2015 Nov 25. PubMed PMID: 26627003; PubMed Central PMCID: PMC4718819

- Laboratory studies show zinc can reverse the inhibition of repair and restore function

- Communities tired of hearing what is wrong, want beneficial action to help fix the problem

- Worked together to design an intervention (in progress) to examine the possibility of zinc restoring function of damaged immune cells

U Damages Immune Cell DNA

+ ZN

Zinc Repairs Damage to DNA

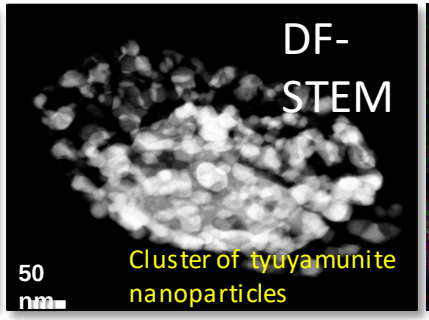
=

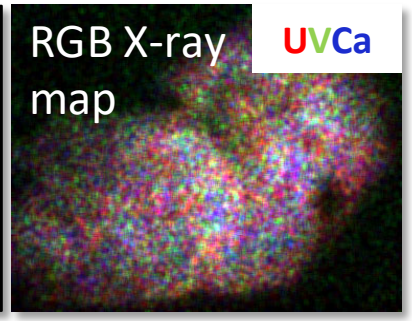
Healthy Immune Function Restored

Key Environmental Mobility Concerns

Potential for Redistribution of Waste via Wind/Water

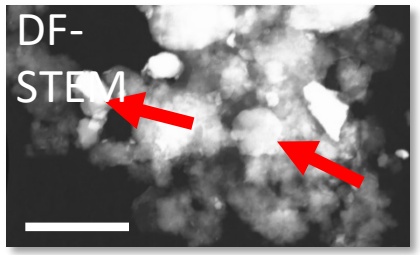
Weathering over decades has resulted in nano-size particles with varying mineral mixtures. Particles are readily lofted in wind and respirable into deep lung.

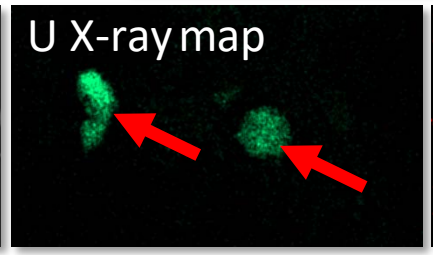


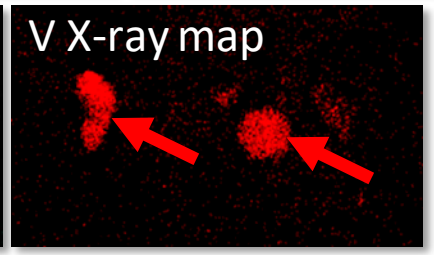


Erosion products of ore-bearing strata at the Jackpile mine also contain identical clusters of Ca-bearing uranyl vanadate, tyuyamunite ($Ca(UO_2)_2(VO_4)_2{\cdot}2H_2O$).

The colors in the electron micrographs in these photos show the presence of ultrafine particles of uranium (U) and vanadium (V) in accumulated windblown dusts

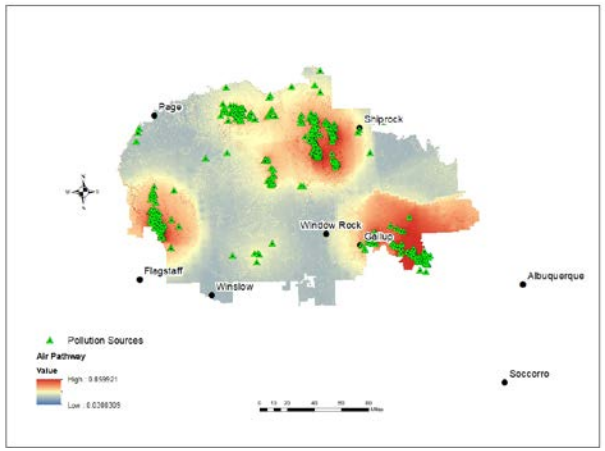






Windblown dust accumulation from attic of Paguate Church, Laguna Pueblo contains submicron carnotite particles embedded in porous mineral aggregates.

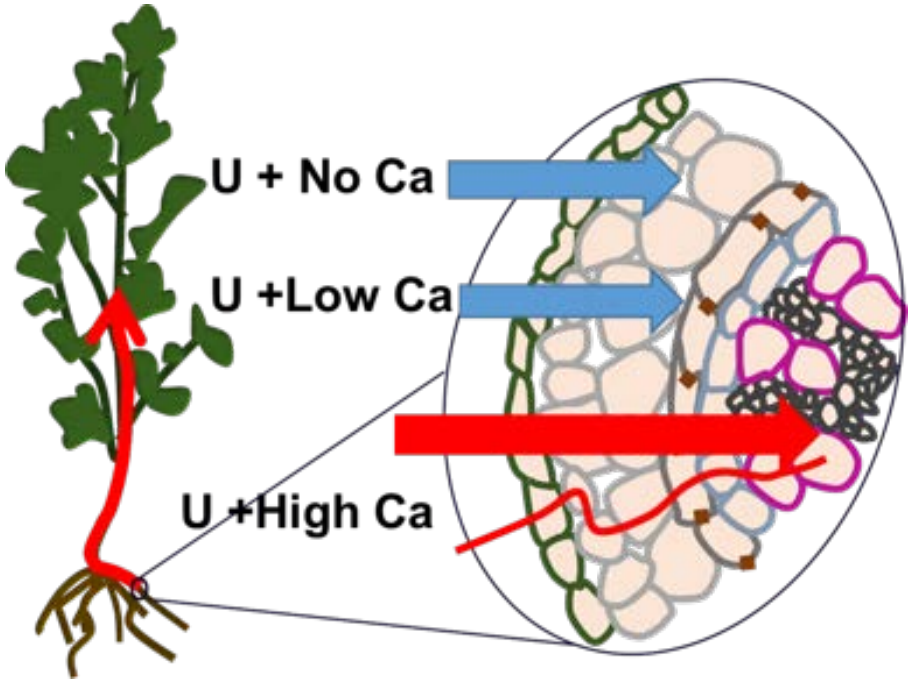
Avasarala S, Lichtner PC, Ali AS, González-Pinzón R, Blake JM, Cerrato JM. Reactive Transport of U and V from Abandoned Uranium Mine Wastes. Environ Sci Technol. 2017 Nov 7;51(21):12385-12393. doi: 10.1021/acs.est.7b03823. Epub 2017 Oct 24. PubMed PMID: 29017012; PubMed Central PMCID: PMC5751750.



Modeling incorporating proximity to abandoned mines, landforms, drainages, wind, and other variables shows areas of highest airborne exposure impacts in orange. Model validation against NURE data is good, but improves greatly when local meteorological data are collected to fill gaps in the sparse availability for current meteorological data

Lin Y, Hoover J, Beene D, Erdei E, Liu Z. Environmental risk mapping of potential abandoned uranium mine contamination on the Navajo Nation, USA, using a GIS-based multi-criteria decision analysis approach. Environ Sci Pollut Res Int. 2020 Aug;27(24):30542-30557. doi: 10.1007/s11356-020-09257-3. Epub 2020 May 28. PubMed PMID: 32468361; PubMed Central PMCID: PMC7387200

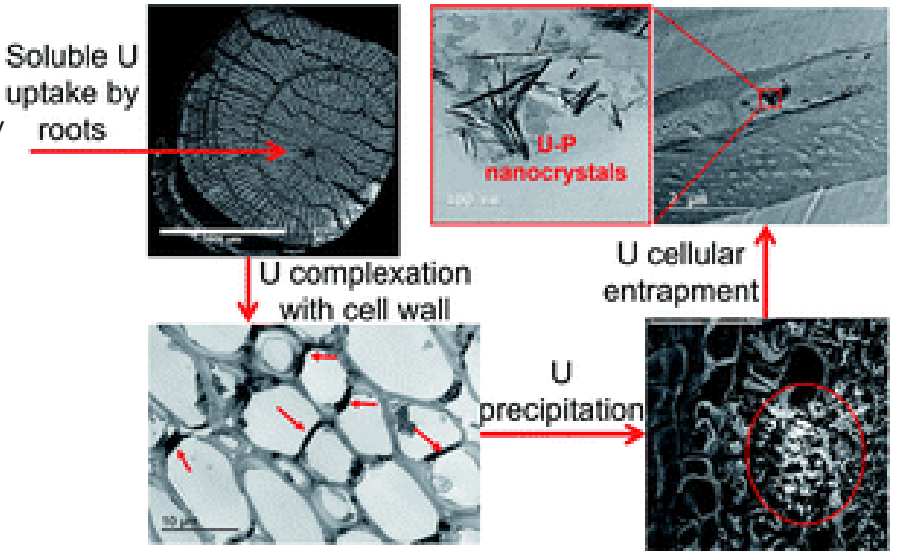
Key Environmental Mobility Concerns



Plant Uptake of uranium from soils and water is significantly influenced by calcium concentrations as well as by fungal communities in soils. In low calcium environments, the metals are primarily associated with roots, but as calcium increases, the metals including uranium and arsenic move from the roots and are transported into the shoots of plants, created an increased exposure risk if plants are ingested by humans, livestock, wildlife. Ongoing work is investigating interactions of bacteria and fungi in the soil in this process, possibly improving strategies for remedial interventions to reduce mobility and therefore exposures.

El Hayek E, Torres C, Rodriguez-Freire L, Blake JM, De Vore CL, Brearley AJ, Spilde MN, Cabaniss S, Ali AS, Cerrato JM. Effect of Calcium on the Bioavailability of Dissolved Uranium(VI) in Plant Roots under Circumneutral pH. Environ Sci Technol. 2018 Nov 20;52(22):13089-13098. doi: 10.1021/acs.est.8b02724. Epub 2018 Nov 9. PubMed PMID: 30412391; PubMed Central PMCID: PMC6341987.

Rodriguez-Freire L, DeVore CL, El Hayek E, Berti D, Ali AS, Lezama Pacheco JS, Blake JM, Spilde MN, Brearley AJ, Artyushkova K, Cerrato JM. Emerging investigator series: entrapment of uranium-phosphorus nanocrystals inside root cells of *Tamarix* plants from a mine waste site. Environ Sci Process Impacts. 2021 Feb 4;23(1):73-85. doi: 10.1039/d0em00306a. PubMed PMID: 33325952; NIHMSID:NIHMS1669765.



When uranium particles are attached to carbon-rich particles, bioavailability and toxicity are enhanced.

El Hayek E, Medina S, Guo J, Noureddine A, Zychowski KE, Hunter R, Velasco CA, Wiesse M, Maestas-Olguin A, Brinker CJ, Brearley A, Spilde M, Howard T, Lauer FT, Herbert G, Ali AM, Burchiel S, Campen MJ, Cerrato JM. Uptake and Toxicity of Respirable Carbon-Rich Uranium-Bearing Particles: Insights into the Role of Particulates in Uranium Toxicity. Environ Sci Technol. 2021 Jul 20;55(14):9949-9957. doi: 10.1021/acs.est.1c01205. Epub 2021 Jul 8. PubMed PMID: 34235927; PubMed Central PMCID: PMC8413144.

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