

# UNM METALS Superfund Research Center

*Metal Exposure and Toxicity Assessment on tribal Lands in the Southwest*



## Overview of Public Health Concerns About Abandoned Uranium Mines: From Miners to Community Members Living Near Waste Sites

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**Southwest Research and Information Center  
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**American Public Health Association Annual Meeting  
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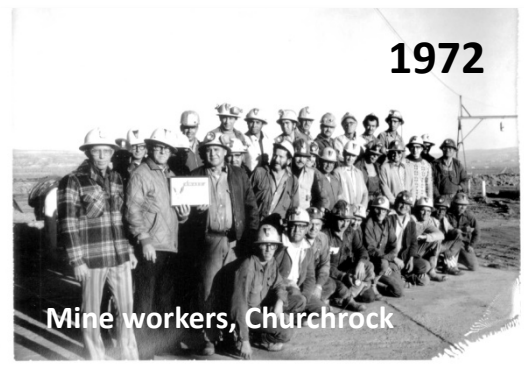
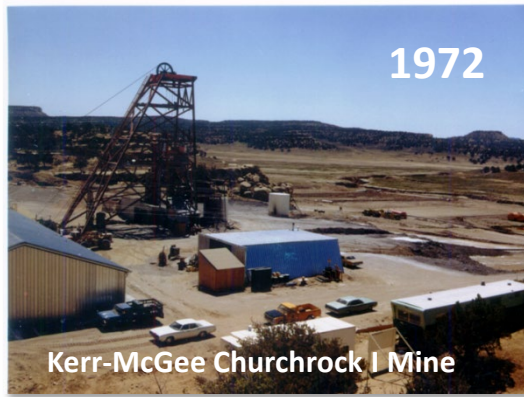
**Communities:** We recognize and honor the communities and community organizations that are partners in the UNM METALS Superfund Research Center:

- Blue Gap-Tachee Chapter
- Cameron Farm Enterprise
- Indigenous Education Institute
- Pueblo of Laguna
- Red Water Pond Road Community Association

***Land Acknowledgement Statement:** The University of New Mexico sits on the traditional homelands of the Pueblo of Sandia. The original peoples of New Mexico have deep connections to the land and have made significant contributions to the broader community statewide. We honor the land itself and those who remain stewards of this land and acknowledge our committed relationship to Indigenous peoples.*



# Presentation Overview



- Indigenous perspectives on EH research
- Epidemiology of uranium workers on the Colorado Plateau
  - RECA reform initiatives 2023-2024
- Findings of UNM's Environmental Health Studies since 2001
  - DiNEH Project
  - Navajo Birth Cohort Study
- Public health perspectives on remediating abandoned uranium mine waste sites

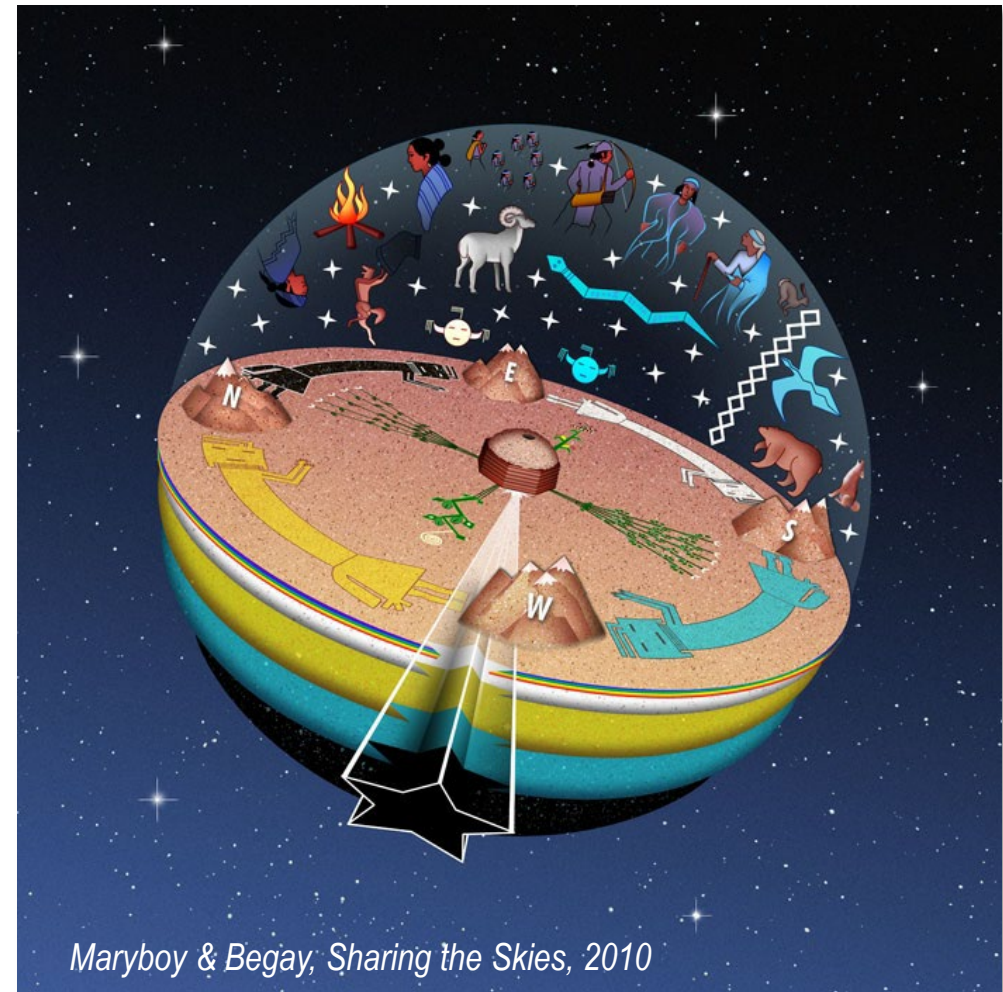


# Understanding Indigenous perspectives for environmental health researchers



## Juxtaposition of Indigenous and Western Perspectives (adapted from Maryboy and Begay, 2018)

| Western Science                                                                                                                     | Indigenous Science                                                                                                                                                                                                         |
|-------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>▪ Separation of man and nature</li></ul>                                                      | <ul style="list-style-type: none"><li>▪ Interrelationship of humans and nature; balance with nature important to stay healthy</li><li>▪ Human health is connected to the health of the land, water, air and food</li></ul> |
| <ul style="list-style-type: none"><li>▪ Objectivity is valued in research; spirituality not part of wellness or treatment</li></ul> | <ul style="list-style-type: none"><li>▪ Subjectivity and objectivity both important</li></ul>                                                                                                                              |
| <ul style="list-style-type: none"><li>▪ Separation of inanimate and animate</li></ul>                                               | <ul style="list-style-type: none"><li>▪ Everything in the universe is animate; respect for nature and reciprocity</li></ul>                                                                                                |
| <ul style="list-style-type: none"><li>▪ Separation of body and mind</li></ul>                                                       | <ul style="list-style-type: none"><li>▪ Unity of body and mind – Native medicine is holistic and may also include spirit, emotions, social relationship, and lifestyle</li></ul>                                           |



Maryboy & Begay, *Sharing the Skies*, 2010



# Big Picture: Indigenous people disproportionately impacted by mining in the West

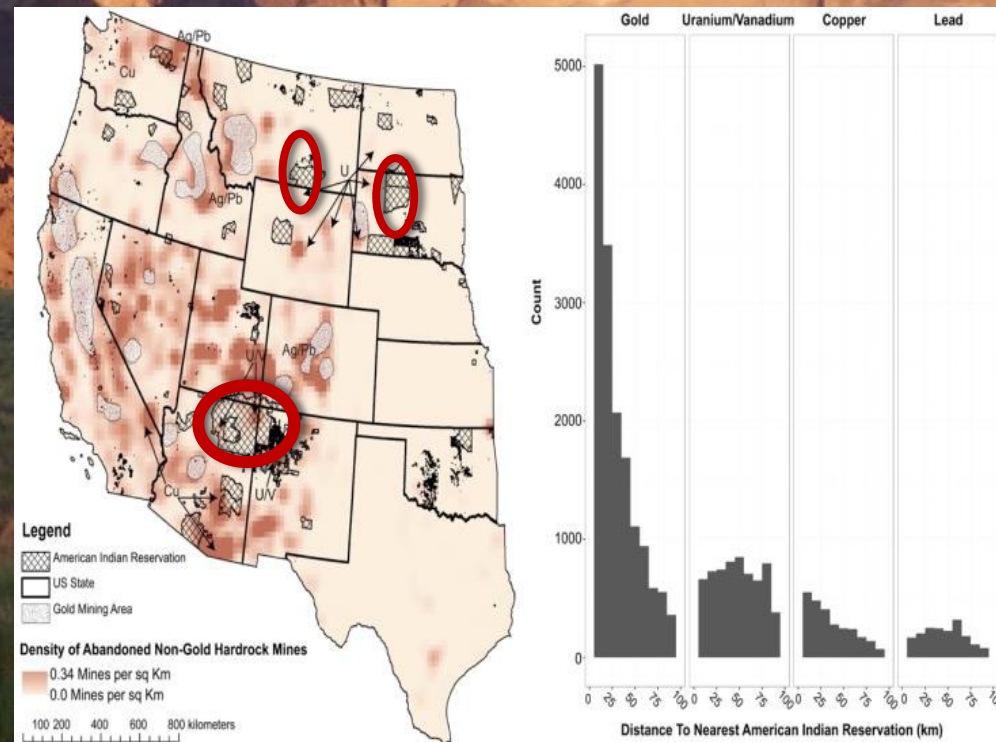


## Mining Legacy in the Western U.S.

- 161,000 abandoned hard rock mines
- Uranium, vanadium mines second only to gold and silver
- >10,400 abandoned uranium mines (AUMs) in region
- >600,000 Native Americans live within 10 km of abandoned mines

## Potential for higher sensitivity to toxicity among Native Americans

- Tied to land, reliance on local resources, “living waters”
- Understudied genetic, epigenetic, metabolic differences
- Tied to land – moving not always an option to reduce exposures



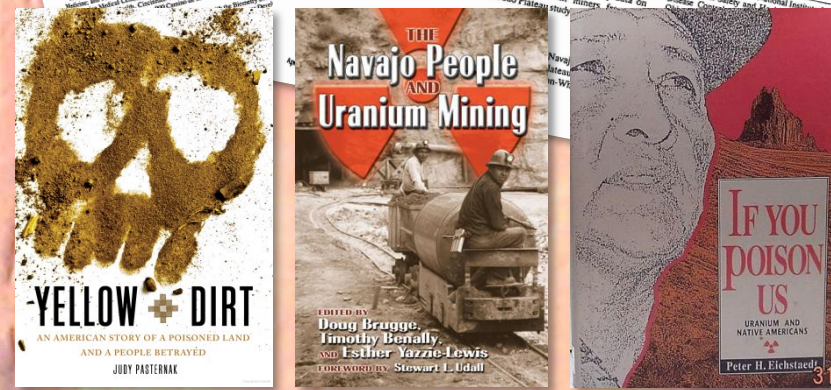
Lewis et al., Current Environmental Reports, 2017



# Uranium mining: sentinel exposure for lung disease, especially among Navajo uranium miners



- Lung disease observed in European pitchblende miners in 1500s (Lorenz, 1944); at least 12 major epi studies of U miners
- High in-mine radon levels comparable to European mines; 1,100 miners and millers screened by 1951 (Holaday et al., 1952)
- Radiation (radon and radon progeny) identified as causing lung cancer in Navajo uranium miners (Wagoner et al., 1965)
- 16 of 17 Navajo men who presented with lung cancer at the Shiprock IHS hospital were uranium miners (Gottlieb et al., 1982)
- Navajo miners face 2-3 fold excess mortality from lung cancer, pneumoconiosis and other respiratory diseases (Roscoe et al., 1995)
- RECA formulae for diminished lung function systematically underestimated effects among Native Americans (Maple et al., 1997)
- Lung cancer risk in Navajo men who were U miners:
  - 20x-30x GREATER than for Navajo men who never mined uranium;
  - 67% of new lung cancer cases among Navajo men between 1969 and 1993 attributed to one exposure, underground uranium mining (Gilliland et al., 2000)
- “Epidemic” of lung cancer among Navajo miners was “inevitable” because US ignored the European evidence (Archer et al., 2004)



Must-reading on the Navajo Uranium Legacy

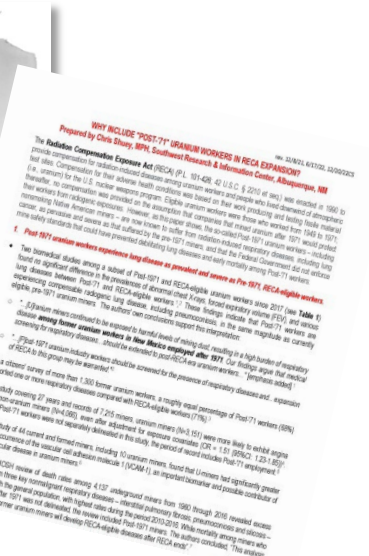
UNM METALS Superfund Center



# Occupational Exposures: Post-'71 Miners Health Studies Since 2000



South Prairie Construction Crew "sinking shaft."



Top L: Construction crew at Kerr-McGee Churchrock Mine. Top R: Post-71 research paper. Right: Edith Hood, former uranium worker, next of the (Kerr-McGee) Quivira waste dump



## Uranium miner health status since the RECA amendments of 2000:

- 11 studies published in peer-reviewed journals, 2 by community-based groups working with Post-71 workers
  - Post-71 uranium workers experience lung disease as prevalent and severe as RECA-eligible workers
  - Native American uranium workers have increased disease risk compared with non-Indian uranium workers
  - Federal Government failed to enforce miner-exposure limits and other requirements of the Mine Safety and Health Act during the 1970s and 1980s
  - Uranium miners exhibit biomarkers of immune impairment greater than non-U miners (Erdei et al., 2023)
- Findings shared with the House Judiciary Committee, Navajo Nation RECA lobbying team, Laguna Governor's office

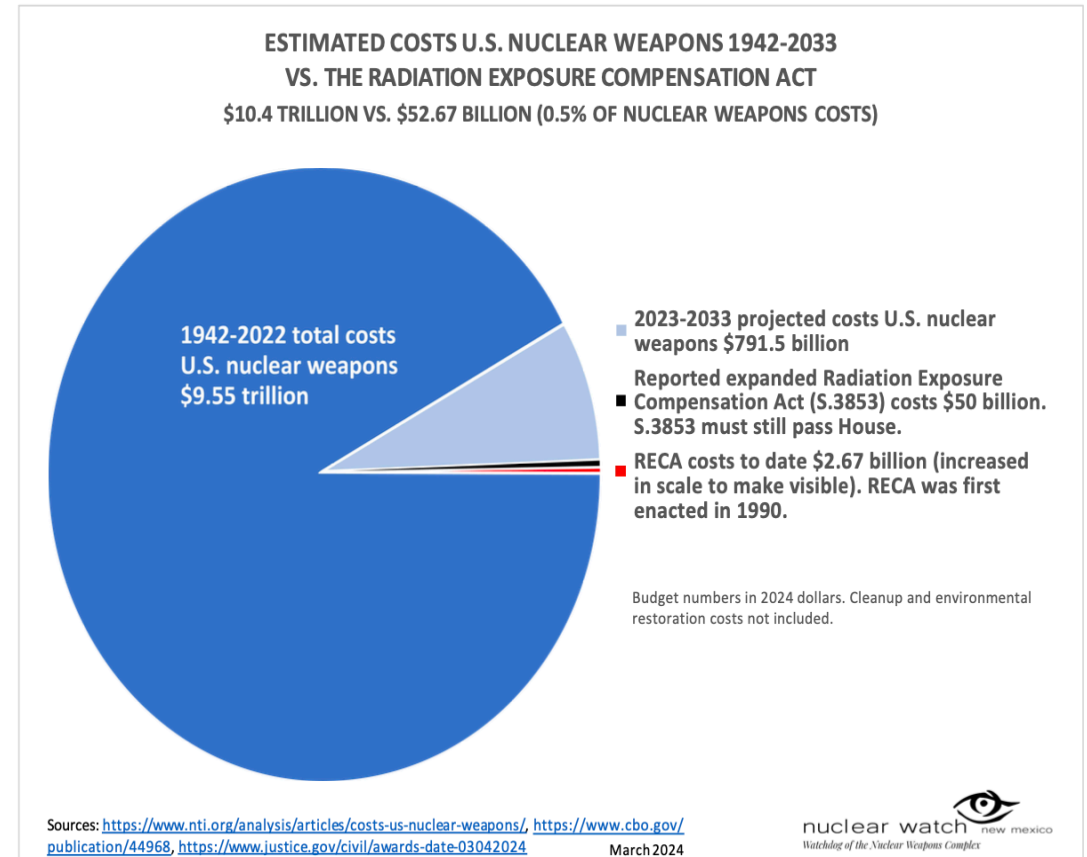
*"...[U]ranium miners continued to be exposed to harmful levels of mining dust, resulting in a high burden of respiratory disease among former uranium workers in New Mexico employed after 1971. Our findings argue that medical screening for respiratory diseases...should be extended to post-RECA era uranium workers..."*  
(Ass'ad et al., 2019)

# RECA reauthorization & expansion bill stalled in U.S. House of Representatives



- Senate passed S.3853 overwhelmingly in April
- RECA expired June 7, 2024 without House action
- **Adds several states to “downwinders” claims, including NM**
- **Makes Post-71 uranium workers eligible**
- Costs of expanding, reauthorizing RECA a small fraction (0.005%) of the money the U.S. has spent on nuclear weapons since 1942
- Speaker Mike Johnson’s office: [202-225-2777](tel:202-225-2777)

Indigenous activists rally for RECA approval in Washington, DC on 9/24/24





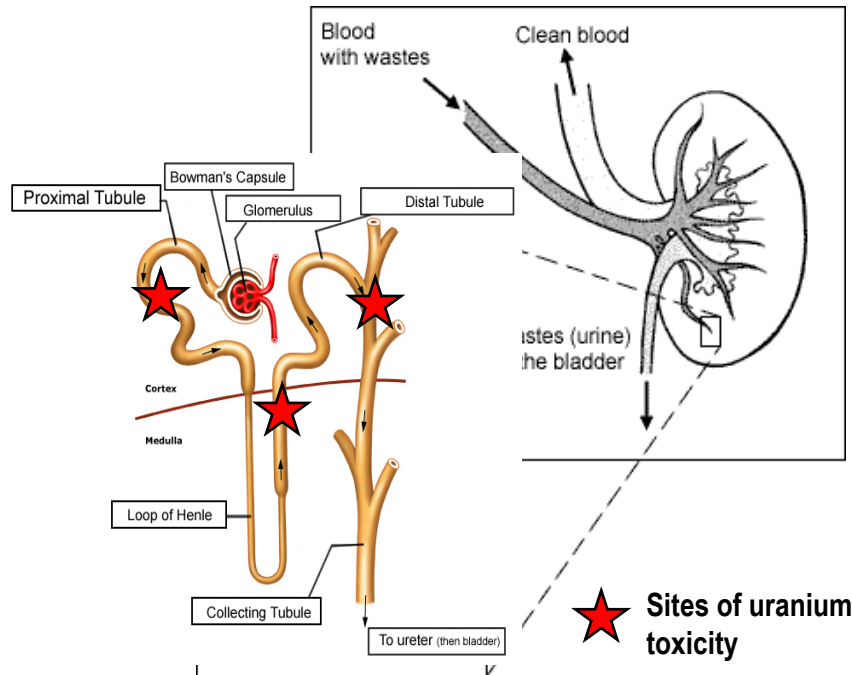
# Chemical and radiological properties of uranium



## Chemical Properties

- Heaviest naturally occurring trace element on Earth
- Found in both sedimentary and igneous rocks throughout the world at average concentration of 2.5-2.7 parts per million
- Well-established **kidney toxicant**: large molecular size of U ion contributes to cell death, inhibiting proximal and distal tubules to reabsorb low-molecular weight proteins, contributing to chronic kidney disease

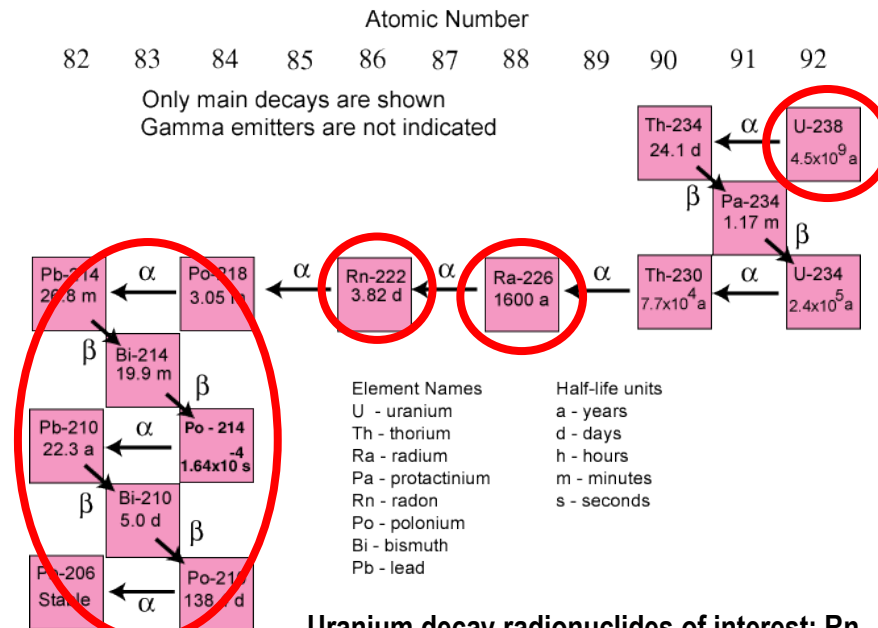
Kidney (cross-section)



## Radiological Properties

- **Uranium-238** -- “Parent” of lighter elements that result from the natural radioactive decay of U, as shown in chart below
- Major uranium decay products in mine and mill wastes: thorium-230, **radium-226**, **radon-222**, polonium-210
- Emits ionizing radiation: alpha, beta, gamma
- **Ra-226** – Known to cause cancers of the bone and blood
- **Radon and Radon Progeny** – inert gas that builds up in uranium mines and indoor environments; said by USEPA to be the second leading cause of lung cancer in the U.S.

The Uranium-238 Decay Chain



Uranium decay radionuclides of interest; Rn progeny shown in large red oval





# Uranium mine wastes: Mixtures of toxic metals and radioactive elements exceeding background

Case Study: Claim 28 AUM in Blue Gap-Tachee Chapter near 17 homes. Uranium and vanadium concentrations (chart) indicate ore-grade levels in waste.

Prius-size boulder reading 2-15 mrem/hr on two different radiation meters

Mine wastes (30->5,000 uR/hr on Ludlum-19)

| XRF Results* for 2014 samples | Elemental Content, ug g <sup>-1</sup> |       |        |        |       |       |        |        |
|-------------------------------|---------------------------------------|-------|--------|--------|-------|-------|--------|--------|
|                               | Si                                    | S     | Al     | Fe     | Mg    | U     | V      | Ca     |
| Undisturbed Soil              | 241,950                               | 1,339 | 52,129 | 26,739 | 3,068 | BDL*  | BDL*   | 16,441 |
| Mine waste1                   | 235,563                               | 223   | 69,533 | 15,259 | 181   | 2,248 | 15,814 | 855    |
| Mine waste2                   | 243,703                               | 1,834 | 59,730 | 3,511  | 405   | 6,614 | 4,328  | 3,293  |

Analyses at UNM Earth & Planetary Sciences lab: crustal average concentrations are 2.7 ppm for U, 1,235 ppm for V



# Navajo Nation Abandoned Uranium Mines Superfund Cleanup Sites

**NBCS Study  
Area, Navajo  
Nation wide**

**Exposures:**  
According to USEPA,  
people live within a  
quarter mile of 14% of  
the 524 AUMs on the  
Navajo Nation

**Monument Valley Area**

- Skyline Mine

**Cove / Mesa Area**

- 2 Transfer Stations
- Mesa Mines
- Cove Wash

**Cameron Area**

- 20 Cameron Area Mines
- Tuba City Open Dump



**Tachee AUMs**  
Added to NNEPA Priority  
AUM list in 2015

**Eastern Agency Area**

- NE Church Rock
- Quivira
- Ruby Mines
- Mariano Lake
- Section 32/33

**DiNEH  
Project  
Study  
Area**

**Ambrosia Lake  
Uranium District**

**Puerco River Valley/  
Nahata' Dził  
Commission**  
(mining discharges)

**★ Thinking Zinc  
enrollment sites**

**Legend**

- AUM Sites
- Cleanup Areas
- AUM Region
- Chapter Boundary

0 20 Miles



Map courtesy USEPA Region-9, modified by SRIC





# Navajo Uranium Legacy: By the Numbers

**TEN-YEAR PLAN**  
Federal Actions to Address Impacts of Uranium Contamination on the Navajo Nation

**DRAFT** **2020-2029**

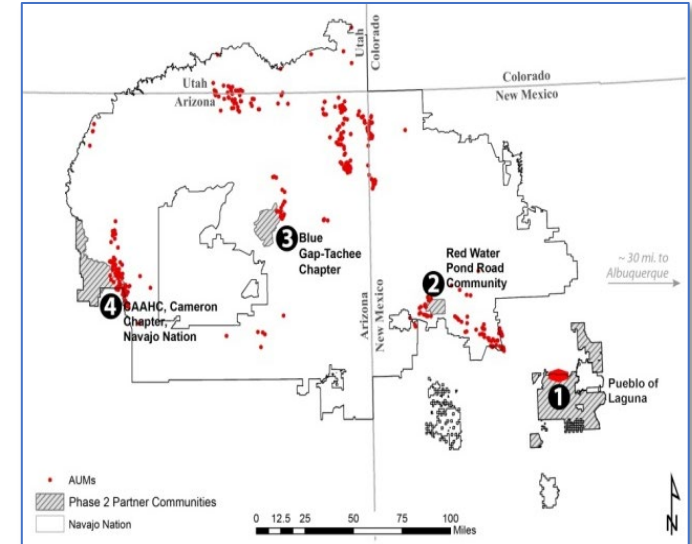
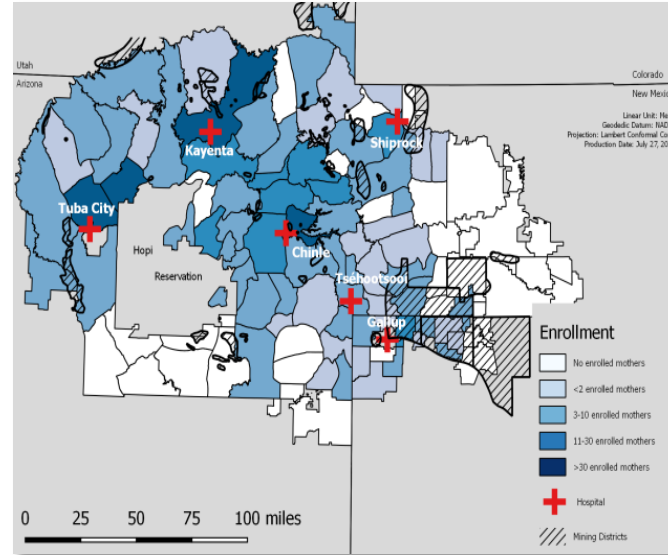
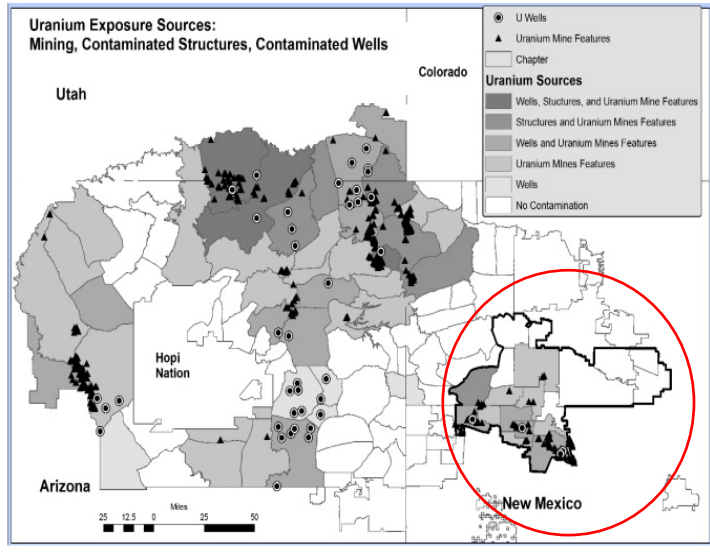
|               |                                                                                                                                                               |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 524           | Abandoned uranium mines (AUMs), plus >1,100 mine “features”                                                                                                   |
| 0             | <b>Fully remediated AUMs</b>                                                                                                                                  |
| ~30           | Interim removal actions to remove wastes near homes                                                                                                           |
| 96            | AUM site radiation screening reports                                                                                                                          |
| 130           | Site assessments expected to be completed by 2022                                                                                                             |
| 10-15<br>8    | EE/CAs* expected to be completed by end of 2022;<br>EE/CAs issued for public comment as of 10/1/24                                                            |
| \$1.7 billion | Money USEPA says it has available for remediating <b>~40% of all AUMs</b> through Tronox bankruptcy, settlements with mining companies, federal contributions |
| 3             | Congressional hearings: 1979, 1993, 2007                                                                                                                      |
| 3             | Federal response plans: 2008, 2014, 2021                                                                                                                      |
| 57            | Navajo Chapters w/ 1-3 uranium exposure sources (AUMs, contaminated water sources, contaminated structures)                                                   |

Cover of USEPA Ten-Year Plan, Jan. 2021

Sources: EPA Ten-Year Plan, 2021; EPA press release, 2024; EPA Fact Sheet 2018; DiNEH Project, 2006; \*EE/CA = Engineering Evaluation/Cost Analysis



# Community questions have driven UNM environmental health research



## DiNEH Project, 2002-2012

- Does U in drinking water increase risk of kidney disease?
- Do multi-pathway exposures to metals in mine wastes increase risks of chronic disease?
- *Community-based trainings to develop study design, implementation methods, consents*

## Navajo Birth Cohort Study, 2010-present





- Do exposures to U mine waste affect children's health, development?
- Do exposures to metals in mine wastes impact chronic disease?
- *Extensive trainings to develop EH capacity among community members hired by UNM, SRIC and NNDOH*

## METALS SRP, 2014-present

- Do mixed-metal U mine wastes contribute to air, water and farmland contamination?
- Do exposures to U wastes result in immunologic, cardiovascular, pulmonary effects?
- Status of remediation?
- *Community defines research Qs*

# Summary of key findings of UNM environmental health studies\* on the Navajo Nation\*\*, 2002-present



| Study                                                                                                                                                            | Design/Population                                                                                                                                                                                              | Key Findings                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>DiNEH Project</b></p>                                                     | <ul style="list-style-type: none"> <li>• <b>Cross-sectional, iterative</b></li> <li>• 1,304 participants in 20 chapters of the Eastern Navajo Agency;</li> <li>• 267 in blood and urine collections</li> </ul> | <ul style="list-style-type: none"> <li>▪ <b>Proximity to U mine wastes</b> -- significantly increased risk of kidney disease during mining era; cardiovascular disease (CVD) and autoimmunity during legacy era</li> <li>▪ <b>Chronic exposures (survey data)</b> – median residency of participants = 33 years</li> <li>▪ Twofold increase in <b>antinuclear antibody (ANA)</b> positivity over U.S. norms</li> <li>▪ <b>Biomarkers</b> of autoimmunity associated with U in drinking water <i>below</i> MCL</li> </ul> |
| <p><b>NBCS-ECHO+</b><br/>Environmental influences on Child Health Outcomes</p>  | <ul style="list-style-type: none"> <li>• <b>Longitudinal cohort</b></li> <li>• &gt;1,800 mothers, fathers, babies throughout the Navajo Nation across three phases;</li> </ul>                                 | <ul style="list-style-type: none"> <li>▪ Pregnant Navajo women have higher U exposures than all U.S. women</li> <li>▪ 92% of babies with detectable urine-U at birth born to mothers who had urine-U levels &gt; than national norms</li> <li>▪ Arsenic exposure increased oxidative stress, a contributor to CVD</li> <li>▪ &gt;60% of pregnant women deficient in zinc, iodine – two essential nutrients for child development</li> </ul>                                                                              |
| <p><b>Thinking Zinc</b></p>                                                    | <ul style="list-style-type: none"> <li>• <b>Clinical trial</b></li> <li>• 71 (three Navajo communities)</li> </ul>                                                                                             | <ul style="list-style-type: none"> <li>▪ 4-fold increase in U levels among Thinking Zinc participants</li> <li>▪ Individuals' metals exposures can be vary greatly across a 10-month period</li> </ul>                                                                                                                                                                                                                                                                                                                   |
| <p><b>METALS Superfund Research Center</b></p>                                | <ul style="list-style-type: none"> <li>• <b>Environmental studies</b> with Indigenous science/art to inform and explain biomedical research, reduce exposures</li> </ul>                                       | <ul style="list-style-type: none"> <li>▪ Mice exposed to solution of mine dust exhibited immune responses indicative of cardiopulmonary (heart-lung) damage</li> <li>▪ Weathered mine wastes replete with submicron particles containing U, other metals</li> <li>▪ Mine wastes characterized by high concentrations of metals, including U and V, and radionuclides, specifically Ra-226</li> </ul>                                                                                                                     |

\*Copies of published papers, fact sheets and presentations documenting these results are available from the presenter, [sric.chris@gmail.com](mailto:sric.chris@gmail.com).

\*\*Diné field staff who contributed to these studies are listed in the Acknowledgements slides at the end of this presentation.



# This is what "proximity" looks like



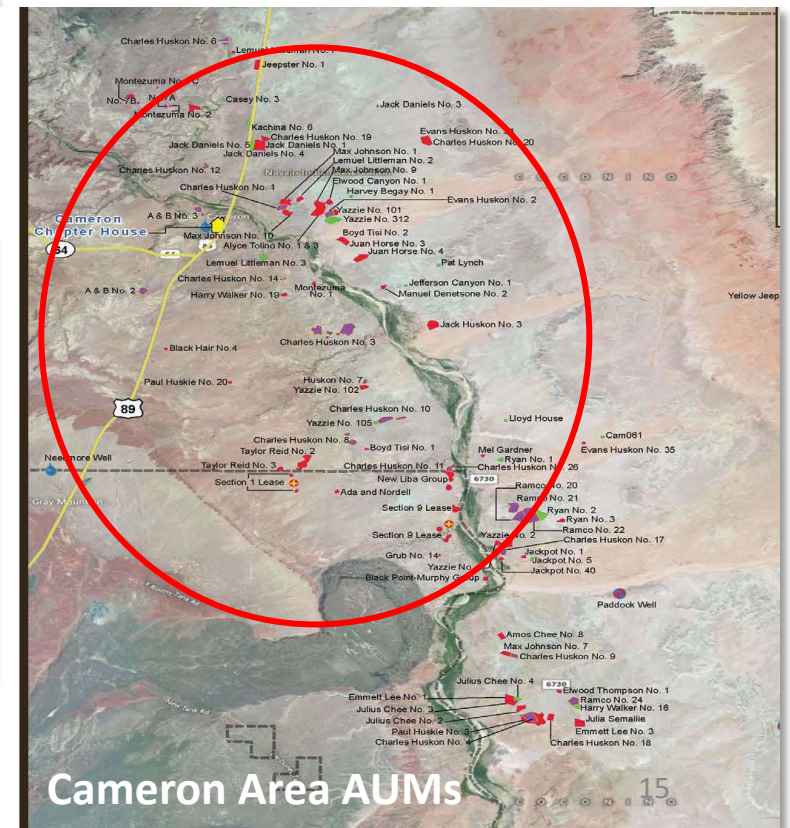
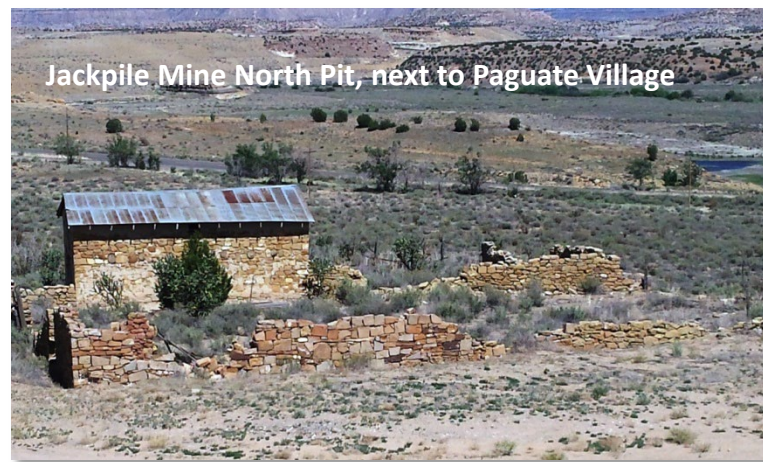
Homes in Red Water Pond Road Community, Coyote Canyon

## Claim 28 Mine in Blue Gap-Tachee



### Example: Mariano Lake Mine

- Operated by Gulf Mineral Resources 1977-1982; closed 1986; Chevron current responsible party
- Interim actions: buildings removed, site graded and fenced; one home abandoned
- 10 to 15 residences surround the mine site



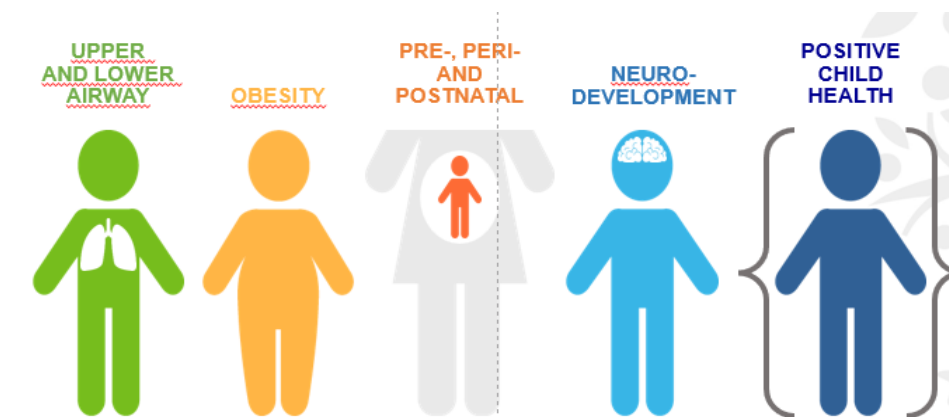
Cameron Area AUMs

Above L: 20 homes next to Mariano Lake Mine; Above R: Village of Paguate sites next to Jackpile Mine, Pueblo of Laguna



# Navajo Birth Cohort Study-ECHO+

- Part of NIH's national ECHO-wide cohort consisting of 84 birth cohorts at 35 sites involving ~150,000 children
- Large size of national ECHO-wide cohort allows comparison with other Indigenous populations as well as with other diverse populations across US
- Primary focus -- pediatric outcomes (graphic) that have a high public health impact
- Includes repeated biomonitoring, survey data collection, medical record reviews, developmental assessments, home environmental assessments
- Informs our understanding
- Provides training, experience in research, building Diné EH capacity
- Multigenerational exposures and outcomes at community level
  - DiNEH (18-96 yrs)
  - NBCS parents (21-45 yrs)
  - NBCS children (prenatal – 18 yrs)
- Trends over lifespan
- Clusters of metals & micronutrients
- Local health care needs



ECHO's primary child health outcomes shown here are applicable to Navajo Nation health concerns



NBCS-ECHO+ staff at NNHRRB conference, October 2023



## Home Environmental Assessment (HEA): Exposure sources in NBCS participants' homes

Chart below shows percentage of homes with contaminants exceeding screening guidelines and percentage of homes having detectable levels of uranium in indoor dust (Results through December 2017)

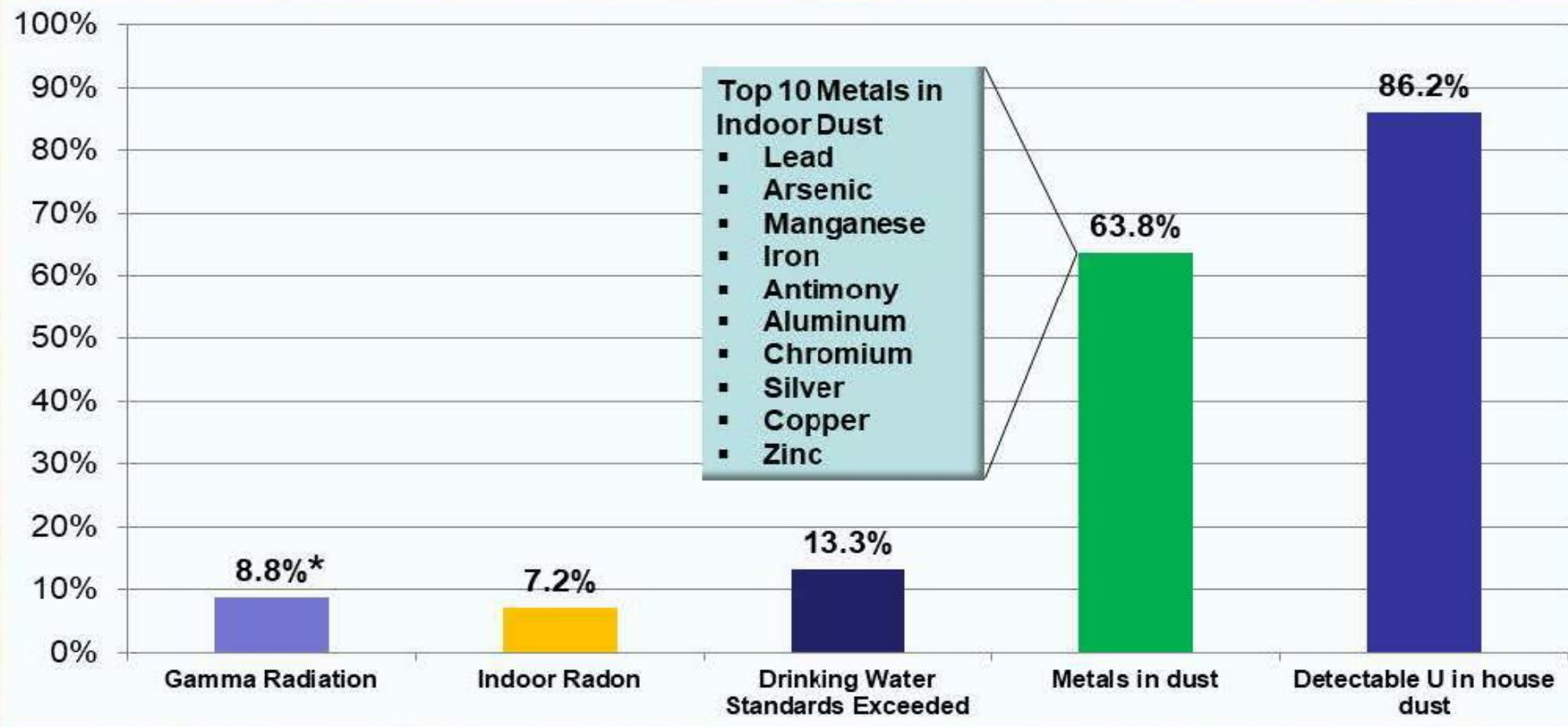


Chart by C. Shuey, SRIC

\*Percentage is skewed upward by exceedances of IL-2 at low gamma rates

# Pregnant women enrolled in NBCS have higher average concentrations of urine uranium compared to national norms

About 20% of NBCS participants exceed the national 95<sup>th</sup> percentile

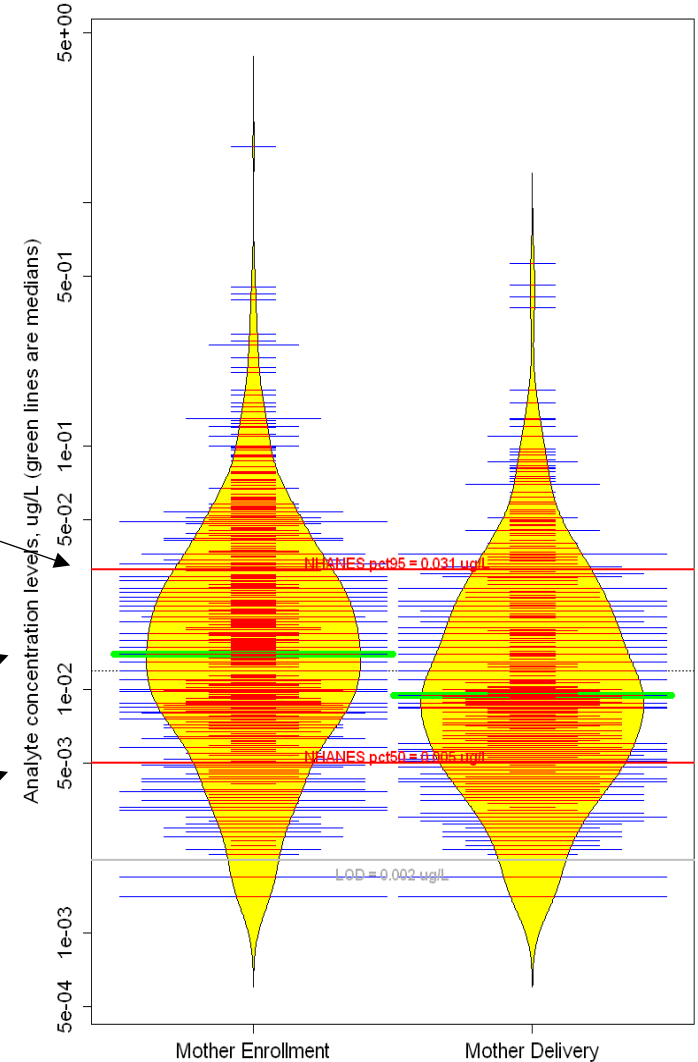


NBCS-ECHO Levels of UUR (Uranium - Urine), ug/L

NHANES 95<sup>th</sup> percentile level

NBCS 50<sup>th</sup> percentile (green line)

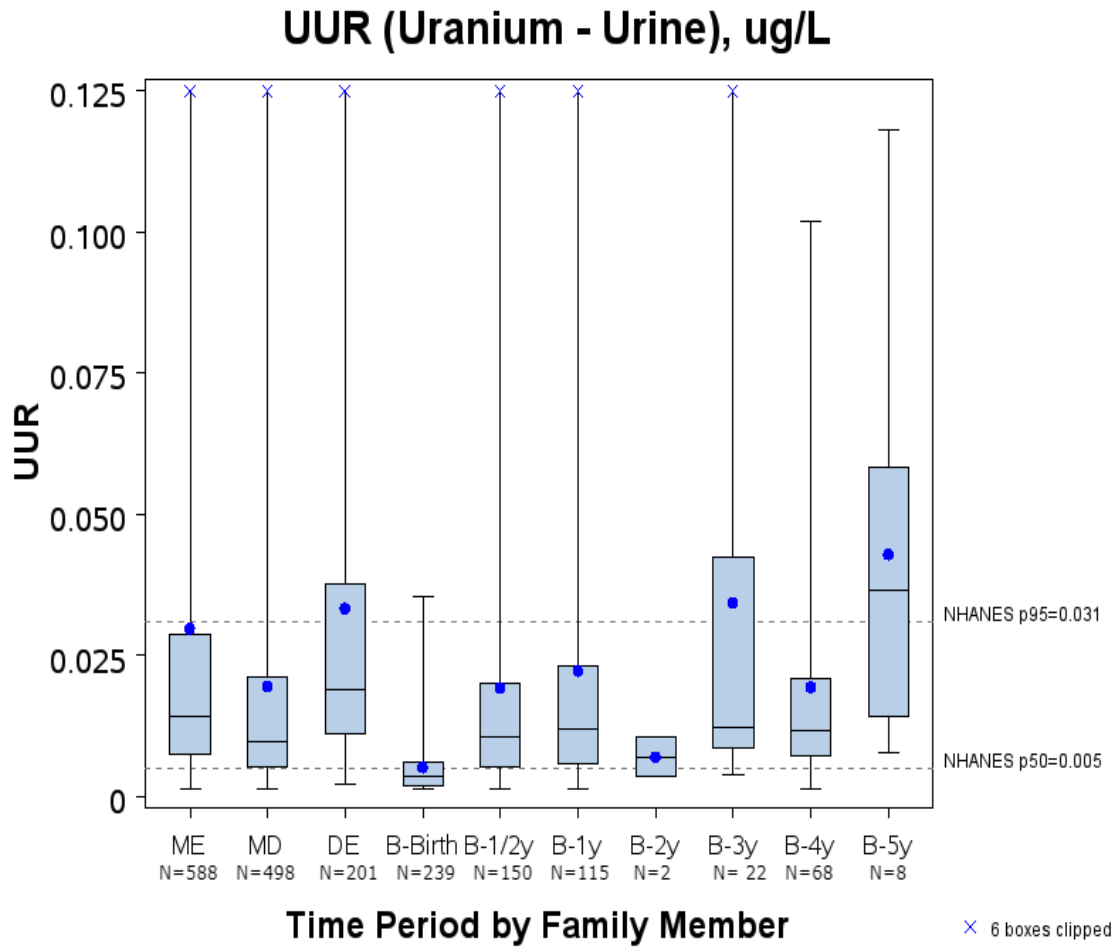
NHANES 50<sup>th</sup> percentile (red line)





# Do we see evidence\* of placental transfer of uranium to fetus and ongoing exposure after birth?

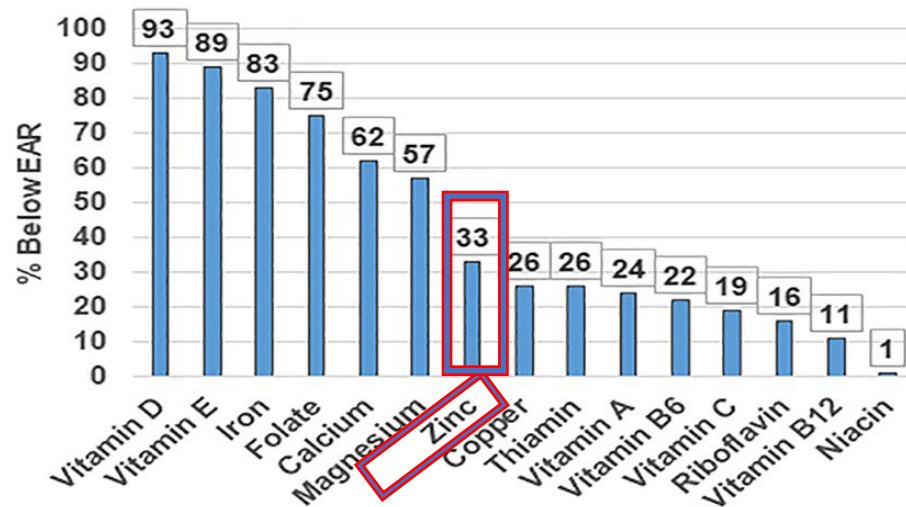
- 28% of **adult participants** have urine uranium >95<sup>th</sup> percentile of NHANES
  - Dads 36%
  - Moms 26%
- Babies** (not creatinine corrected)
  - Infant @ birth 0.5%
  - Infant @ 6 months 15%
  - Infant @ 12 months 19%
- 25% of babies (13/52) had uranium concentrations **above** the NHANES 50% for adults (0.007 µg/ml)
- 92% of babies with detectable uranium at birth were born to mothers with urine-U levels >NHANES 50%
- Urine U increases over early childhood at least to age 5, indicating ongoing exposures (chart)
- NBCS subgroup with the highest overall U exposure had a relative risk of **pre-term birth** of 2.9 times (95CI: 1.1,6.1) (Hoover et al., 2023)
- Long-term consequences of these exposures remain to be determined



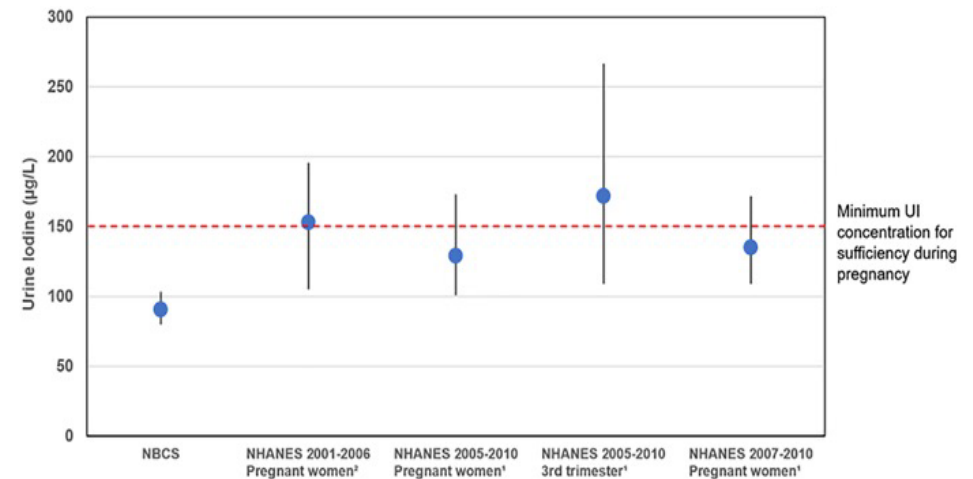
\*Based on biomonitoring data through January 2020. Note: We have not done direct placental transfer calculations. Inferential data based on urine measurements in infants at delivery.

# NBCS diets during pregnancy deficient in micronutrients important for normal child development

Zinc and other nutrients as % Estimated Average Requirement



Iodine deficiency: ~50% of NHANES total and pregnant women

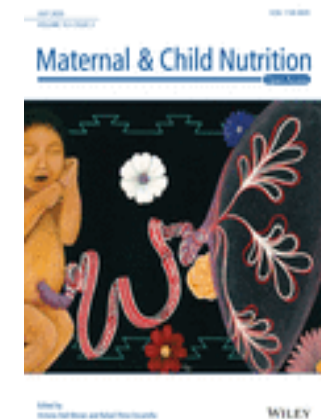


<sup>1</sup>Caldwell et al 2013

<sup>2</sup>Perrine et al 2010

- Deficiencies only minimally improved since 1981!
- Iodine and zinc critical in normal child development
- Opportunities for future interventions? Ex: Thinking Zinc
- Folate intervention had huge impact

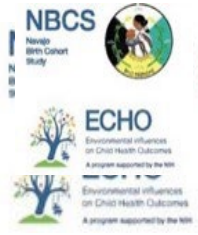
DeLa Rosa et al., Diet quality among pregnant women in the Navajo Birth Cohort Study. *Maternal & Child Nutrition*. 2020 | <https://doi.org/10.1111/mcn.12961>





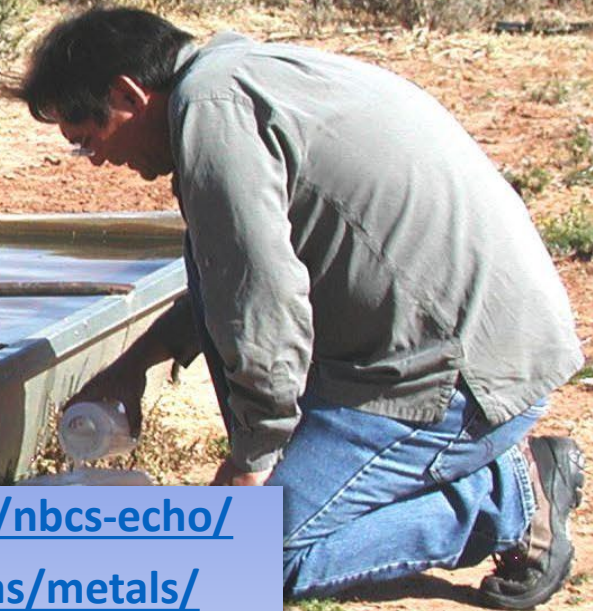
# Discussion

- DiNEH Project – Largest cross-sectional study of exposure to uranium on the Navajo Nation
- Navajo Birth Cohort Study – Largest cohort study of Diné mothers, fathers and babies documenting ongoing environmental exposures
- Thinking Zinc – First-ever community-based clinical trial showing elevated levels of metals in blood and urine, exceeding national norms
- Studies developed in partnership with community members, designed to answer community questions about effects of exposures
- Proximity to mine wastes, contaminants in drinking water, and metals in blood and urine associated with increased risks of chronic, metabolic diseases
- Metals – As, Ra, Hg, Ni, U – in drinking water associated with biomarkers of cardiovascular disease, autoimmunity
- Biomonitoring of contaminant levels in people living near mines can supplement risk assessments
- Findings of health studies can inform remediation plans for AUMs, e.g.,
  - Prioritize remediation of waste sites located near residences
  - Reduce exposures by consolidating wastes into fewer sites; develop central disposal sites





# More Information and Resources



- <https://hsc.unm.edu/pharmacy/research/areas/nbcs-echo/>
- <https://hsc.unm.edu/pharmacy/research/areas/metals/>
  - <http://sric.org/uranium/index.php>
- NavajoWaterGIS: <https://unmcop.unm.edu/metals/>
  - [Navajosafewater.org](http://Navajosafewater.org)
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# METALS Acknowledgements



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Navajo Birth Cohort Study