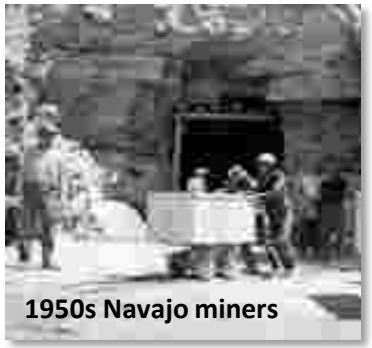
Health Effects of Uranium Exposure

Results of health studies in tribal communities across parts of three decades


1950s Navajo miners


1979 Churchrock tailings dam breach


2003 Citizen radiation monitoring, Churchrock

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Director, Uranium Impact Assessment Program
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Albuquerque, NM

April 10, 2026

*Contributions by Qeturah Anderson, Wendy Atcitty, David Begay, Daniel Beene, Matt Campen, Jose Cerrato, Erica Dashner-Titus, Vanessa De La Rosa, Esther Erdei, Sarah Henio-Adeky, Joseph Hoover, Laurie Hudson, Johnnye Lewis, Debra MacKenzie, Nancy Maryboy, Donald Molony, Sara Nozadi, Carolyn Roman, Sandy Ramone, Red Water Pond Road Community Association, Kirena Tsosie, Shasity Tsosie, Ashley Wegele and numerous community members impacted by uranium wastes.

METALS

COLLEGE OF PHARMACY
METAL EXPOSURE AND TOXICITY ASSESSMENT ON TRIBAL LANDS IN THE SOUTHWEST

NIH National Institute of Environmental Health Sciences
Your Environment. Your Health.

SOUTHWEST RESEARCH AND INFORMATION CENTER

PUEBLO OF LAGUNA

INDIGENOUS EDUCATION INSTITUTE

Acknowledgements

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- **Approvals:** Human research is approved and monitored by the UNM Human Research Protections Office and Navajo Nation Human Research Review Board: DiNEH Project, NNR-04-145; NBCS, NNR-11.323; NBCS-ECHO+, NNR-19.360; Thinking Zinc, NNR-18.330T.

Disclaimer: This material was developed in part under cited research awards to the UNM and SRIC. It has not been formally reviewed by the funding agencies. The views expressed are solely those of SRIC staff and do not necessarily reflect those of the agencies. The funders do not endorse any products or commercial services mentioned in this research brief. The UNM METALS Superfund Research Center is not affiliated with the USEPA's Superfund regulatory program.

Conflicts of Interest: None

Communities: We recognize and honor the communities and community organizations that have been partners with SRIC and UNM for 40+ years

- Blue Gap-Tachee Chapter
- Cameron Farm Enterprise
- Indigenous Education Institute
- Nahata Dziil Commission Governance
- 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.*

Outline

- What is exposure, and how is it measured?
- Chemical and radiological properties of uranium
- Uranium mines as sources of exposure: examples
- Proximity -- consistently significant exposure
- Health studies, results

Maryboy & Begay, Sharing the Skies, 2010

UNM Environmental Health Studies

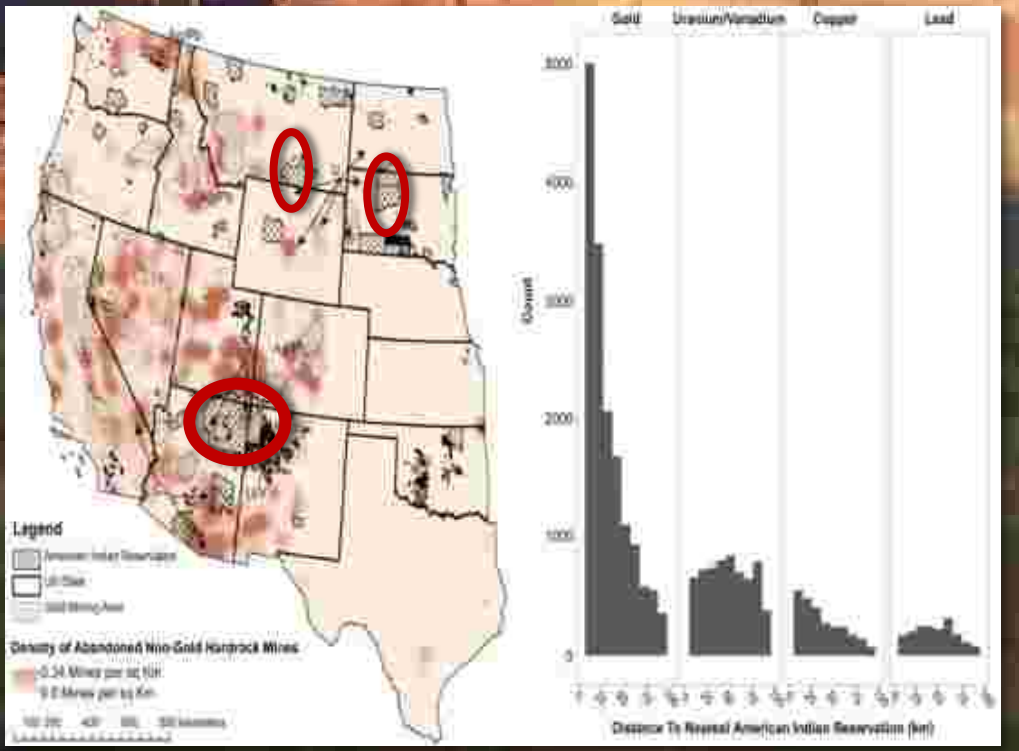
Big Picture: Indigenous people disproportionately impacted by mining in the West

Mining Legacy in the Western U.S.

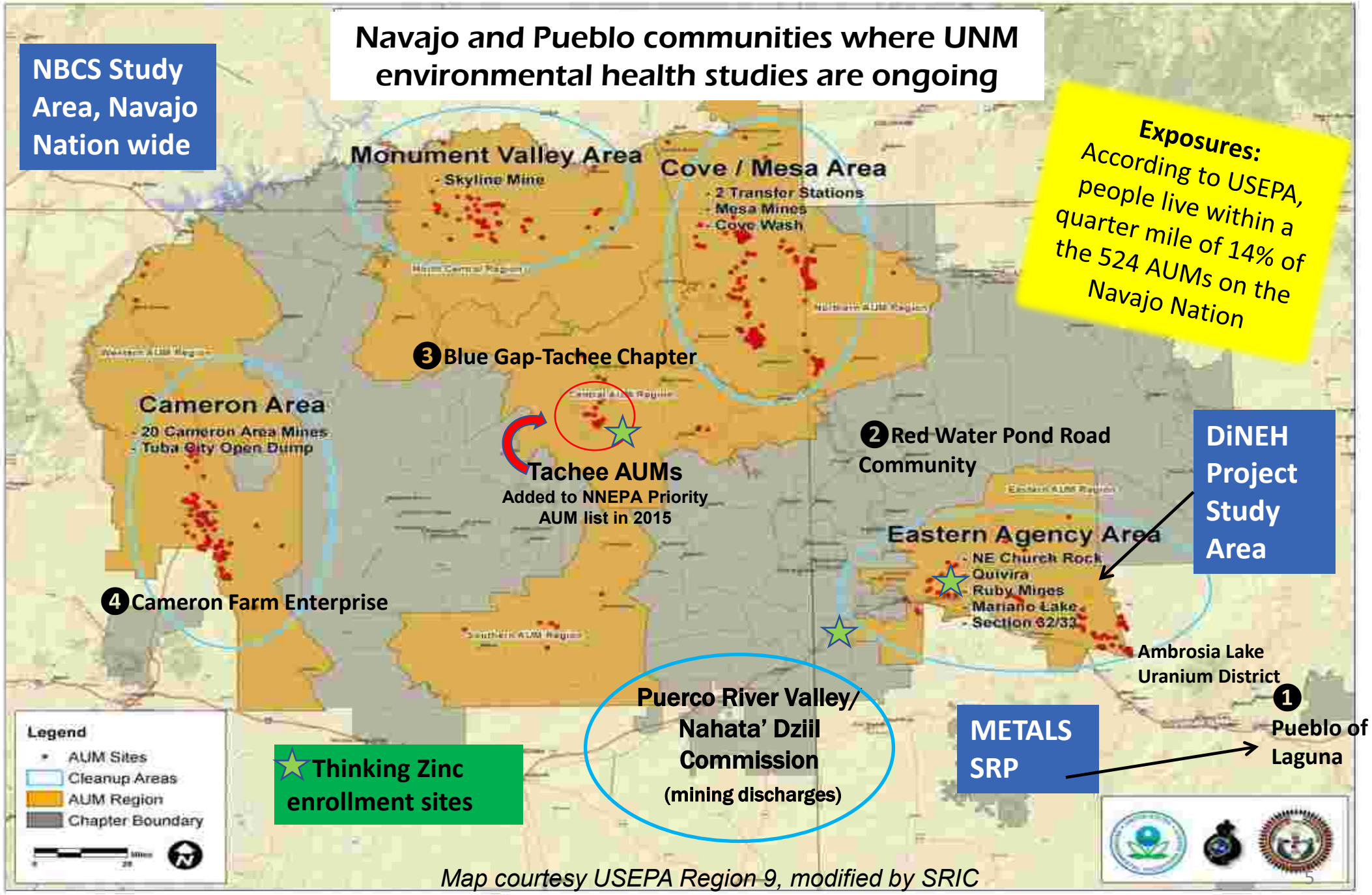
- Uranium, vanadium mines second only to gold and silver
- >10,400 abandoned uranium mines (AUMs) in region
- >600,000 Native Americans live within 10 km of abandoned mines

Potential for higher sensitivity to toxicity among Native Americans

- Understudied genetic, epigenetic, metabolic differences
- Tied to land – moving not always an option to reduce exposures

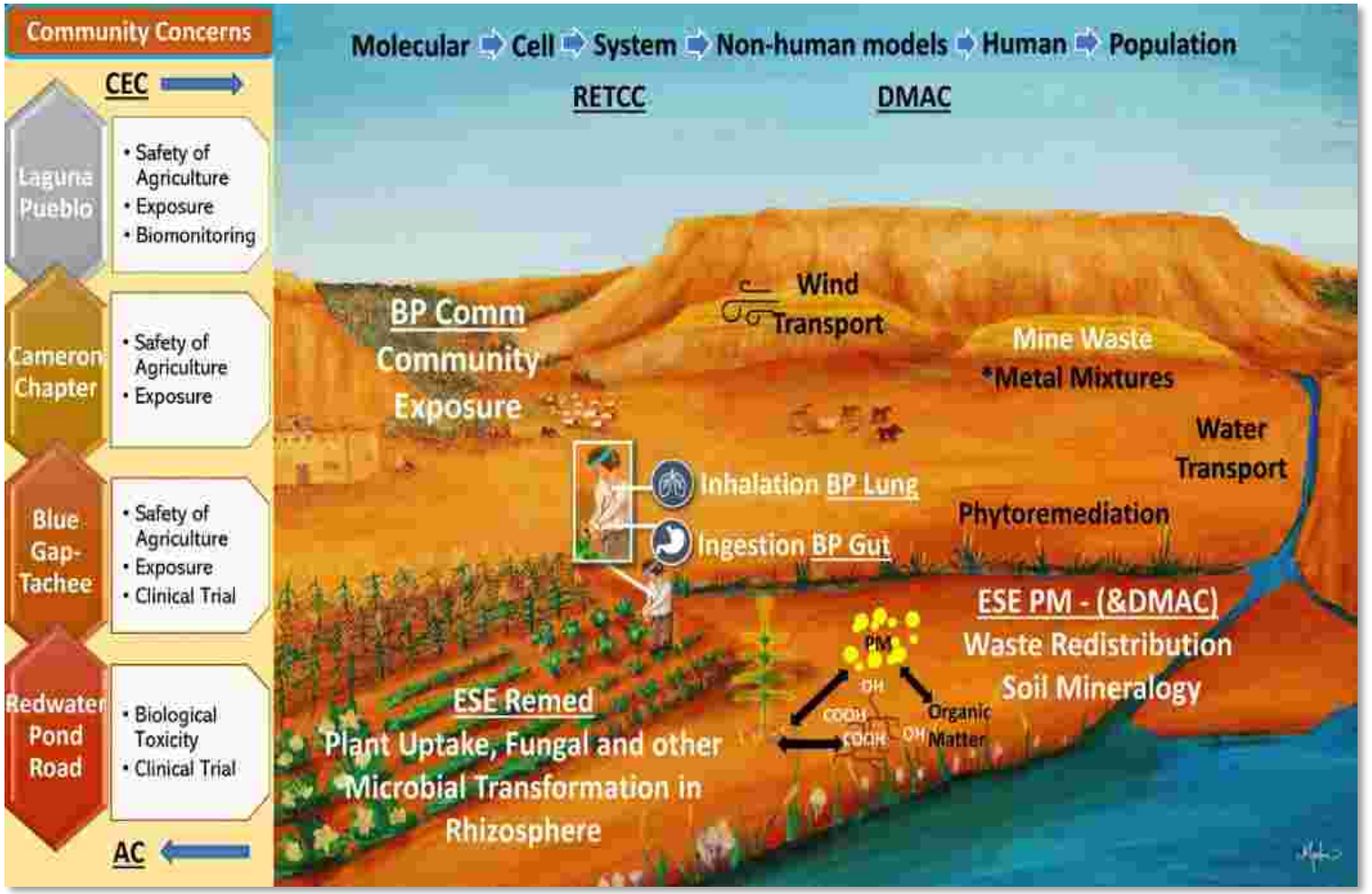


Lewis et al., Current Environmental Reports, 2017



Map courtesy USEPA Region 9, modified by SRIC

Indigenous Science and Art Explain METALS Conceptual Model



This original painting by Mallery Quetawki, UNM Artist in Residence from Zuni Pueblo, illustrates how **community concerns** about exposures to mine wastes are linked to research that assesses community exposures for the first time and possible effects of metals exposures on lung and gut health. Pathways of exposure are shown

Exposure Source on Pueblo of Laguna since 1952

Jackpile-Paguate Uranium Mine

- Largest open-pit mine in U.S.
- Operated from 1952 to 1982
- Reclamation, 1989-1995
- Designated federal Superfund site by USEPA, December 2012
- UNM METALS Superfund Research Center studies, 2014-present
- Currently in USEPA remedial investigation stage

Blasting during operations, 1950s

Mine waste hauling during reclamation

North Pit seen from Paguate Village, 2016

In 2025, UNM METALS SRP started first-ever exposure studies with approvals by Pueblo of Laguna Council and Southwest Tribal Institutional Review Board

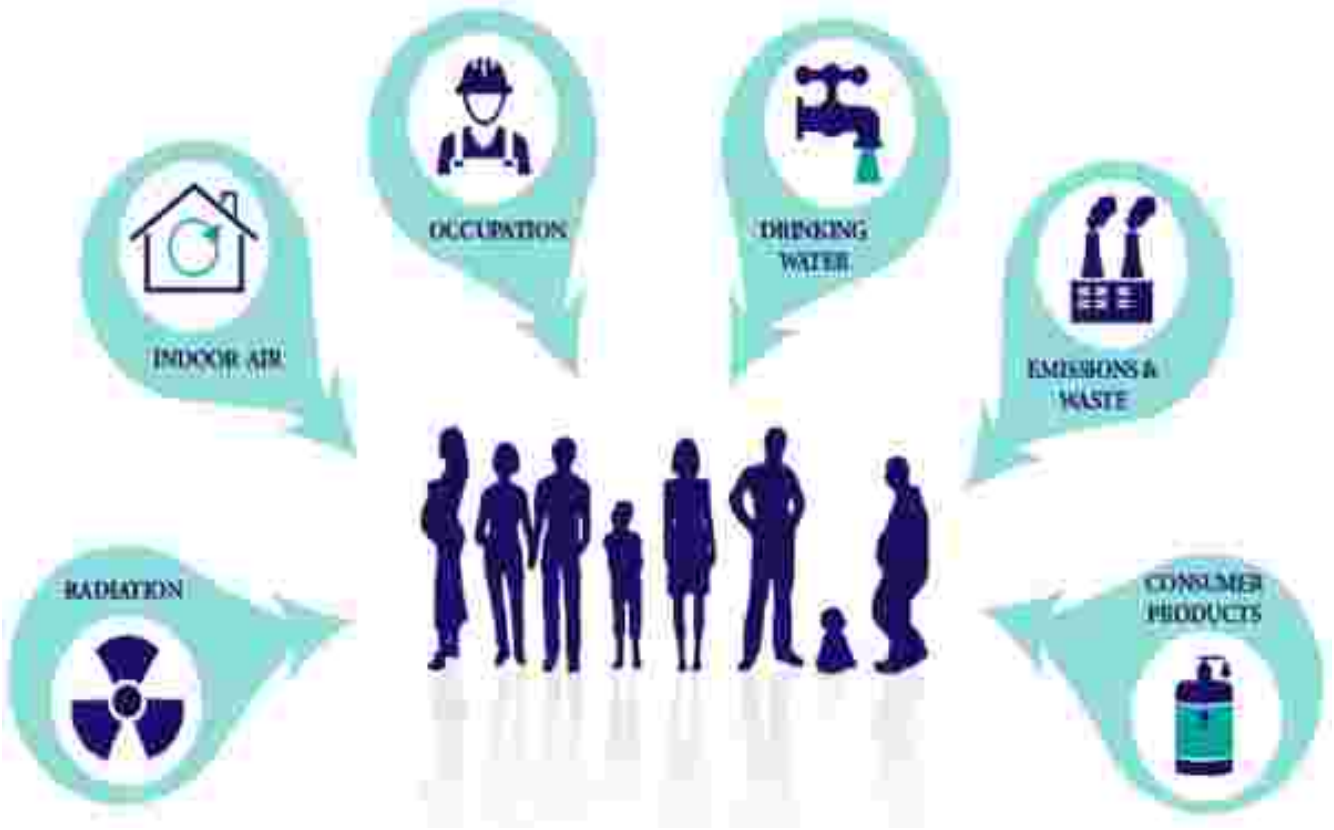
Paguate Village surrounded on east and south side by Jackpile Mine during operations late-1970s

UNM METALS Superfund Center

What is "exposure"?

Exposure is the contact between a person and a hazardous substance through breathing, eating, drinking, and skin absorption, and in the case of pregnant women, placental transfer

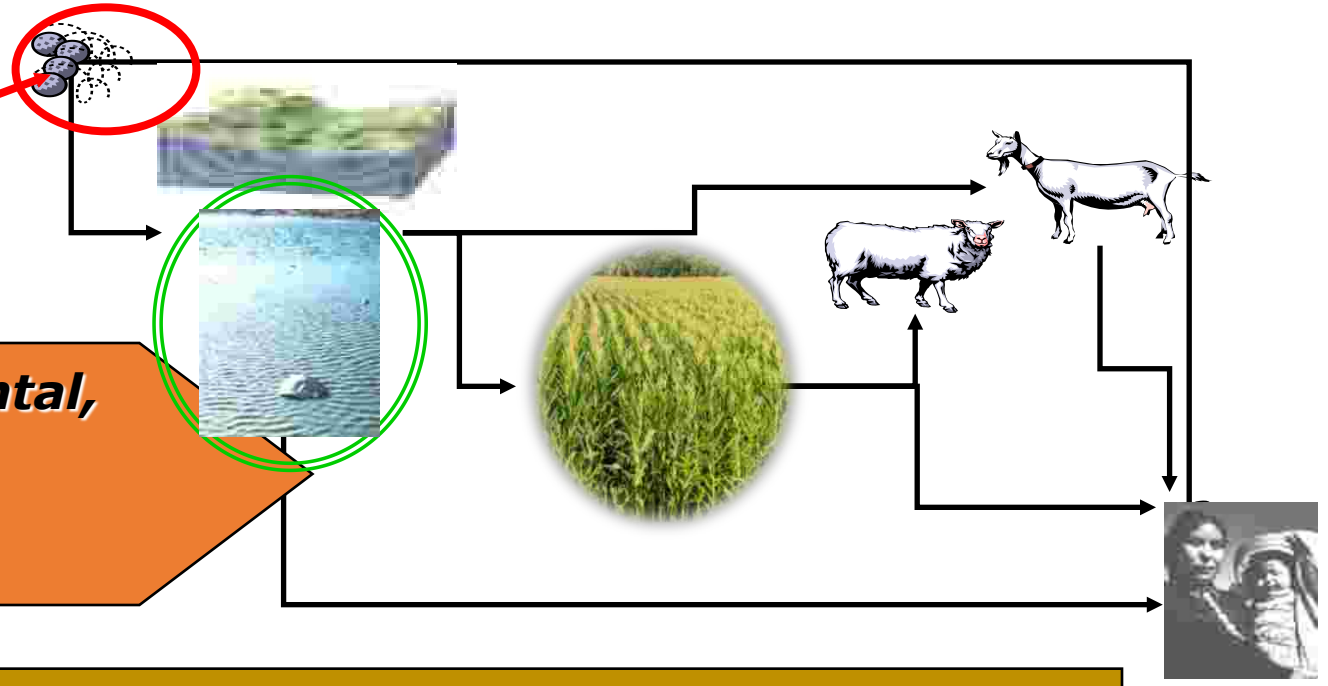
General Sources of Exposure



Source: National Cancer Instiute, https://epi.grants.cancer.gov/chemical-physical-exposures/

Pathways and *routes* of exposure

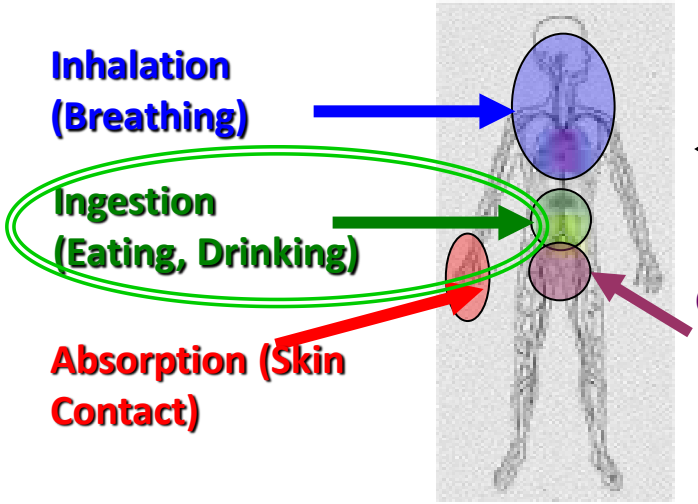
SOURCES: Potentially harmful contaminants in the environment



Exposure Pathways: environmental, outside the body

Air, water, plants, animals, humans

(can be very simple or quite complex)



Inhalation (Breathing)

Ingestion (Eating, Drinking)

Absorption (Skin Contact)

Exposure Routes: inside the body

How contaminants enter the body

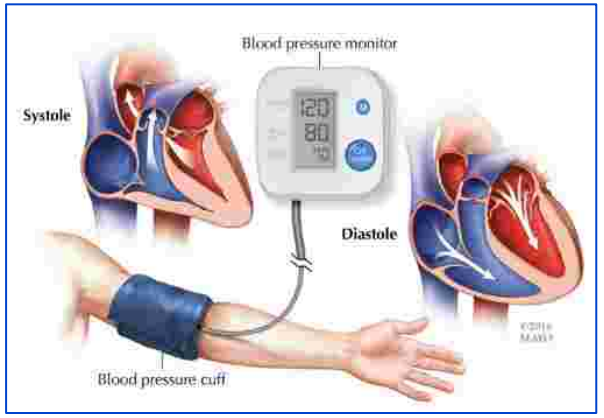
Circulation:

- **Transplacental transfer?**
- **Epigenetic changes?**

Target Organ:

Where a contaminant ends up in the body; e.g., bone, kidney, lung

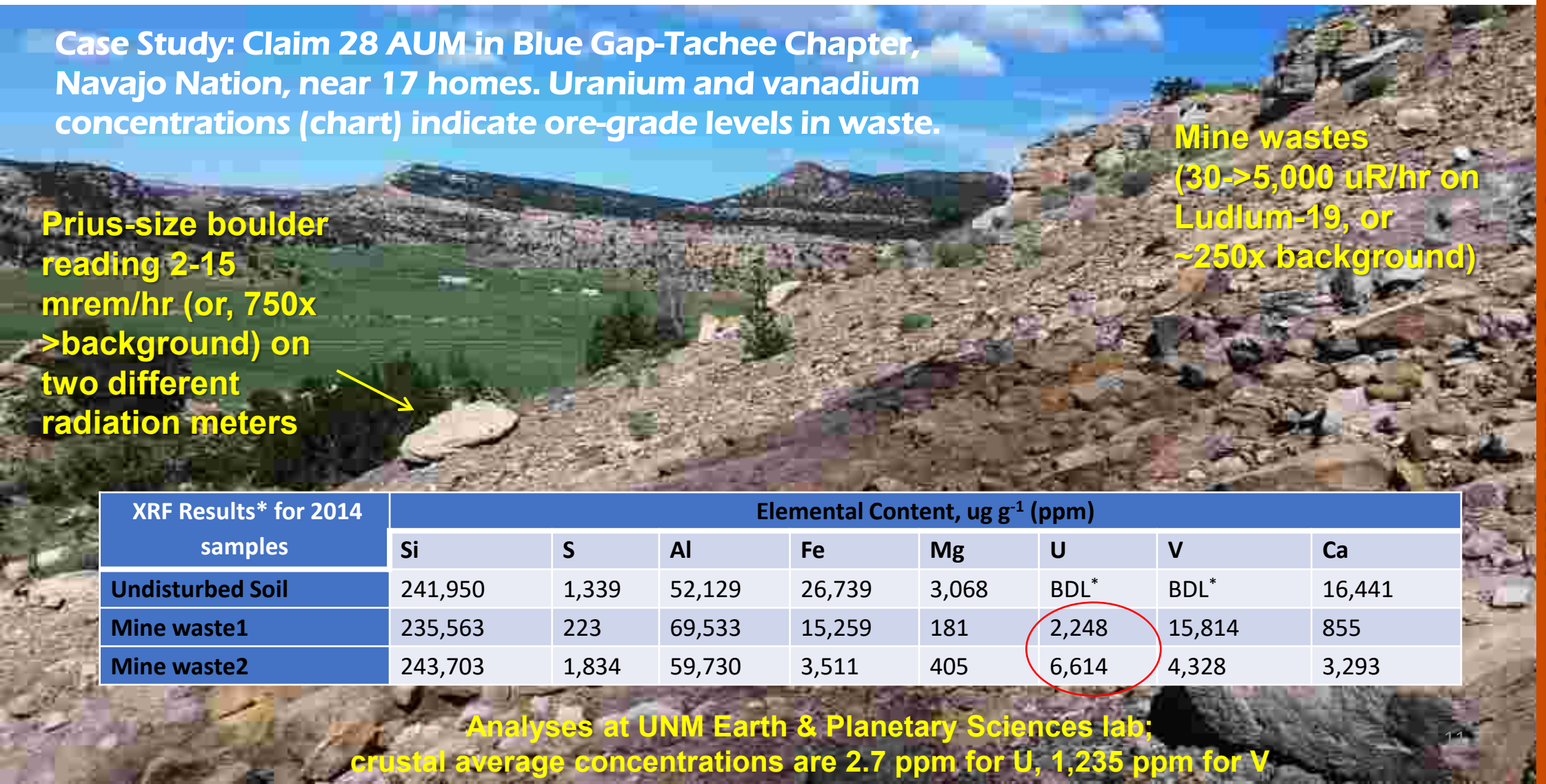
How is exposure measured, estimated?



Standard medical tests, like blood pressure

- Self-reported exposures through *written, oral surveys*
- *Detect/measure contaminants* in air, water, soils, forage, crops and livestock
- Measure exposure through *inhalation* (breathing), *ingestion* (eating, drinking), *dermal contact* (getting it on your skin)
- *Biomonitoring* – measuring contaminants in bodily fluids and tissue, largely through laboratory analysis of metals in blood and urine
- Explore the molecular and cellular *mechanisms of toxicity*

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



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

Prius-size boulder reading 2-15 mrem/hr (or, 750x >background) on two different radiation meters

Mine wastes (30->5,000 uR/hr on Ludlum-19, or ~250x background)

XRF Results* for 2014 samples	Elemental Content, ug g^{-1} (ppm)							
	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

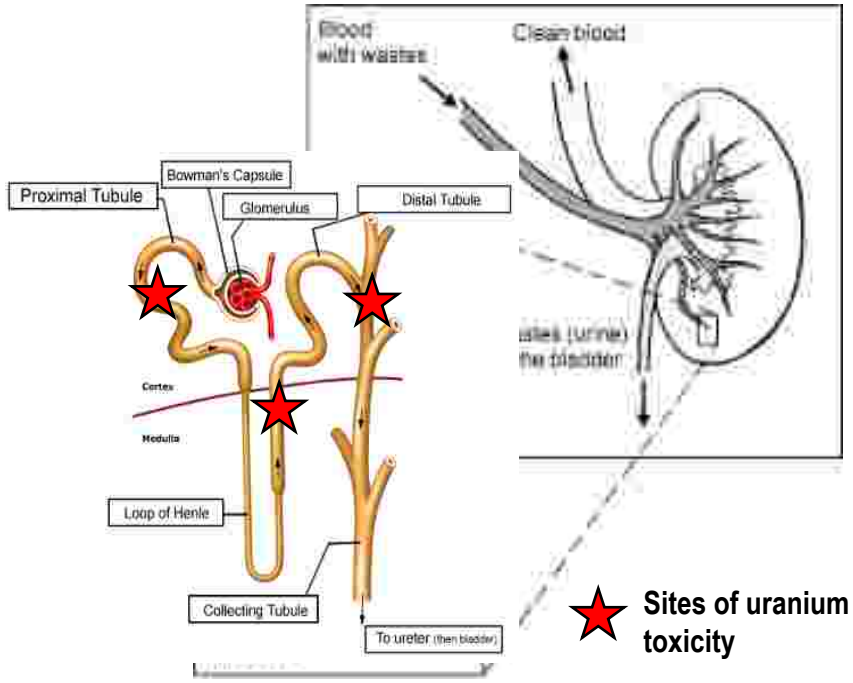
Analyses at UNM Earth & Planetary Sciences lab; crustal average concentrations are 2.7 ppm for U, 1,235 ppm for V

Chemical and radiological properties of uranium

Chemical Properties

- Heaviest naturally occurring trace element on Earth
- Found in surface rocks and soils at average concentration of 2.5-2.7 parts per million (ppm)
- **U — Kidney toxicant**; contributes to chronic kidney disease

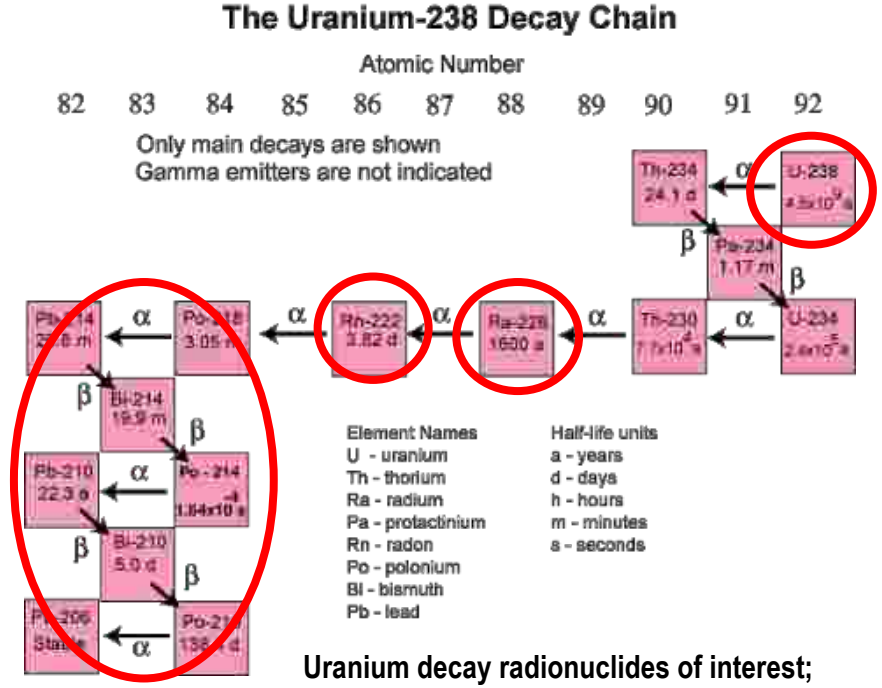
Kidney (cross-section)



Sites of uranium toxicity

Radiological Properties

- **Uranium-238** – 99.3% of all "natural" uranium
- Major uranium decay products in mine and mill wastes: thorium-230, **radium-226**, **radon-222**,
- Emits **ionizing radiation**: alpha, beta, gamma
- **Ra-226** – Known to cause cancers of the bone and blood
- **Radon and Radon Progeny** – Radioactive gas that builds up in uranium mines and indoor environments; second leading cause of lung cancer in the U.S.



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

Radiation Characteristics of Various Nuclear Wastes, Compared with Background

Arrow indicates increasing rates* of gamma radiation

(A) Normal soils: naturally occurring radiation
(B) Mine wastes: elevated gamma radiation, heavy metals; dry dirt, rocks
(C) Uranium ore: elevated radiation (gamma, alpha), heavy metals
(D) Uranium mill tailings: high chemical toxicity, high radiation
(E) Transuranic wastes: high radiation, remote-handled
(F) Spent fuel: deadly radiation, remote handled

Elevated radiological risk *>background* →

A

"Background," or natural conditions

B

Mine waste (Quivira CR1 Mine)

C

Uranium ore hauling on AZ Strip

D

Uranium mill tailings (UNC, Churchrock)

E

Transuranic wastes (WIPP)

F

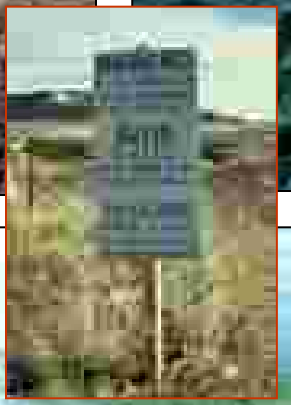
Spent nuclear fuel (Palo Verde NGS)

**We have compiled and calculated numerical dose rates for each category of wastes, and those data are undergoing peer review.*

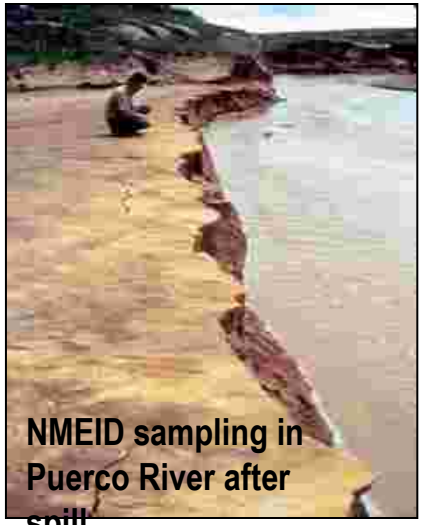
SRIC, 4/18/24, 07/2/24, 4/18/25, 4/7/26

Church Rock Uranium Mill Tailings Spill July 16, 1979*

*Remains the largest release of radioactive wastes, by volume, in US history; third largest radiological disaster after Fukashima (2011) and Chernobyl (1986)



Puerco River warning sign, 1979



NMEID sampling in Puerco River after spill

Livestock tracks in Puerco River downstream of spill, July 17, 1979

Community leaders Larry J. King and the late Robinson Kelly (right) emerged as community leaders in

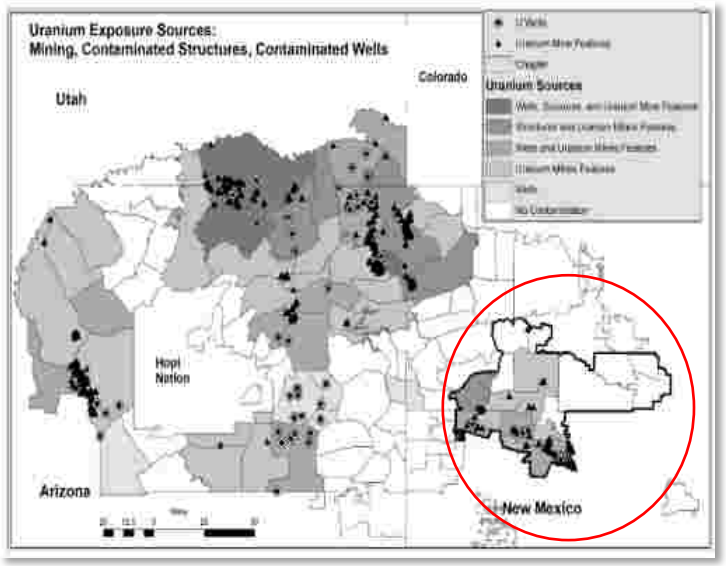
Photo credits: KOAT-TV, Paul Robinson, Chris Shuey, public domain

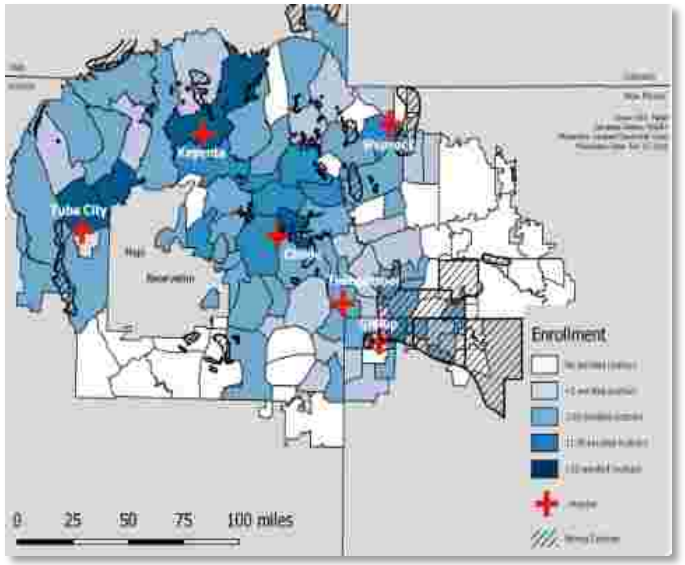
Uranium mining – sentinel exposure for lung disease, especially among Navajo miners

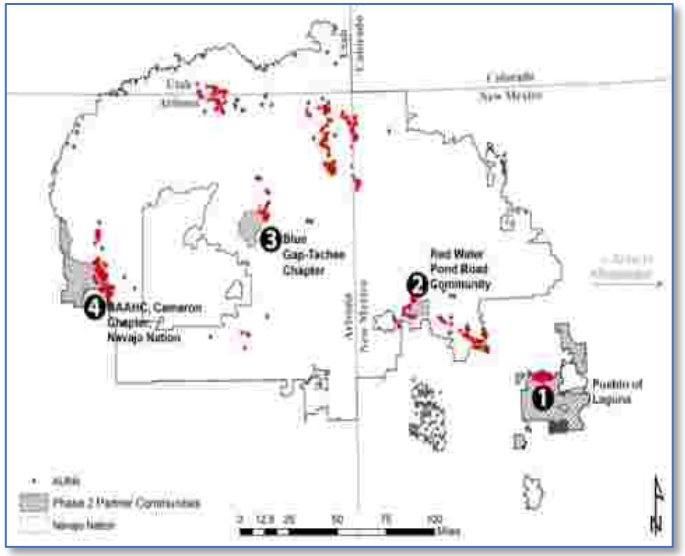
- Lung disease in European pitchblende miners in 1500s; at least 12 major epi studies of U miners worldwide
- Studies on Colorado Plateau: High in-mine radon levels comparable to European mines; 1,100 miners and millers screened by 1951
- Radiation (radon, radon progeny) identified as causing lung cancer in Navajo U miners
- Navajo miners face 2-3 fold excess mortality from lung cancer, pneumoconiosis, other respiratory diseases
- Lung cancer risk in Navajo men who were U miners:
  - 67% of new lung cancer cases among Navajo men between 1969 and 1993 attributed to one exposure, underground uranium mining
  - Dr. Victor Archer (2004) concluded that an "epidemic" of lung cancer among Navajo miners was "inevitable" because US ignored the European evidence

Must-reading on the Navajo Uranium Legacy

Community questions, community concerns have driven UNM environmental health research, 2002-present







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

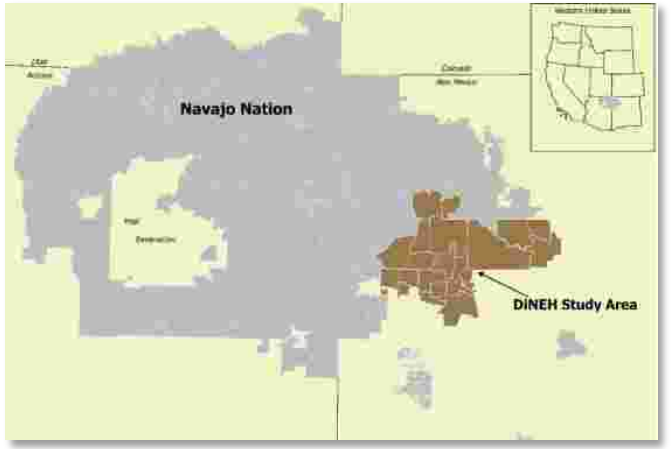
- Do exposures to U mine waste affect children's health, development?
- Do exposures to metals in mine wastes impact chronic disease?
- *Extensive trainings to develop EH capacity among community members hired by UNM, SRIC and NNDOH*

METALS SRP (since 2014) and Thinking Zinc Clinical Trial, 2018-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?
- Does Zinc help repair cells?
- *Community defines research Q's*

Diné Network for Environmental Health (DiNEH) Project,* 2001 to present

- 2001-2004: Community-engaged research and trainings
  - 20 chapters in Eastern Agency
- 2004-2010 (Phase I): **Land-use-water-health survey** administered to 1,304 participants
- 2010-2011 (Phase II) – **Blood and urine samples** collected from 267 participants at 14 community collection events
- 2012-present: Data analysis, publications, community report-backs and workshops
- >15 Navajo-speaking field staff (2002-2011)
- Cross-sectional study design with surveys, geospatial data, biomonitoring



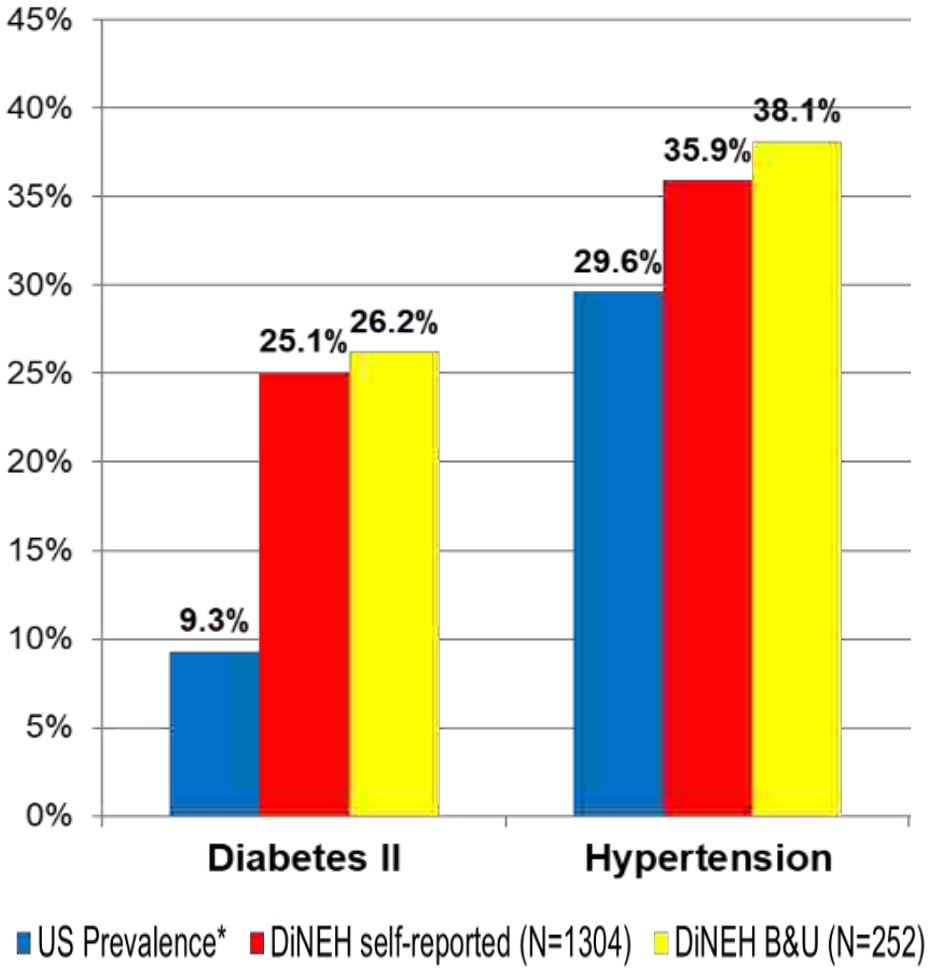
Study Area in Eastern Navajo Agency

DiNEH Project team, 2009

DiNEH Project approved by the Navajo Nation Human Research Review Board (NNR-04-145) and UNM Human Research Review Committee. Grant support from NIEHS, RO1 ES014565; R25 ES013208; P30 ES-012072; USEPA/ERRG pass through contract; with support from DHHS/NIH/NCRR #1UL1RR031977-01. This material was developed in part under cited research but has not been formally reviewed by the funding agencies. Views expressed are solely those of the authors and do not necessarily reflect those of the agencies.

DiNEH Project major findings*

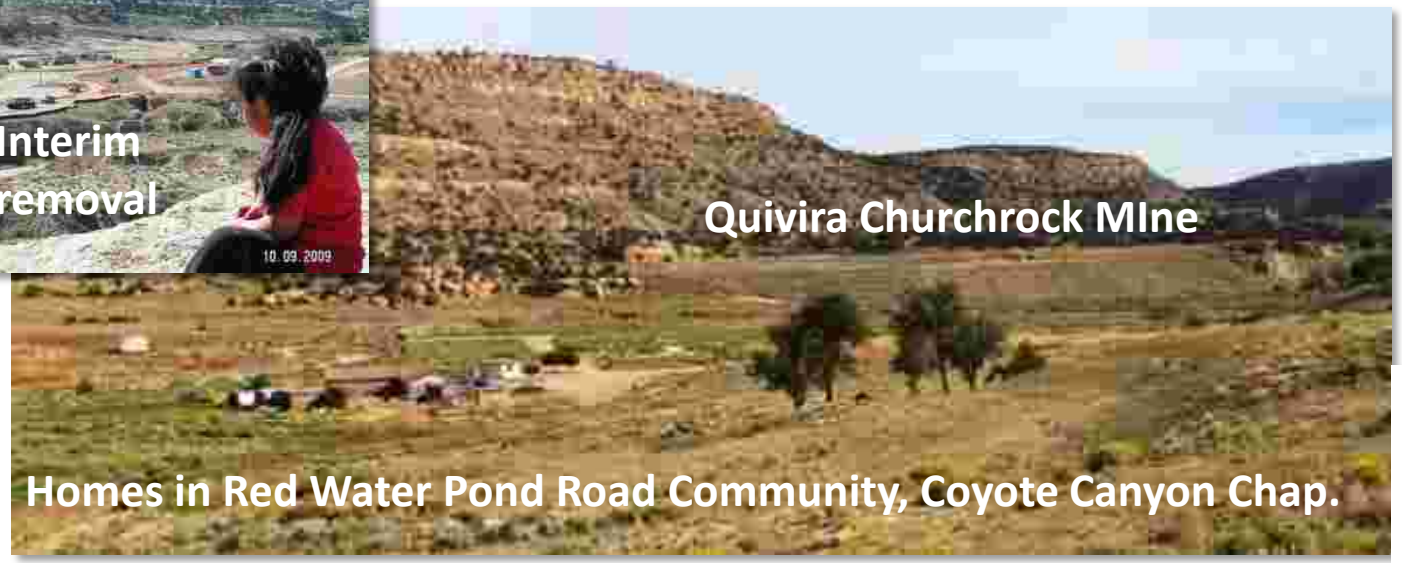
DiNEH participants' rates of diabetes, high blood pressure greater than 2012 U.S. rates



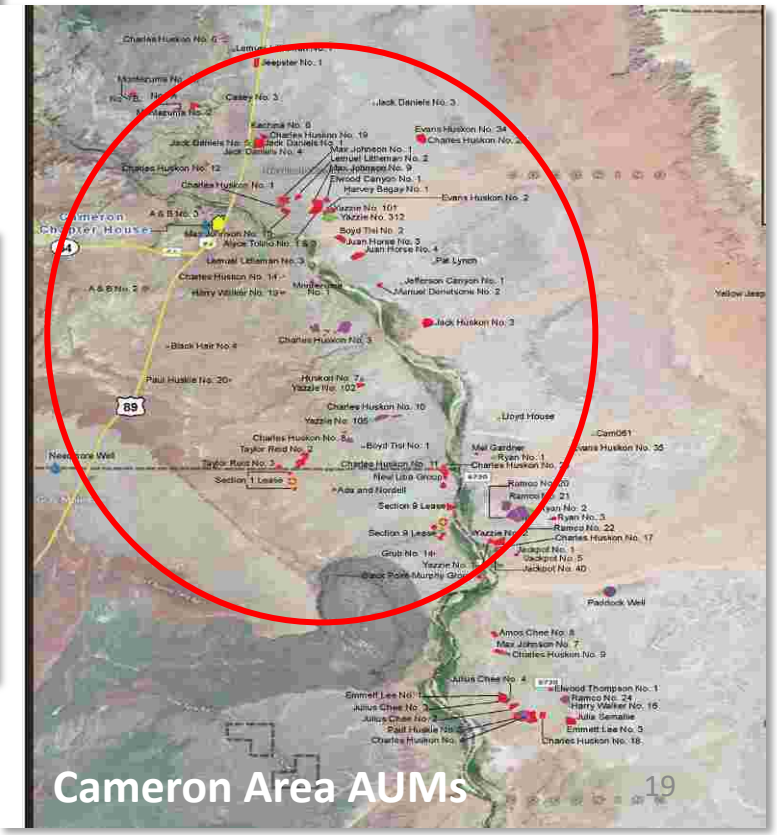
- *Findings summarized in 10 peer-reviewed papers published by the DiNEH Project team since 2015
- **Proximity to U mine wastes** -- significantly increased risk of kidney disease during mining era; cardiovascular disease (CVD) and autoimmunity during legacy era
- **Chronic exposures (survey data)** – median residency of participants = 32 years
- Twofold increase in **antinuclear antibody** (ANA) positivity over U.S. norms
- **Biomarkers** of autoimmunity associated with U in drinking water *below* MCL
- **Chronic kidney disease associated with exposures to environmental metals**, including U, *but not with common diabetes measures, HbA1c and T2DM* (in preparation)
- **DiNEH Project findings informed development of Navajo Birth Cohort Study.**

DiNEH Project

This is what "proximity" looks like



Claim 28 Mine in Blue Gap-Tachee



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

DiNEH Project

Navajo Birth Cohort Study-ECHO+

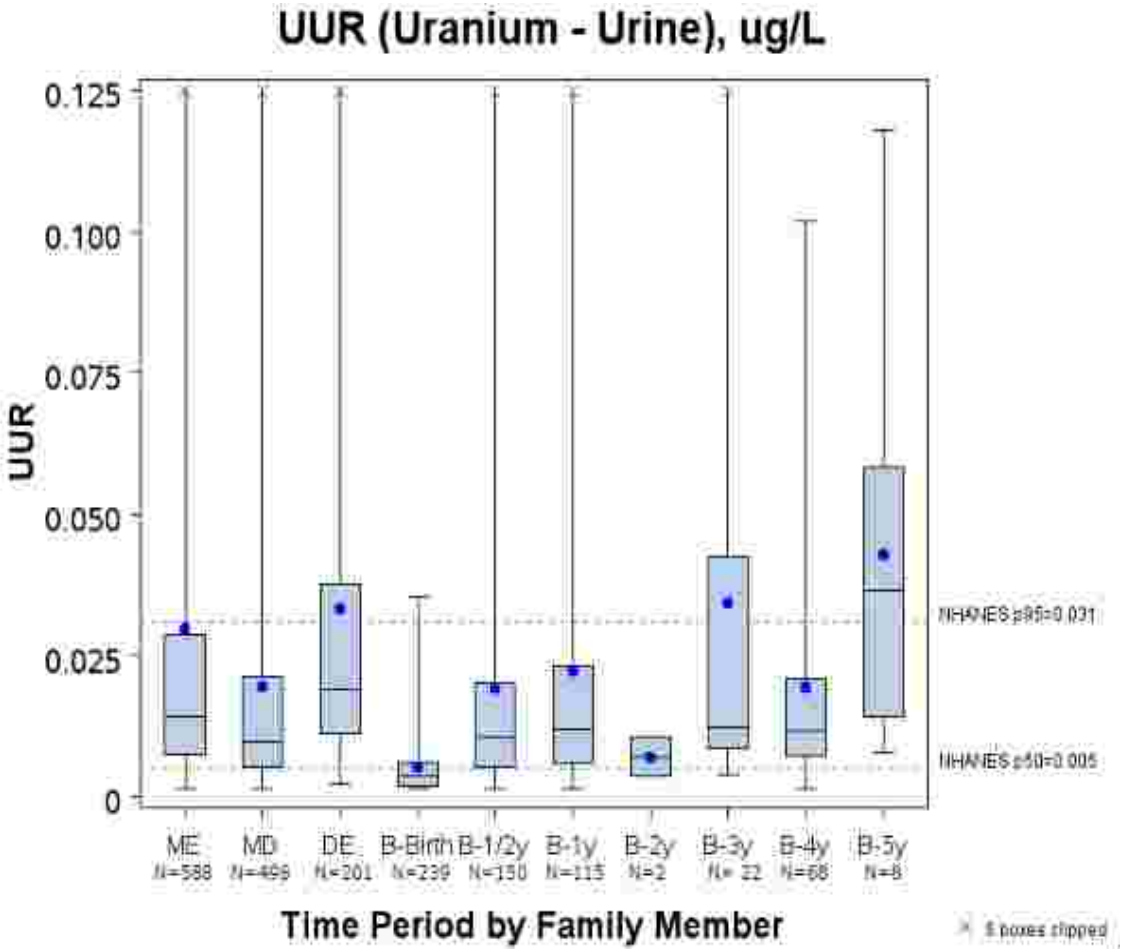
- Part of NIH's national ECHO-wide cohort consisting of 84 birth cohorts at 35 sites involving ~150,000 children
- Primary focus — pediatric outcomes (graphic) that have a high public health impact
- Includes repeated biomonitoring, survey data collection, medical record reviews, developmental assessments, home environmental assessments
- 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)

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

NBCS-ECHO+ staff at NNHRRB conference, October 2023

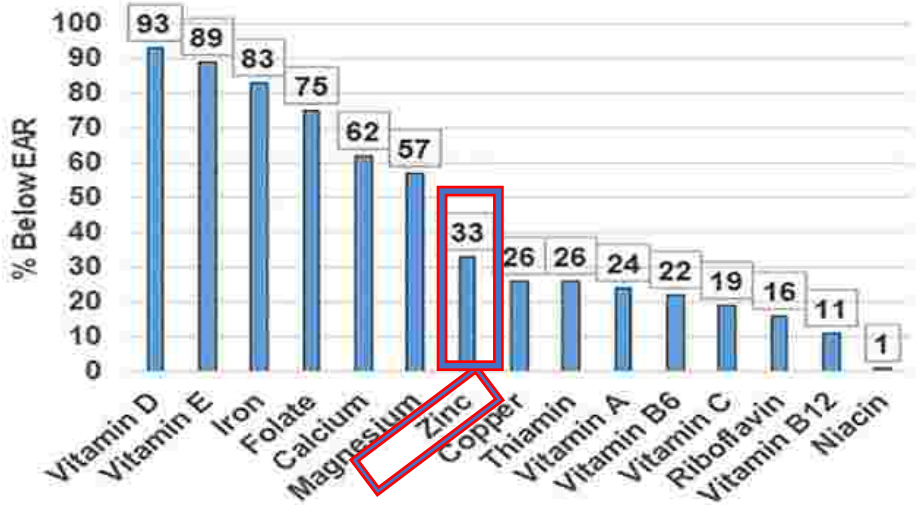
NBCS-ECHO+ finds U exposure among mothers, fathers, newborns

- Pregnant women enrolled in NBCS have higher average concentrations of urine uranium compared to national norms
- Placental transfer of uranium to unborn baby and ongoing exposure after birth
- **Adult participants** – 28% have urine uranium >95th percentile of NHANES
  - Dads 36%
  - Moms 26%
- **Babies** (not creatinine corrected)
  - Infant @ birth 0.5%
  - Infant @ 6 months 15%
  - Infant @ 12 months 19%
- NBCS subgroup with the highest overall U exposure experienced **pre-term birth** of nearly 3 times greater than normal

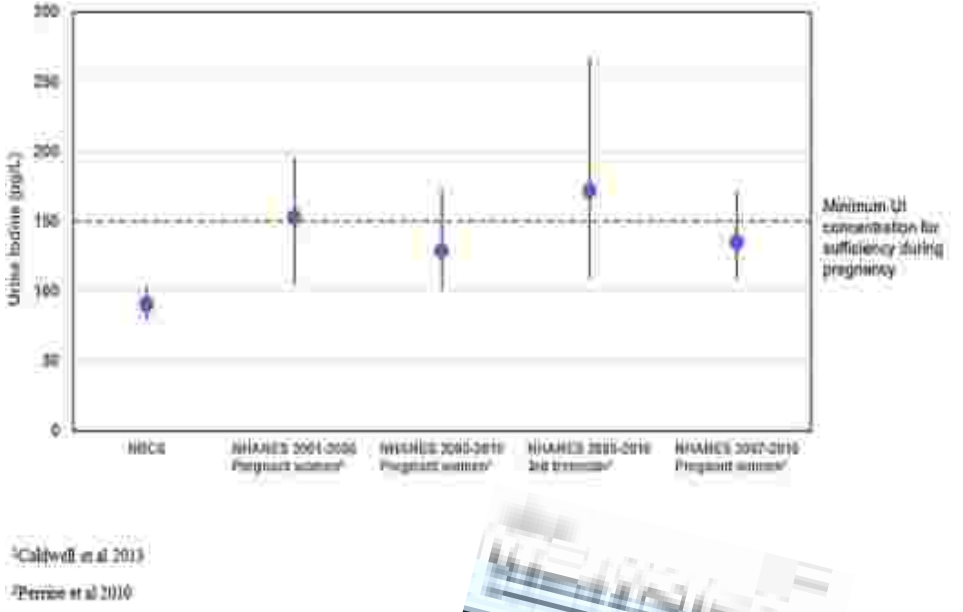


NBCS mothers' diets during pregnancy deficient in micronutrients important for normal child development

Zinc and other nutrients as % Estimated Average Requirement



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



[1]Caldwell et al 2013

[2]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

Navajo Birth Cohort Study

Translating research through an Indigenous lens

Thinking Zinc — *Beesh Dootł'izh Bantsáhákees*

A study to assess how taking the recommended daily amount of zinc may help repair damage from harmful metals among Navajo Nation residents

U Damages Immune Cell DNA

Zinc Leads to Repair of DNA Damage

Healthy Immune Cells Can Function

See, Hudson et al., Current Environmental Health Reports, 2025; original paintings by Mallery Quetawki, Zuni Pueblo, 2022

Thinking Zinc Goals and Study Design*

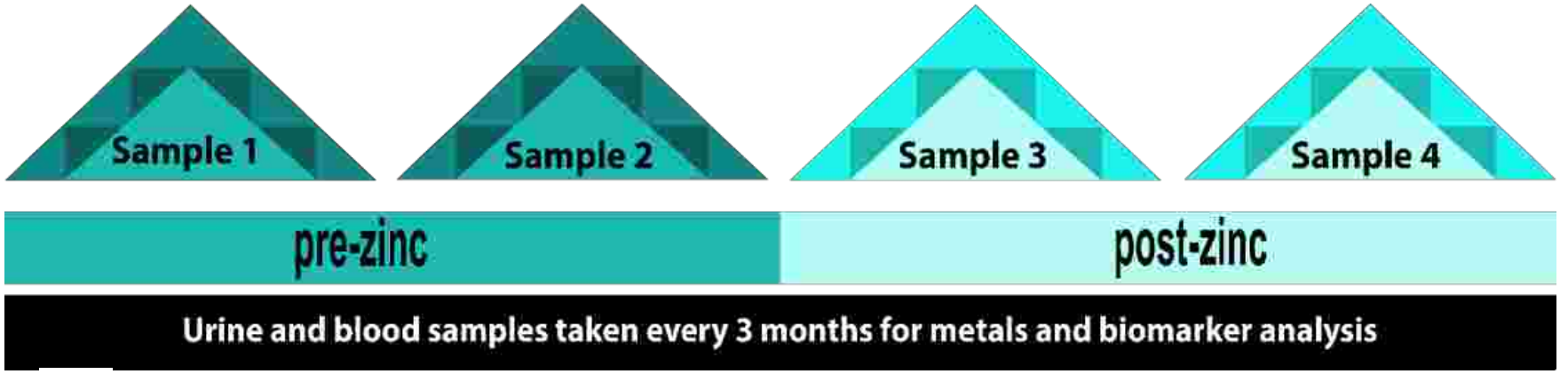
Adapted from L. Hudson, 12th Conference on Metals Toxicity and Carcinogenesis, Oct. 2025

Beesh Dootł'izh Bantsąhákees
Thinking Zinc

Project Goal: Conduct pilot clinical trial of dietary zinc supplementation to assess effects on biomarkers of metal-induced toxicity

Long Term Goal: Determine whether dietary zinc supplementation reduces metal-induced human disease

Vetting Process: Study design, name recommended by community members to respect Native cultural practices



Zn at RDA

Urine: metals, urinary biomarkers of oxidative stress and DNA damage

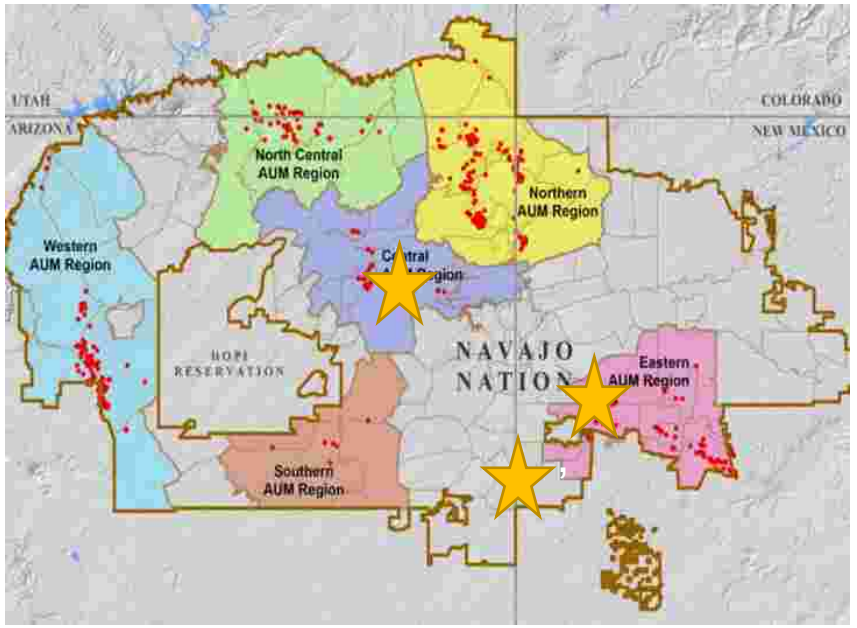
Serum: Zn, cytokines and inflammatory biomarkers
Cells: DNA damage, autoimmune markers, immune cell phenotype

UNM Environmental Health Studies

Biomarker Response to Zn by Community

Beesh Doot'izh Bantsáhákees
Thinking Zinc

Enrollment	RWPR	Blue Gap	Manuelito	Total
Enrolled M/F	37 (12/25)	15 (6/9)	19 (8/11)	**71 (26M/45F)**
Median Age	51 (21-64)	56 (23-63)	52 (32-64)	**53.0 (21-64)**



Principal Finding: After taking zinc tablets for up to 180 days, most biomarkers of altered immune function *decreased*, while blood Zinc levels *increased.*

Measure	Community	Pre vs Post Zn (p value)	Direction post Zn
8OHdG ng/mg Cr	RWPR BG-Tachee Manuelito	0.05 0.2 0.2	↓ NC ↓
Tail Moment (mean)	RWPR BG-Tachee Manuelito	0.2 0.2 **<0.001**	↓ ↓ ↓
PAR (pmoles/ mg protein)	RWPR BG-Tachee Manuelito	**<0.001** **<0.001** **<0.001**	↓ ↓ ↓
Serum Zn µg/dL	RWPR BG-Tachee Manuelito	0.3 0.15 0.6	NC ↑ ↑

RWPR n=57; BG-Tachee n=26; Manuelito n=36

UNM Environmental Health Studies

In light of these widespread exposures, is cancer increasing in New Mexico counties impacted by uranium mining?

Selected Cancer Incidence Rates for Cibola and McKinley Counties versus New Mexico (SEER data, 2017-2021)

Cancer Site		Age-Adjusted Incidence Rates[1]	
Comparison		All races	American Indian
All Cancers	Cibola County	357.6	***347.5***
	McKinley County	305.9	294.3
	New Mexico	370.0	301.7
Kidney & renal pelvis	Cibola County	***32.3***	***55***
	McKinley County	29.2	***36.9***
	New Mexico	16.6	30.7
Liver and Bile Duct	Cibola County	***21.1***	***38.2***
	McKinley County	8.7	9.0
	New Mexico	9.8	13.0
Stomach	Cibola County	*/	*/
	McKinley	***12.4***	***15.2***
	New Mexico	6.6	13.1
Lung and Bronchus	Cibola County	28.0	*25.6*
	McKinley County	14.1	7.7
	New Mexico	32.7	12.0

[1]Incidence rates (cases per 100,000 population per year) are age-adjusted to the 2000 US Standard population age groups (19 groups), calculated using SEER*Stat. Data is for 2017-2021 and pulled from the National Cancer Institute's State Cancer Profiles > Incidence Rates Table

Bold italic values highlight Incidence Rates greater in Cibola and McKinley Counties vs. New Mexico

- **Cancer — Common health concern** in tribal communities impacted by U mining
- Cibola and McKinley counties hosted most U production in N.M.
- *Ecological approach*: We examined incidence rates using National Cancer Institute SEER data
- ***Cancer incidence among Native Americans exceeded NM rates for all cancers, kidney, liver, stomach and lung cancers in Cibola County and kidney and stomach cancer in McKinley County***
- Navajo DOH (2023): Navajo adults had **significantly higher incidence of liver, kidney, stomach, myeloma, and gallbladder cancers**, 2014-18
- Studying cancers limited by confidentiality requirements; cancer "clusters" not identified

Discussion

Environmental Health Projects

- **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 that Zinc dietary supplementation can *reduce* levels of metals in blood and urine
- **Indigenous Art** – Explains research methods, findings in Native symbols for respectful report-back of results

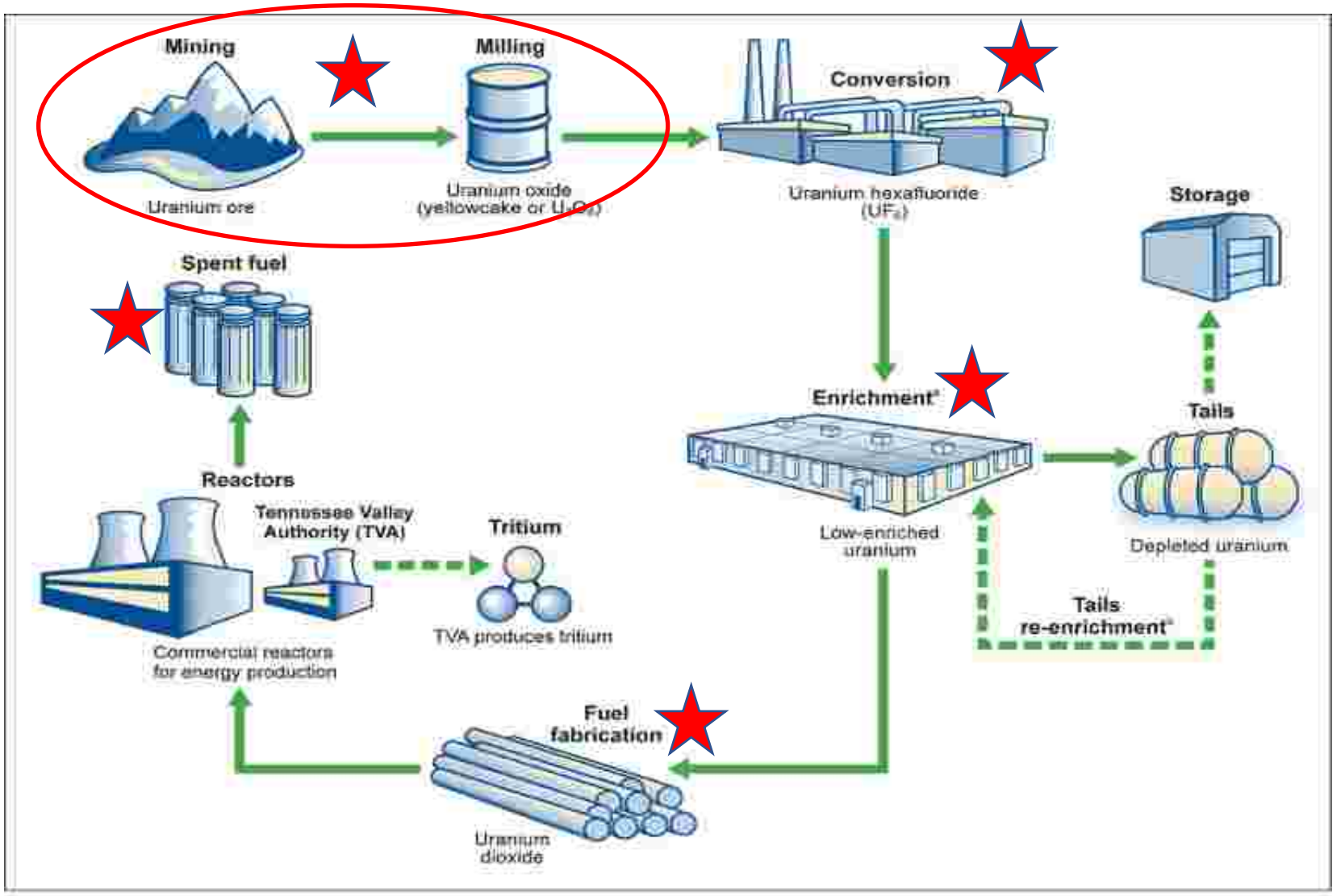
DNA Damage + Zn-rich foods = DNA Repair

Summary of Results

- Studies developed in partnership with community members, designed to answer community questions
- ***Proximity to mine wastes, contaminants in drinking water, and metals in blood and urine associated with increased risks of chronic, metabolic diseases***
- ***Metals – As, Hg, Ni, Ra, U – in drinking water associated with biomarkers of cardiovascular disease, autoimmunity***
- Ecological approach: Cancer rates decreasing or holding steady in NM ***except for certain cancers*** in the two predominant uranium mining counties
- Biomonitoring of contaminant levels in people living near mines can supplement regulatory risk assessments
- Findings of health studies can inform remediation plans for AUMs, e.g.,

Remember the nuclear fuel cycle

★ Emits Carbon



Sources: GAO analysis of International Atomic Energy Agency, Nuclear Regulatory Commission, Congressional Research Service, Department of Energy, and TVA documents. | GAO-15-123

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