Environmental health considerations from mining in the American Southwest

Jonathan Credo, Ph.D.

MS-4

University of Arizona College of Medicine - Tucson

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NAU NORTHERN ARIZONA UNIVERSITY

Northern Arizona University's Land Acknowledgement

Our Land Acknowledgement recognizes the unique and enduring relationship existing between Indigenous Peoples and their traditional territories:

Northern Arizona University sits as the base of the San Francisco Peaks, on homelands sacred to Native Americans throughout the region. We honor their past, present, and future generations, who have lived here for millennia and will forever call this place home.

We respectfully acknowledge the University of Arizona is on the land and territories of Indigenous peoples.

Today, Arizona is home to 22 federally recognized tribes, with Tucson being home to the O'odham and the Yaqui.

Committed to diversity and inclusion, the University strives to build sustainable relationships with sovereign

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Outline and Learning Objectives

Outline

- Case presentation
- Hard-rock mining in the Western US
  - Four Corners
  - Navajo Nation and Uranium
- Mechanism of environmental contamination from mining
- Clinically relevant environmental metals and clinical evaluation
- Community recognition and interpretation
- Engagement with patients as healthcare professionals

Learning Objectives

- Explain pertinent historical mining context in the Four Corners, including uranium
- Outline basic mechanisms leading to environmental contamination from mining
- Identify the large prospective cohort studies for environmentally relevant region metals
- Describe introductory clinical information, including manifestation, management, and potential risks, of discussed metals
- Describe some on-going research work in Four Corners region

AZ – 45M

- 45M no notable PHx, presenting to telehealth w/ **several days progressive** fatigue, dizziness, N/D, h/a, subjective fever/chills. Does not regularly see healthcare professionals, last visit years ago – healthy. OTC acetaminophen PRN & NKDA
- FHx: T2DM, HTN, HLD, obesity, various solid organ tumors (grandparents and aunts/uncles)
- SoHx:
  - Neg EtOH, recreational substances
  - Lives East Coast and Navajo Nation
- **Occupation**: Post-doctorate - Frequently travels to Four Corners region, most recently last week and visited various abandoned uranium mine features collecting water and soil samples. No visible signs displaying hazard or limiting barrier, therefore no PPE.

AZ – 45M, cont.

- Reported to local ED and advised potential contamination. Facility radiation protocol activated – notification of local Hazmat and local poison control center.
- Vitals: 147/88, 94 on RA, RR 20, 98.6F
- PE: Obese, NAD, Skin – no rash/trauma, Neuro – AOx4, CN II-XII grossly intact, Motor BUE/BLE 5/5, Cereb FTN
- Labs:
  - Negative reactivity Geiger-Mueller counter
  - CBC, LFTs, Resp Panel, UA, Coag Studies – WNL; CMP: Borderline elevated Cl (107.6) and Random Glu (108.0)
- Ddx: Uranium exposure, N-H/a, Dizziness, dehydration

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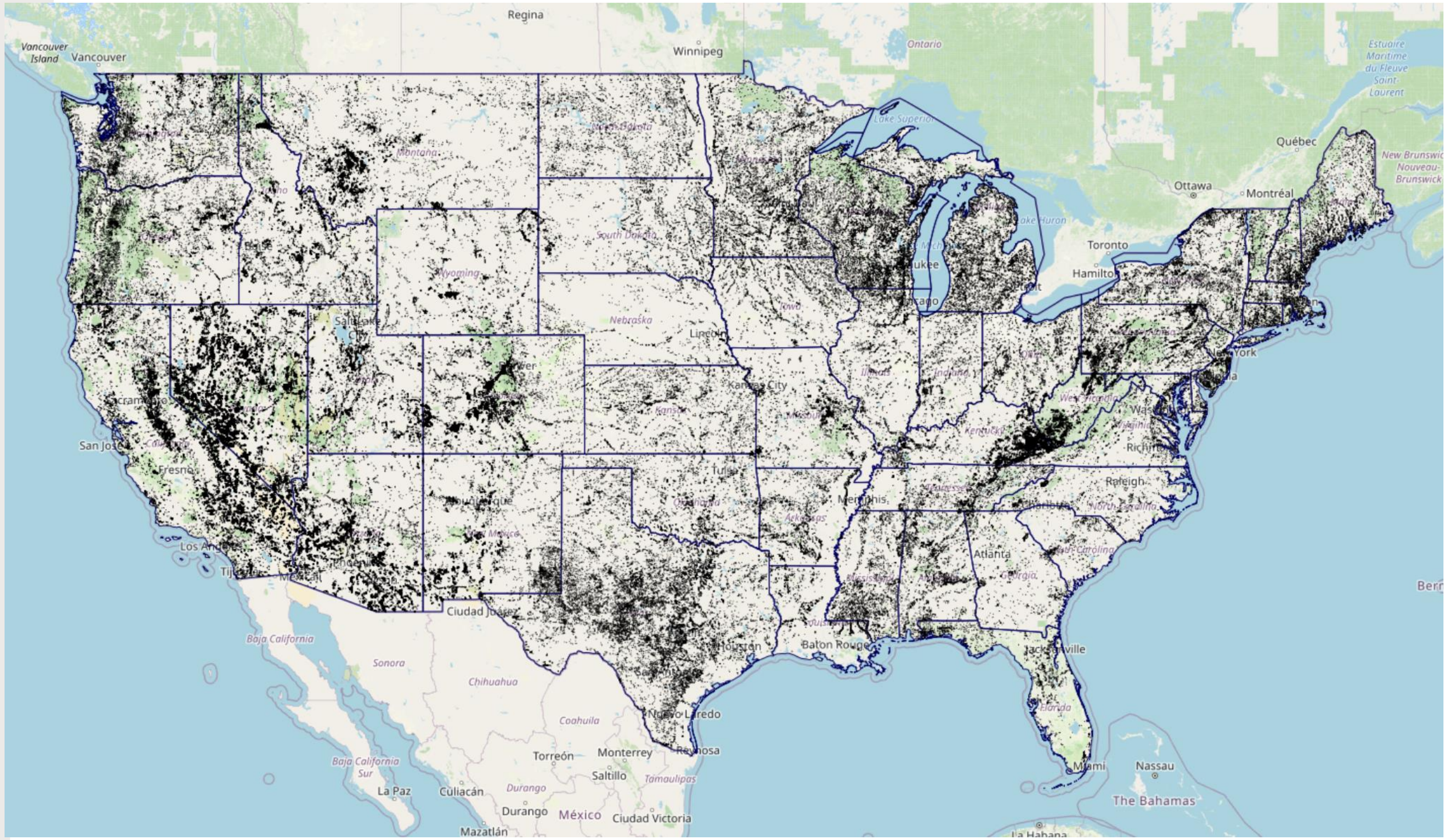
Hard-rock mining & uranium

- 140,000 per Government Accountability Office
- Four-Corners
  - Mining on-going since 1800s
- Uranium mining, 1890s – 1920s; 1940s – 1980s
  - AEC/USDOE
  - Mine and processing jobs staffed by residents – primarily Tribal or minority
- 1955 USPHS Report on miner safety
  - Recommendations
  - 1960s and 1970s
- 1990s and beyond
  - UMTRA
  - DNRPA



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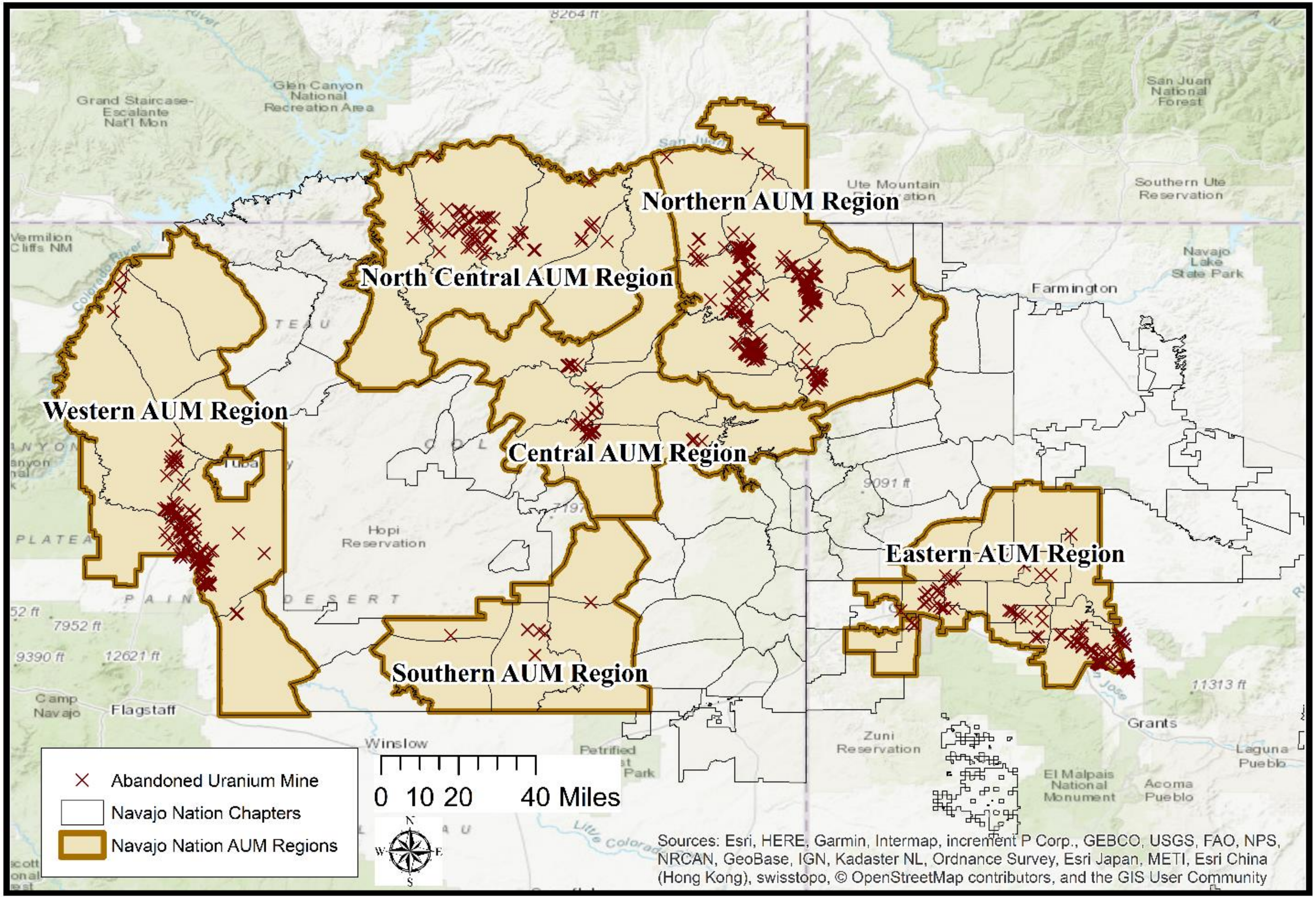
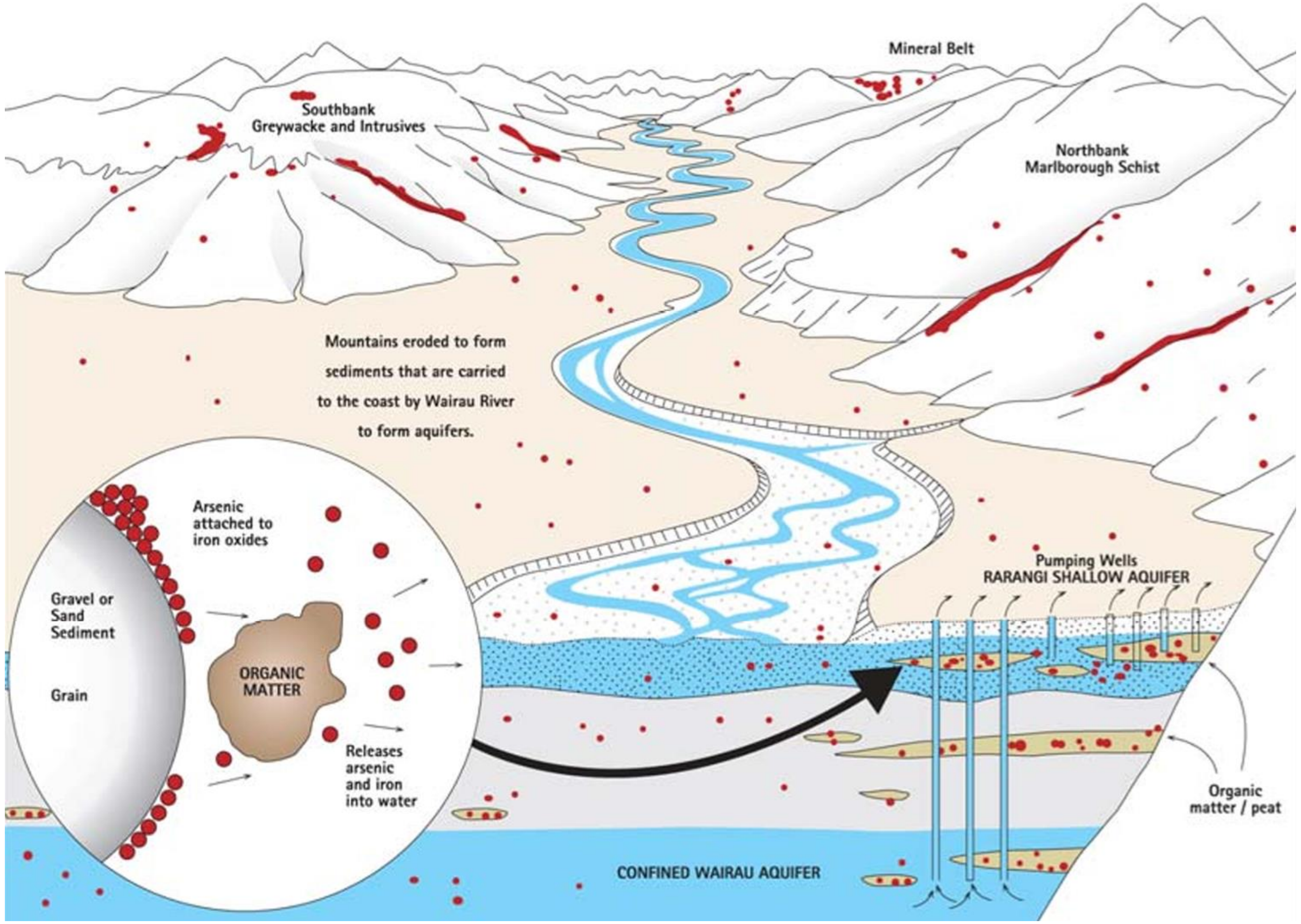

Northern AUM Region
North Central AUM Region
Western AUM Region
Central AUM Region
Southern AUM Region
Eastern AUM Region
Glen Canyon National Recreation Area
Grand Staircase-Escalante Nat'l Mon
San Juan National Forest
Ute Mountain
Southern Ute Reservation
Vermilion Cliffs NM
Navajo Lake State Park
Farmington
Hopi Reservation
Tuba
Flagstaff
Camp Navajo
Winslow
Petrified
Park
Zuni Reservation
El Malpais National Monument
Acoma Pueblo
Laguna Pueblo
Grants
8264 ft
9091 ft
7952 ft
9390 ft
12621 ft
11313 ft
Abandoned Uranium Mine
Navajo Nation Chapters
Navajo Nation AUM Regions
0 10 20 40 Miles
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Environmental contamination

- Mechanism
  - Mining
  - Water exploration
    - Regulated vs unregulated
  - Industrial disasters
- Real world examples
  - Bangladesh
  - New Hampshire
  - Church Rock Spill
  - Gold King Mine Spill



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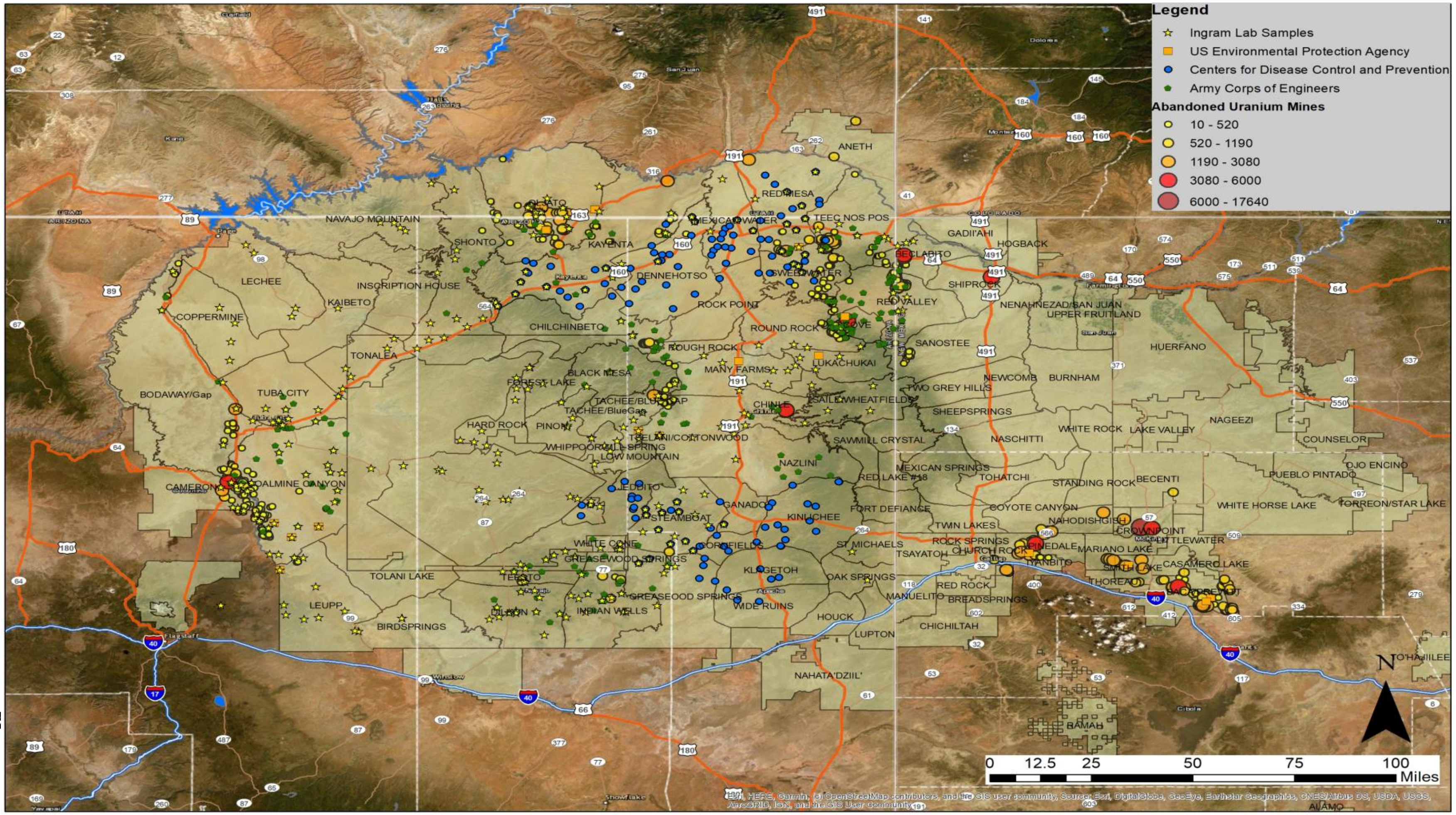
Analytes for investigation

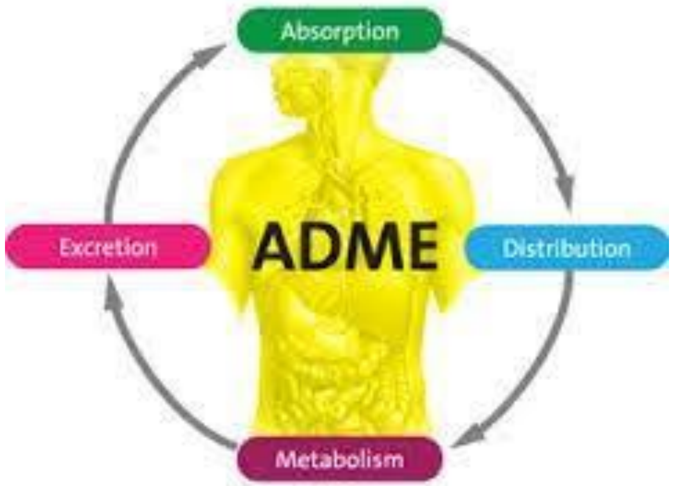
- Credo, J. et al. (2019) – Quantification of elemental contaminants in unregulated water across western Navajo Nation
- Hoover, J. et al. (2017) – Elevated arsenic and uranium concentrations in unregulated water sources on the Navajo Nation, USA
- Army Corps of Engineers & USEPA Water Atlas (2000)

- “Navajo WaterGIS 2.0” (https://unmcop.unm.edu/metals/platform.html)



Toxicology and Pharmacology

- Absorption – Route of exposure: inhalation, ingestion, dermal, injection
- Distribution – Target organ(s)
- Metabolism – Processing and storage
- Excretion - Removal
- Acute and chronic
  - Progression in research and manifestation
- Additive, synergism, potentiation
- Elements: uranium, arsenic, manganese



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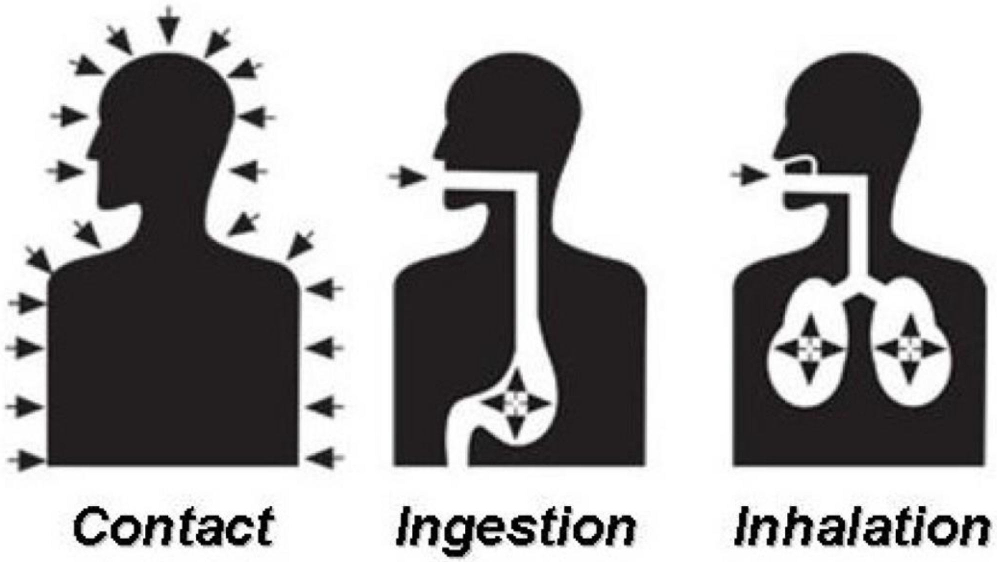

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Uranium

- Radiologic
  - Life-Span Study, Chernobyl, Fukushima-Daiichi
  - Deterministic – Acute
  - Stochastic – Chronic
- Chemical/heavy metal
  - Environmental exposure
    - USPHS uranium miners (e.g., Navajos and Hopis)
- Psychological impact

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Acute Radiation Syndrome (ARS)

- Hours – week timescale w/ nonspecific initial presentation
- Dependent on dose and degree of exposure
- Prodromal Phase (0-2d)
    - Non-specific
    - Early onset and persistence
    - 1-2 Gy
- Latent Phase (2-20d)
    - Period of improvement
    - Inversely related to dose
- Manifest Phase (21-60d)
    - Predictable pattern of progression
- Recovery
    - Dependent on extent of organ damage and healthcare resources
    - Life-long morbidity

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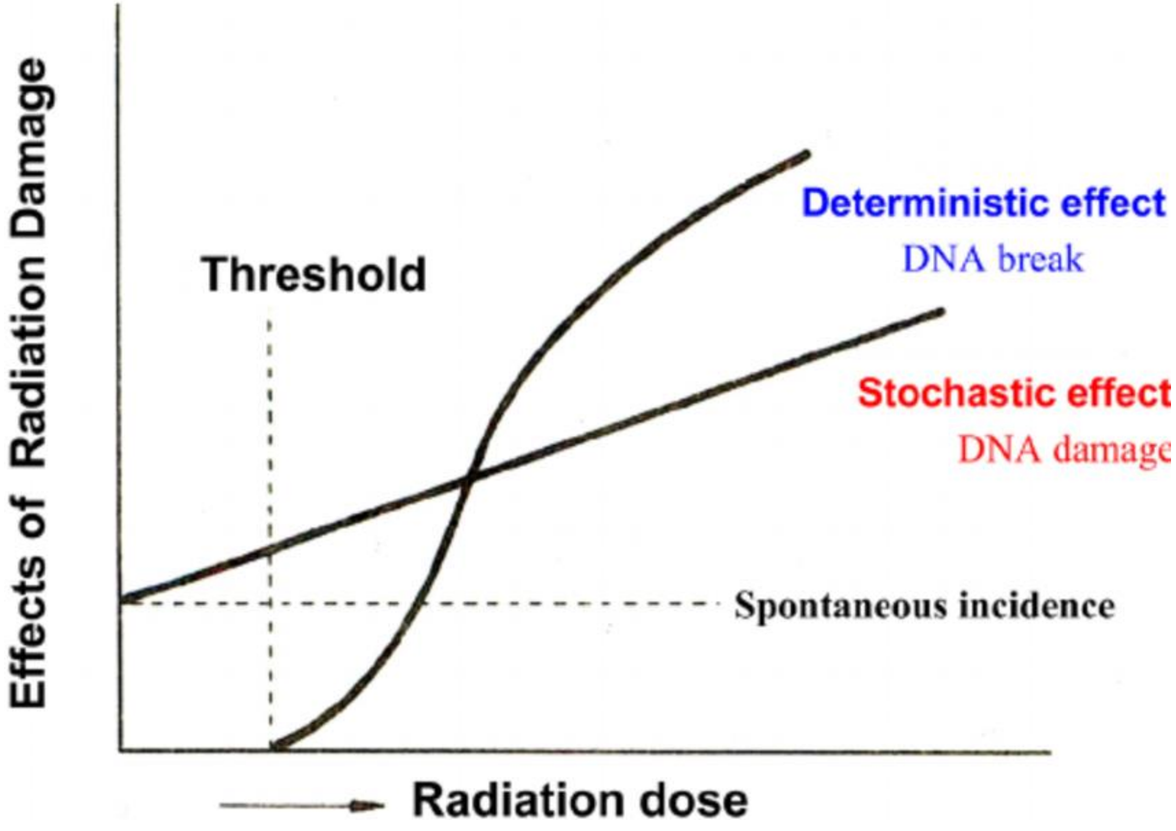
ARS Sub-syndromes

- Cutaneous
  - >3Gy, >6Gy, >10Gy, >15Gy, >20Gy
- Hematopoietic
  - Predictable dose and time-dependent effects manifesting as cytopenias
- Gastrointestinal
  - Varies w/ dose and time from exposure
- Neurovascular
  - Nonspecific and overlapping to severe cognitive impairment

Long-term morbidity & chemical considerations

- Stochastic effect
  - Carcinogenesis – Stomach and liver
  - Immunological dysfunction
  - Age-dependent
    - In utero, pediatrics, adolescence
- Chemical
  - IARC and USEPA – Not a carcinogen, association related to radiation
  - Localization – Kidneys and bone
    - Additive risk w/ potential for extinction
  - Impacts on brain, heart, reproductive, estrogenic
  - Immunological dysfunction



Immunological dysfunction

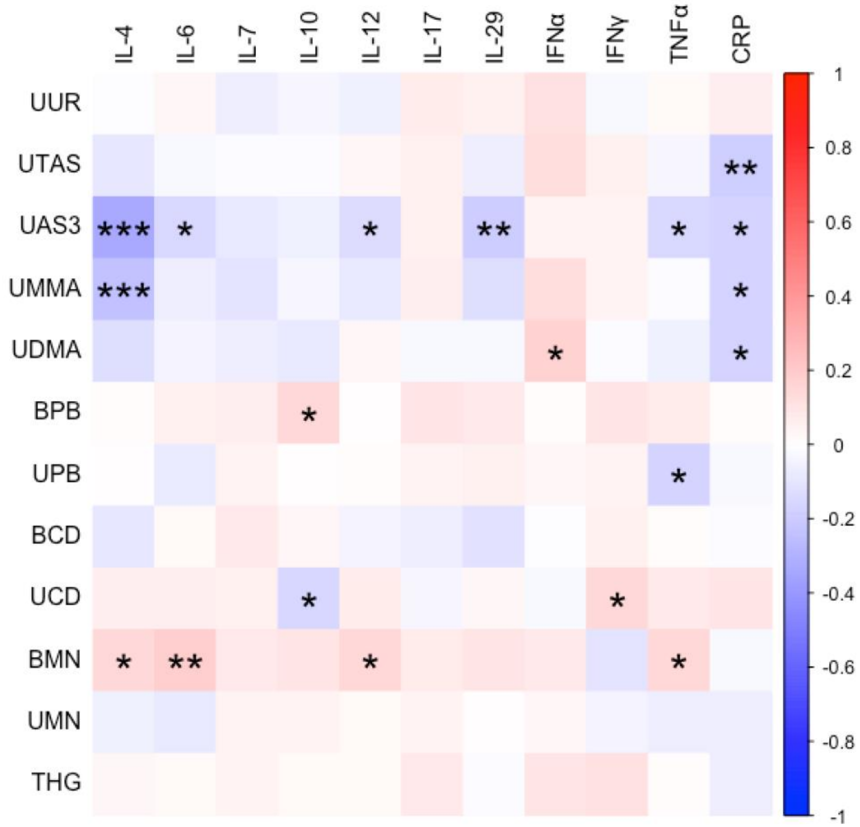


Figure 3. Spearman's correlations between metal biomonitoring and biomarkers. Correlation coefficient is designated by color with blues designating negative correlations and reds designating positive correlations. Asterisks denote significant correlations at the $p < 0.05$ (*), 0.01 (**), and 0.001 (***).

Abbr.	Metal/Metabolite
UUR	**Uranium**
UTAS	Total arsenic
UAS3	**Arsenite (AsIII)**
UMMA	**Monomethylarsonic acid**
UDMA	**Dimethylarsinic acid**
BPB	Lead
UPB	Lead
BCD	**Cadmium**
UCD	**Cadmium**
BMN	**Manganese**
UMN	**Manganese**
THG	Total mercury

Patient approach

Emergent

- Determine source and timing
- +/- decontamination and isolation
- History
- PE & vitals – Focus on subsyndromes
- Labs – CBC w/ diff serialized, clotting times, CMP and LFT, 24hr – Li-heparin

Primary Care/Ambulatory

- Symptom manifestation and timing
- Family history
  - Cancers – solid organ
- Social history
  - Residence (current and historic), occupation, recreational substance use, water source, building material
- Counseling
  - Behavioral/mental health resources

Psychological consideration

- Unable to visualize, images of destruction, polarized, misconceptions about radiation, social stigma, delayed manifestations
- LSS, Chernobyl, Navajo Nation
  - Generational trauma
- Non-specific manifestation overlap
- Radiation Emergency Medical Management
  - https://remm.hhs.gov/psych.htm

Table 2 Differences in Chornobyl risk perceptions among exposure groups

	Evacuees ($n = 265$) %	Classmate controls ($n = 261$) %	Population controls ($n = 327$) %	Overall χ^2	Pairwise comparisons[a]
Adolescent reports					
Health very affected by Chornobyl	19.6	8.8	13.8	12.8**	E > C
Chornobyl most influential event of life	22.6	5.4	6.1	53.0***	E > C, P
Future generations very affected by Chornobyl	12.8	16.1	17.4	2.4	
Consequences worse than feared	17.7	14.9	21.4	4.1	
Number of negative beliefs					
0	51.3	66.7	59.9	14.4**	E > C
1	30.6	23.4	27.2		
2+	18.1	10.0	12.8		
	Evacuees ($n = 243$) %	Classmate controls ($n = 234$) %	Population controls ($n = 296$) %	Overall χ^2	Pairwise comparisons[a]
Mother reports					
Health very affected by Chornobyl	54.3	25.6	24.0	65.2***	E > C, P
Chornobyl most influential event of life	70.8	17.5	13.9	231.8***	E > C, P
Future generations very affected by Chornobyl	47.7	41.0	36.5	7.0*	
Consequences worse than feared	37.0	26.5	25.7	9.7**	E > P
Number of negative beliefs					
0	19 (7.8)	84 (35.9)	106 (35.8)	112.4***	E > C, P
1	40 (16.5)	62 (26.5)	87 (29.4)		
2+	184 (75.7)	88 (37.6)	103 (34.8)		

E evacuees; *C* classmate controls; *P* population controls

[a] Pairwise comparisons were performed using the Bonferroni adjustment; the sign ">" indicates significant pairwise differences ($p < 0.05$)

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3 Associations of risk perceptions with 12-month MDD/GAD and current symptom severity

	12-month MDD/GAD[a]		Anxiety/depression symptoms[b]	
	Unadjusted model OR (95% CI)	Adjusted model aOR (95% CI)	Unadjusted model β (95% CI)	Adjusted model β (95% CI)
Chornobyl risk factors				
Adolescent perceptions				
0	1.0	1.0	0.00	0.00
1	1.2 (0.7–2.1)	1.3 (0.7–2.5)	0.20 (0.05–0.36)**	0.09 (−0.05 to 0.23)
2+	2.2 (1.2–4.0)**	1.8 (0.9–3.9)	0.47 (0.26–0.67)***	0.26 (0.08–0.44)**
Mothers' perceptions				
0	1.0	1.0	0.00	0.00
1	0.9 (0.5–1.7)	0.8 (0.4–1.8)	0.10 (−0.09 to 0.29)	−0.02 (−0.17 to 0.14)
2+	1.2 (0.7–2.1)	1.1 (0.5–2.1)	0.16 (−0.01 to 0.33)	−0.08 (−0.23 to 0.07)
Exposure group				
Evacuee	0.6 (0.3–1.1)	0.4 (0.2–0.9)*	−0.034 (−0.2 to 0.13)	−0.12 (−0.27 to 0.04)
Classmate	0.9 (0.5–1.5)	1.1 (0.6–2.0)	−0.16 (−0.32 to 0.01)	−0.09 (−0.23 to 0.06)
Population control	1.0	1.0	0.00	0.00
Epidemiologic risk factors[c]				
Female gender	3.2 (1.9–5.4)***	2.8 (1.5–5.1)***	0.64 (0.52–0.77)***	0.52 (0.4–0.64)***
Not attending university	1.3 (0.8–2.1)	1.2 (0.7–2.2)	0.03 (−0.11 to 0.17)	−0.06 (−0.19 to 0.07)
Self-esteem[d]	1.8 (1.4–2.3)***	1.7 (1.3–2.2)***	0.48 (0.42–0.53)***	0.36 (0.30–0.42)***
Life events[d]	1.7 (1.4–2.1)***	1.8 (1.3–2.3)***	0.23 (0.16–0.30)***	0.14 (0.08–0.20)***
Peer support[d]	1.3 (1.1–1.6)**	1.4 (1.1–1.9)**	0.24 (0.17–0.31)***	0.16 (0.10–0.22)***
Parental communication[d]	1.5 (1.2–1.9)***	1.3 (1.0–1.7)	0.29 (0.22–0.35)***	0.20 (0.14–0.26)***
Father belligerent when intoxicated	1.1 (0.5–2.2)	0.7 (0.3–1.7)	0.52 (0.30–0.74)***	0.33 (0.15–0.51)***
Neither parent graduated from university	0.9 (0.6–1.5)	0.7 (0.4–1.3)	0.18 (0.04–0.32)**	0.10 (−0.02 to 0.23)
Mother MDD/GAD	1.4 (0.8–2.4)	1.3 (0.7–2.4)	0.29 (0.12–0.5)***	0.19 (0.05–0.33)**
		Pseudo R^2 0.22		Adjusted R^2 0.40

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] Logistic regression analysis: *OR* odds ratio; *aOR* adjusted odds ratio; *CI* confidence interval

[b] Ordinary least squares (OLS) regression analysis: betas for continuous variables were standardized

[c] Interaction terms for group × each of the other risk factors were all non-significant

[d] High score = worse. Standardized to facilitate interpretation of odds ratios

Arsenic

- Elemental, inorganic, organic
- Bangladesh
  - Unicef – 1970s
  - Health Effects of Arsenic Longitudinal Study (HEALS)
- Acute and chronic nature
  - Dose-dependent
    - High, moderate, low
  - Life-long risk w/ significant dose

Mechanism of Action/Toxicity

- Trivalent
  - Proteins, enzymes
- Pentavalent
  - Energy production
- Cardiotoxicity
  - Clotting and remodeling
- Carcinogenesis – IARC Class 1 and 2B
  - Epigenetics

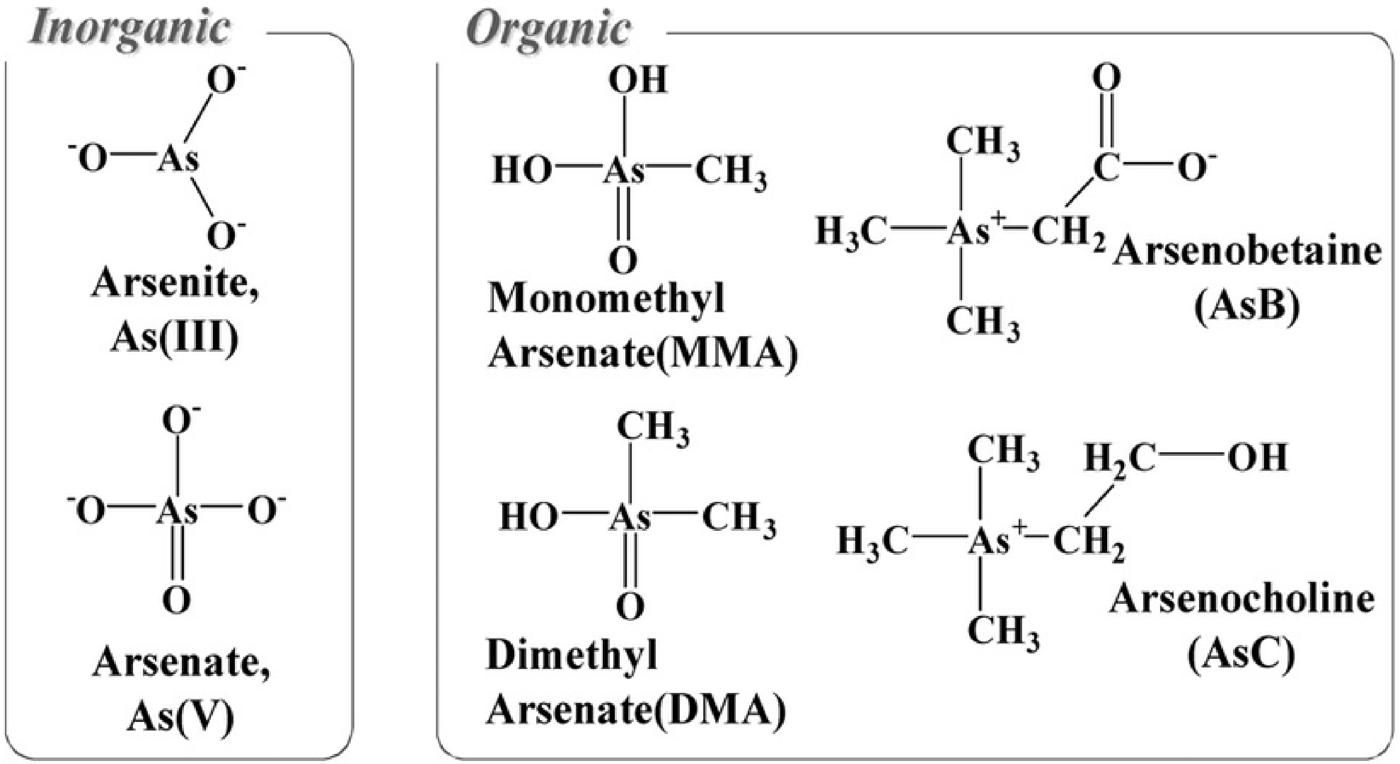
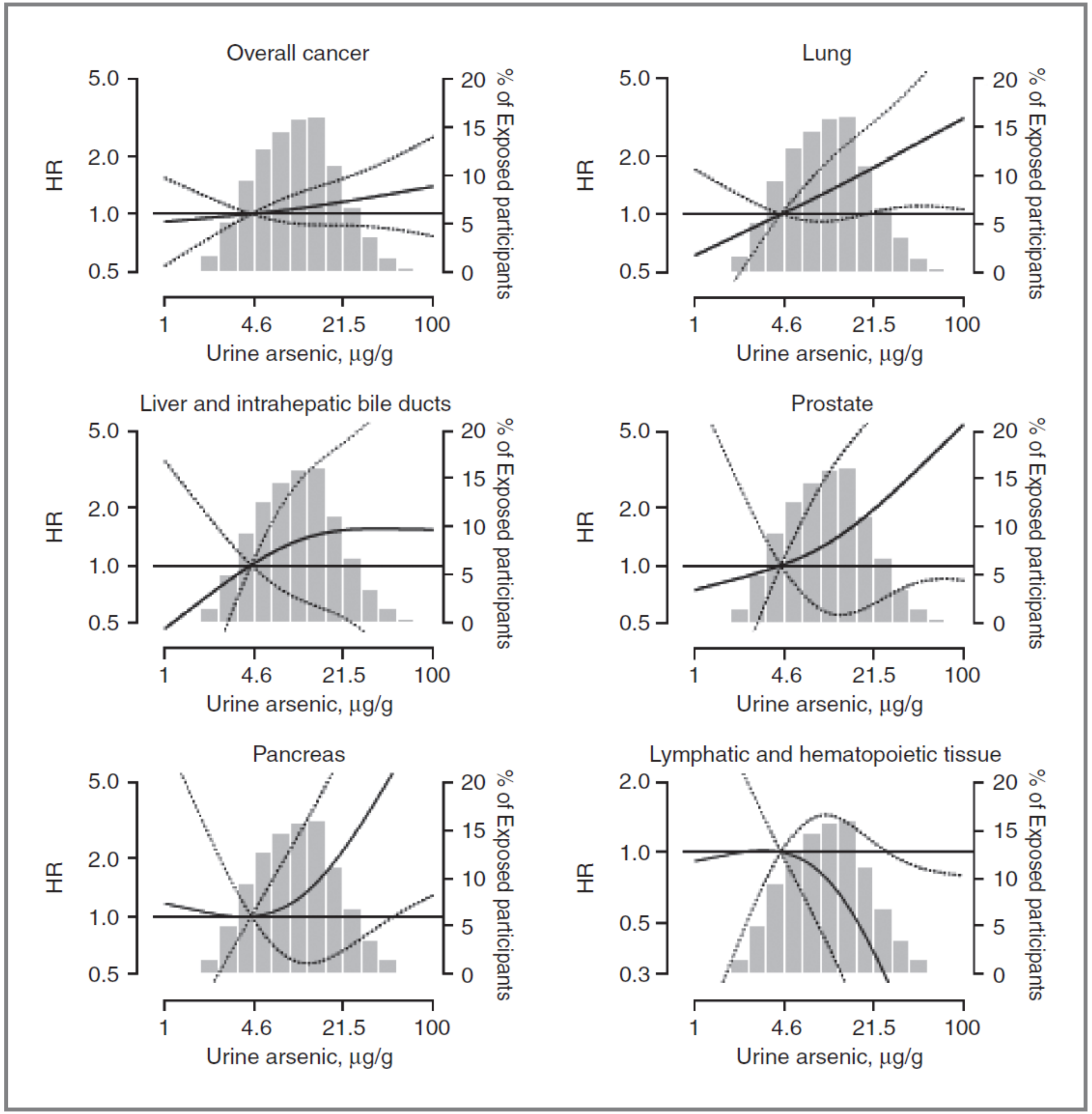
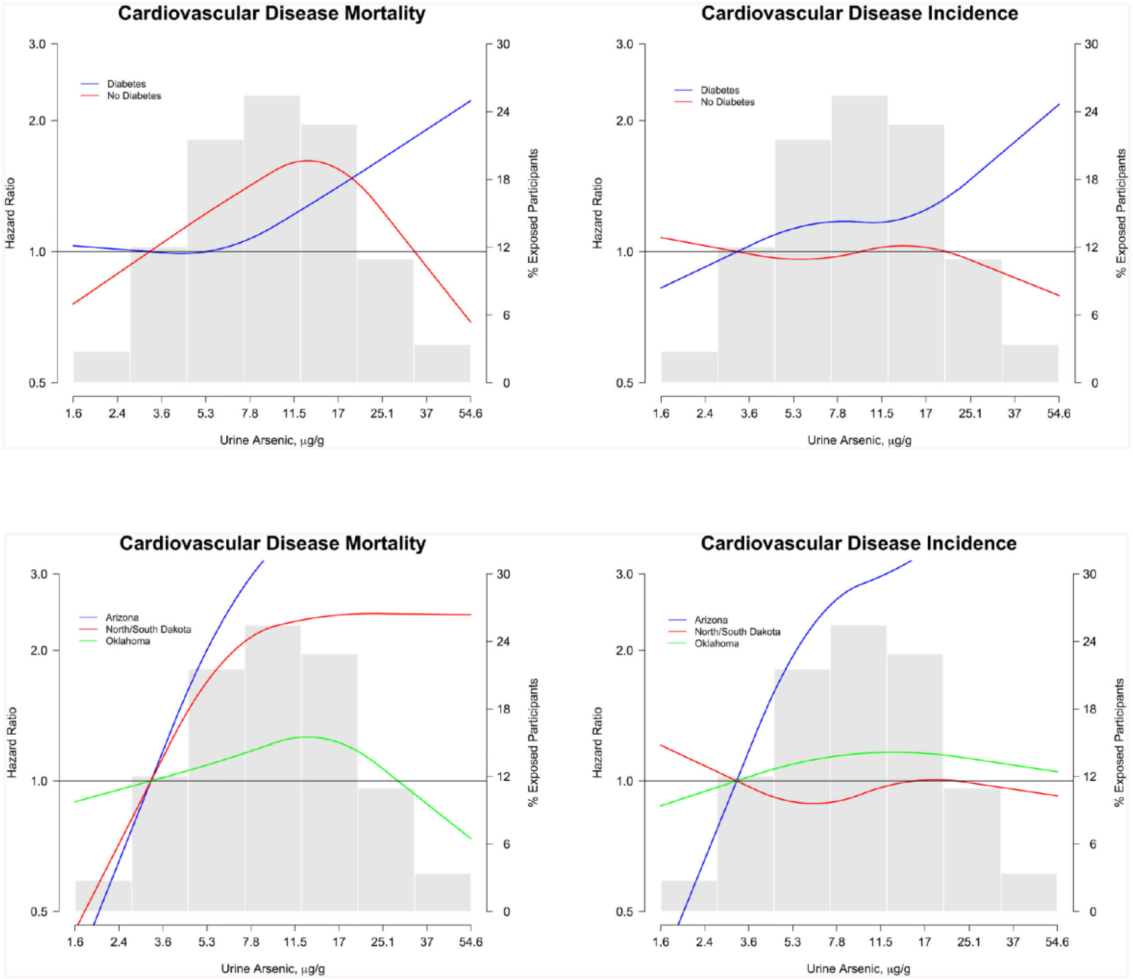
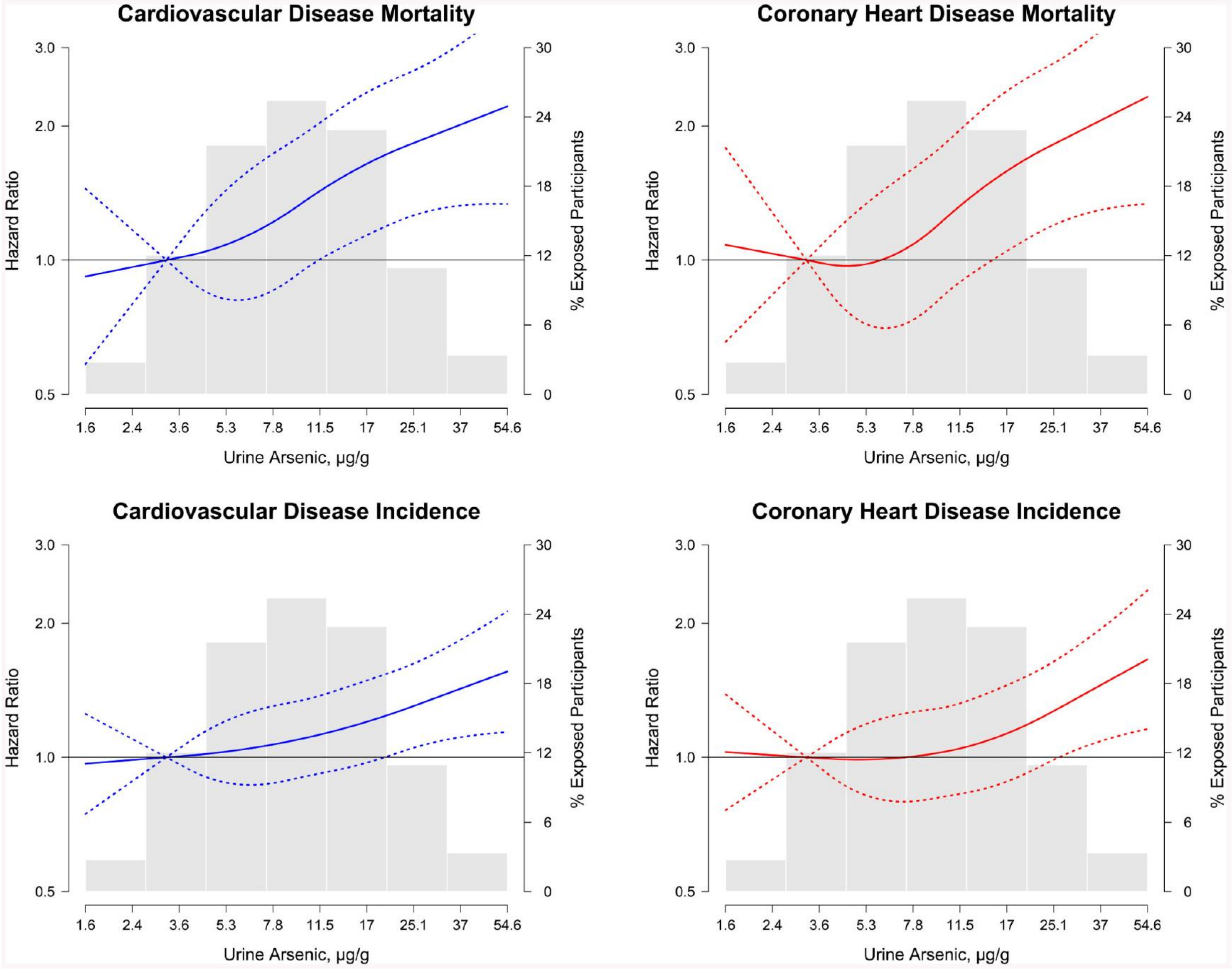


Figure 1. HRs for cancer mortality by urinary arsenic concentrations. Lines represent the HR (thick line) and 95% CIs (thin line) for overall and specific cancer mortality based on restricted cubic splines for log-transformed sum of inorganic and methylated species with knots at the 10th (3.8 μg/g creatinine), 50th (9.7 μg/g), and 90th (24.0 μg/g) percentiles. The reference was set at the 10th percentile of arsenic distribution. Models were adjusted for age, sex, education (no high school, some high school, or completed high school), smoking status (never, former, or current), drinking status (never, former, or current), and BMI (kg/m^2). Vertical bars represent the histogram of arsenic distribution in the study population.



Cardiotoxicity





- Moon, K. A. et al. (2013) – Association between low to moderate arsenic exposure and incident cardiovascular disease. A prospective cohort study
- James K. A. et al. (2015) – Association between lifetime exposure to inorganic arsenic in drinking water and coronary heart disease in Colorado residents
- Moon, K. A. et al. (2018) – Association of low-moderate urine arsenic and QT interval: cross-section and longitudinal evidence from the Strong Heart Study
- Kononenko, M. & Frishman, W. H. (2021) – Association between arsenic exposure and cardiovascular disease

Table 3 Weighted Odds Ratio (95% Confidence Interval) of Airflow Obstruction and Restrictive Pattern, Defined Based on Fixed Ratios, by Urinary Arsenic Concentration

	Inorganic Plus Methylated Arsenic Species μg/g creatinine			P-trend[e]
	Tertile 1 ≤7.0[d]	Tertile 2 7.1–13.9[d]	Tertile 3 ≥14.0[d]	
Airflow obstruction[a]/Healthy[b]	157/600	167/469	134/298	
Model 1	1.00 (Ref)	1.15 (0.93, 1.43)	1.45 (1.10, 1.91)	
Model 2	1.00 (Ref)	1.11 (0.89, 1.39)	1.34 (1.01, 1.77)	
Model 3	1.00 (Ref)	1.12 (0.90, 1.40)	1.33 (0.99, 1.77)	
Model 4	1.00 (Ref)	1.12 (0.90, 1.41)	1.33 (0.99, 1.79)	
Restrictive pattern[c]/ Healthy[b]	125/600	89/469	93/298	
Model 1				
Model 2				
Model 3				
Model 4				

Model 1: adjusted for age, sex
Model 2: further adjusted for s
Model 3: further adjusted for e
Model 4: sensitivity analysis: fu
[a]Fixed airflow obstruction: FEV
[b]Healthy: FEV1/FVC > 0.70 & F
[c]Restrictive pattern: FEV1/FVC
[d]Tertiles are range; calculated
[e]P-trend calculated modeling l
[f]Comparison of the 75th and 2

Table 4 Weighted Odds Ratio (95% Confidence Interval) of Airflow Obstruction and Restrictive Pattern, Defined Based on the Lower Limit of Normal (LLN), by Urinary Arsenic Concentration (*N* = 2132)

Airflow obstruction[a]/Healthy	
Model 1	
Model 2	

Table 5 Weighted Mean Difference (95% Confidence Interval) of Lung Function at Visit 2 (Concentration at Baseline (1989–1991)

	N	Inorganic Plus Methylated Arsenic Species μg/g creatinine		
		Tertile 1 ≤7.0[b]	Tertile 2 7.1–13.9[b]	Tertile 3 ≥14.0[b]
FEV1, % predicted				
All	2132	0 (Ref)	0.92 (−0.52, 2.37)	−1.64 (−3.60, 0.32)
Healthy[a]	1367	0 (Ref)	0.67 (−0.86, 2.19)	−0.49 (−2.58, 1.61)
FVC, % predicted				
All	2132	0 (Ref)	2.09 (0.72, 3.47)	−1.01 (−2.85, 0.83)
Healthy[a]	1367	0 (Ref)	1.15 (− 0.23, 2.53)	− 0.73 (− 2.60, 1.14)
FEV1/FVC (%)				
All	2132	0 (Ref)	−0.62 (−1.26, 0.002)	− 0.16 (− 1.01, 0.69)
Healthy[a]	1367	0 (Ref)	− 0.31 (− 0.85, 0.25)	0.26 (− 0.49, 1.01)
FEV1, mL				
All	2132	0 (Ref)	0.007 (−0.04, 0.06)	−0.09 (− 0.15, − 0.03)
Healthy[a]	1367	0 (Ref)	0.003 (− 0.05, 0.06)	−0.06 (− 0.14, 0.01)
FVC, mL				
All	2132	0 (Ref)	0.06 (−0.004, 0.11)	−0.10 (− 0.17, − 0.02)
Healthy[a]	1367	0 (Ref)	0.02 (− 0.05, 0.09)	−0.09 (− 0.19, − 0.0001)

Adjusted for age, sex, education, site, smoking status, smoking pack-year, eGFR, tuberculosis, and BMI
[a]Healthy: FEV1/FVC > 0.70 & FVC > 80% predicted
[b]Tertiles are range; calculated based on overall population; sum of inorganic and methylated species μg/g crea
[c]Comparison of the 75th and 25th percentiles (interquartile range) of the sum inorganic and methylated urinar 5.8 μg/g creatinine)
[d]*P*-trend calculated modeling log-arsenic as continuous

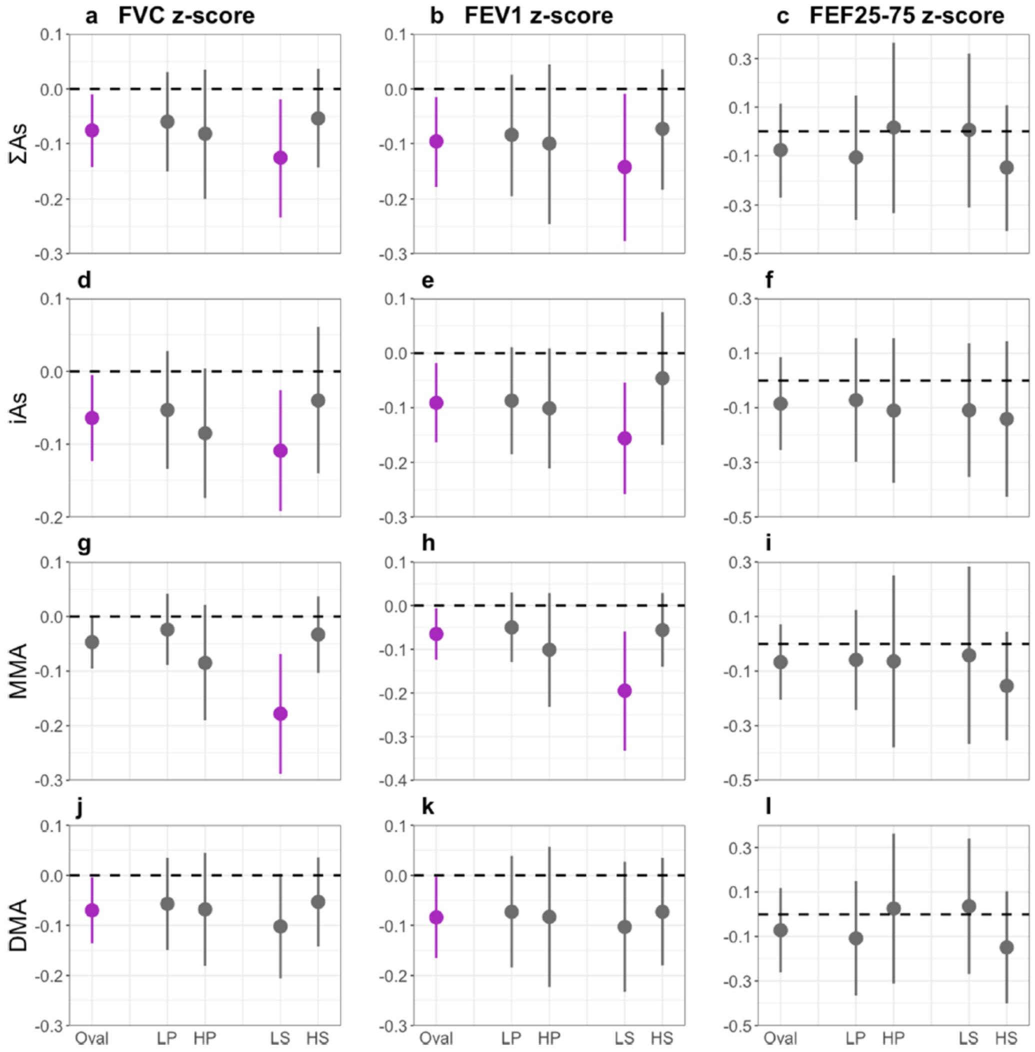


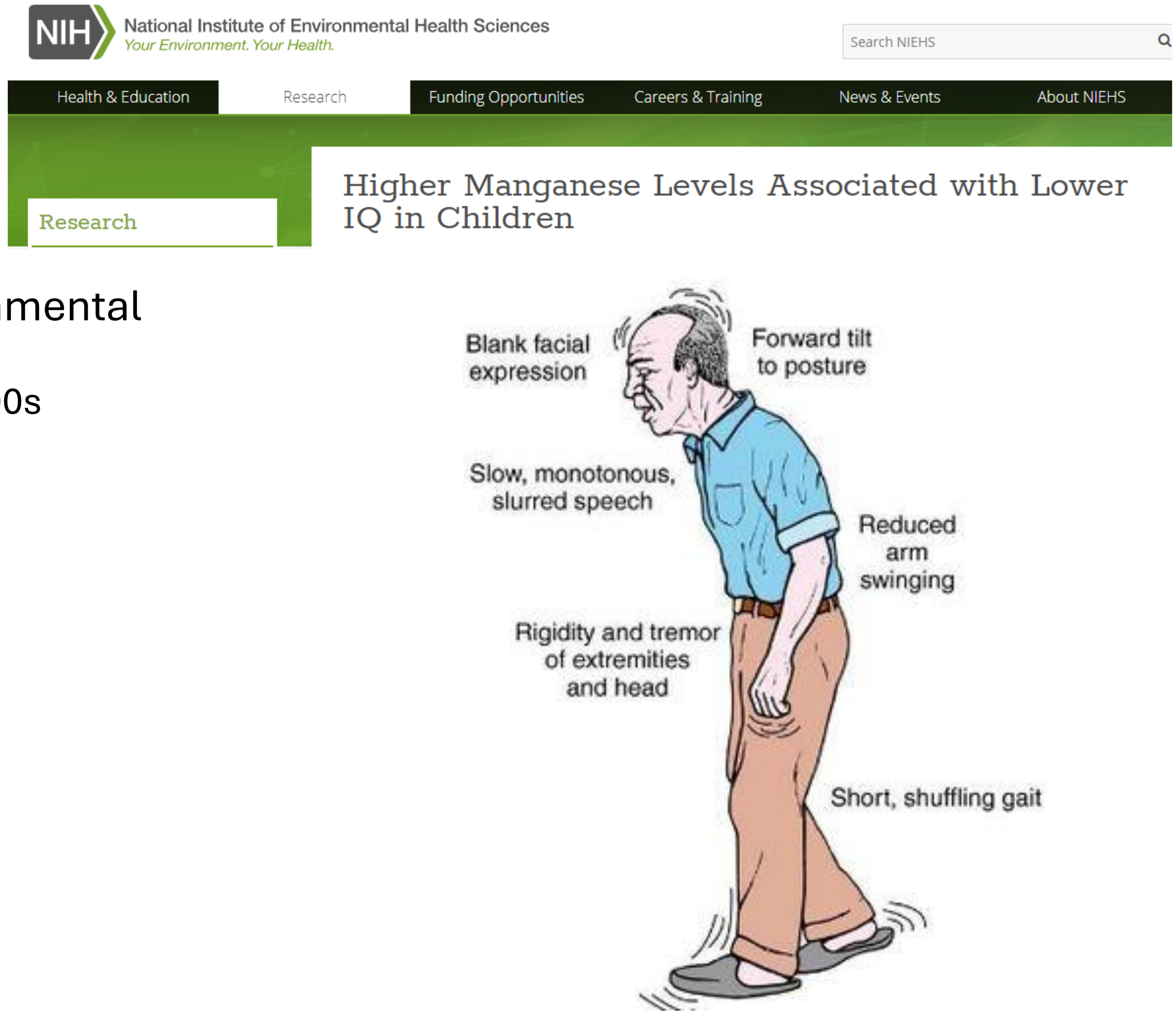
Fig. 1. Association between maternal urinary arsenic species concentration and standardized z-scores from children's spirometry. Oval = overall (*n* = 358); LP = low primary methylation index (PMI < median; *n* = 179); HP = high primary methylation index (PMI > median; *n* = 179); LS = low secondary methylation index (SMI < median; *n* = 179); HS = high secondary methylation index (SMI > median; *n* = 179). Linear regression models with spirometry parameters standardized z-score as dependent variables and log_2-transfomed maternal urinary arsenic species concentrations specific gravity corrected as independent variables adjusted for maternal smoking status, children's age, sex, and height. Notice that the scale of the y-axis vary in order to facilitate the visualization of the estimates in each plot.

Clinical evaluation

- Acute
  - “Poisoner of Kings”
  - Pattern of GI distress progressing to CV collapse
- Chronic – primary care/ambulatory
  - History
    - Occupation, residence, water source, lifestyle – exercise and diet
  - PE – High dose
  - Laboratory
    - Blood
    - Urine
    - Hair and nail
- Seafood consideration
- Pregnancy and Pediatrics

Manganese

- Acute and chronic
  - Occupation versus environmental
  - High to low concentration
    - Canada studies in late 2000s
- Age-dependent
  - State of development
- Adults
  - Extrapyramidal preference
    - “Parkinson’s-like”
- Children
  - Learning
- Clinical evaluation



Behavioral manifestation

Table 2. Associations of W-Mn (mg/L) during pregnancy and at 5 and 10 y of age with measures of cognitive abilities at 10 y.

	Age- and gender-adjusted model		Multivariable-adjusted model 1[a]		Multivariable-adjusted model 2[b]		
Exposure windows	β (95% CI)	*p*-Value	β (95% CI)	*p*-Value	β (95% CI)	*p*-Value	*p*-Interaction[c]
W-Mn in pregnancy	(*n*=1,265)		(*n*=1,201)		(*n*=554)		
Full-Scale IQ	4.5 (2.5, 6.5)	<0.001	1.0 (–0.69, 2.7)	0.25	0.42 (–1.6, 2.5)	0.69	0.029
Verbal Comprehension	1.5 (0.87, 2.1)	<0.001	0.37 (–0.17				
Perceptual Reasoning	1.2 (0.50, 1.9)	0.001	0.26 (–0.40				
Working Memory	0.61 (0.24, 0.98)	0.001	0.17 (–0.17				
Processing							
W-Mn at 5							
Full-Scale I							
Verbal Cor							
Perceptual							
Working M							
Processing							
W-Mn at 1(							
Full-Scale I							
Verbal Cor							
Perceptual							
Working M							
Processing							

Abbreviation
[a]Adjusted fo
bin concentr
Measuremen
[b]Adjusted as
[c]In model 2,

Table 4. Multivariable-adjusted odd ratios (95% confidence intervals) for raised SDQ difficult scores (low prosocial) at 10 y in relation to W-Mn (mg/L) during pregnancy and childhood.

ted model 1[a]	Multivariable-adjusted model 2[b]		
p-Value	OR (95% CI)	*p*-Value	*p*-Interaction[c]
	(*n*=554)		
0.013	1.29 (1.08, 1.53)	0.005	0.22
0.20	1.03 (0.86, 1.23)	0.74	0.090
0.85	0.96 (0.81, 1.14)	0.66	0.16
0.14	0.70 (0.51, 0.97)	0.034	0.18
0.093	1.27 (1.03, 1.57)	0.025	0.35
	(*n*=705)		
0.016	1.26 (1.07, 1.48)	0.005	0.44
0.56	1.06 (0.89, 1.26)	0.49	0.25
0.66	0.98 (0.83, 1.15)	0.79	0.18
0.077	0.72 (0.52, 0.99)	0.045	0.57
0.63	1.11 (0.92, 1.34)	0.28	0.60
	(*n*=801)		
0.007	1.18 (1.05, 1.34)	0.007	0.31
0.69	0.96 (0.84, 1.11)	0.61	0.43
0.12	0.89 (0.78, 1.01)	0.073	0.074
0.037	0.83 (0.66, 1.05)	0.12	0.71
0.031	1.23 (1.05, 1.43)	0.009	0.25

Questionnaire; W-Mn, water manganese concentration.
(years), gender, education (<3, 3, and >3 years), height for age (HAZ) at 10 years,
O (nonprofit private), and English medium (private) school], Home Observation for
at each respective time point (natural log–transformed).
int.

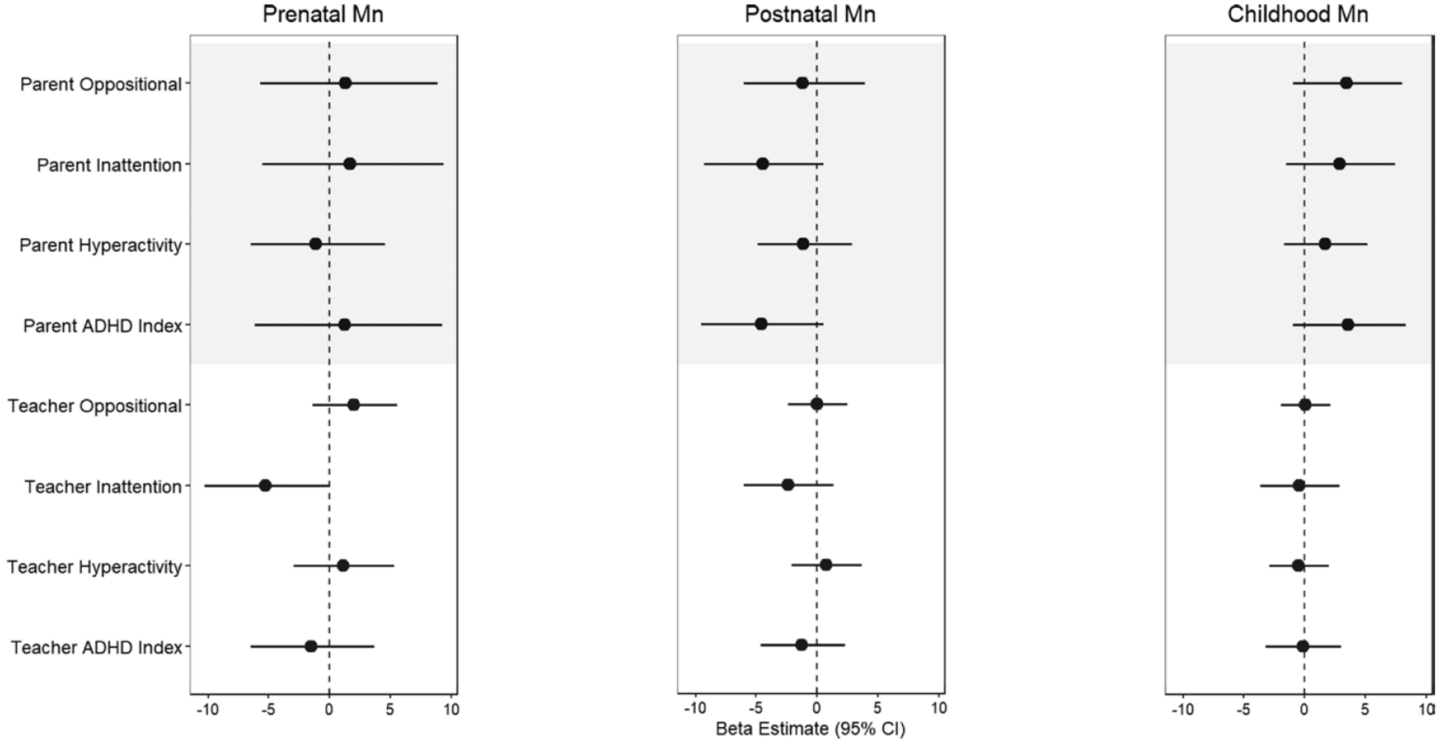


Figure 2. Adjusted beta (β) estimates and 95% CIs from multivariable linear regression models assessing associations between prenatal, postnatal, and childhood tooth Mn levels with parent- and teacher-reported scores from the Conners Rating Scales. Beta coefficients reflect the percent change in age- and sex-adjusted Conners T-scores for a doubling in tooth Mn levels. *Multivariable linear regression models were mutually adjusted for Mn in all exposure periods, and socioeconomic status, HOME score, tooth attrition, and ln-transformed blood Pb. **prenatal period = 2nd trimester of gestation to birth, postnatal period = birth to ~1.5 years, childhood = ~1.5 to 6 years.

Community Recognition

- Context of mining history
  - “Bringing ‘badness’ to the surface”
- Holistic interpretation
- Legacy contamination
  - Water
  - Food
- Rock, T. et al. (2019) – Traditional sheep consumption by Navajo people n Cameron, Arizona
- ***<INSERT RELEVENT LISTER PUB>***

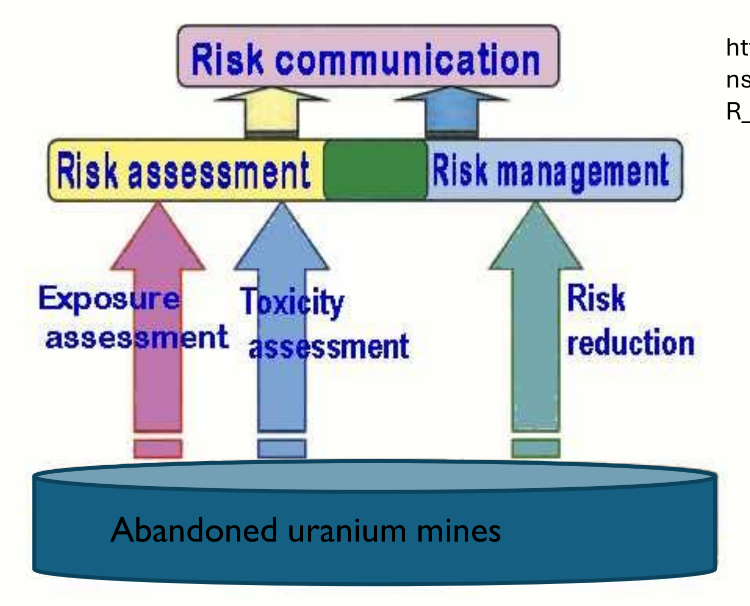


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Table 3. Mutton eating habits among participants who completed the sheep survey, 2017 (N = 72)

Question	Response, N (%)							
	All Participants	Gender		Age Group (years)				
		Men	Women	18-25	26-39	40-55	56-70	>70
Do you think or worry whether it's safe to eat mutton?								
Yes	23 (32.4)	7 (25.0)	16 (37.2)	2 (28.6)	2 (15.4)	3 (17.7)	7 (33.3)	9 (69.2)
No	34 (47.9)	18 (64.3)	16 (37.2)	4 (57.1)	9 (69.2)	10 (58.8)	9 (42.9)	2 (15.4)
Sometimes	14 (19.7)	3 (10.7)	11 (25.6)	1 (14.3)	2 (15.4)	4 (23.5)	5 (23.8)	2 (15.4)
Missing *	1	1	0	0	0	0	0	1
At what events to you eat sheep? **								
Regular meal	18 (25.0)	5 (17.2)	13 (30.2)	0 (0.0)	2 (15.4)	6 (35.3)	4 (19.1)	6 (42.9)
Ceremony	39 (54.2)	15 (51.7)	24 (55.8)	6 (85.7)	7 (53.9)	9 (52.9)	8 (38.1)	9 (64.3)
Holiday	38 (52.8)	9 (31.0)	29 (67.4)	4 (57.1)	9 (69.2)	7 (41.2)	12 (57.1)	6 (42.9)
Family gathering	60 (83.3)	22 (75.9)	38 (88.4)	7 (100.0)	11 (84.6)	14 (82.3)	18 (85.7)	10 (71.4)
Community event	30 (41.7)	10 (34.5)	20 (46.5)	1 (14.3)	6 (46.2)	6 (35.3)	12 (57.1)	5 (35.7)
Do you think people eat more mutton in your childhood compared to today?								
Yes	52 (73.2)	20 (71.4)	32 (74.4)	6 (85.7)	7 (53.9)	10 (58.8)	17 (81.0)	12 (92.3)
No	19 (26.8)	8 (28.6)	11 (25.6)	1 (14.3)	6 (46.1)	7 (41.2)	4 (19.0)	1 (7.7)
Missing *	1	1	0	0	0	0	0	1

* Missing not included in percent
** Participants may choose more than one response

Table 4. Frequency of consumption among participants who completed the sheep survey, 2017 (N = 72)

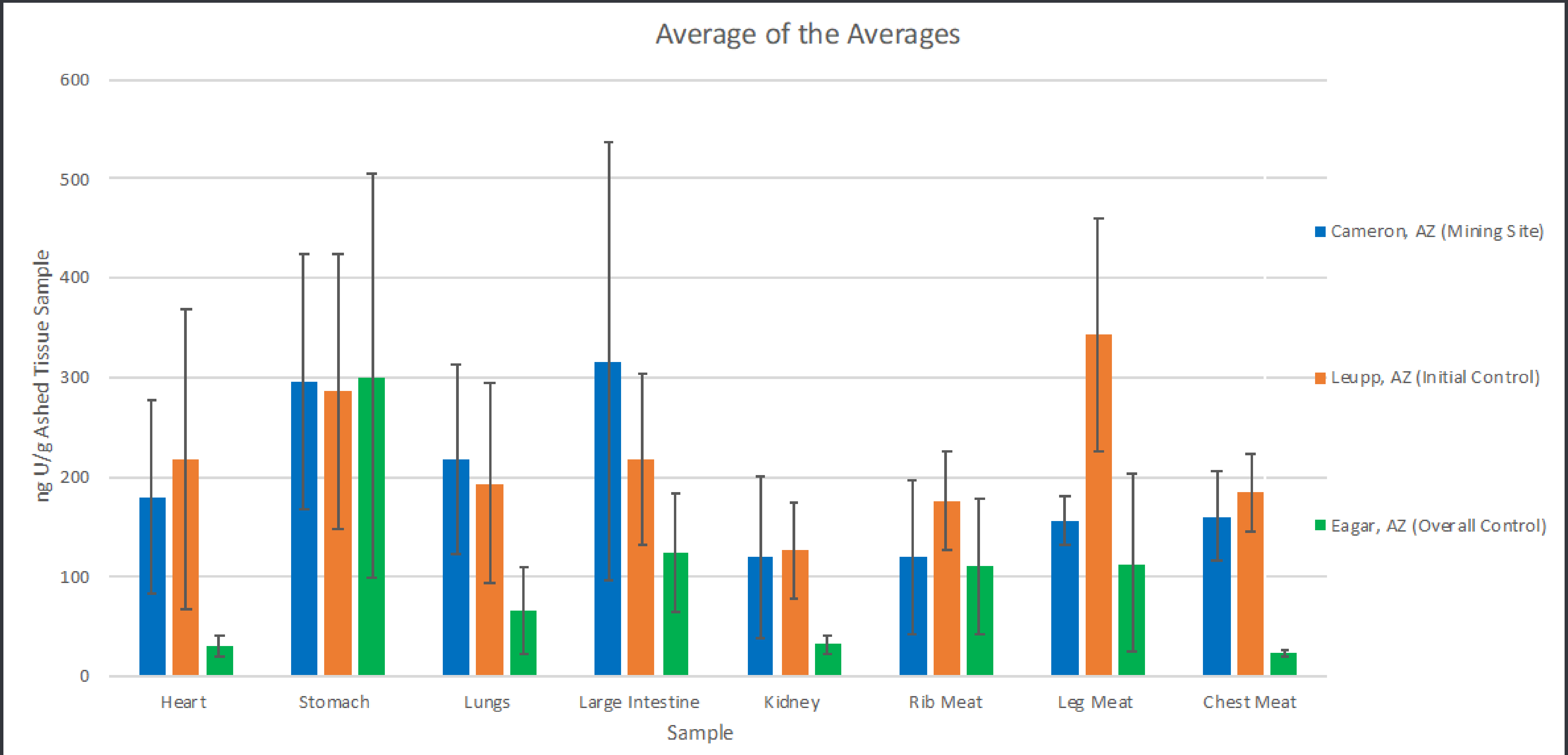
		Frequency of Consumption					
Part of Sheep Consumed	Number of Participants	Every Day	Every Week	Every Month	Every Few Months	Once a Year	Missing
	N (%)	N (%)*					
Blood sausage	52 (72.2)	1 (1.9)	3 (5.8)	14 (26.9)	26 (50.0)	6 (11.5)	2 (3.8)
Mutton stew	63 (87.5)	2 (3.2)	8 (12.7)	20 (31.8)	32 (50.8)	0	1 (1.6)
Roasted Mutton Sandwich	59 (81.9)	2 (3.4)	5 (8.5)	20 (33.9)	30 (50.9)	0	2 (3.4)
Mutton ribs	60 (83.3)	2 (3.33)	3 (5.0)	17 (28.3)	36 (60.0)	1 (1.7)	1 (1.7)
Roasted mutton meat	60 (83.3)	2 (3.33)	6 (10.0)	17 (28.33)	34 (56.7)	0	1 (1.67)
Hind leg	57 (79.2)	1 (1.8)	6 (10.53)	15 (26.3)	33 (57.9)	0	2 (3.5)
Intestines (Achii)	53 (73.6)	1 (1.9)	4 (7.6)	17 (32.1)	28 (52.8)	2 (3.8)	1 (1.9)
Liver	53 (73.6)	1 (1.9)	3 (5.7)	13 (24.5)	30 (56.6)	4 (7.6)	1 (1.9)
Heart	45 (62.5)	1 (2.2)	3 (6.7)	11 (24.4)	25 (55.6)	3 (6.7)	2 (4.4)
Kidneys	47 (65.3)	1 (2.1)	2 (4.3)	11 (23.4)	26 (55.3)	5 (10.6)	2 (4.3)
Lungs	38 (52.8)	1 (2.6)	2 (5.3)	8 (21.1)	22 (57.9)	4 (10.5)	1 (2.6)
Esophagus	18 (25.0)	0	0	4 (22.2)	8 (44.4)	4 (22.2)	2 (11.1)
Hoof	15 (20.8)	1 (6.7)	1 (6.7)	1 (6.7)	8 (53.3)	2 (13.3)	2 (13.3)
Skin	12 (16.7)	0	0	2 (16.7)	5 (41.7)	3 (25.0)	2 (16.7)
Head	46 (63.9)	1 (2.2)	4 (8.7)	11 (23.9)	24 (52.2)	5 (10.9)	1 (2.2)
Tongue	39 (54.17)	1 (2.6)	4 (10.3)	6 (15.4)	22 (56.4)	5 (12.8)	1 (2.6)
Eyes	39 (54.2)	1 (2.6)	4 (10.3)	7 (18.0)	21 (53.9)	4 (10.3)	2 (5.1)
Ears	24 (33.3)	1 (4.2)	3 (12.5)	2 (8.3)	13 (54.2)	4 (16.7)	1 (4.2)
Stomach	45 (62.5)	1 (2.2)	3 (6.7)	12 (26.7)	22 (48.9)	6 (13.3)	1 (2.2)

***percent is of the number of participants who consumed the respective part of the sheep**

Sample Collection

<u>**Kidney**</u>	Liver	<u>**Heart**</u>
Esophagus	Small Intestine	Large Intestine
Stomach	Hoof	Wool
Rib Meat	Leg Meat	Chest Meat
Lungs	Fat	Leg Bone

Q: Andee and Jani --- What publication and/or figure should I use?



Role of healthcare professional

- “At what point in history did a doctor become something more than a trusted and learned friend who visited and treated the ill?”
  - Primary care and preventive medicine

https://upload.wikimedia.org/wikipedia/en/0/0b/HouseGregoryHouse.png

https://upload.wikimedia.org/wikipedia/commons/thumb/d/df/Patch_Adams.jpg/640px-Patch_Adams.jpg

Gold King Mine Spill

Table 3.2 – Comparison of heavy metals and metalloids in water and their standard deviations in ppb, where BDL = below detection limit.

Site ID	As (ppb)	Cd (ppb)	Pb (ppb)	U (ppb)
Site A	0.56 ± 0.09	BDL	BDL	0.27 ± 0.09
Site T	0.86 ± 0.14	BDL	0.41 ± 0.03	1.95 ± 0.30
Site Y	0.89 ± 0.06	BDL	0.38 ± 0.27	1.20 ± 0.06

Table 3.6 – Field topsoil concentrations of heavy metals and metalloids and their standard deviations in ppm.

SITE ID	As (ppm)	Cd (ppm)	Pb (ppm)	U (ppm)
Site A	1.61 ± 0.34	0.07 ± 0.02	4.21 ± 0.26	0.16 ± 0.04
Site T	3.62 ± 0.22	0.33 ± 0.04	21.92 ± 1.58	0.57 ± 0.05
Site Y	4.54 ± 0.23	0.33 ± 0.02	28.39 ± 0.30	0.60 ± 0.05
Site M	3.49 ± 0.24	0.19 ± 0.02	19.07 ± 4.89	0.48 ± 0.04

Table 3.9 – Means and standard deviations for all sites separated by each corn segment in ppb of dry biomass, where N=5, and BDL = below detection limit.

Segment	SITE ID	As (ppb)	Cd (ppb)	Pb (ppb)	U (ppb)
Kernels	Site A	1.51 ± 0.34	2.03 ± 0.04	10.03 ± 0.94	BDL
	Site T	BDL	15.09 ± 0.08	3.25 ± 0.32	BDL
	Site Y	BDL	5.92 ± 0.21	1.59 ± 0.21	0.14 ± 0.03
	Site M	BDL	4.40 ± 0.05	6.02 ± 0.66	0.42 ± 0.02
	NAPI	BDL	2.22 ± 0.06	8.48 ± 0.67	BDL
Cobs	Site A	15.55 ± 1.26	2.90 ± 0.10	34.76 ± 6.71	0.31 ± 0.18
	Site T	4.13 ± 0.56	71.43 ± 7.23	23.62 ± 6.55	BDL
	Site Y	6.68 ± 1.18	14.74 ± 1.47	2.83 ± 1.32	BDL
Husks	Site A	BDL	2.37 ± 0.18	3.14 ± 0.47	BDL
	Site T	BDL	69.88 ± 0.56	7.67 ± 0.41	BDL
	Site Y	8.78 ± 2.39	37.11 ± 0.36	57.04 ± 1.90	3.59 ± 0.20
	Site M	BDL	31.71 ± 0.32	23.48 ± 0.28	0.40 ± 0.04
Stems	Site A	121.2 ± 4.2	18.46 ± 0.18	131.7 ± 4.2	12.34 ± 0.37
	Site T	30.50 ± 4.52	184.5 ± 1.4	252.5 ± 2.9	19.26 ± 0.69
	Site Y	67.31 ± 4.47	200.2 ± 1.5	186.8 ±5.3	16.01 ± 0.68
	Site M	20.90 ± 0.62	59.38 ± 0.62	121.2 ± 1.4	9.45 ± 0.37
Roots	Site A	955.6 ± 7.1	63.16 ± 1.65	3707 ± 30	490.3 ± 6.0
	Site T	1432 ± 27	223.7 ± 10.3	8285 ± 107	789.6 ± 8.4
	Site Y	1831 ± 21	224.4 ± 4.0	10220 ± 192	759.4 ± 22.0
	Site M	685.3 ± 38.0	143.3 ± 3.0	6985 ± 78	487.1 ± 6.0

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Journal of Rural Studies

Diné-centered research reframes the Gold King Mine Spill: Understanding social and spiritual impacts across space and time

Rebecca J. Clausen[a,*], Carmenlita Chief[b], Nicolette I. Teufel-Shone[c], Manley A. Begay[c], Perry H. Charley Jr.[d], Paloma I. Beamer[e], Nnenna Anako[f], Karletta Chief[g,h]

Exposure and Health
https://doi.org/10.1007/s12403-023-00583-8

ORIGINAL PAPER

A Community-Based Health Risk Assessment Following the Gold King Mine Spill: Results from the Gold King Mine Spill Diné Exposure Project

Yoshira Ornelas Van Horne[1] · Karletta Chief[2,3] · Perry H. Charley[4] · Mae-Gilene Begay[5] · Nathan Lothrop[6] · Robert A. Canales[7] · Paloma I. Beamer[6]

Cancer Data/Report

REPORT OF THE

Navajo Epidemiology Center

November 13, 2023

By Navajo Cancer Workgroup

Cancer Among the Navajo

Incidence, Mortality, Stage of Diagnosis & Screening

2014 - 2018

Perceptions of cancer causes, prevention, and treatment among Navajo cancer survivors

Jennifer W. Bea[1,2,3], Hendrik Dirk de Heer[4], Brian Kinslow[5], Luis Valdez[6], Etta Yazzie[1,7], Pearl Curley[8], Shelby Dalgai[9], Anna L. Schwartz[4,7]

Published in final edited form as:
J Cancer Educ. 2020 June ; 35(3): 493–500. doi:10.1007/s13187-019-01487-5.

- Cancer defined as "a sore that does not heal" and "a disease for which we have not found a cure"
  - Skepticism of Western medicine
  - Prior mistreatment
  - Cultural misunderstanding by "Western health professionals"
- "Participants were not aware of screening recommendations"
- "*You can't go over to her house, she has cancer, it's contagious.*"

New uranium mine opening at GC

Alarm as first uranium mine in years opens near Grand Canyon

Pinyon Plain's start comes amid US's push to boost production, but tribes fear contamination of water and cultural sites

The Pinyon Mine in Arizona. Photograph: US Forest Service

A uranium mine in Arizona located just 7 miles south of the Grand Canyon national park has begun operations, one of the first in the US to open in eight years.

Closing – Tie back to presented case

- Possible mild radiation exposure
  - Ingestion of dust material and localized GI distress
- Additional history
  - In the area with some community members, all reported differing degrees of non-specific symptoms but post-doc the only one that reported to healthcare
  - Hazmat swept post-doc hotel room and removed some samples
- Counseling

Other related studies & resources

- Impact of arsenic and uranium on wound healing and diabetic ulcers
  - Northern Arizona University
  - Matthew Salanga, Ph.D. and Rob Keller, Ph.D.
- *“Helicobactor pylori* in Native Americans in Northern Arizona”
  - Northern Arizona University and University of Arizona
  - Fernando Monroy, Ph.D. and Robin Harris, Ph.D.
- Air pollution
  - Northern Arizona University
  - Institute of Tribal Environmental Professionals
  - Robin Harris, Ph.D.
- ECHO Study – Predecessor of Dine Birth Cohort
  - University of New Mexico
  - Johneye Lewis, Ph.D. and Debra Mackenzie, Ph.D.
- Native Americans for Cancer Prevention (NACP)
  - Jani Ingram, Ph.D.
- Environmental Health Module
  - Audrey Yang (aryang@arizona.edu), Julie Jernberg M.D., M.B.A. (jbj1@arizona.edu), Jonathan Credo, Ph.D. (jmcredo@arizona.edu)

Birth Cohort Study to continue, expand with new grant

Courtesy photo Members of the birth cohort team include, left to right, Dr. Johnnye Lewis, Carley Prynn, Betsy Carretta, Victoria Bia, Christian Bia and his mother Marlene, Dr. Carol Blaisdell holding participant Michael Bia, and Qeturah Anderson at the Bias’ home during a visit to the Navajo Nation in November.

https://navajotimes.com/reznews/birth-cohort-study-continue-expand-new-grant/

Community Collaborators

Funding

National Institute of General Medical Sciences (S06GM127164-04, 1T32GM141830)
National Institute of Minority Health and Health Disparities (Grant U54MD012388)
National Institute of Environmental Health Sciences (P50ES026089)
National Cancer Institute (U54CA143925)
National Institute on Aging (1T32AG061897-01)
USEPA (IT-84008901)
Flinn Foundation (2102 and 2187)

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