Human Exposure Assessment Practices In the Navajo Birth Cohort Study*

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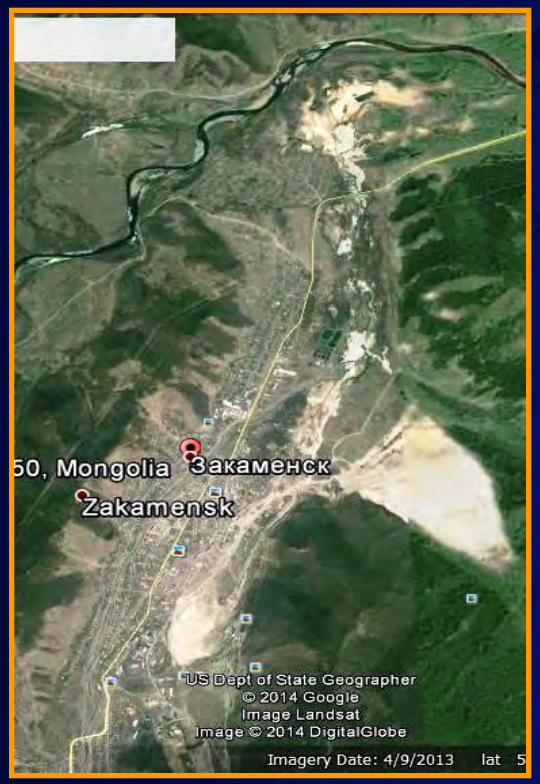
SOUTHWEST RESEARCH AND INFORMATION CENTER

Greetings to our Russian Colleagues



Our research team is comprised of scientists with the University of New Mexico Community Environmental Health Program (UNM-CEHP), the UNM College of Pharmacy and Southwest Research and Information Center (SRIC), working in collaboration with the people of the Navajo Nation. We share your concerns about long-term exposures to environmental contaminants in mining wastes. This presentation is intended to summarize the practices we use to assess exposure around the homes of participants. We are committed to supporting the community's need to remediate mining and milling waste sites and to compensate the people of Zakamensk, Buryatia, including and especially the children (photo).

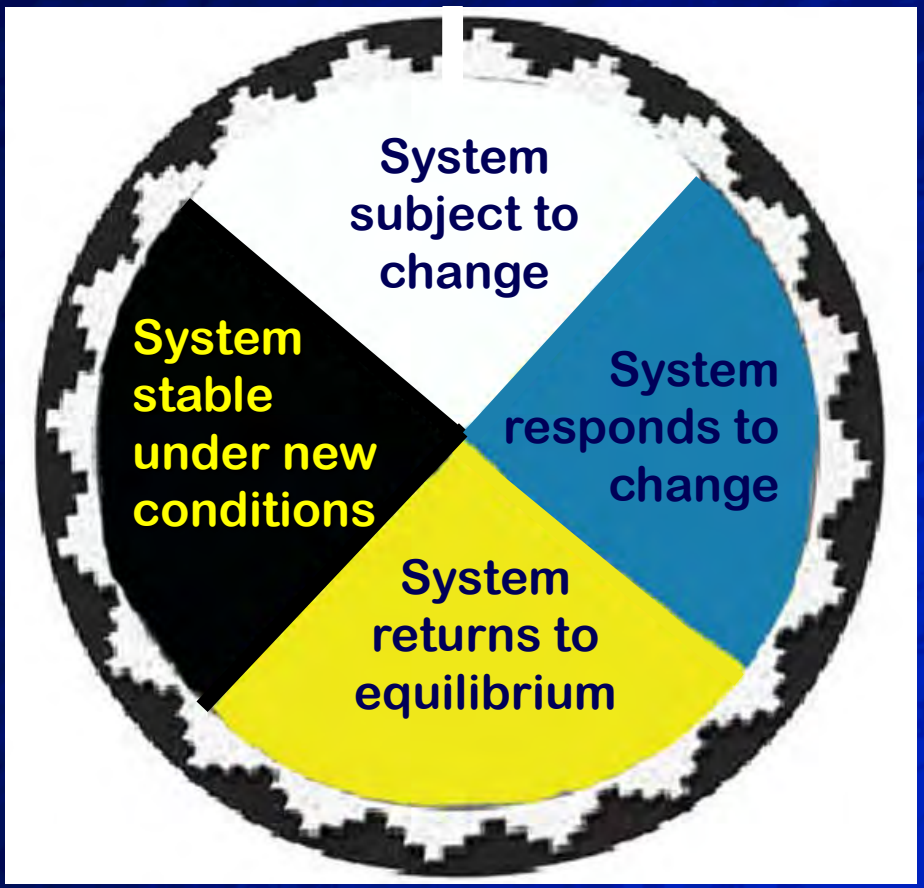
Map and photo by Paul Robinson

Diné (Navajo) concepts of acquiring knowledge parallel scientific research method

Ha'a'aah **(East):** ***Nitsáhákees*** **(Thinking, beginning)**
New hypothesis advanced

Náhookǫs **(North):** ***Siihasin*** **(Security)**

Research evaluated, refined; findings reported



Shádí'ááh **(South):** ***Nahat'á*** **(Planning, action)**

Research planned, developed

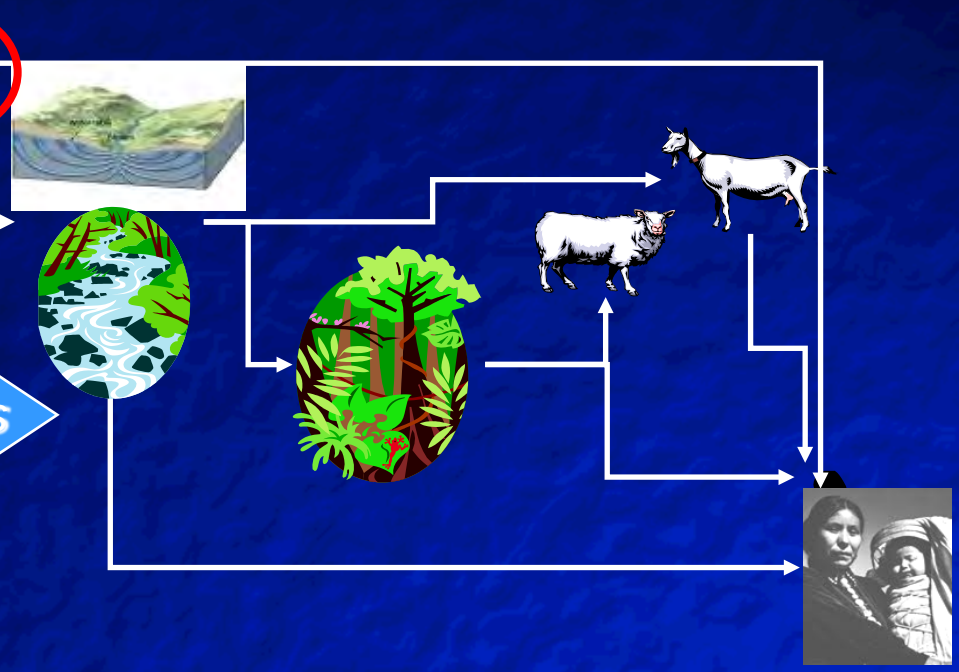
E'e'aah **(West):** ***Iiná*** **(Life). Assessment, hypothesis testing**

Navajo Birth Cohort Study

A community-university-tribal and federal government partnership to investigate the relationship between uranium exposures and birth outcomes and early child development on the Navajo Nation

Exposure assessment methods based in understanding of *pathways* and *routes* of exposure

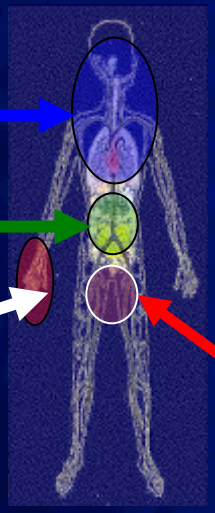
SOURCES: Potentially harmful contaminants in the environment



Exposure Pathways:

Air, water, plants, animals, humans

(can be very simple or quite complex)



Inhalation (Breathing)

Ingestion (Eating, Drinking)

Absorption (Skin Contact)

Circulation (Contaminant transfer across placenta)

Exposure Routes:

How contaminants enter the body

Target Organ:

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

Exposures to uranium mine wastes cross multiple generations, increase with proximity

Above: RED WATER POND ROAD COMMUNITY, Coyote Canyon Chapter (NM): Some of the children playing near a uranium mine waste dump (white pile, far left background) in 1976 became the adults of 2005, living in homes (above, right) within 600 feet (183 m) of another uranium mine waste dump.

Uranium mine wastes on cliff within 0.25 mi (0.4 km) of three-generation homes, Blue Gap-Tachee Chapter, June 2014

- Occupied structure within 0.25 mi (0.4 km) of 14% of 521 AUMs on Navajo Nation
- DiNEH finding: *Proximity predicts increased health risk*
- Concern for inhalation: *submicron particles in Tachee mine wastes*

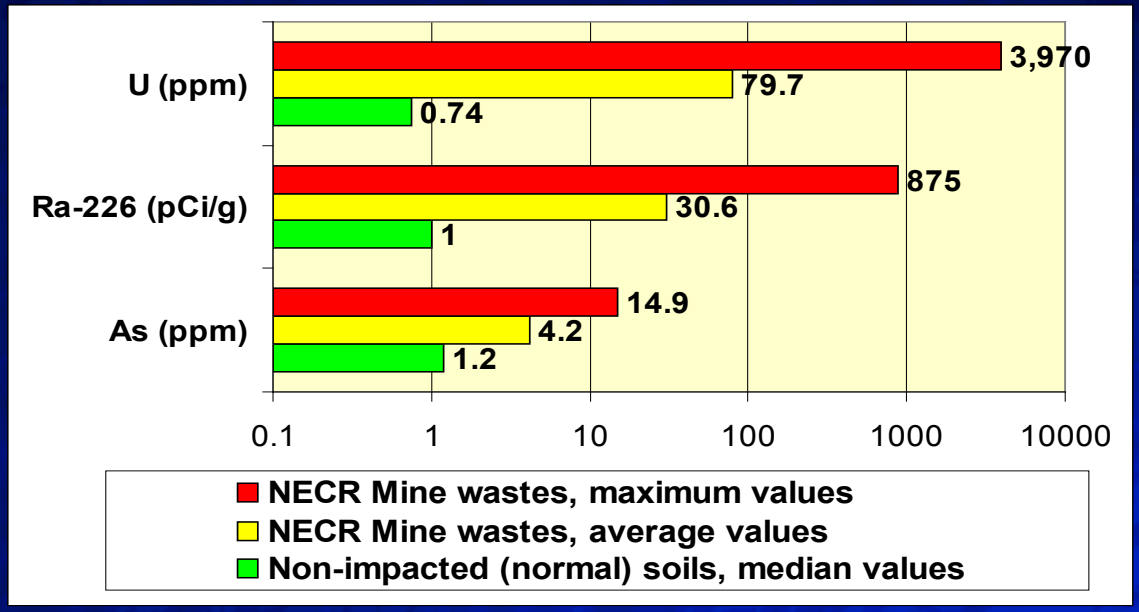
Uranium wastes: complex mixtures of heavy metals, radionuclides

Common metals:

- ***Arsenic (As)***
- Copper (Cu)
- Iron (Fe)
- Nickel (Ni)
- Selenium (Se)
- Uranium (U)
- Vanadium (V)

Radionuclides:

- Uranium-238
- Thorium-230
- ***Radium-226+228***
- ***Radon-222***
- Polonium-210
- Lead-210



Top: Selected metal and radionuclide constituents in Northeast Church Mine wastes, Pinedale, NM (MWH, Inc. 2007). Bottom: Metal concentrations in AUM wastes in Blue Gap-Tachee Chapter (UNM-E&PS, 2014)

Claim 28 Mine Waste Characteristics, Tachee AZ	Elemental Content, ug/g (or, parts per million, ppm)							
	Si	S	Al	Fe	Mg	U	V	Ca
Non-impacted Soil	241,950	1,339	52,129	26,739	3,068	BDL*	BDL*	16,441
January samples: Mine waste collected under dirt cover	235,563	223	69,533	15,259	181	**2,248**	**15,814**	855
June samples: Waste rock on slope of Claim 28 site	243,703	1,834	59,730	3,511	405	**6,614**	**4,328**	3,293

Uranium wastes are not the only common contaminant sources on the Navajo Nation

Indoor heat: wood and coal burning

Jewelry making

Unregulated water sources

Runoff from contaminated mine sites

Outcomes Model Structure

EXPOSURE INPUTS

Uranium
Proximity, dust, occupation, water, land use
Survey, GPS, NURE data, Biomonitoring, Existing water quality, in-home dust, parent biomarker analyses

Radiation
Home scans
Biomonitoring, Existing data

Radon
In-home
Canister monitoring

MODIFIERS

Reproductive History
Mot
Surv

Nut
Mot
WIC

Demographic Variables
Parental income, education, parental ages
Survey

Alcohol, Substance Abuse
Surveys, Meconium, Medical Record

Co-Exposures
Other metals, PAHs, Particulates, Sulfur Compounds
Biomonitoring, Surveys, Home Assessments

Home Environmental Assessments (HEAs) obtain four major exposure inputs

REPRODUCTIVE OUTCOMES

very
Medical Record

Low Birth Weight
Medical Record Review

Congenital Malformation
Medical Record, Survey

DEVELOPMENTAL OUTCOMES

Development: Behavior
communication, gross & fine motor skills, problem solving and personal social skills
ASQ-I & Mullen

Development: Physical
Length, weight, head circumference
Anthropometry

Development: Medical
Infections, Morbidity, Mortality
Medical Record Review

Development: Biomarker
Inflammation, Immune system
Laboratory Analysis

Elements of Home Environmental Assessments (HEAs)

- Record the home's **location**
- ***Observe*** possible contaminant sources in homes
- Note home infrastructure
  - electricity
  - running water
  - indoor plumbing
- Survey inside and outside of home for **gamma radiation**
- Measure indoor **radon** during the winter months
- Sample indoor **dust** for heavy metals
- Sample nearby unregulated **water** sources if needed

Note: Monitoring indoor hydrogen sulfide not yet implemented

Our Navajo staff is trained and certified to conduct HEAs

Lynda Lasiloo,
Two Grey Hills, NM

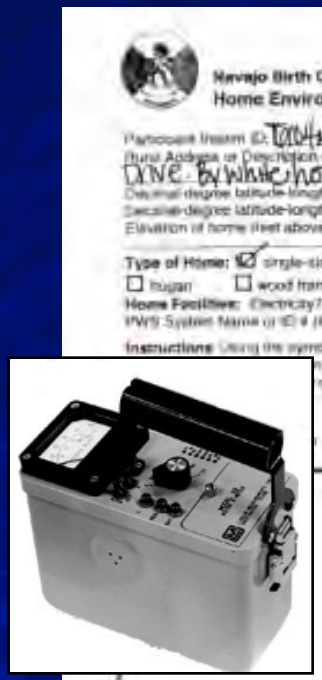
Teddy Nez,
Gallup, NM
(with Diane Denish, former NM Lt. Gov.)

Sandy Ramone,
Crownpoint, NM

Maria Welch,
Tuba City, AZ

Gamma radiation screenings

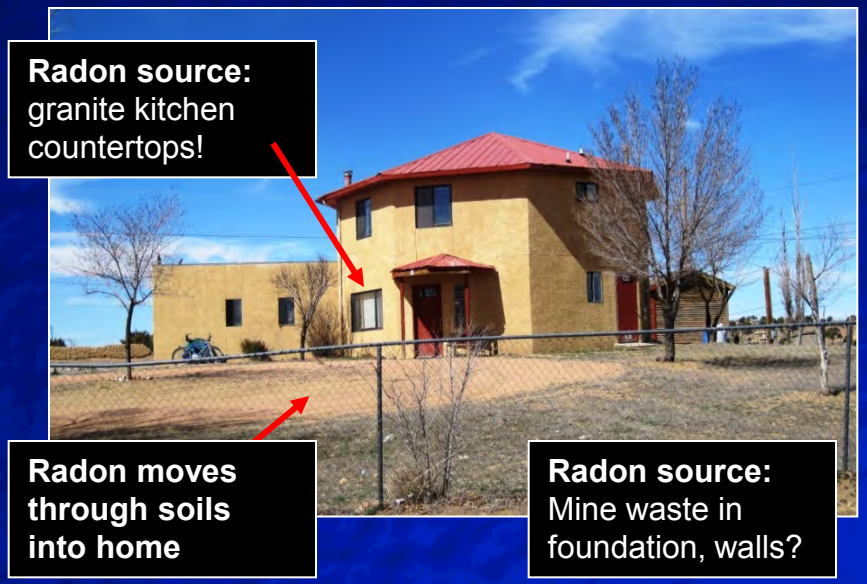
- Gamma radiation rates indicate possible presence of radioactive materials around and inside homes
  - Uranium wastes used in construction of at least 36 homes on Navajo Nation
- Hand-held Ludlum-19 MicroR radiation detector used for surveys
- Gamma rates recorded outside and inside of participant homes, recorded on data sheets
- Background radiation determined for each site



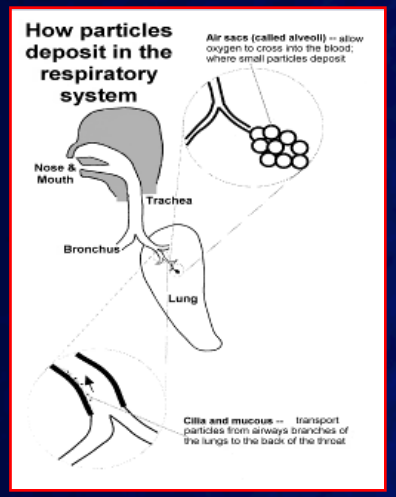
Measurements of indoor radon

Radon (Rn) — colorless, odorless gas that occurs in rocks, soils, air and water from the radioactive decay of uranium

- *"Radon is the second most important cause of lung cancer after smoking in many countries"*
  — Dr. Maria Neira, World Health Organization
- Testing *only* way to know indoor radon levels
- Use 6-day charcoal canisters to obtain average indoor Rn level
- 1 canister placed in livingroom, 1 in participant's bedroom
- Retrieved by field staff and sent to lab for analysis



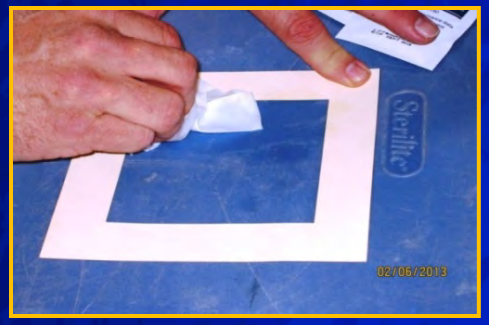
Indoor dust samples collected to assess risks of inhaling heavy metals

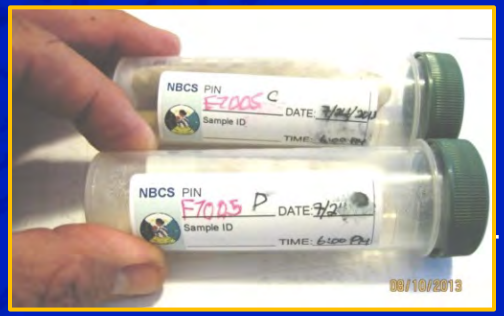


- Indoor dust presents *inhalation* and *ingestion* risks to mother, baby and other family members
- Dust may contain *heavy metals* from uranium wastes, wood and coal burning, jewelry making

Methods:

- Dust samples collected on cloth “wipes” from 2 or more rooms in home
- 3 swipes across area of about 100 square centimeters (10x10cm)
- Tested for 22 metals and metalloids





Drinking water exposures:

Unregulated water sources and public water supplies

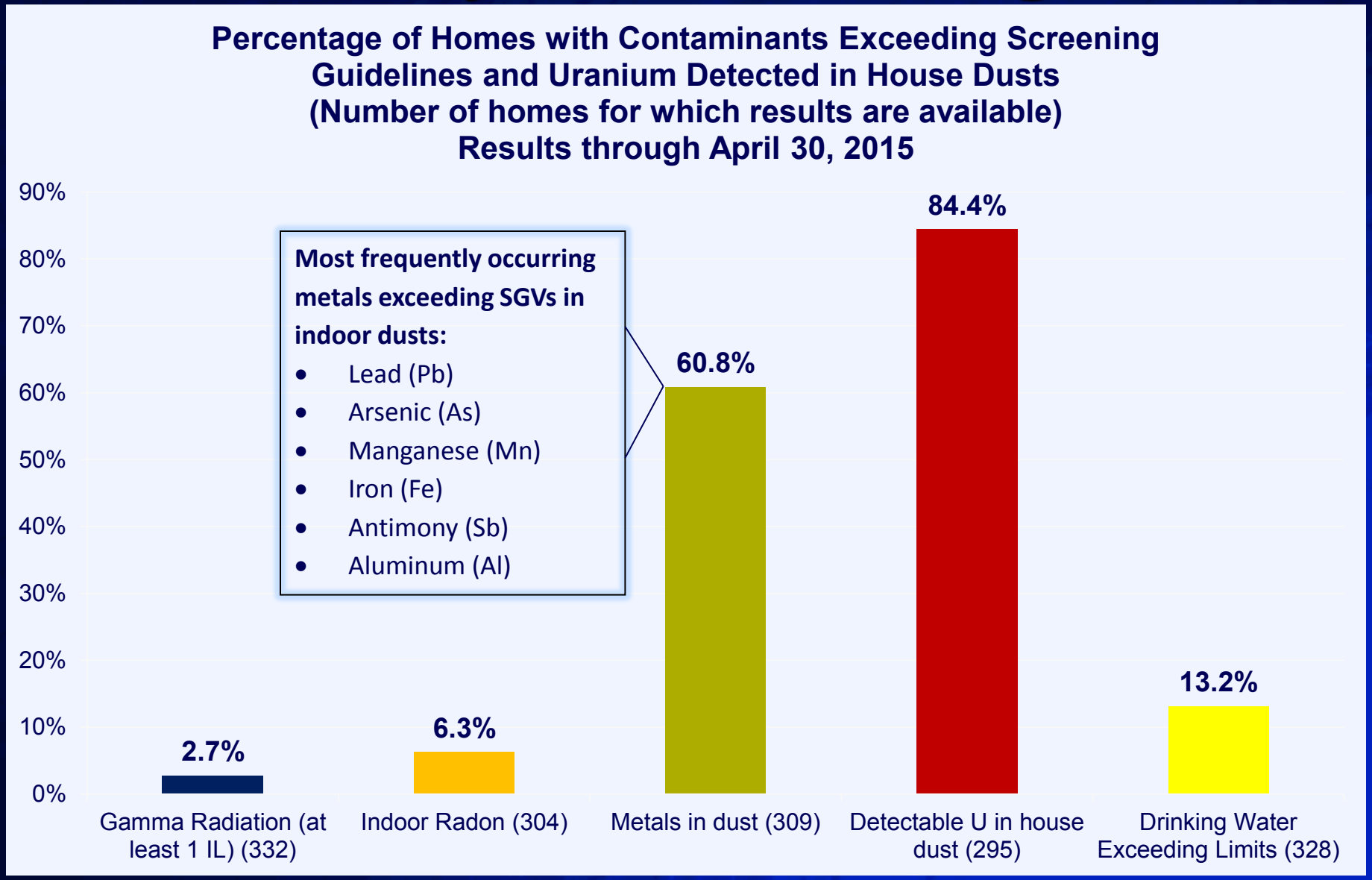
- Water → major pathway of exposure to metals like uranium, arsenic
  - *Chronic U ingestion associated with kidney toxicity*
- Participants' drinking water source(s) ascertained during home visit
- Water quality in public water supplies: Utility Consumer Confidence Reports
- For unregulated water sources, find *existing* water quality data or collect samples for laboratory analyses
- Conduct field tests
  - Temperature, pH, conductivity
- Samples analyzed for general chemistry, heavy metals

Summary of HEA results to date
(thru 4/30/15)

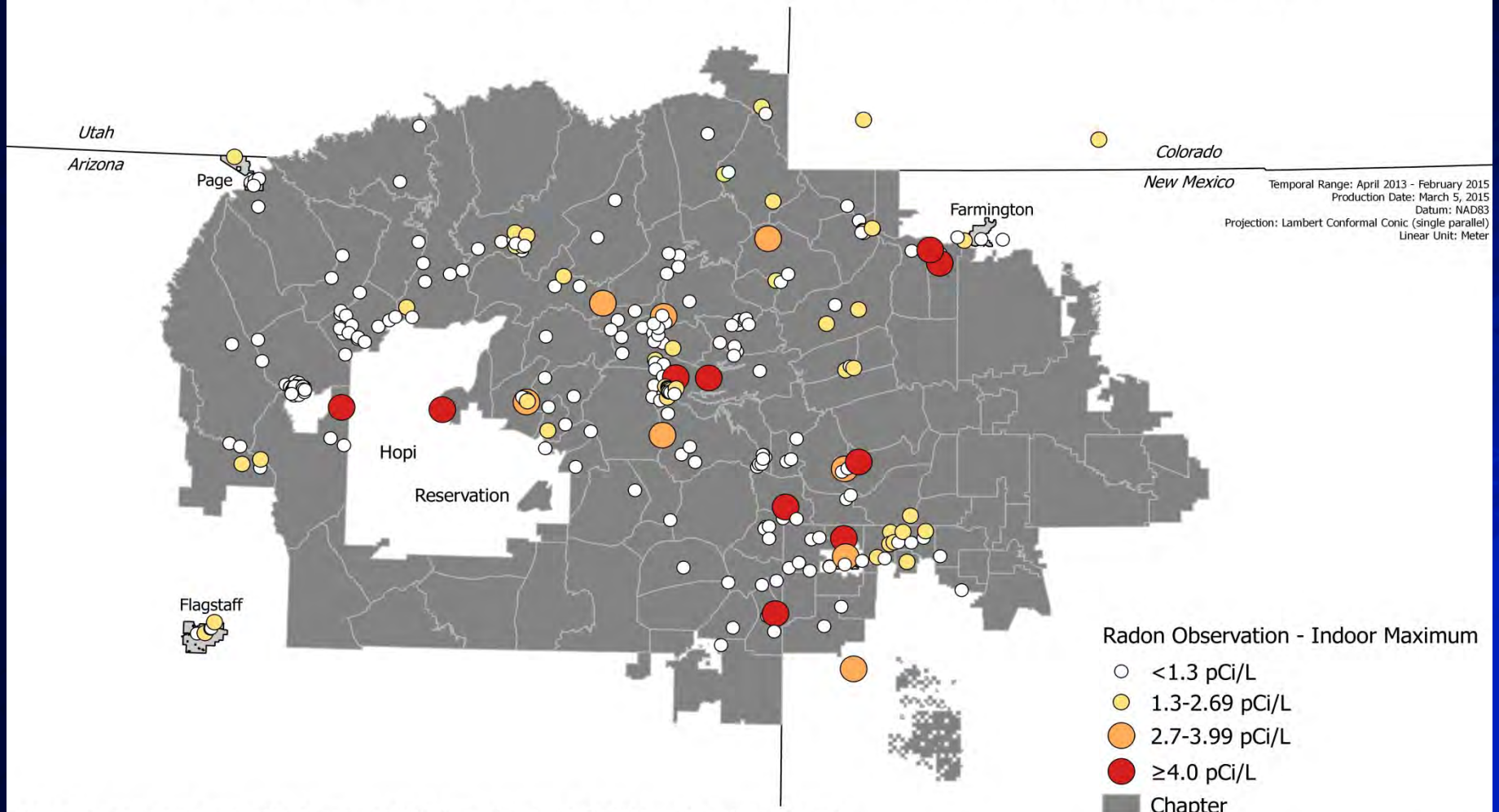
Metric	Count (percentage)
HEAs conducted (% of enrollments)	345 (77%)
Homes with electricity	87.9%
Homes with piped-in water	80.4%
Participants with at least 1 exposure source	61.7%
Participants with 2 or more exposure sources (maximum number = 5)	25.5%

First NBCS participants interviewed for enrollment survey.

Prevalence of exceedances of screening values across major contaminant categories



Maximum Measured Indoor Radon Concentrations for NBCS Participants



Note: A geomasking method was used that randomly shifted home locations based on chapter/municipality population density. This method enables appropriate geographic representation of observed radon concentrations while maintaining participant confidentiality.

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Indoor Radon levels higher in colder months, lower in warm months

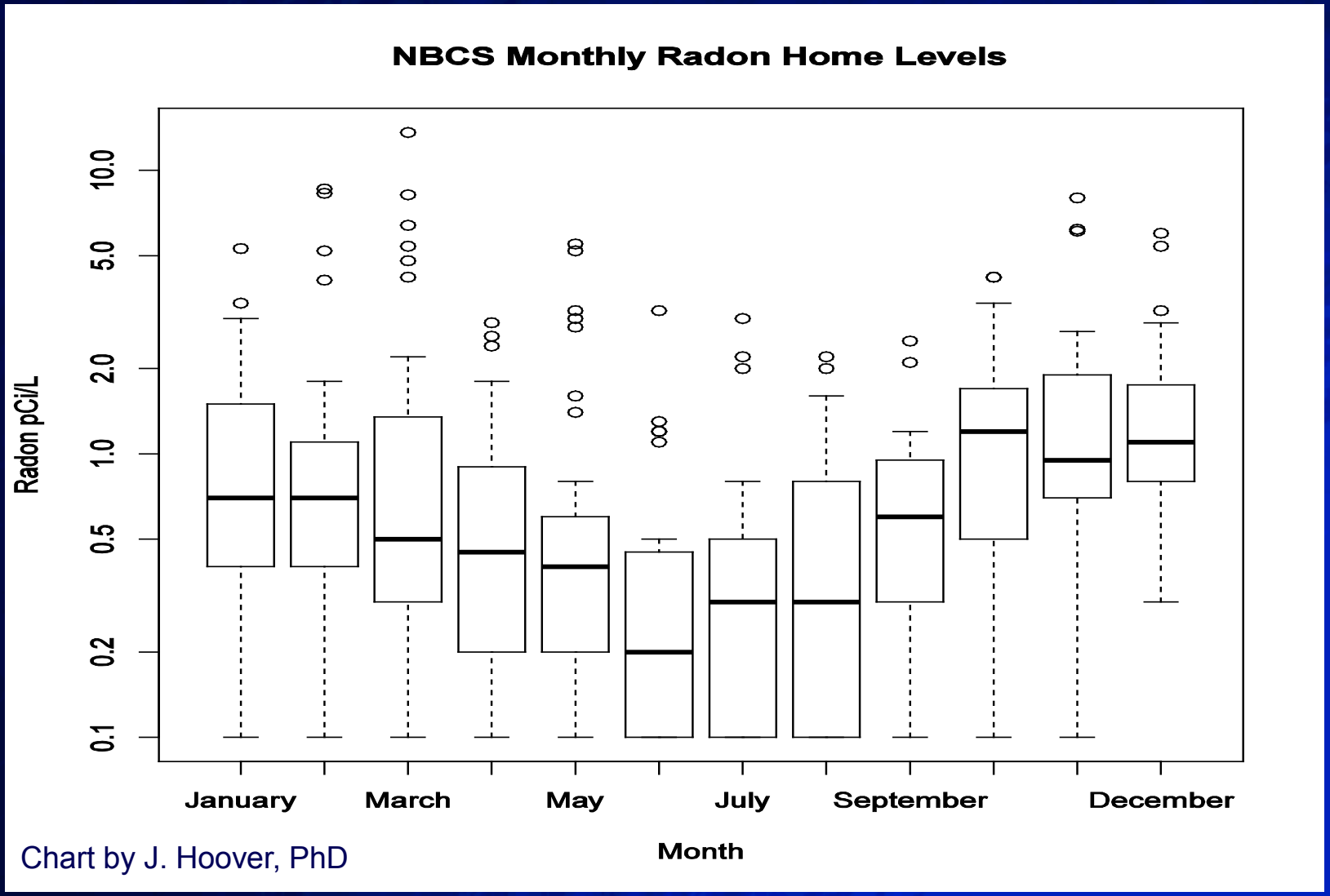
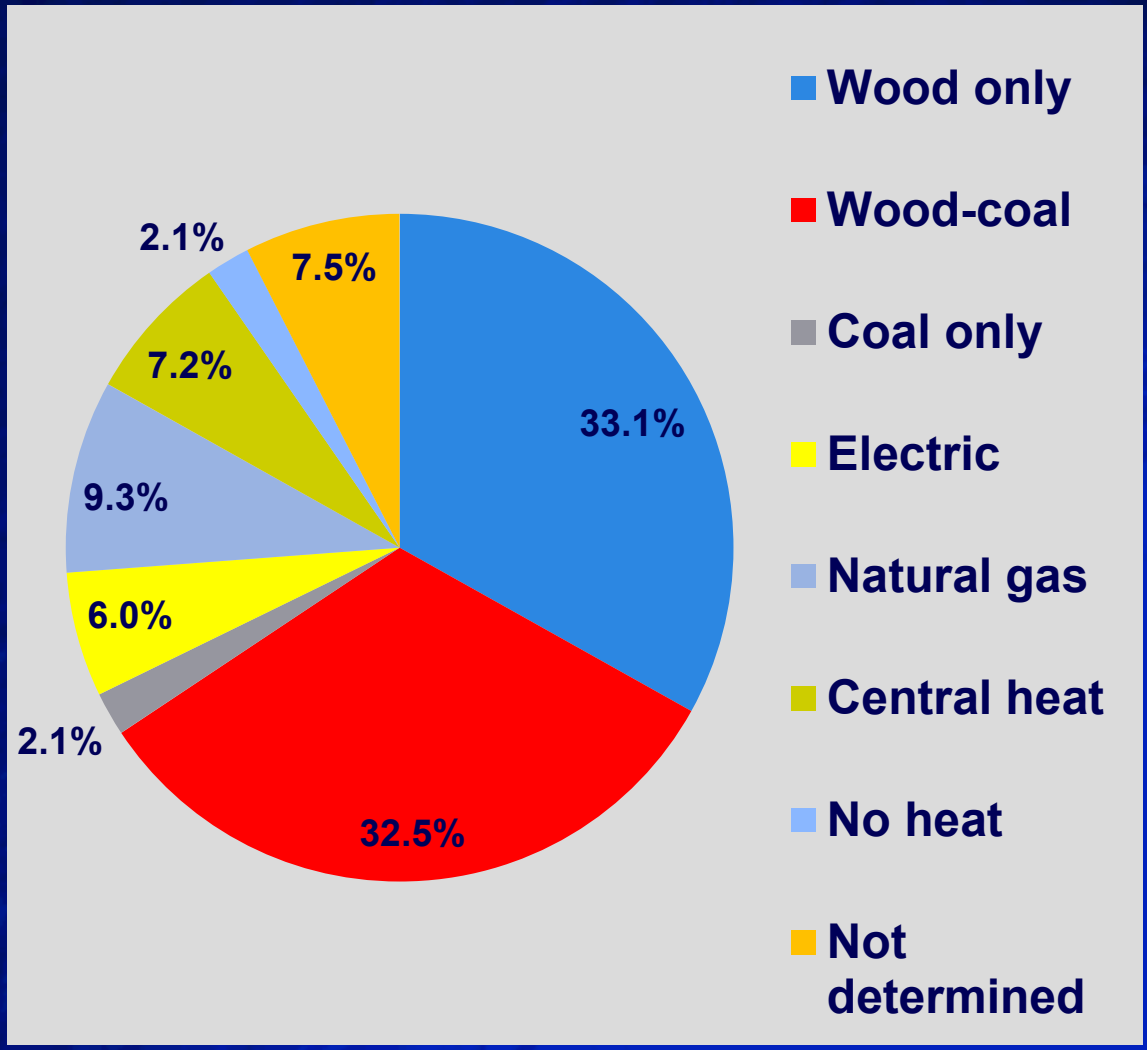


Chart by J. Hoover, PhD

Home Heat Sources
(N=332 homes)

- Wood and wood-coal largest categories of home heating, making up nearly two-thirds of all heat sources
- Preliminary analysis indicates higher frequency of metals ≥SGVs in homes burning wood and coal in wood-burning stoves

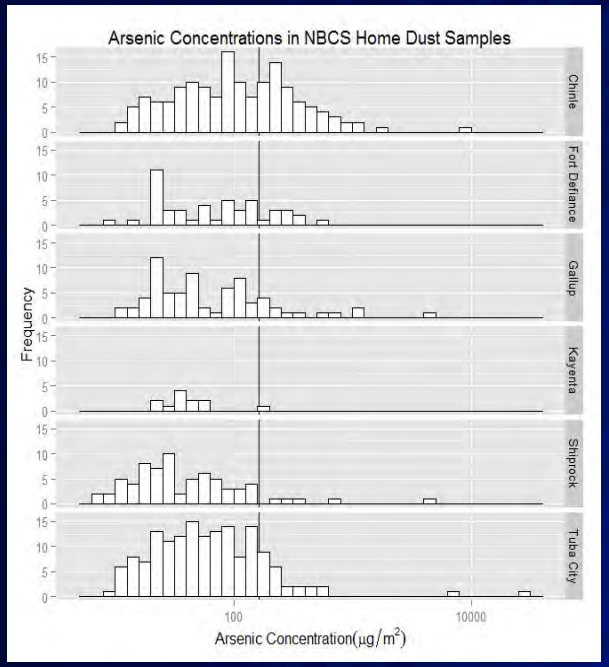


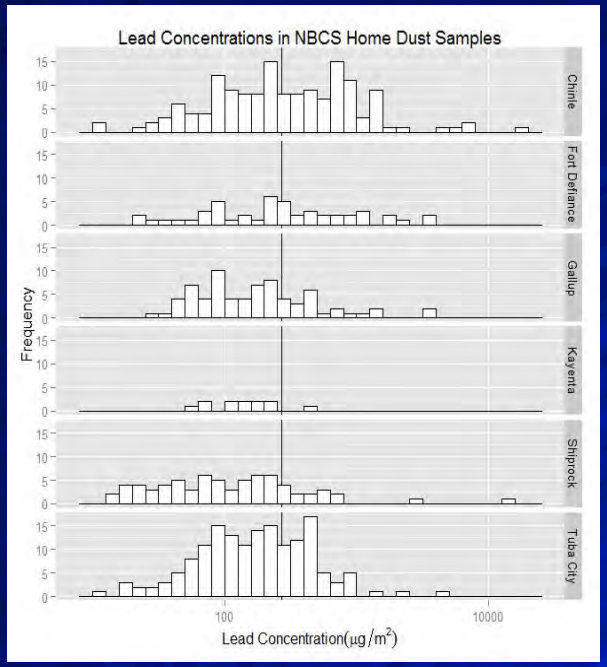
Metals in indoor dust compared with SGVs

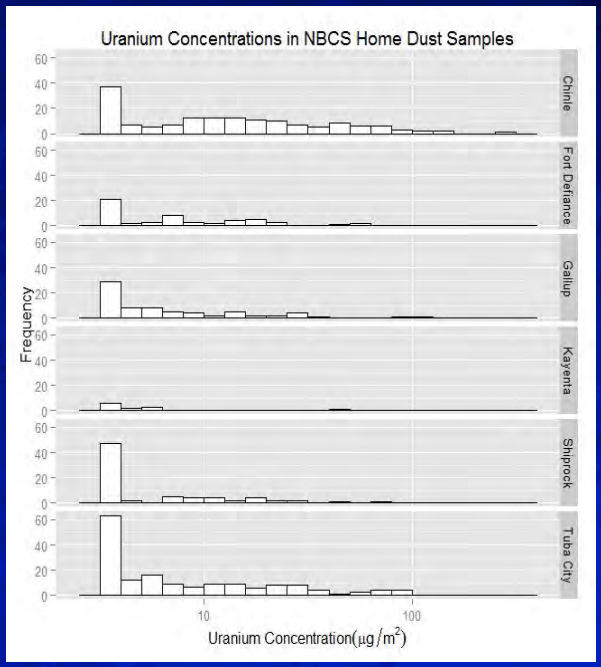
- Screening Guideline Values (SGVs) adapted from guidelines developed by multiagency task force responding to World Trade Center collapse, 2001
  - Modified to reflect chronic exposures in Navajo homes
- SGVs range over 4 orders of magnitude, indicating relative toxicity of various metals
- Uranium SGV not used for comparison; all uranium concentrations reported to participants
- Top metals in dust: lead, arsenic, manganese, iron, antimony, aluminum

Metal	Symbol	SGV (in µg/m²)	Total Occurrences ≥ SGV
Aluminum	Al	653,720	48
Antimony	Sb	261	56
Arsenic	As	163	113
Barium	Ba	45,760	4
Beryllium	Be	1,307	0
Boron	B	313,578	1
Cadmium	Cd	649	6
Chromium	Cr	1,961	14
Cobalt	Co	13,074	0
Copper	Cu	26,148	8
Iron	Fe	392,232	79
Lead	Pb	270	207
Manganese	Mn	13,704	88
Mercury	Hg	65	3
Nickel	Ni	13,704	2
Selenium	Se	3,269	0
Silver	Ag	3,269	2
Thallium	Tl	46	0
Tin	Sn	470,366	0
Uranium	U	3,135.8	0
Vanadium	V	4,576	0
Zinc	Zn	196,116	7

Concentration frequencies of selected metals in dust
(charts prepared by J. Hoover, PhD)





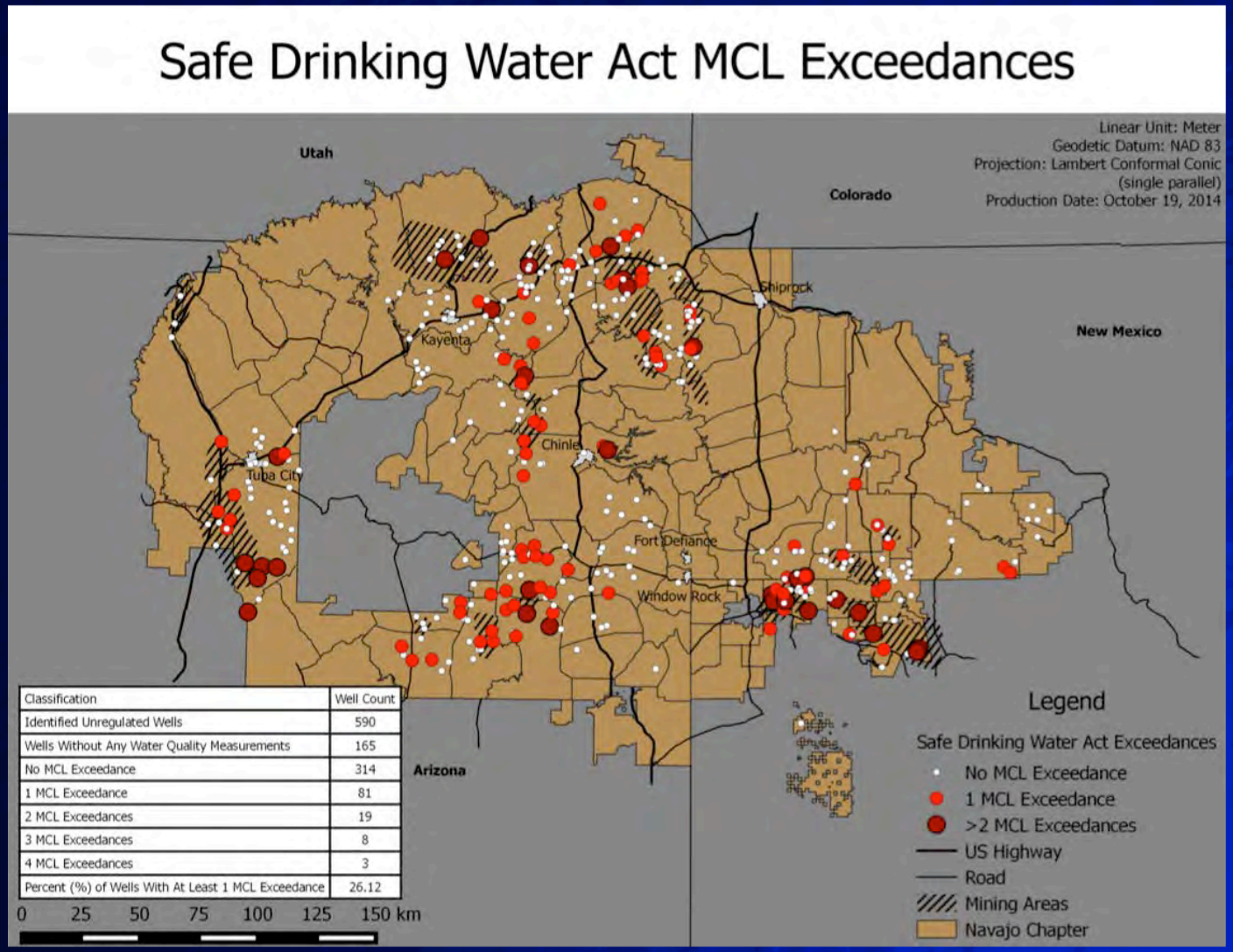


- Black vertical line indicates SGV concentration
- Lead (Pb) only metal to occur ≥SGV in more than 50% of homes
- Large columns on left side of Uranium chart are “non-detects”
- Frequencies suggest metals occur more often in dusts in homes in the Chinle and Tuba City regions (top and bottom of all charts)
- Do metals in dusts predict metals in blood & urine of participants?

Distribution of water contaminants in unregulated water sources, Navajo Nation

J. Hoover, PhD, UNM-CEHP

Inorganic Metals for 427 of 702 unregulated wells compiled from sampling conducted by DiNEH Project, USACE, USEPA, USGS, CRUMP, CDC/NNEPA



- **Sampling bias in regions of known uranium mining**
- **DiNEH project sampled wells used by participants for drinking in 20 chapters**
- **Arsenic (~13%) and uranium (~13%) account account for the majority of water sources (26%) exceeding the established MCL.**
- **CDC-NNDOH study (2006-2007) found bacteriological contamination by coliforms (72%) and E. coli (23%) in >170 wells tested**

MCL = maximum contaminant level, EPA standard for safe drinking water

DiNEH Project Results:

Arsenic in water associated with cardiovascular inflammation*

Total number *different* water sources in DiNEH database, thru Nov. 2011	376	100%
Water Sources Exceeding at least 1 MCL* at least 1 time	103	27.4%
Arsenic	65	17.3%
Uranium	38	10.1%
Gross alpha radioactivity	9	2.4%
Selenium	8	2.1%
Nitrate	7	1.9%
Radium-226+228	7	1.9%
Fluoride	6	1.6%
Thallium	5	1.3%
Lead	3	0.8%

- Arsenic (As) and uranium (U) — two most frequent contaminants in unregulated water sources on Navajo Nation (see table at left)
- Unregulated water sources contributed *vast majority* of As and U intake among DiNEH participants
- Annual arsenic intake *associated* with oxLDL** (p=0.04) (see chart below left)
- Age, occupational exposures (M), distance to and contacts with mine wastes (E) also *significant predictors* of oxLDL

	Estimate (β)	Standard Error	*t* value	P value
(Intercept)	3.9835	0.0951	41.8834	
Age	-0.0032	0.0016	-2.0240	0.04
M	0.0788	0.0268	2.9409	0.004
E	-0.4609	0.1725	-2.6716	0.008
ahigh	0.2092	0.0989	2.1141	0.04

*Results based on analyses by C. Miller, PhD, UNM-CEHP, in Shuey and Miller, 2013

*oxLDL = oxidized low-density lipoprotein

DiNEH Project Results:

Discussion of Water Ingestion Findings*

- Arsenic intake from contaminated drinking water may influence oxidative modifications of lipoproteins and promote cardiovascular disease in Navajo populations
- Uranium intake associated with oxLDL, a biomarker of CVD, *only* when modeled as a continuous numerical value, and not associated when modeled as a binary variable (i.e., high v. low intake)
- Detecting a health effect from uranium intake limited by
  - Most of the sampled unregulated water sources, and nearly all of the regulated waters, had very low levels of uranium (range ND-260 ug/l), and
  - Only a few participants drank from the most contaminated wells

*Source: Harmon et al., Environmental Predictors of Oxidized LDL Cholesterol (oxLDL) in Navajo Populations Exposed to Uranium-Contaminated Mining Sites. Society of Toxicologists Annual and Mountain Region meetings, 2013.

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- NNEPA (1 yr)

DiNEH Project and NBCS are reviewed, approved and monitored by Navajo Nation Human Research Review Board

(Navajo Team Members)