The Navajo Birth Cohort Study
Design, Progress, Future Directions
March 9, 2016

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            DiNEH Project — Navajo Birth Cohort Study

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          Native EH Equity:  NIEHS/NIMHD P50ES026102
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          NSF EPSCOR:  IIA-1301346
          NIMHD/USEPA:  P20MD004811 – 02S1
Why do we care about children specifically?

Many sites are extremely close to communities. Example shown in these photos is the Red Water Pond Road Community (RWPRC) in Coyote Canyon Chapter near Church Rock, NM.

Community had three emergency removal actions to remove contaminated soils from around homes between 2007-2012; mine waste pile remains in place.

- Multigenerational exposures underscore the need to protect future generations
- Understanding relationship between exposures, birth outcomes, and development key to ensuring children can develop to their maximum potential
History

- **2010**
  - Three years into first 5-year plan, decision to add health studies
  - CDC/ATSDR scoping on Navajo
  - Researchers, Navajo Agency Staff, Community members
  - Competitive RFP released
  - UNM-CEHP team awarded research leads
  - CDC/ATSDR directly funded NAIHS, NNDOH as cooperating partners

- **2010 – 2013 (planning phase)**
  - IRB and OMB approvals delay start of recruitment
  - Feb 2013, after 18 mos OMB approves start of recruitment

- **2013 – 2018 (implementation)**
  - CDC/ATSDR renews funding to UNM-CEHP to implement study
  - NAIHS & NNDOH funded as well to support
Navajo Birth Cohort Study
2010-2017 – Congressional Mandate
Cooperating Organizations

DiNEH Project Team
• UNM Community Environmental Health Program (CEHP)
• UNM Pediatrics Department, Center for Development and Disability
• Southwest Research and Information Center (SRIC)
• Consultants

Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry

Birth Cohort
Navajo mothers, fathers and babies; other community members; chapters

Navajo Area Indian Health Service (NAIHS)

Navajo Nation Division of Health

With Help From

Growing in Beauty
(developmental disabilities services provider)

PL93-638 Facilities
(Tséhootsooi, Tuba City)

Other Navajo Nation Agencies
(环境保护署和有毒物质与疾病登记处)

USEPA Region 9
Common Limitations of Birth Cohort Studies

• Insufficient characterization of exposure to link to outcomes
  • Exposures almost always to mixtures: understanding of mixture toxicity poor

• Insufficient understanding of modifying factors to draw conclusions

• Primarily epidemiologic – identify potential significant association, but causal relationship not possible

• Duration insufficient to recognize late-onset effects

• Follow-up rates poor due to long-term nature of study

• Funding insufficient – very expensive studies to do well
Navajo Birth Cohort Objectives

• Co-operatively design (with input from communities, Navajo Nation, and federal agencies) and conduct a study to examine pregnancy outcomes and child development in relation to uranium waste exposures among Navajo mother-infant pairs.

• Characterize the cohort with respect to mobility, exposures, co-exposures, demographic & cultural characteristics that may influence outcomes

• Provide extensive outreach on goals and results, prenatal care, and mitigation of exposure-induced health effects

• Work with Navajo agency partners to develop EH capacity and a sustainability plan for continued follow-up of the cohort.
DINEH PROJECT RESULTS:
ACTIVE-MINING ERA EXPOSURES (WORKERS AND FAMILY)
INCREASED RISK OF KIDNEY DISEASE

Active-mining related exposures were estimated from self-reported survey data

A: Washed the clothes of a uranium worker (22%)
B: Worked in a uranium mine (10%)*
C: Lived in a mining camp (4%)
D: Worked in a uranium mill (2%)*
E: Worked on a uranium mine or mill reclamation or hauled uranium ore or tailings in a pickup truck (2%)

*Many workers have already died from lung cancer, cohort had more family members than workers

**DINEH RESULTS:**

**ONGOING ENVIRONMENTAL LEGACY EXPOSURES → INCREASED RISK FOR HYPERTENSION, AUTOIMMUNE DISEASE**

Exposures to legacy uranium mine and mill waste estimated from:
1) Integrated proximity of each resident’s home* to all of the 100 abandoned uranium mine and mill waste features

2) Reported activities resulting in contact with uranium mine and mill wastes

   A: Used materials from abandoned uranium mine or mill (17%)
   B: Herded livestock next to uranium mine, mill or waste dump (13%)
   C: Drunk or contacted uranium mine waste water (13%)
   D: Played on a uranium tailings pile or waste dump (13%)
   E: Played outdoors near a uranium mine, mill, or waste dump (12%)
   F: Sheltered livestock in an abandoned uranium mine (2%)

*Note: Median length of residence in current homes was 33 years
REPRODUCTIVE AND DEVELOPMENTAL CONCERNS – TRIBAL POPULATIONS

- AI/AN historically higher rates of:
  - preterm birth
  - low (and high) birthweight
  - Miscarriage
  - Stillbirth
  - infant death
  - hypertensive disorders
  - Preeclampsia
  - gestational diabetes

- 50% higher prevalence for 8 tracked birth defects (Canfield et al., 2014)
  - Doesn’t count states with highest % tribal populations – small tribal N
  - No assessment of environmental risk factors
How anticipated uncertainties addressed in NBCS (part 1)

• Primary emphasis on exposure characterization
  • Redundancy of input sources to reduce uncertainty
  • Biomonitoring, Home Environmental Assessments, Extant data, Surveys

• Emphasis on known modifying factors
  • Diet, prior reproductive outcomes, alcohol, co-exposures, demographic factors, health histories, inclusion of fathers where possible

• Efforts to move beyond epidemiologic constraints
  • Complex mixture modeling to understand exposure complexity, role of modifying factors, continuum vs. +/- uranium exposures
  • Bayesian approaches to utilize what we know – understand relationships
  • Studies in lab and field to build understanding of exposure & confirm effect likelihood and mechanism to design interventions
How anticipated uncertainties addressed in NBCS (part 2)

• Community staff to increase follow-up
  • Integration of staff into team, motivation of staff key in achieving long-term follow-up
• Seek alternative funding sources to implement underfunded aspects of protocol & sustain follow-up
Planning Phase

- Extensive meetings and discussions with communities, NNDOH, NNGIB, NNEPA, NAIHS, CDC/ATSDR, and a working group of Navajo language & cultural experts
  - Discussions on how to approach sensitive topics, how to integrate hospital staff, data sharing processes, necessary staffing
  - Development of agreements to support final protocol
- Approval by 4 IRBs received by October 2011
- Extensive training of staff at SRIC, NAIHS, PL-638s, NNDOH-CHR program
- Updates on progress throughout to HESSC, Council, Executive Branch, Health Boards, NNHRRB, communities
- OMB, despite 60 day mandatory response, took until Feb 2013 to approve
- Recruitment initiated at Chinle the next day
Where we are today

- **Enrollments:**
  - Moms: 599 (9 are minors)
  - Dads: 185
  - Babies: 485

- **Follow-up rates:**
  - Families we are in contact with 6-12 mos post-partum (from enrollment) ~ 85%
    - Follow-up generally measured relative to most recent contact in other birth cohorts
    - Urban cohorts frequently only able to remain in contact with 50%
  - ~ 50% of cohort screened for development at any 2 mo interval (2,4,6,8,10,12 mo)

- **Note:** rates of biological specimen collections substantially lower
  - Efforts in progress to correct that situation
  - Result of not having research team working within the hospitals & clinical conflicts, hiring barriers
<table>
<thead>
<tr>
<th>General</th>
<th>Mothers</th>
<th>Fathers</th>
<th>Babies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>590</td>
<td>195</td>
<td>480</td>
</tr>
<tr>
<td>Age, mean years (min - max)</td>
<td>27 (14 - 42)</td>
<td>29 (18 - 52)</td>
<td>-</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Education</th>
<th>Mother % (n/total)</th>
<th>Fathers % (n/total)</th>
<th>US Females &lt;50 yrs %</th>
<th>US Males &lt;60 yrs %</th>
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<tbody>
<tr>
<td>No high school diploma</td>
<td>22.9 (100/436)</td>
<td>9.7 (11/113)</td>
<td>11.1</td>
<td>12.8</td>
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<tr>
<td>High school diploma or GED</td>
<td>33.5 (146/436)</td>
<td>45.1 (51/113)</td>
<td>27.8</td>
<td>30.6</td>
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<tr>
<td>College (Some, no degree)</td>
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<td>31.0 (35/113)</td>
<td>19.3</td>
<td>18.5</td>
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<tr>
<td>Associates or Bachelor’s Degree</td>
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<td>8.8 (10/113)</td>
<td>30.9</td>
<td>27.6</td>
</tr>
<tr>
<td>Post-baccalaureate</td>
<td>0.9 (4/436)</td>
<td>0.9 (1/113)</td>
<td>10.8</td>
<td>10.5</td>
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<tr>
<td>Other</td>
<td>2.3 (10/436)</td>
<td>4.4 (5/113)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Employment</th>
<th>US Females, &gt;20 yrs</th>
<th>US Males, &gt;20 yrs</th>
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<tbody>
<tr>
<td>Employed (Full Time)</td>
<td>19.32 (100/440)</td>
<td>27.97 (11/143)</td>
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<tr>
<td>Employed (Part Time)</td>
<td>8.64 (146/440)</td>
<td>9.09 (51/143)</td>
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<tr>
<td>Unemployed</td>
<td>67.50 (124/440)</td>
<td>55.94 (35/143)</td>
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<tr>
<td>Self-employed</td>
<td>3.86 (52/440)</td>
<td>5.59 (10/143)</td>
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<tr>
<td>Did not answer</td>
<td>0.68 (4/440)</td>
<td>1.40 (1/143)</td>
</tr>
</tbody>
</table>

*as of March 7, 2016
Exposure Assessment
Metals Exposure Assessment

- **Home Environmental Assessment**
  - Indoor dust
  - Radon
  - Gamma survey indoors and outdoors
  - Drinking water

- **Land Use Survey**
  - Location of residence
  - Occupational history
  - Activity Survey
  - Family history of exposures

- **Biomonitoring (mom, dad, baby)**
  - Urine Metals (36-element panel)
  - Whole Blood (Pb, Cd, total Hg)
  - Serum (Cu, Se, Zn)

### Sample Collection Timepoints

<table>
<thead>
<tr>
<th></th>
<th>Blood</th>
<th>Urine</th>
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<tbody>
<tr>
<td><strong>Mother</strong></td>
<td>Enrollment</td>
<td>Enrollment</td>
</tr>
<tr>
<td></td>
<td>Delivery</td>
<td>Delivery</td>
</tr>
<tr>
<td><strong>Father</strong></td>
<td>Enrollment</td>
<td>Enrollment</td>
</tr>
<tr>
<td><strong>Baby</strong></td>
<td>Birth (cord blood)</td>
<td>Birth</td>
</tr>
<tr>
<td></td>
<td>2-6 months</td>
<td>2-6 months</td>
</tr>
<tr>
<td></td>
<td>12 months</td>
<td>12 months</td>
</tr>
</tbody>
</table>
• Indoor dust screened against WTC screening levels corrected for dissipation factor

• No Screening Guideline for uranium as it is focus of study

• Many fewer drinking unregulated water in this younger cohort

• No clear indoor U exposure source yet identified

• Likely combination of windblown dusts, wood & coal combustion products, human transport

• All currently being examined as potential sources
Radon data

- <7% homes (N=27) with Rn ≥2.7 pCi/l referral level
  - 12 homes ≥4.0 pCi/l EPA “action level”

- Map (March 2015 version) shows Rn distribution random, difficult to predict

- NNHRRB approved data-sharing plan with Sheldwin Yazzie, Navajo Ph.D. student (UW), who’s developing predictive model for indoor radon based on home construction, NURE-U data, local geology, other factors

Map by J. Hoover, UNM-CEHP
Drinking water, hauling, and co-exposure concerns

- ~30% of Navajo population lack access to regulated drinking water (frequency among NBCS participants ~22%)

- Water quality in ~500 unregulated sources shows 18-20% exceed arsenic MCL; 15% exceed uranium MCL, often co-located (Hoover et al., submitted)

- In contrast to previous studies, only 5.5% of NBCS participants report drinking from unregulated sources

- ~13% NBCS participants drinking from PWSs out of compliance with As and/or U during pregnancies

*Maps by J. Hoover, UNM-CEHP*
Median As & U by Distance from Abandoned U Mine

- As and U concentrations directly related to distance from abandoned U mines
- Includes both anthropogenic and natural contributions
- Important to inform community usage & prioritization of infrastructure decisions
NBCS PARTICIPANTS REPRESENT COMMUNITIES THROUGHOUT THE NAVAJO NATION

- ~600 Mothers now enrolled
- ~7% of mapped homes in former mining areas (within black outline regions)
- Includes non-mined chapters as well
- Looking at continuum of exposure
• 26% of participants have urine uranium > 95% of NHANES (2011-2012)
  • Dad Enrollment: 22%
  • Mom Enrollment: 24%
  • Mom Delivery: 30%

• Babies: not creatinine corrected*:
  • Infant Birth: 0.6%
  • Infant 6 month: 17%
  • Infant 12 month: 24%

*Controversial whether to correct baby data
Babies generally well-hydrated
Kidneys developing
Very high creatinine excretion relative to adults

Urine-uranium in our population shifted well to the right of US NHANES.

Babies show continual increase over first year of life.
• 91% report breastfeeding at some point, 44% at 2 months post-partum
• Only 18% of 12 mo urine currently being captured through hospitals
MATERNAL/INFANT URINE URANIUM AT DELIVERY/BIRTH ARE MODERATELY CORRELATED

REFLECTING CHANGING EXPOSURES DURING PREGNANCY?
RELATIONSHIP STABLE ACROSS LARGER N AND WITH OUTLIERS REMOVED

Correlation between Maternal Urine Uranium and Infant Urine Uranium at Delivery

Correlation: $\rho=0.394$  p-value=$<0.0001$
Urine total arsenic distribution for NBCS mothers, fathers and infants has lower GM and 95th percentile than the US population (NHANES).

Surprising because:

- Arsenic a component of the waste
- Arsenic prevalent in home dust
- Arsenic >MCL in 20% of unregulated water sources
- Comparable to New Hampshire Cohort drinking 80 ug/L As
- Currently looking at metabolic pathways
Blood lead for NBCS mothers, fathers and infants is lower than the GM and 95th percentile for the US population

Only seeing in one service unit in urban area with old infrastructure
Other metals > expected from NHANES

Manganese
• Higher than expected in babies (blood and urine)
• Neurotoxicant

Mercury (inorganic and total)
• Of concern due to coal burning in regional power plants and in homes
• Known neurotoxicant
• Elevated above US population for moms, dads, babies at birth

Antimony
• Replaced cadmium in solder
• Used in semiconductors, alloys, hardens lead in batteries, used as fire retardant
• Toxicity to lungs, skins, liver, cardiovascular system reported, potential carcinogen
• Similar mechanism of action to arsenic -- increased DNA damage. Hypothesized to inhibit repair enzymes
• Elevated in moms, dads, babies

Tin
• Combustion byproduct of coal, waste; common in dusts
• Toxicity relatively low – some reproductive and neurotoxic studies

Tungsten
• Used in bullets, fishing weights, darts, golf clubs, grinding wheels & cutting tools (and light bulbs)
• Used to replace depleted uranium in armour penetrating weapons, lead in bullets
• Often alloyed with nickel, copper – toxicity not well studied for metal or alloys
• Only elevated in babies at birth!
Developmental Screening
Ages and Stages Questionnaire

- Ages and Stages Questionnaire (ASQ) used by GIB and many other programs to screen development as first step in determining needs for early intervention

- No Navajo specific norms – no comparisons to date of appropriateness of instrument

- Evaluate 5 domains:
  - Communication
  - Gross Motor
  - Fine Motor
  - Problem Solving
  - Personal-Social

- Falling below cut-off norm for 2 or more domains → referral for EI evaluation
Comparison of NBCS to US Normative Sample

- Relationship to exposure in progress
- Substantial lag at 8 and 10 months – motor skill primary domains affected
- Referrals of ~40 children to GIB for more in-depth evaluation
- Data will be shared with instrument developers to establish norms specific to Navajo population
- Pattern consistent with informal observations of GIB – lag followed by rebound underscores need for longer-term follow-up as well as Navajo-specific norms
Modifying Factors
Alcohol Exposure

• Self-report of drinking generally thought unreliable
• Nationally >10% consume alcohol during pregnancy
• Can lead to developmental behavioral and physical delays in development (FASD)
• Metabolites of alcohol eliminated through feces, therefore, stable in meconium for ~ 20 wks during gestation
• U of Maryland developed and validated techniques to measure – collaborated with our team to assess
• NIAAA funding to analyze in cohort – determine if there is an interaction with metals exposure
Alcohol Exposure

- 225 meconium samples analyzed
- Exposure confirmed by metabolite analysis is actually lower than we see in other populations
- Surprising to see that self-report exceeds measured metabolites – can reflect earlier period in pregnancy
- Not seeing relationship between exposure and either physical or developmental screening performance at this time
Breastfeeding and Formula Use

• Contribution to exposure, nutrient status important to assess

• Statistical analyses in progress – reduction in breastfeeding over time suggests NOT the source of increasing U exposure

<table>
<thead>
<tr>
<th></th>
<th>Proportion responding &quot;Yes&quot;</th>
<th>Yes</th>
<th>Total responses</th>
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<td><strong>2 months</strong></td>
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<tr>
<td>Breastfeed, any amount</td>
<td>0.91</td>
<td>222</td>
<td>243</td>
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<tr>
<td>Breastfeed, exclusively</td>
<td>0.44</td>
<td>96</td>
<td>220</td>
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<tr>
<td>Formula, any amount</td>
<td>0.59</td>
<td>145</td>
<td>244</td>
</tr>
<tr>
<td><strong>6 months</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Breastfeed, any amount</td>
<td>0.53</td>
<td>98</td>
<td>184</td>
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<td>Breastfeed, exclusively</td>
<td>0.45</td>
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<td>98</td>
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<tr>
<td>Formula, any amount</td>
<td>0.86</td>
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<td><strong>9 months</strong></td>
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<td>Breastfeed, any amount</td>
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<td>Breastfeed, exclusively</td>
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<td>85</td>
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<td>Formula, any amount</td>
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<td><strong>12 months</strong></td>
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<tr>
<td>Breastfeed, any amount</td>
<td>0.43</td>
<td>65</td>
<td>150</td>
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<tr>
<td>Breastfeed, exclusively</td>
<td>0.28</td>
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<tr>
<td>Formula, any amount</td>
<td>0.37</td>
<td>49</td>
<td>131</td>
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</tbody>
</table>
Micronutrient status in NBCS cohort

• Iodine, zinc, copper, selenium measured

• Last evaluation in 1981 – moms low in most micronutrients at that time

• We examine
  • Diet recall – food frequency questionnaire (Harvard) (UNM-CTSC)
  • Micronutrient biomonitoring (CDC – IRAT)
  • Micronutrient measurement to validate self-report (UNM-CTSC)
Iodine

- Critical for normal neurodevelopment
- Highly variable diurnally — population indicator only
- “Sufficiency” for pregnant women even higher
- Low on Colorado Plateau soils
- Not readily supplemented
- Dietary sources not in Navajo diet
  - lactose intolerant
  - culturally don’t eat fish
  - wheat grown locally

*controversial whether to correct baby data
  Babies generally well-hydrated
  Kidneys developing
  Very high creatinine excretion relative to adults
Serum Zinc

- Mom’s deficient – common in pregnancy
- Most babies sufficient
- Many dads also low
- Important in reversing arsenic- and uranium-induced inhibition of DNA repair in laboratory systems
- Preliminary data show same reversal in cohort parents
- Looking for markers other than serum to reflect intracellular sufficiency
- Vitamins only effective prior to pregnancy
Nutrient Status During Pregnancy

- **NOTE:** Still missing many delivery weights, so normalization not yet complete
Mechanisms of Toxicity
Arsenic (arsenite) increases retention of DNA damage at sub-uM exposure — most sensitive effect — selective

Zinc protects against AsIII increased DNA damage and mutation in keratinocytes

- DNA regularly damaged — in most cases it is repaired, and no long-term effects are seen
- Proteins involved in repair of damage require Zn binding to become active
- Graph at left shows how much DNA damage induced by exposure to UV radiation persists over time (1-6 hrs)
- As successfully competes with the zinc, makes protein inactive, and damage to DNA is retained. (3rd set of bars)
- While Zn alone added to the system has no effect (second set of bars), if added in the presence of As it restores activity of repair proteins.

DNA Damage
U also inhibits PARP activity, causes zinc loss from DNA repair proteins, and inhibits multiple DNA repair proteins — not selective like As

Like As, Zinc reverses U effect

Mechanisms differ

VERY preliminary ongoing analyses in parents show DNA damage and relationship to exposure

Zn diminishes U effect

As x U interact

3-way metals & age interaction unclear

In some models, vitamin use restores

Interactions among metals complex and still being investigated --- Need much larger N
Increased Autoimmunity in Exposed Population

• 17.7% of NBCS parents (average age 26) are positive for serum ANA.

• 45% of ANA positive individuals are male, 55% female
  • typical ratio 9:1 female/male - environmental cause?

• ~10% of NBCS mothers have documented autoimmune disease (31/291 medical record abstractions) which is higher than National Averages

• Effect on development? Mothers with autoimmune disease have increased risk of having offspring with autism spectrum disorder.
  • ANA can cross placental barrier, interact with fetal tissue (brain)

• Exposure analysis in progress pending larger N (now N=100)

• Could result from alterations in cytokines (e.g. IL-17)? DNA damage → apoptosis?

Supported by funding from NIEHS, NIMHD, Lewis, UNM-COP
Cytokine Alteration: Preliminary

• In older DiNEH population, metal mixtures accounted for 50-80% of cytokine production

• Preliminary analysis on 110 samples:
  • increased urine uranium levels $\rightarrow$ increased IL-4 and TNF$\alpha$ ($p>0.01$)
  • IL-7 and IL-12p70 increased with increased UUR ($p>0.05$)
  • IL-12p70, the $p$-value for U increases if As removed from model, suggesting interaction where As suppresses effect
  • Both IL-4 and TNF$\alpha$ are associated with the development of autoimmune diseases
  • Both IL-4 and TNF$\alpha$ were higher in males than in females (basis for = ANA?)
  • Mixed metal x cytokine interactions complex – need more power to describe.

• ANA + individuals have $>\text{IL-17}$; preliminary trends indicate positive relationship between UUR, UAS, and IL-17
Modeling to identify relevant mixtures

- Bayesian predictive models (PReMiuM in R)

- Iteratively clusters predictor variables from mixture datasets to identify exposure clusters relevant to outcomes rather than evaluating many independently

- Can also identify patterns of exposures

- Evaluate group of best-fit models to identify most-robust variables
Exposure clusters identified: NBCS

- **Cluster 1**: N = 93
  - highest quartiles of As (total), As (dimethyl), Cs, Co, Mo, Pb, Tl, W, Cd, Sr, Sb, Sn, U, Mn, Ba

- **Cluster 2**: N = 55
  - Selenium and Cesium dominate though still average, average for other metals

- **Cluster 3**: N = 12
  - generally average to low for all metals

- **Cluster 4**: N = 135
  - majority of participants to date, dominated by relatively low exposures to both U and As (U slightly higher) and other metals

- **Cluster 5**: N = 14
  - Dominated by Ba, Sr, Mn, Sb; U & As > than in cluster 4

- Cluster 1 likely most important toxicologically, but interactions with other variables (reclustering against outcome measures) will be essential in interpretation of exposure-response relationships

- Currently determining spatial relationships of exposure profiles
Geochemistry, Minerology and Exposure
Toxic Metals Enriched in Fine Fraction of Wastes

Small-sized grains are highly enriched in specific metals

Free uranium particles in waste available for resuspension & Aeolian transport -- respirable to deep lung – toxicity unclear for particles this fine

Image: Sumant Avasarala
Uranium in Waste Also Mobile in Water

Table. Water quality data from water sources in the proximity of mine wastes in Blue Gap Tachee (BGT), AZ and Laguna, NM.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameter</th>
<th>U (µg/L)</th>
<th>As (µg/L)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring-BGT</td>
<td></td>
<td>163.2</td>
<td>5.7</td>
<td>7.4</td>
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<td>135.4</td>
<td>9.6</td>
<td>3.8</td>
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<tr>
<td>Well-BGT</td>
<td></td>
<td>2.0</td>
<td>36.7</td>
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<tr>
<td>Rio Paguate</td>
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<td>711</td>
<td>11.9</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Uranium in water sources used for drinking by humans and livestock exceed drinking water standards by 5 - >20 fold
Context for Continued Investigation
Gold King Mine Spill -- Geospatial Data Visualization

- Visualized movement of metal plum down the Animas River into San Juan River
- Total Iron (Fe) Concentrations
- Observe possible re-mobilization of metals around Mexican Hat

Data source: Total metal results by US EPA Regions 6, 8 and 9
Gold King Mine – Navajo Nation Chapters (and municipalities) Adjacent to San Juan River

Animas River 2 weeks after release of 3,000,000 gallons of mine water

Biomonitoring and home environmental data collected for ~20 NBCS participant families who live near San Juan River prior to release

Monitoring of spill pointed to risks from existing mine and mill sites
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- > 2000 Navajo families
- Many supporting chapters
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- NAIHS & PL-638 hospital laboratory staff, leadership, and health boards

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- UNM-COP
- UNM-CTSC
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DINEH and NBCS Research is reviewed and monitored by Navajo Nation Human Research Review Board

(Navajo Team Members)
THANK YOU....

Is this OK?