A Grand Rounds Presentation for Primary Care Providers

Lead and Arsenic Exposure Near the Former Colorado Smelter in Pueblo, Colorado

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Division of Community Health Investigations

Agency for Toxic Substances and Disease Registry (ATSDR)

What is ATSDR?

- A federal public health agency
- Based in Atlanta, Georgia
- Charged with
  - Assessing the presence of environmental health hazards in communities
  - Preventing harmful exposures to contaminants
  - Increasing the knowledge about the health effects from chemical and radiation exposure

Presentation Outline

- Learning Goals
- Children and Environmental Exposure
- Lead
- Arsenic
- ATSDR's Colorado Smelter Exposure Investigation
- Questions

Learning Goals

Recognize and understand:

1. Why children are more vulnerable?
2. CDC's reference level for lead
3. Sources of lead and arsenic exposure
4. The health effects from exposure to lead and arsenic
5. Methods of testing for lead and arsenic exposure
6. Ways to prevent lead and arsenic exposure
7. The findings and recommendations of ATSDR's Colorado Smelter Exposure Investigation (EI)

Children are at Higher Risk than Adults for Environmental Exposure to Contaminants

- Children are uniquely vulnerable to environmental exposures.
- Children are not just "little adults."
- Children's age-specific risk factors for exposure to environmentally related illness are:
  - Exposure
  - Absorption
  - Metabolism
  - Distribution
  - Target organ susceptibilities

Environmental Health Perspectives. September 1995; 103(Supplement 6):7-12. How Are Different from Adults? Bearer, C.F.

Children are at Higher Risk than Adults for Environmental Exposure to Contaminants (cont…)

- Children will be in different environments throughout the day, depending on age.
- Pre-ambulating children cannot remove themselves from an unsafe environment.
- Young children have age-appropriate hand-to-mouth behavior.
- The metabolic rate of children is higher than adults because of their larger surface-to-volume ratio.
- The amount of food consumed per body weight is much higher in children than in adults; therefore, children have higher exposure to ingested toxins in food.

Environmental Health Perspectives. September 1995; 103(Supplement 6):7-12. How Are Children Different from Adults? Bearer, C F.

LEAD

What Is the Problem?

Over half a million children (>500,000) ages 1 to 5 years in the U.S. have blood lead levels high enough to affect their health.

What is Lead Poisoning?

Is one of the most significant and prevalent disease of environmental origin among children living in the U.S. and…

It is preventable!

MMWR. November 2, 2007; 56(RR08):1-14;16.

Personal
Risk Factors for Lead Exposure

Risk factors	Prevention strategy
Genetics, does not change	Prevent exposure
Age of organ development	Prevent exposure
Young males <6 years of age	Supervise kids/Prevent exposure
Pica behavior	Supervise kids/Discourage behavior
Poor nutrition	Balanced diet, rich in Iron, Calcium, Vitamin C and Vitamin E
Poverty-Income-Ratio (PIR) <1.3	Access to WIC program /health care
Cultural practices/ Ayurveda/spices	Avoid use/Prevent exposure

Environmental Sources for Lead Exposure

Environmental sources	Prevention strategy
Year house built <1978 (lead-based paint)	Identify/Evaluate/Remediate
Dust from lead-based paint chips	Control sources
Soil contaminated with lead	Restrict play area/cover source
Drinking water	Check information from water department
Home renovation	Proper containment
Worker take-home contamination	Shower/Remove shoes and clothes
Some hobbies	Proper use/storage/ventilation
Some imported toys, cosmetics/spices and ceramic cookware	Avoid use

CDC Reference Value for Lead Guidance

- Before 2012 "Level of Concern"
  - ⩾10 µg/dL
  - All children

- 2012 – to present "Reference Value"
  - ⩾5 µg/dL
  - Children 1 to 5 years of age and pregnant women
  - The reference value will be updated every 4 years as appropriate.
  - Follow-up required

http://www.cdc.gov/nceh/lead/ACCLPP/blood_lead_levels.htm

What should be the blood lead level (BLL) for children 1 to 5 years of age and for pregnant women?

No safe blood lead level for children has been identified.

Health Effects from Low Level Lead Exposure

Human Lead Exposure

In general, exposure occurs via one or more of the main components of the human environment:

- Inhaled air
- Soil and dust of various types (can be ingested or inhaled)
- Drinking water and
- Food

Health Effects in Adults (including pregnant women)

Blood lead level (µg/dL) in adults	Organ system	Sufficient evidence of
At levels below 10µg/dL and even at levels below 5µg/dL	Renal	▪ Decreased GFR[1]
	Cardiovascular	▪ Increased BP[2] ▪ Increased Risk HTN[3]
	Neurologic	▪ Increased incidence of essential tremors

[1] GFR Glomerular filtration rate; [2] BP Blood pressure; [3] HTN Hypertension
National Toxicology Program (NTP). 2012.

Health Effects in Unborn Babies

Blood Lead Level in Pregnant women	Affects the Unborn Baby's	Sufficient Evidence of
Even at levels below 5µg/dL	Development	▪ Reduce growth in the unborn baby (SGA) ▪ Reduced postnatal growth

National Toxicology Program. Monograph on Health Effects of Low-level Lead. 2012. US Department of Health and Human Services. June

Health Effects in Children

BLL in Children	Organ system	Sufficient evidence of
At levels below 10µg/dL and even at levels below 5µg/dL	Neurologic	• Decreased academic achievement • Decreased IQ /specific cognitive measures • Increased incidence of attention-related behavior and • Increased behavioral problem
	Reproductive	• Delayed puberty

National Toxicology Program. Monograph on Health Effects of Low-level Lead. 2012. US Department of Health and Human Services. June

Pearls of Lead Exposure

Women of Childbearing Age (17 – 44 years)

- Over 40 % of the U.S. population consists of women of childbearing age.
- Eleven out of one hundred-thousand (11/100,000) women of childbearing age have BLLs ≥5 µg/dL.
- In a study conducted in 2006, 50% of pregnancies in women of childbearing age were *unintended (not planned)*
- Women of child-bearing age should not be exposed to lead.

Contraception. November 2011; 84(5): 478-485. Unintended pregnancy in the U.S: incidence and disparities, 2006.

Risk Factors of Lead Exposure for Pregnant Women

- Recent migration,
- Pica,
- Occupational exposures,
- Nutritional status,
- Culturally specific practices such as the use of some traditional medicines or imported cosmetics
- The use of traditional lead-glazed pottery for cooking and storing food.

Maternal Child Health J. 2013 January ; 17(1): 172–179.

Lead in Bone

- A woman who has had increased blood lead levels (BLLs) in the past (as a child) will have about 90% of the lead stored in bone.

- Lead stored in bone may be mobilized during pregnancy and lactation (source of endogenous exposure), exposing the fetus and breastfed infants.

MMWR. November 2, 2007; 56(RR08):1-14,16

Lead in Breastmilk

- In a lead exposed mother, lead in her breastmilk can expose the nursing infant.
- In a study of 255 mother–infant pairs, infant BLL at 1 month post-partum significantly correlated with lead levels in breastmilk and accounted for 30% of the variation in the infant BLLs.
- Infant exposure to lead in breastmilk is in addition to environmental and in-utero exposures.
- Longer duration of breastfeeding was associated with higher BLLS in the infant.

Environmental Health Perspectives. January 2014; 122(1). Maternal Blood, Plasma, and Breast Milk Lead: Lactational Transfer and Contribution to Infant Exposure"

Lead in Breastmilk (cont…)

- The transfer of lead from *plasma* to breastmilk is substantially higher than previously reported (0.1 ± 0.1 µg/Liter), and it may be higher at lower levels of plasma lead.

- The transfer of lead from *plasma* to breastmilk has implications for policy decisions regarding counseling the lead-exposed woman on breastfeeding.

Environmental Health Perspective. January 2014; ; 122(1). "Maternal Blood, Plasma, and Breast Milk Lead: Lactation Transfer and Contribution to Infant Exposure"

Diagnosis

Whom and When to Test for Lead?

- *Recommendations for Preventive Pediatric Health Care*. Tab # 2. (Bright Futures by American Academy of Pediatrics [AAP]), 2014.

- *Recommendations on Medical Management of Childhood Lead Exposure and Poisoning.* Tab # 10. (Pediatric Environmental Health Specialty Units [PEHSUs]/AAP/AOEC/ATSDR), 2014.

- *Interpreting and Managing Low Blood Lead Levels*: Tab # 15. (PEHSU Supplemental Information for Clinicians) .

Blood Lead Testing Methods

- Confirmatory method
  - Venous sample
- Screening methods
  - Capillary, analyzed by *traditional* laboratory.
  - Capillary, analyzed by LEAD CARE II instrument;
    - The reportable range is from 3.3 to 65 µg/dL
    - Clinical Laboratory Improvement Amendments (CLIA) waived.

Follow-up BLLs ⩾5 µg/dL

Re-test patient

- At BLLs 5 to 14 µg/dL, within 1 – 3 months
- At BLLs 15 to 44 µg/dL, within 1 – 4 weeks
- At BLLs > 44 µg/dL , within 48 hours

Pediatric Environmental Health Specialty Units (PEHSU). Updated, June 2013. Located in Tab # 10

Prevention

Primary Prevention

Since no safe blood lead level in children has been identified, CDC and ATSDR recommend primary prevention of lead exposure wherever possible.

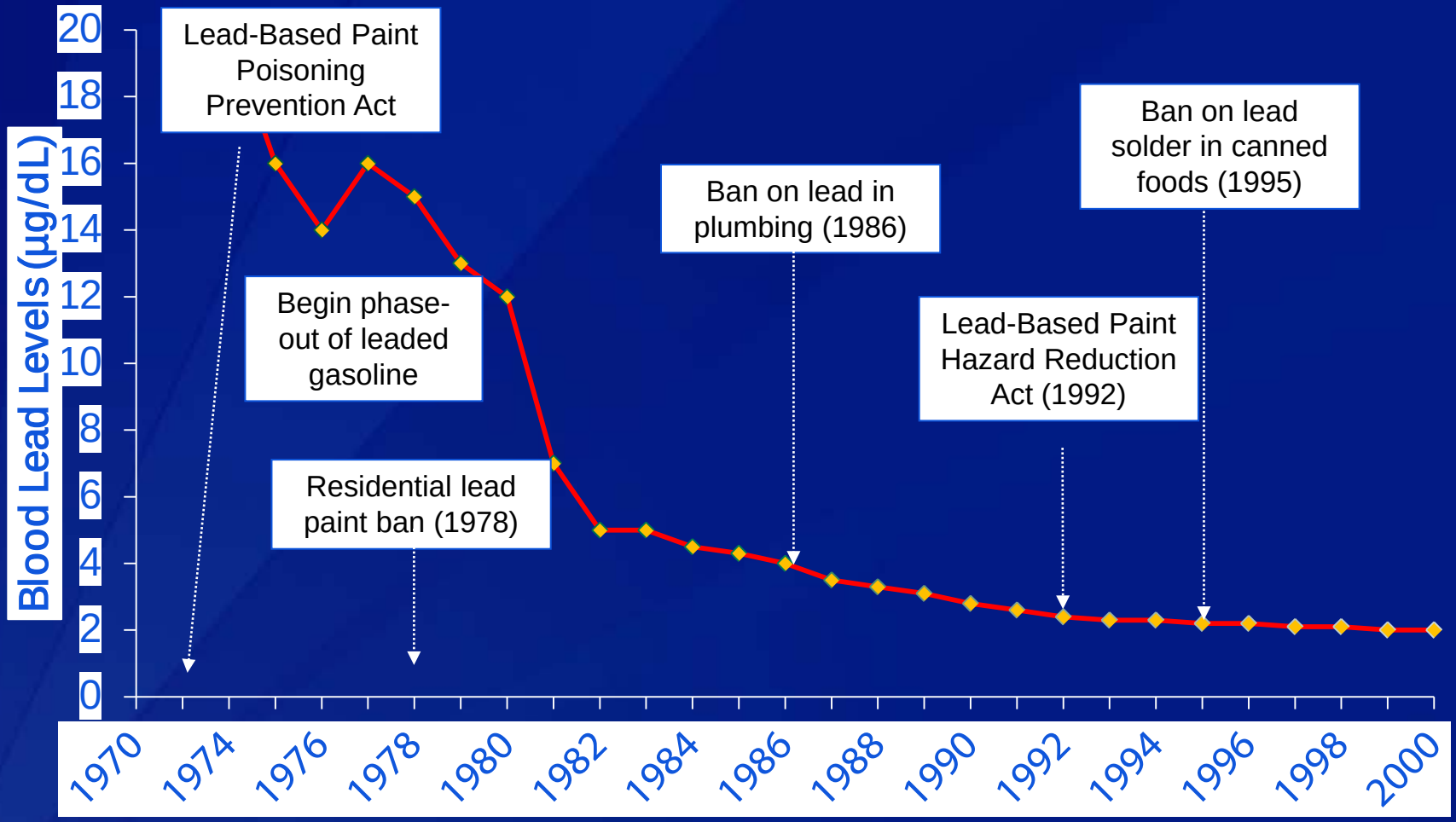
CDC's Advisory Committee on Childhood Lead Poisoning Prevention, 2007.

Why Primary Prevention?

- Adverse effects of lead are dangerous.
- Adverse effects are systemic.
- Adverse effects are persistent.
- Chelation does not result in improved neurobehavioral outcomes.
- No discernible threshold exists for adverse effects.
- Prevention is cost-beneficial.

http://www.cdc.gov/nceh/lead/publications/PrimaryPreventionDocument.pdf

Decline in Children's Blood Lead Levels due to Regulations



Bruce Lanphear. 2008. PowerPoint presentation: The CDC Should Lower the Level of Concern to Protect Children from Lead Toxicity .

Preventing Lead Exposure

Primary care providers:

- Test children for lead based on risk factors and the state of Colorado Lead Screening Recommendations,. (Tab # 13). https://www.colorado.gov/pacific/sites/default/files/DC_Env_Exposure_Lead_Colorado-Lead-Screening-Guidelines.pdf
- Make *Pediatric Exposure History (Tab # 6)* part of your patient's medical history.
- Recommend frequent nutritious meals rich in calcium, iron, zinc, vitamin C, and vitamin E to prevent absorption of lead.
- Stay current about sources of lead in your area that may potentially affect your patients.

Preventing Lead Exposure according to Bruce Lanphear M.D.

- Eliminate all non-essential uses of lead worldwide and strengthen regulations to control lead emissions.
- Screen housing units for lead hazards before purchase or occupancy and after renovation and abatement.
- Lower reference level to <1µg/dL as a public health goal--not as a clinical "action level."
- Begin environmental interventions in high-risk communities.

Presentation Summary : The CDC Should Lower the Level of Concern to Protect Children from Lead Toxicity Bruce P. Lanphear, MD, MPH Cincinnati Children's Hospital Medical Center

Diets Rich in Calcium Prevent Increased BLLs

- Calcium decreases the mobilization of bone lead to blood, especially during high metabolic activity of the bone such as in
  - Pregnancy
  - Lactation
  - Childhood growth and development
  - Menopause

- Calcium supplementation may play a role in
  - Decreasing intestinal lead absorption
  - Increasing lead excretion from the circulation and
  - Reducing bone reabsorption.

National Toxicology Program. Monograph on Health Effects of Low-level Lead. 2012. US Department of Health and Human Services. June

Calcium and Lead during Pregnancy

- During pregnancy, the fetus needs 100-140 mg/kg/day accretion of calcium for skeletal formation and growth.
- Pregnant and lactating women require about 1,200-1,500 mg/day of calcium, depending on their age.
- Lead competes with calcium absorption; thus, intake of a calcium-rich diet helps decrease lead absorption.

Pediatrics. October 1, 2005; 116(4):1036 -1046

Nutritional Deficiencies that Increase Lead Absorption

- Most lead uptake occurs through the gastrointestinal tract.
- Increased absorption occurs with dietary deficiency of
  - Calcium
  - Iron
  - Vitamin C
  - Zinc
- The absorption of ingested lead ranges from 20% – 70% *unless* a good nutritional diet is in place.

British Journal of Nutrition. 2001; 85(Suppl. 2):S181- S185

Arsenic

Forms of Arsenic

- Organic
  - Non-toxic
  - Exposure is mainly from fish and seafood
- Inorganic
  - Very toxic
  - Mainly from ground water and dietary products such as rice (especially brown rice) and apple juice.
  - Carcinogenic, affecting almost every organ in the body (skin, lungs, stomach, liver, bladder and cardio-vascular)
  - Associated with diabetes mellitus: > 150µg/L arsenic in drinking water.

Arsenic Exposure

Sources of Inorganic Arsenic Exposure

- Some foods (e.g. , apple juice and rice)
- Water (e.g., arsenic is naturally-occurring in groundwater in many areas of the U.S.)
- Soil; arsenic compounds can accumulate in soil because they are not biodegradable.
- Air

Health Effects

Arsenic affects many biologic systems, sometimes years or decades after exposure reductions.

Naujokas MF, Anderson B, Ahsan H, et al. The Broad Scope of Health Effects from Chronic Arsenic Exposure: Update on Worldwide Public Health Problem.
Environmental Health Perspectives. March 2013; 121(3).

Arsenic Health Effects

❑ Non-Cancer Health Effects:

- The chemical form of arsenic (organic, versus inorganic)
- Exposure route,
- Duration (acute versus chronic exposure)
- Dose and
- The health of the person at the time of exposure

❑ Cancer:

- Skin, (synergistic action with sunlight for causing skin cancer??)
- Lung (smoking may increase the risk for mortality from lung cancer)
- Bladder

Arsenic Health Effects in Pregnant Women/Fetus and Children

- In Pregnant Women/Fetus at very high levels:
  - Increased spontaneous abortions, & stillbirths

- In Children at very high levels:
  - Increased infant mortality and altered;
    - developing immune system in newborn
    - motor function
    - verbal and full-scale IQ in *girls*
    - neurological impairments in children

Naujokas MF, Anderson B, Ahsan H, et al. The Broad Scope of Health Effects from Chronic Arsenic Exposure: Update on Worldwide Public Health Problem. Environmental Health Perspectives. March 2013; 121(3).

Prevention

Preventing Arsenic Exposure

Primary care providers:

- Make *Pediatric Exposure History (Tab # 6)* part of your patient's medical history.

- Recommend nutritious meals appropriate for age and growth, rich in Folate (Vitamin B_9) found in cornmeal, spaghetti, bagels, pita and sourdough breads and more.

- Stay current about sources of arsenic in your area that may potentially affect your patients.

Folate for Prevention of Arsenic Poisoning

- Low folate in diet increases blood arsenic absorption, allowing accumulation in the body and increasing the risk of
  - Arsenic skin lesions
  - Skin and bladder cancers and
  - Peripheral vascular disease.

- Suggest that folic acid supplementation may reduce the risk of inorganic-arsenic-related health outcomes.

Naujokas MF, Anderson B, Ahsan H, Aposhian HV, et al. The Broad Scope of Health Effects from Chronic Arsenic Exposure: Update on a Worldwide Public Health Program. EHP Volume 121/Number 3/March 2013.

Diagnosis

Methods to Measure Urinary Arsenic

- A 24-hour urine collection is the most reliable method to correct for fluctuations in excretion rates.

  Biomonitoring for Environmental Exposures to Arsenic. Journal of Toxicology and Environmental Health, Part B: Critical Reviews. 12:7, 509-524. Orloff K, Metcalf S, Mistry K. 2009

- In the Colorado Smelter Exposure Investigation, we collected a "spot" urine sample,
  - that is why, the urine specimens were creatinine-corrected, to adjust for dilution and
  - for determining whether a spot urine sample was valid for assessing arsenic exposure.

  Environmental Health Perspectives. Jul 2005; 113(7): 192-200.

Colorado Smelter Exposure Investigation

Colorado Smelter Exposure Investigation (EI)

- PCCHD requested an exposure investigation from ATSDR.
- A biologic EI (blood lead and urinary arsenic) was conducted during September and November 2013.
- The purpose of the EI was to investigate whether people living within half a mile of the smelter at higher risk for health effects had elevated levels of lead in blood and/or arsenic in urine.

Colorado Smelter EI (cont…)

- The Colorado Smelter operated in the Eilers and Bessemer neighborhoods for 25 years. The smelter closed 117 years ago.

- Smelter operations resulted in the slag pile and soil contamination with lead and arsenic.

Slag Pile

Unrestricted access and evidence of children riding bikes

Criteria for Participation/ Target Population

People living within half a mile of the former smelter and belonging to one of the following groups:

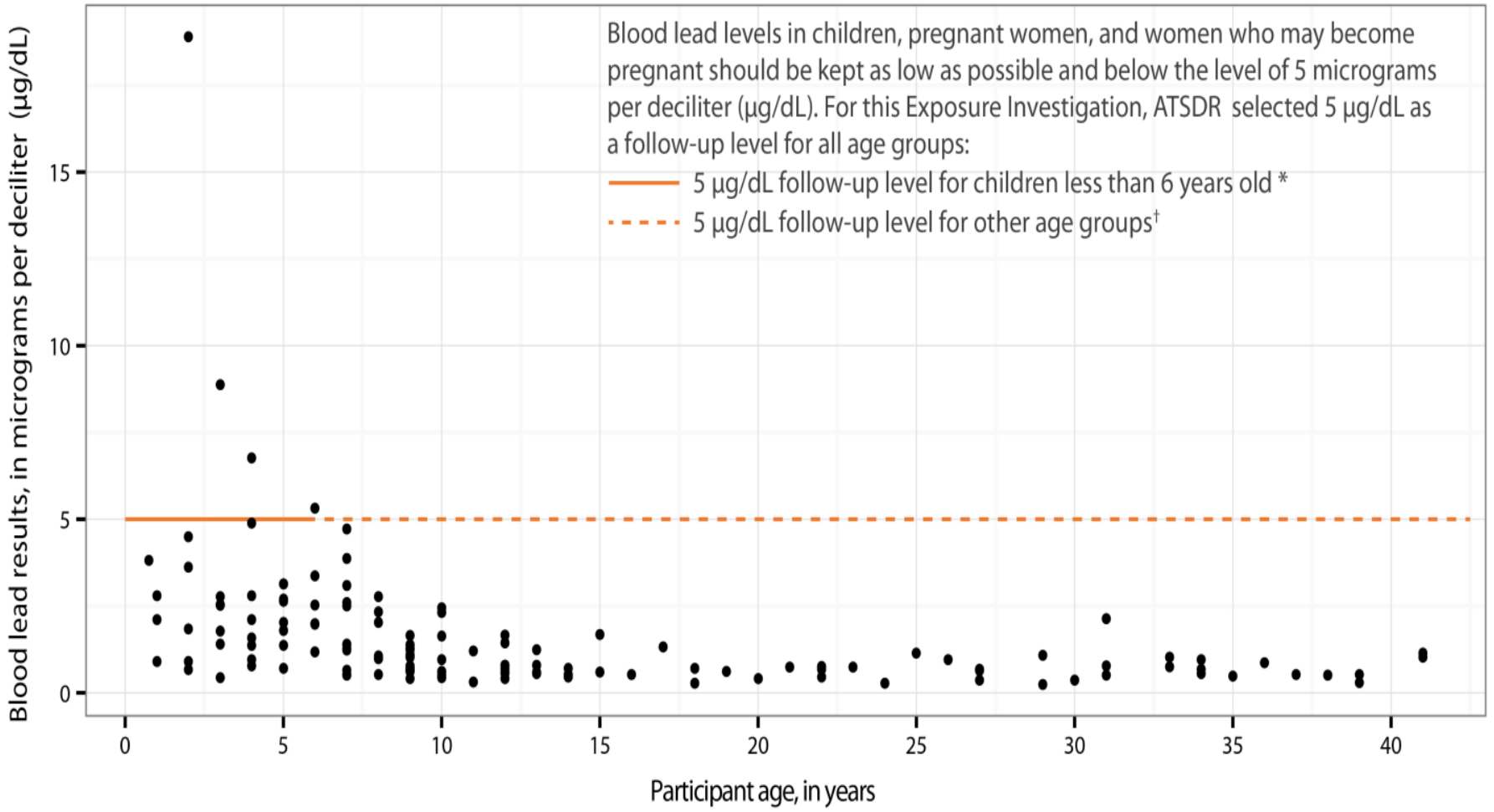
- Children from 9 months to younger than 6 years (blood lead testing only)
- Children from 6 to 16 years (blood lead and urine arsenic testing)
- Pregnant women and women of childbearing age (blood lead and urine arsenic testing)

Blood Lead Results Exceeding 5µg/dL by Age Group

Age	n*	# ≥5 µg/dL	Specific result (µg/dL)
9 months to <6 years	33[1]	3	18.9, 8.87, 6.77
6 to <12 years	47	1	5.32
12 to <20 years	23	0	–
20 to <45 years	32	0	–

*One vial arrived at the laboratory empty

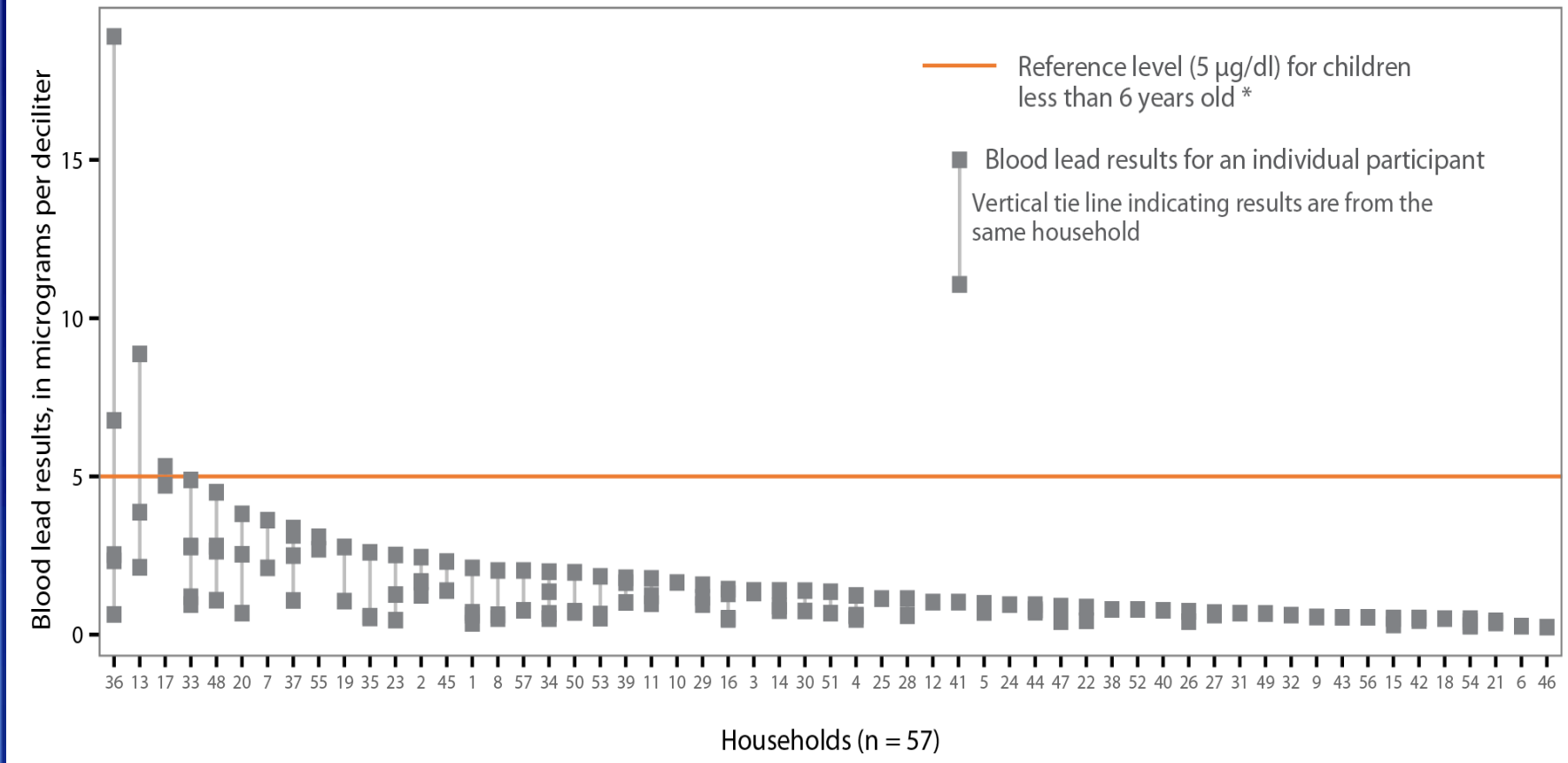
Blood Lead Results



* Centers for Disease Control and Prevention (CDC 2012a).

† ATSDR selected a 5 µg/dL investigation follow-up level for all age groups based on the demographics (age and gender distribution) of the participants in this Exposure Investigation.

Blood Lead Levels by Household



* Source: Centers for Disease Control and Prevention (CDC 2012a).

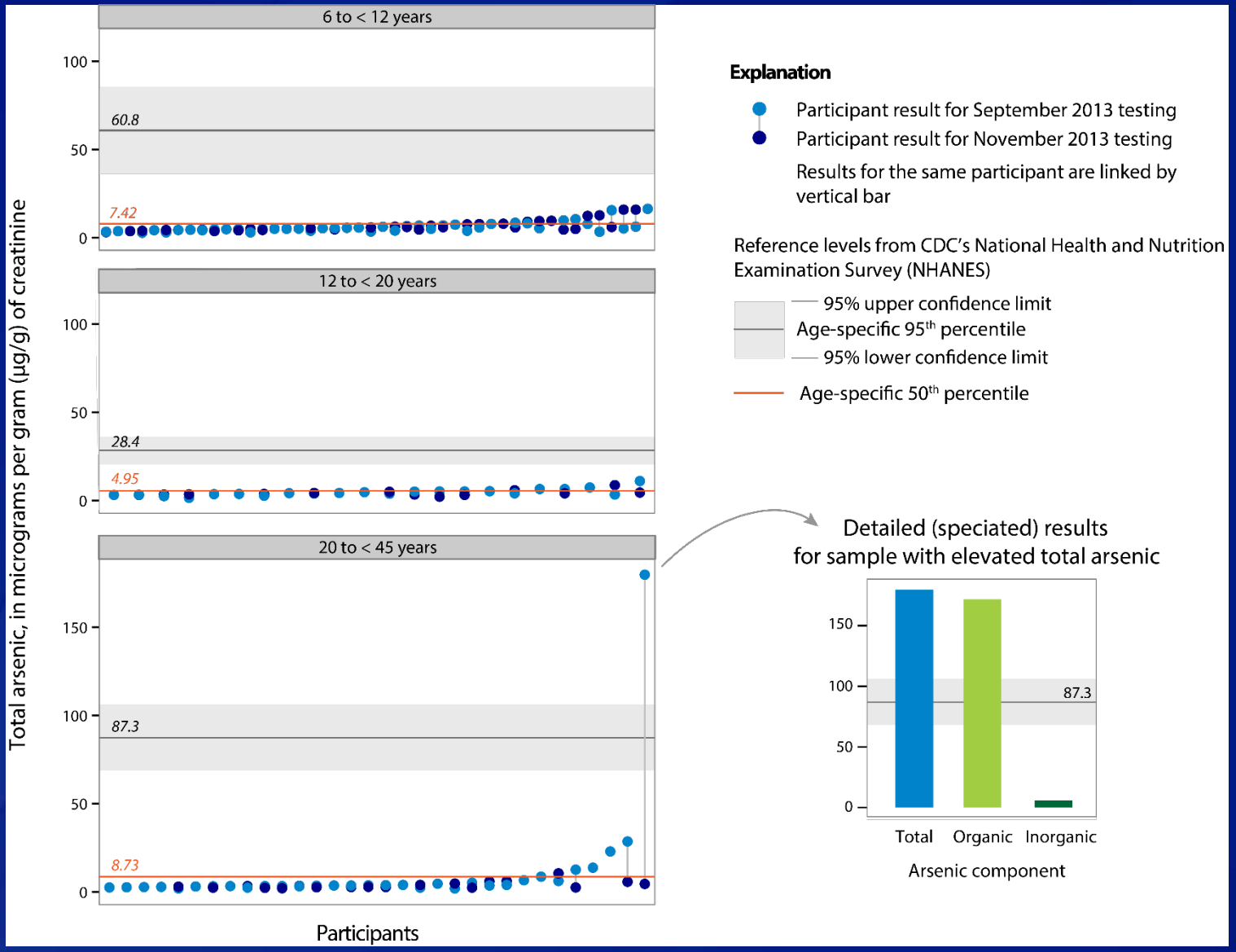
Colorado Smelter Exposure Investigation (EI)

Arsenic level ATSDR used

- We compared the total creatinine corrected urinary arsenic results to the age specific 95th percentile of the NHANES 2009 – 2010 (Feb 2015).
- The 95th percentile for the various age-groups
  - 6 to < 12 years: 60.8 µg/g creatinine
  - 12 to < 20 years: 28.4 µg/g creatinine
  - 20 < 45 years: 87.3 µg/g creatinine
- Only one elevated total urinary arsenic was found in the first round, but it was of dietary origin, non toxic arsenic.

Fourth Report of the National Report on Human Exposure to Environmental Chemicals, Updated Tables, February 2015.

Arsenic Graph



Why Two Urinary Arsenic Tests?

- ATSDR conducted 2 rounds of urinary arsenic testing to increase the likelihood of finding arsenic exposure.
- Arsenic is rapidly metabolized and excreted from the body within 2 – 3 days of exposure; thus, urinary arsenic testing measures only recent exposures.
- Therefore, a urine sample needs to be collected soon after exposure has occurred.

Number of Participants by Age Groups

Arsenic testing

Participants Ages	1st Round September 2013 (n=99)	2nd Round November 2013 (n=65)
6 to <12 years[2]	45 Total[1]	33 Total
12 to <20 years	22 Total	13 Total
20 to <45 years	32 Total	19 Total

[1] There were two 5 years old included
[2] Males and Females participants

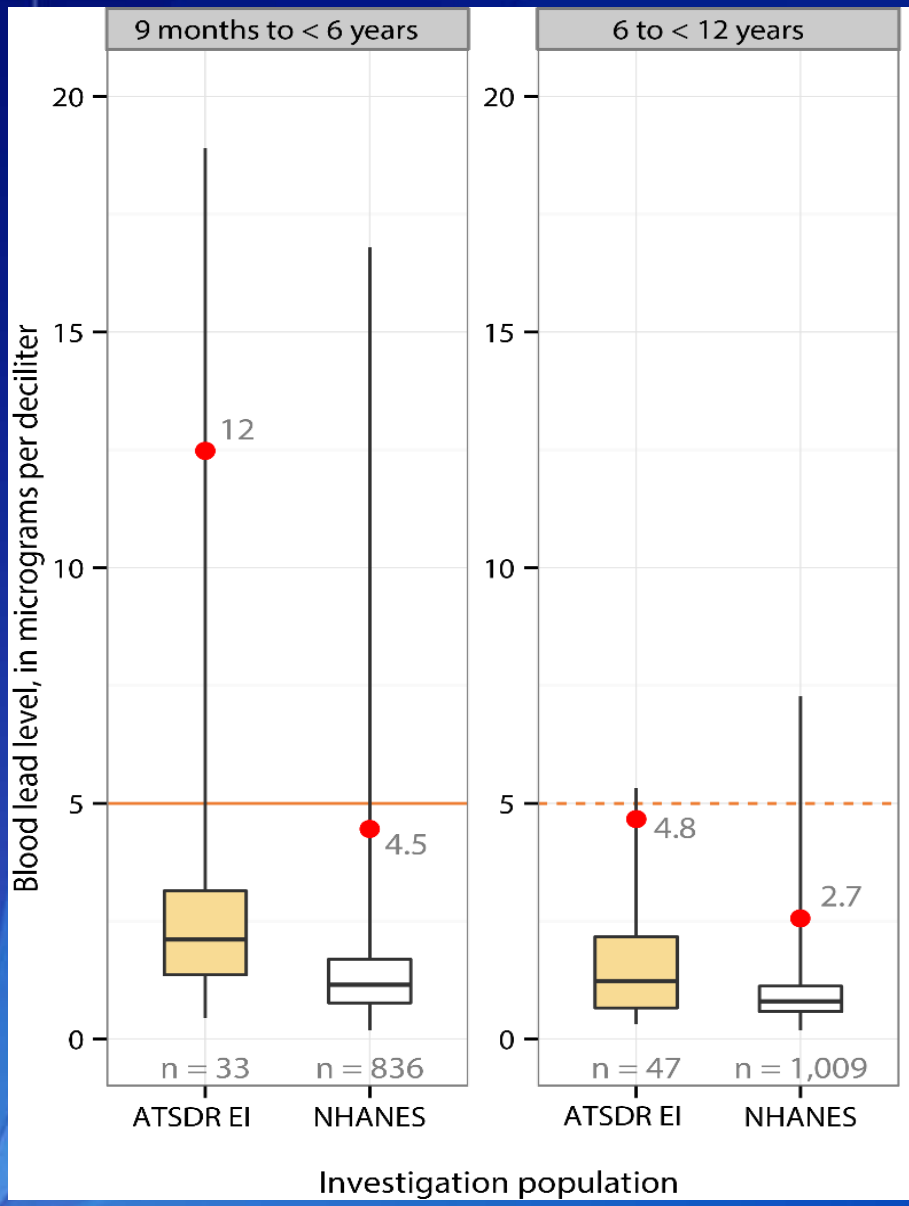
Lead Findings of the El
Blood Lead Levels (BLLs)

Findings

- Young children living within half a mile of the former smelter and who were at increased risk of lead exposure had higher BLLs; these exposure levels can harm children's health.

- Blood lead levels for the youngest age groups (9 months to less than 6 years old and 6 to less than 12 years old) are higher than corresponding national levels from NHANES 2009-10 (February 2013).

Blood Lead Level Results - Youngest Age Groups



Explanation

ATSDR EI, Agency for Toxic Substances and Disease Registry Exposure Investigation (2013)

NHANES, National Health and Nutrition Survey (data from 2009–2010)

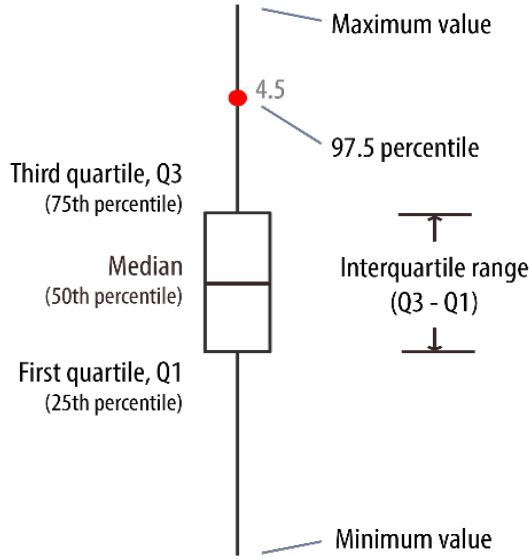
Investigation follow-up levels

Blood lead levels in children, pregnant women, and women who may become pregnant should be kept as low as possible and below the level of 5 micrograms per deciliter (µg/dL). For this Exposure Investigation, ATSDR selected 5 µg/dL as a follow-up level for all age groups:

- 5 µg/dL CDC Reference Level for children less than 6 years old *
- 5 µg/dL follow-up level for other age groups †

* Centers for Disease Control and Prevention (CDC 2012a).

† ATSDR selected a 5 µg/dL follow-up level for all age groups based on the demographics (age and gender distribution) of the participants in this Exposure Investigation.



Arsenic Findings of the El

Urinary Arsenic

- The concentration of total urinary arsenic in all but one participant was below the 95th % of the NHANES.
- The speciation of the total arsenic found the elevated arsenic to be arsenobetaine, a dietary form of arsenic mostly found in seafood that is relatively nontoxic.
- ATSDR did not find evidence of elevated inorganic arsenic in the population living within half a mile of the former Smelter tested in September 2013 or in November 2013.

ATSDR Recommendations

1. Continue blood lead testing for area residents: children, pregnant women, and women of child-bearing age.
2. Instruct area primary care providers on lead/arsenic sources and risks of exposures, diagnosis, and more.
3. Characterize the nature and extent of lead and arsenic contamination.
4. Stop/reduce exposure to mining wastes in residential soil and slag pile.
5. Develop a sustainable health education program in the area.

Public Health Action Plan

1. PCCHD received a 5 year EPA grant to
   - Conduct health education and BLL screening
   - Assist in coordinating developmental and cognitive evaluations in affected children
   - Conduct other public health actions/investigations

2. In 2014, EPA listed the Colorado Smelter site on the National Priority "Superfund Fund" list for clean-up.

3. ATSDR published its EI report and is holding public availability meetings in the community.

"It is essential to guide clinicians and community leaders in advocating to protect children from harmful levels of lead exposure; it provides a goal for the local, state and federal health agencies to set policy and provide funding to protect children from the adverse consequences of lead toxicity."

Bruce P Lanphear, MD, MPH

Acknowledgements

ATSDR appreciates the Pueblo City County Health Department (PCCHD)'s assistance with the Exposure Investigation. PCCHD was instrumental in the recruitment, implementation, notification of information, and Healthy Home Inspections conducted for the participants of the Colorado Smelter EI.

Especially we want to thank

Sylvia Proud, MS, IPMA-CP. Public Health Director, PCCHD.

Dr. Christine Nevins-Woods, D.O. Medical Officer, PCCHD.

Ken Williams, BS. ,Director Environmental Health Division, PCCHD.

ATSDR also appreciates the Regional Offices of the Environmental Protection Agency (EPA) for their hard work and strong collaboration with our Exposure Investigation for the area within 0.5 mile from the former smelter in Pueblo.

Last but not least, ATSDR appreciates the community which so graciously participated in this Exposure Investigation, we want to thank them for their participation and collaboration with the EI!

Thanks for your attention
Any Questions?

For more information please contact Agency for Toxic Substances and Disease Registry

4770 Buford Hwy, NE Chamblee, GA 30341
Telephone: 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
Visit: www.atsdr.cdc.gov | Contact CDC at: 1-800-CDC-INFO or www.cdc.gov/info