Association between children's blood lead levels, lead service lines, and use of chloramines for water disinfection in Washington DC, 1998-2006

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Introduction

- DC Water and Sewer Authority (WASA) modified its drinking water disinfectant process in preparation of the Disinfection Byproducts Rule (EPA 2006a)
- In late 2000, DC WASA began using chloramine as a disinfectant for drinking water to reduce the byproducts in the drinking water
- New disinfectant process raised concerns of possible leaching of lead into the drinking water

Background

- Chloramine strips the mineral scale from water services lines entering residences
- Lead Service Lines – These lines connect the water main to the house
- EPA action level for lead in drinking water is 15ppb

Objective

Examine the association between childhood blood lead levels (BLL), exposure to lead service lines (LSL), and chloramine as a water disinfectant in Washington DC from 1998 - 2006

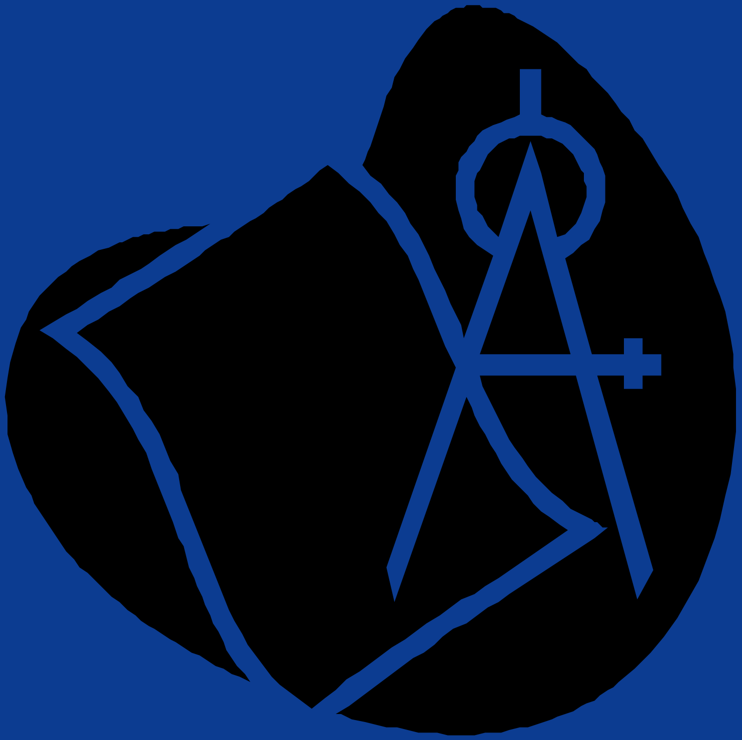
Hypotheses

- Is there an association between LSL and BLL among children < 6 years of age living in Washington DC?
- Is there an association between chloramine use and BLL among children < 6 years of age living in Washington DC?
- Is there a synergistic concomitant association between chloramine use and LSL and increasing BLL within this population?

Methods

Study Design

Cross-sectional study conducted to examine association between LSL, chloramine use, and BLL between 1998 and 2006 in Washington DC



Methods (2)

Study Population

- 49,084 unique children received a blood lead test between 1998 and 2006
- 26,141 dwellings had LSL during the same time period (Data from DC WASA)
- 6,670 children tested lived in a dwelling with a LSL (16,311 children tested lived in a dwelling without a LSL)
- 22,981 – Final sample size

Methods (3)

Variables Examined

Primary Exposure variables

- LSL
- Chloramine use (pre, during, post)

Primary Outcome variable

- BLL (≥ 5 µg/dL, ≥ 10 µg/dL)

Covariates

- Gender
- Age at time of test
- Sample type
- Age of housing unit
- Year of BL test

Methods (4)

Analysis Plan

- Univariate analyses conducted to examine first order associations
- Generalized Linear Models developed to examine trends in BLL over time: pre, during, and post chloramine use
- Multiple logistic regression models developed to describe interaction and control for confounding

Univariate Analysis

	Blood Lead Levels						
	< 5 µg/dL		5 - 9 µg/dL		≥ 10 µg/dL		Chi-Square
Characteristic	**n**	**%**	**n**	**%**	**n**	**%**	**p-Value**
Gender							
Male	18,205	*73.8*	5,247	*21.3*	1,217	*4.9*	< 0.0001
Female	17,574	*75.0*	4,772	*20.4*	1,080	*4.6*	
Unknown	738	*74.6*	228	*23.1*	23	*2.3*	
Age							
0-11 months	6,216	*75.0*	1,685	*20.3*	385	*4.6*	<0.0001
12-23 months	7,003	*74.4*	1,928	*20.5*	476	*5.1*	
24-35 months	6,631	*70.5*	2,223	*23.6*	546	*5.8*	
36-47 months	5,498	*72.5*	1,720	*22.7*	364	*4.8*	
48-72 months	11,169	*77.5*	2,691	*18.7*	549	*3.8*	
Sample Type							
Capillary	1,492	*72.4*	515	*25.0*	55	*2.7*	<0.0001
Venous	29,535	*74.5*	7,986	*20.1*	2,134	*5.4*	
Unknown	5,490	*74.5*	1,746	*23.7*	131	*1.8*	

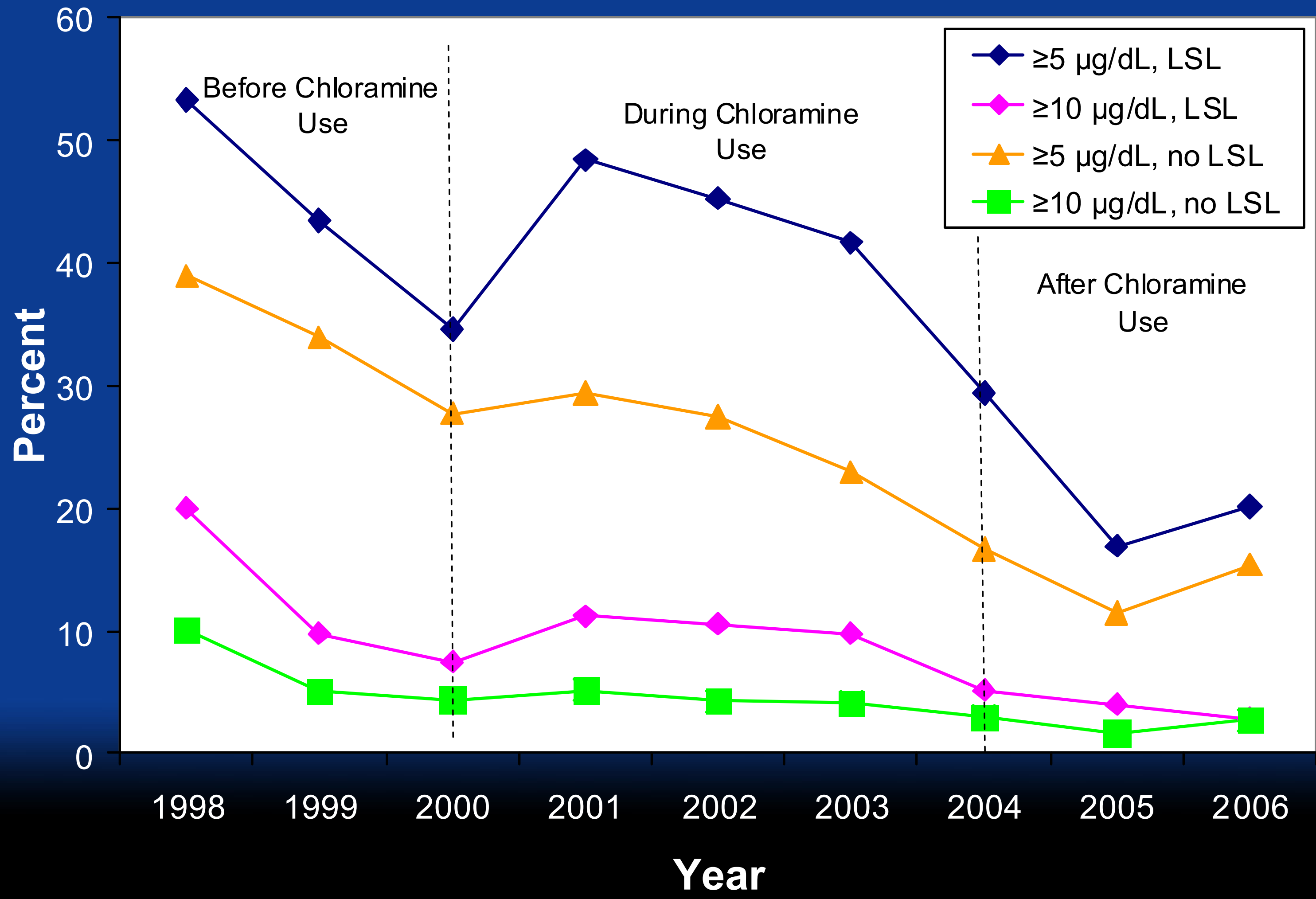
Univariate Analysis (2)

	Blood Lead Levels						
	< 5 µg/dL		5 - 9 µg/dL		≥ 10 µg/dL		Chi-Square
Characteristic	**n**	**%**	**n**	**%**	**n**	**%**	**p-Value**
Chloramine Use							
Pre-Chloramine	9,719	*65.9*	4,042	*27.4*	976	*6.6*	<0.0001
During Chloramine	17,147	*74.1*	4,916	*21.2*	1,086	*4.7*	
Post Chloramine	9,651	*86.2*	1,289	*11.5*	258	*2.3*	
Age of Housing							
Pre- 1950	12,484	*68.0*	4,588	*25.0*	1,300	*7.1*	<0.0001
1951-1978	1,469	*83.0*	258	*14.6*	43	*2.4*	
Post 1978	642	*84.4*	108	*14.2*	11	*1.4*	
Unknown	21,922	*77.8*	5,293	*18.8*	966	*3.4*	

Univariate Analysis (3)

	Blood Lead Levels						
	< 5 µg/dL		5 - 9 µg/dL		≥ 10 µg/dL		Chi-Square
Characteristic	**n**	**%**	**n**	**%**	**n**	**%**	**p-Value**
Lead Service Line							
Yes	4,329	*64.0*	1,863	*27.6*	568	*8.4*	<0.0001
No	13,732	*84.7*	2,069	*12.8*	420	*2.6*	
Unknown	18,456	*70.7*	6,315	*24.2*	1,332	*5.1*	
Sample Year							
1998	1,984	*58.9*	998	*29.6*	386	*11.5*	<0.0001
1999	3,776	*64.9*	1,714	*29.5*	328	*5.6*	
2000	3,959	*71.3*	1,330	*24.0*	262	*4.7*	
2001	3,780	*67.9*	1,450	*26.0*	338	*6.1*	
2002	4,019	*70.1*	1,418	*24.7*	294	*5.1*	
2003	3,039	*74.4*	846	*20.7*	200	*4.9*	
2004	6,309	*81.2*	1,202	*15.5*	254	*3.3*	
2005	5,430	*87.7*	641	*10.3*	124	*2.0*	
2006	4,221	*84.4*	648	*13.0*	134	*2.7*	

Percentage of children with EBLL, by year and water-line type



Associations of BLL between LSL and chloramine use

	During use of Chloramine (2001-2004)				Post Chloramine use (2005 - 2006)			
	LSL	**No LSL**	**POR**	**95% CI**	**LSL**	**No LSL**	**POR**	**95% CI**
≥ 5 µg/dL	1,343	1,250	3.0	(2.7, 3.3)	244	1,216	1.4	(1.2, 1.7)
< 5 µg/dL	2,062	5,698			1,122	8,003		
≥ 10 µg/dL	292	229	2.8	(2.3, 3.3)	50	184	1.9	(1.4, 2.6)
< 10 µg/dL	3,113	6,719			1,316	9,035		

POR = Prevalence Odds Ratio

Adjusted multivariate model for BLLs ≥ 5 µg/dL among children < 6 years of age living in Washington DC

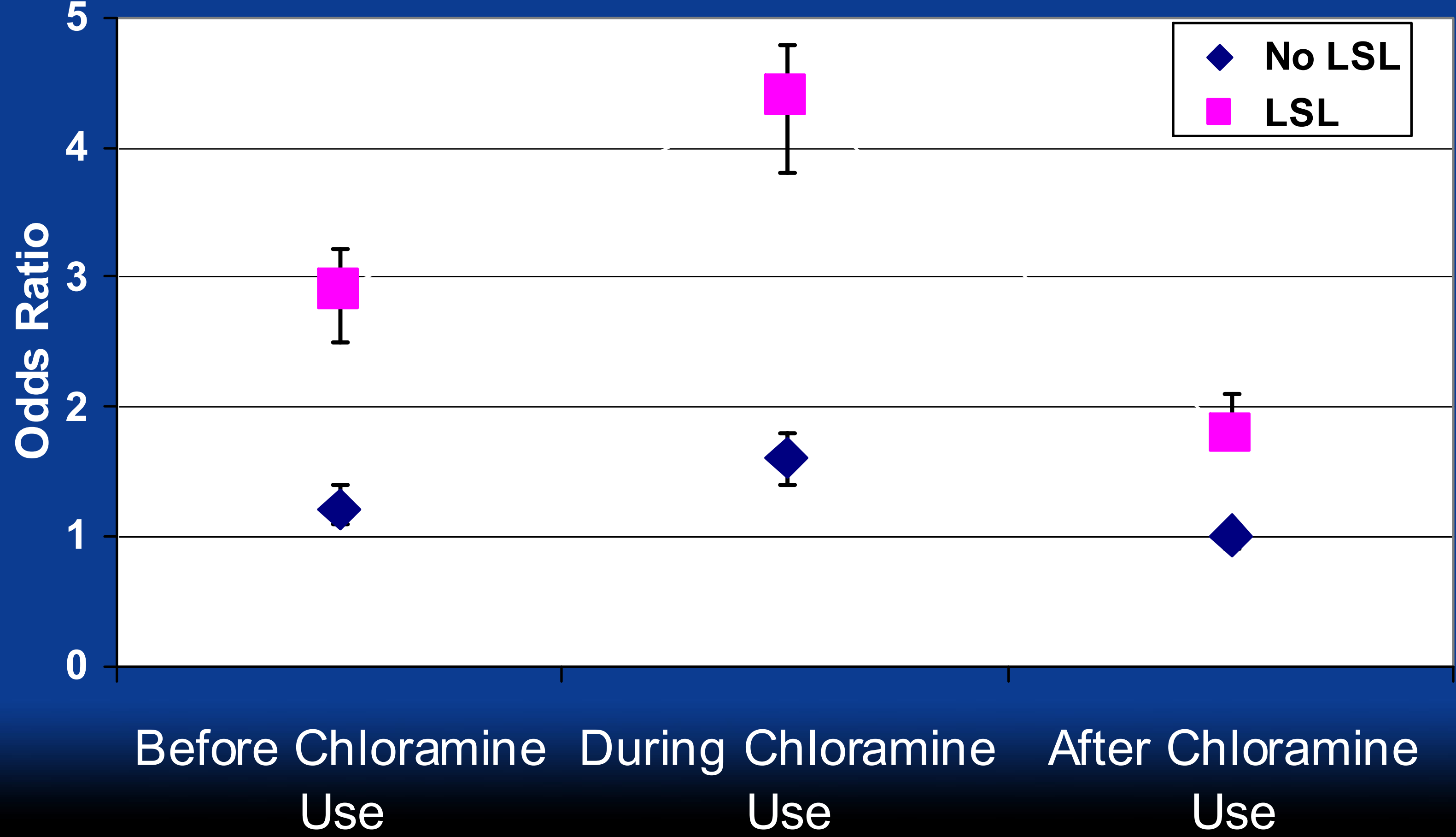
Variable	*Adjusted Model*			
	Parameter Estimates	OR	95% CI	P-value
Age of Housing (referent = post 1978)				
Pre-1978		1.5	(1.3, 1.8)	<0.0001
Pre-1950		2.3	(1.9, 2.8)	<0.0001
Lead Service Line (LSL)		4.4^		<0.0001
Chloramine Use	0.2225			<0.0001
LSL*Chloramine Use	0.2178			<0.0001

^ Represents the OR for a child living in a house with a LSL, when chloramine was used

Adjusted multivariate model for BLLs ≥ 10 µg/dL among children < 6 years of age living in Washington DC

Variable	*Adjusted Model*		
	OR	**95% CI**	**P-value**
Sample Type (referent=capillary)	3.6	(1.9, 6.5)	<0.0001
Age of Housing (referent = post 1978)			
Pre-1978	2.1	(1.4, 3.1)	0.0004
Pre-1950	4.2	(3.7, 4.9)	0.0004
Lead Service Line (LSL)	2.7	(2.2, 3.2)	<0.0001
Chloramine Use	1.4	(1.3, 1.5)	<0.0001

Graphic interpretation of interaction between LSL and chloramine use for BLLs ≥5 µg/dL



Discussion

- Age of Housing continued to be significantly associated with BLLs ≥5 μg/dL and ≥10 μg/dL even after controlling for confounders.

- Lead paint in older housing continues to be the main source of lead exposure in children < 6 years of age
  - Chipping and peeling paint
  - Lead paint dust

Discussion (2)

- LSL – Children who were tested and had BLL ≥5 µg/dL or ≥10 µg/dL were significantly more likely to have lived in a HU with a LSL compared to children with lower BLLs even after adjusting for confounders.

- LSL are found across Washington DC

- Possible that children with BLLs <5 µg/dL or <10 µg/dL
  - Lived in a HU that had a non-lead service line
  - Tended to drink bottled water

Discussion (3)

- Chloramine use – The proportion of children tested with BLL ≥5 µg/dL or ≥10 µg/dL was significantly higher during the time that chloramine use was in effect compared to after use was discontinued.

- Chloramine may have stripped the lead from LSL resulting in subsequent leaching into the drinking water.

Discussion (4)

- There is a significant interaction between LSL exposure and chloramine use among children with BLLs ≥5 µg/dL

- Concomitant use of chloramine and LSL resulted in a significant increase in the proportion of children with BLLs ≥5 µg/dL because of the leaching of lead from the LSL during the use of chloramine as the water disinfectant.

Conclusion

- The use of chloramine in the water system as a water disinfectant may have caused LSL to leach lead into the water, contributing to the rise of BLLs in young children.

- When chloramine was eliminated as the drinking water disinfectant, we saw a dramatic reduction in BLLs in children < 6 years old in Washington DC.

Conclusion (2)

- Lead paint in older housing (pre-1950, pre-1978) continues to be a significant source of lead exposure in children < 6 years of age living in Washington DC.
- There is no safe level of lead and all exposure to this environmental hazard should be avoided.

Thank you!

Co-Investigators

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