Designing Sampling for Targeting Lead and Copper: Implications for Exposure

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Key Points

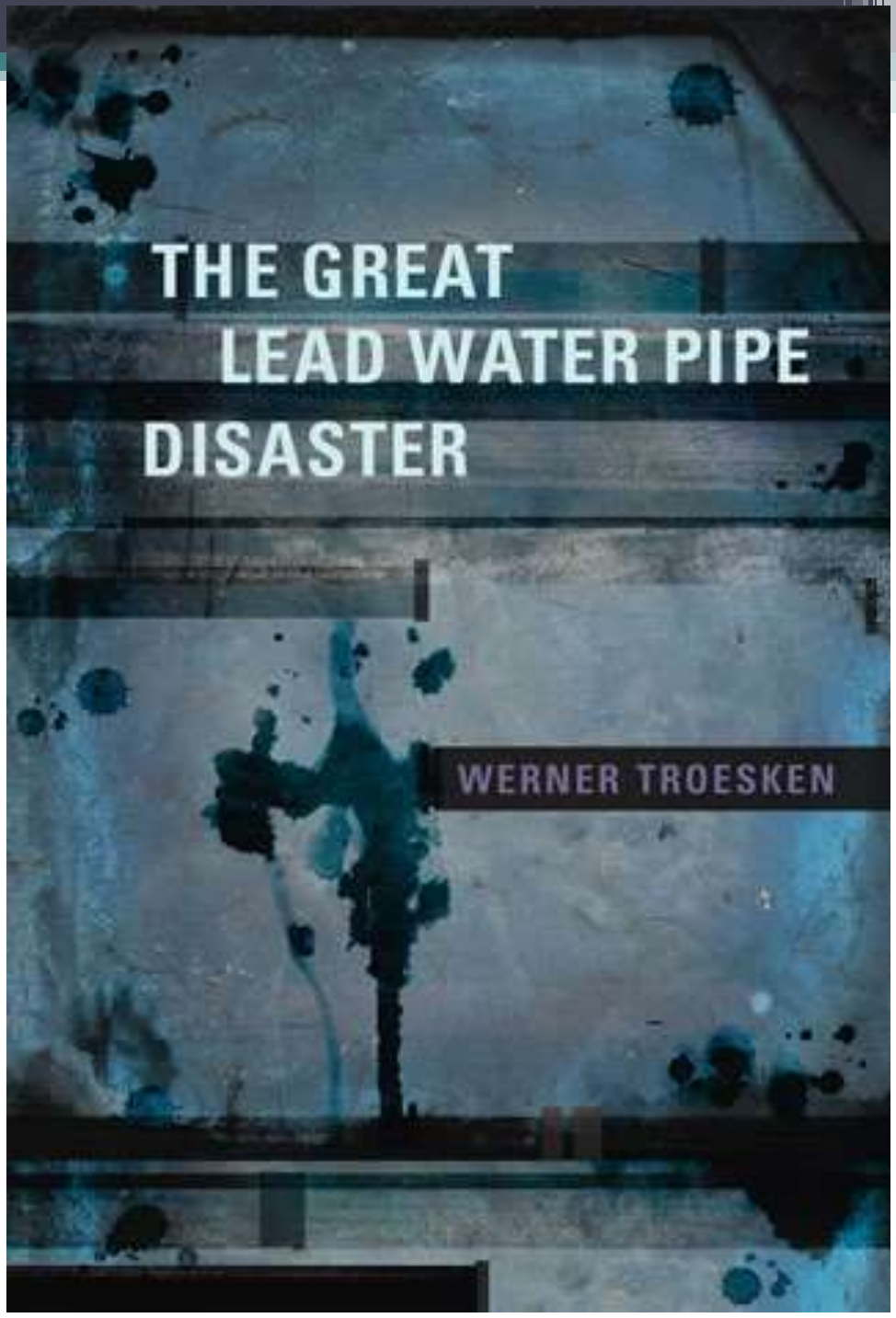
We know how to find risks from high water Pb (unfortunately we are often doing just the opposite)

Missing lead in water hazards during sampling provides a false sense of security to all parties and endangers public health

Current levels of lead in U.S. potable water pose an unacceptable acute/chronic health threat

Decision by cities to allow/require use of lead service lines….

caused one of the most serious environmental disasters in US History



Perspective on Legacy Plumbing Lead Sources

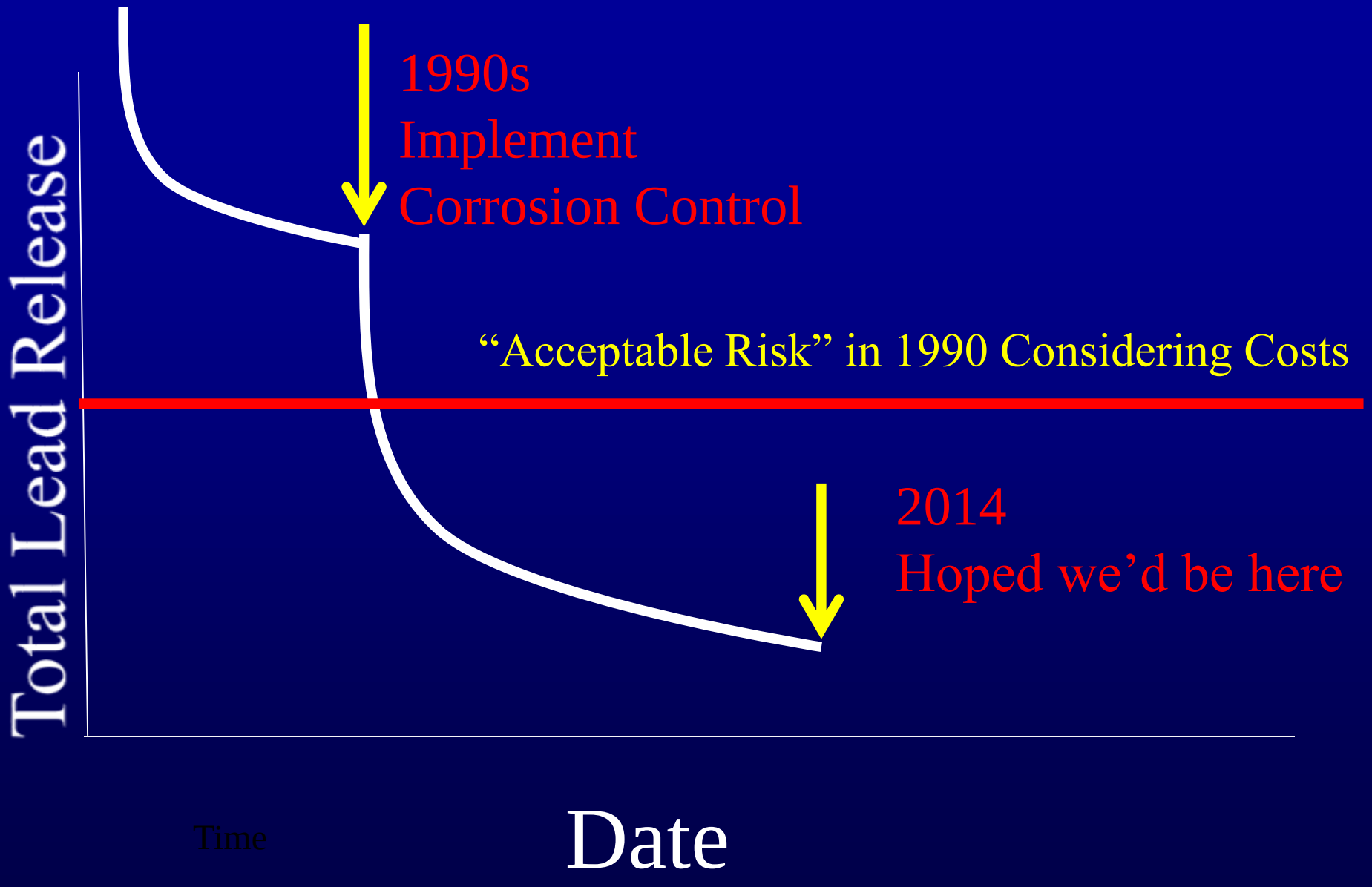
Lead-Bearing Plumbing Material	Age of US Homes at Potential Risk	Estimated number of US homes at potential risk	Estimated Mass of Lead per home at potential risk (kg)	Responsibility/ Average Performance Lifetime
Brass Plumbing Components **If 2% lead by weight** **If 8% lead by weight** **> 8% lead by weight**	All All Pre 1986	All All 81million[a]	0.1[b] 0.3[b] 0.4[b]	**Mostly private ≈ 20-70 years**
Lead pipes, lead service lines, and lead goosenecks (100% lead by weight)	Pre 1986	3.3 - 6.4 million[c]	19.1[d]	**Undeniable Public Responsibility ≈ 100-1000 years**
Lead solder (40% - 50% lead by weight)	Pre 1986	81 million[a]	Highly variable, but believed very significant[e]	**Mostly private ≈ 20-70 years**
Lead joints in water mains (100% lead by weight)	Pre 1986	All homes served by water mains installed pre 1986	Unknown but believed inconsequential[f]	NA

Modified from Triantafyllidou and Edwards (2011)[18]

Even 1 foot of lead pipe, contains enough lead to raise every drop of water used by a family of 4 over 100 years, to over the 15 ppb AL

Lead pipe is the most concentrated lead source in US homes, and it directly affects a product (tap water) that is intended for human consumption

Conceptualization of LCR Goals for Water in Lead Pipe



Changes affecting peak LSL Lead since 2000

Recent Changes	Decreases Pb	Increases Pb
Utilities Add Less Chlorine		X
Aggressive Water Conservation		X
Chloramine Instead of Chlorine		X
Reduce Phosphate Doses to "Optimize" Corrosion Control and Save $$		X
Created Millions of Disturbed and Partially Replaced LSLs		X
More Exposed Iron Pipe in Mains → More Fe, Less Cl_2 = More Pb		X
More Accumulated Pb Scale, More Pb Particulates from Corrosion Control and Older Pipes		X
Higher temperatures?		X

Science Predicts Higher Peak LSL Pb Release in Many Systems Due to These Changes-Little Reason to Hope Things are Improving

Conceptualization of LCR for Lead Pipe

Lead on tap
An alarming return of lead in drinking water is being ignored by the EPA and municipal officials

By Rebecca Renner

Nov. 27, 2006 | WASHINGTON --

http://www.salon.com/2006/11/27/lead_3/

Utility Sampling Instructions Have Evolved (Devolved) to Miss Many LSL Pb and Particulate Pb Problems in Water When Present

Generation of Pb Particles

Corrosion or Rusting

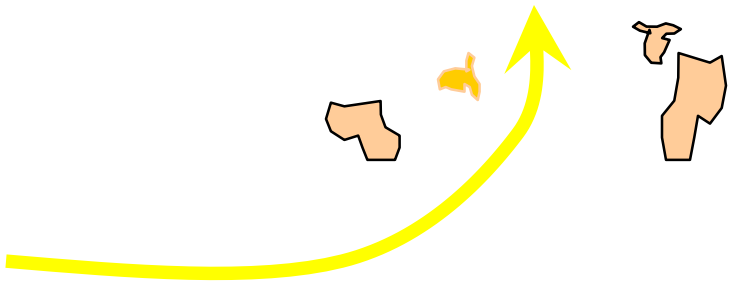
Lead Solder, Lead Scale or “Rust” layer

Lead Solder, Lead Pipe or Leaded Brass

Detachment During Flow

Faster water flow in some systems, means more particulate lead

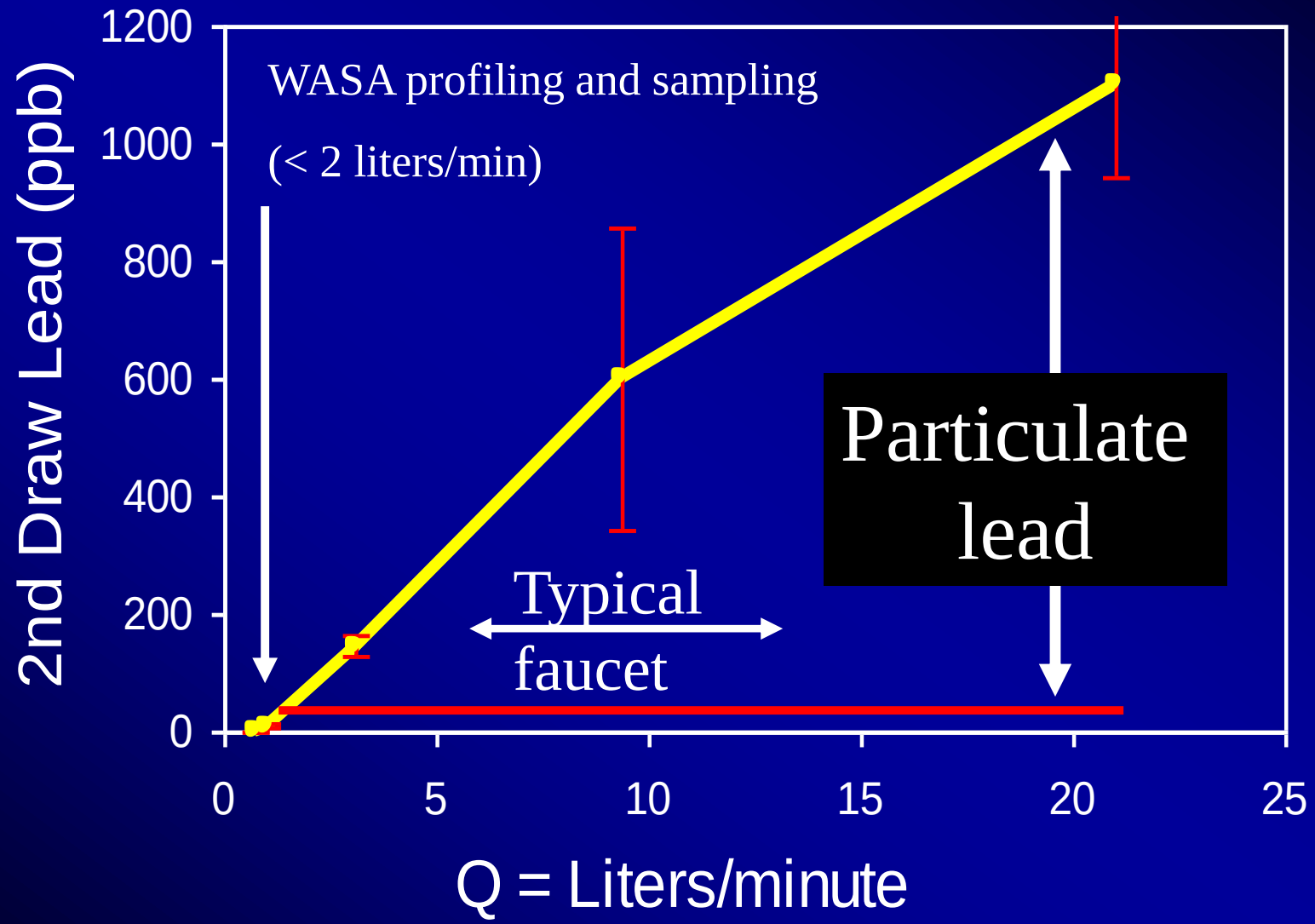
Scouring



Lead Solder, Lead Scale or “Rust” layer

Pb Plumbing Material

Water Samples of LSL Lead from DC in 2004

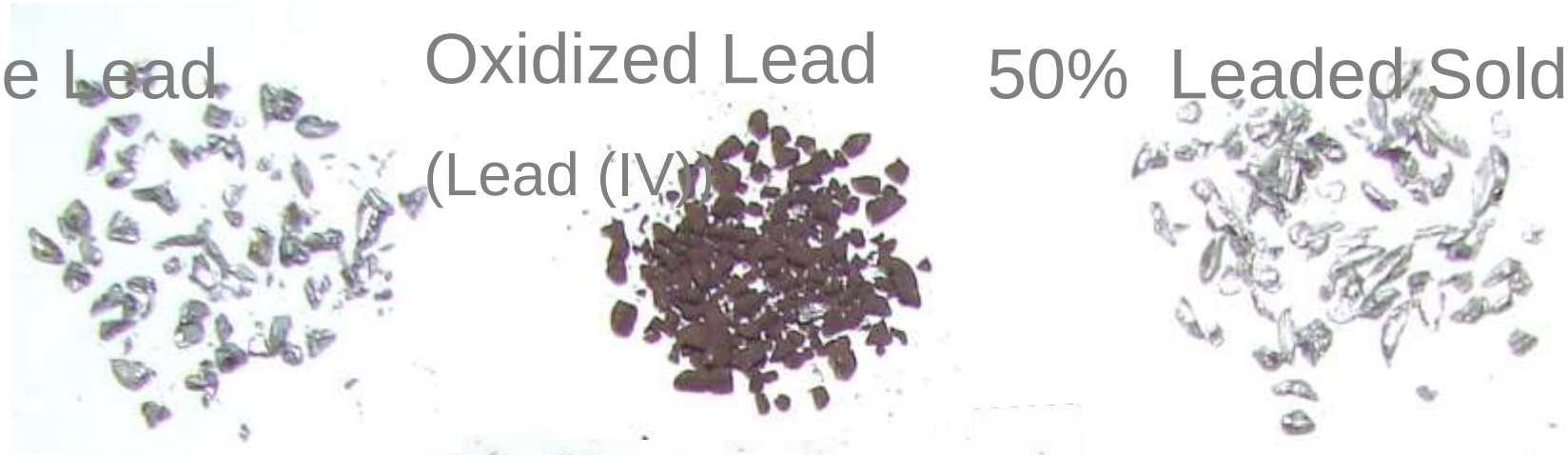


Pure Lead

Oxidized Lead

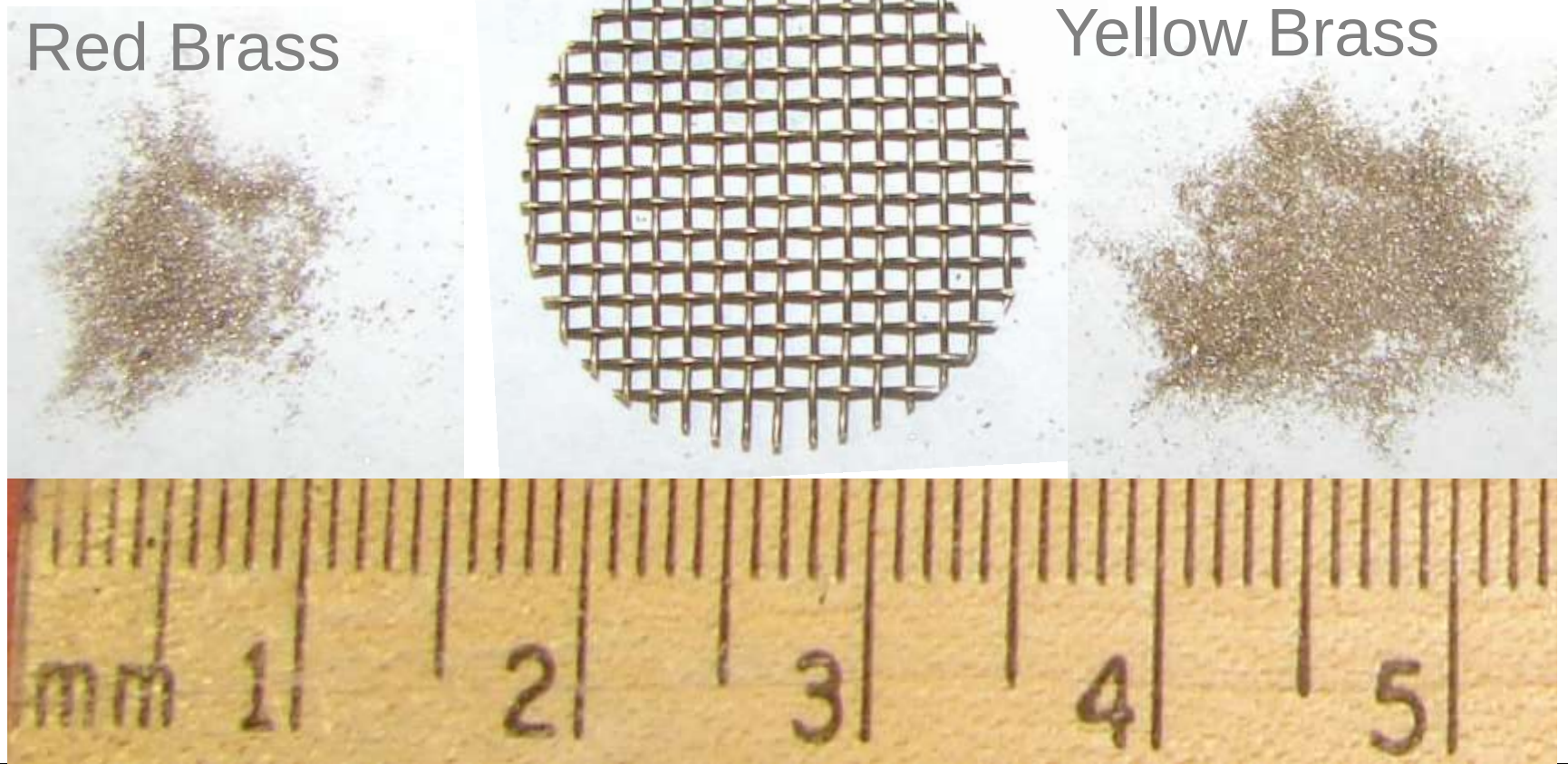
(Lead (IV))

50% Leaded Solder



Red Brass

Yellow Brass



Sampling Instructions	Effect vs. Normal Use
Sample at low flow	Reduce particulate Pb
Open tap slowly	Reduce particulate Pb
Pre-flushing pipes	Reduce LSL and particulate Pb in first draw sample
Pre-clean aerator	Reduce particulate Pb

Use of these instructions and "missing" high risk sites has resulted in documented childhood lead poisoning when the utility was officially meeting the LCR and the water was supposedly "safe"

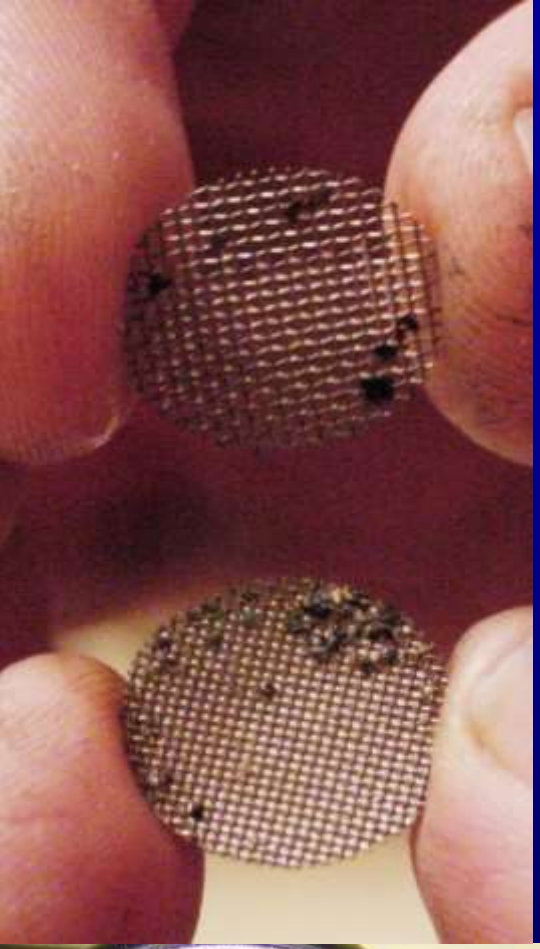
Example: Durham 2005-2007

Consumers instructed to clean aerators the night before LCR sampling

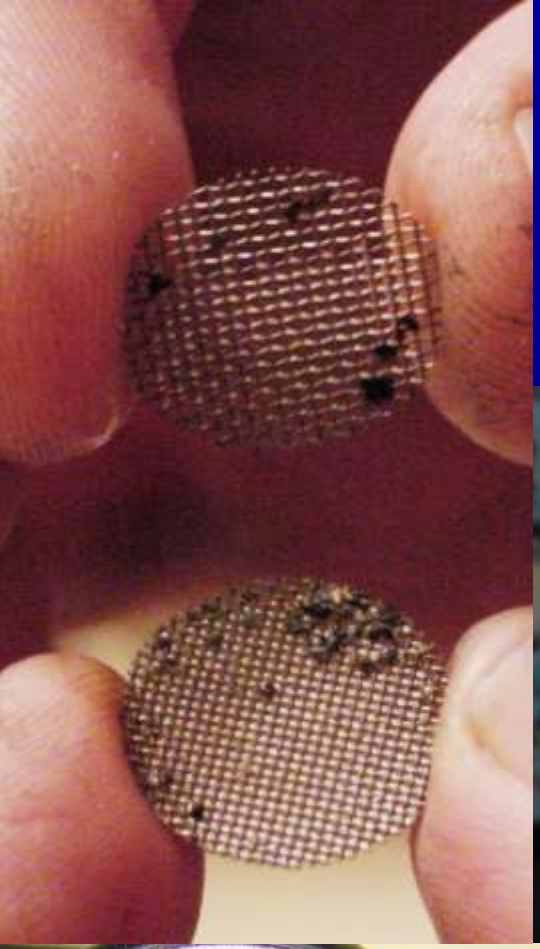
Health Department Identified Lead Poisoned Child and Many Dwellings with Extremely High Lead, While City Was Meeting LCR

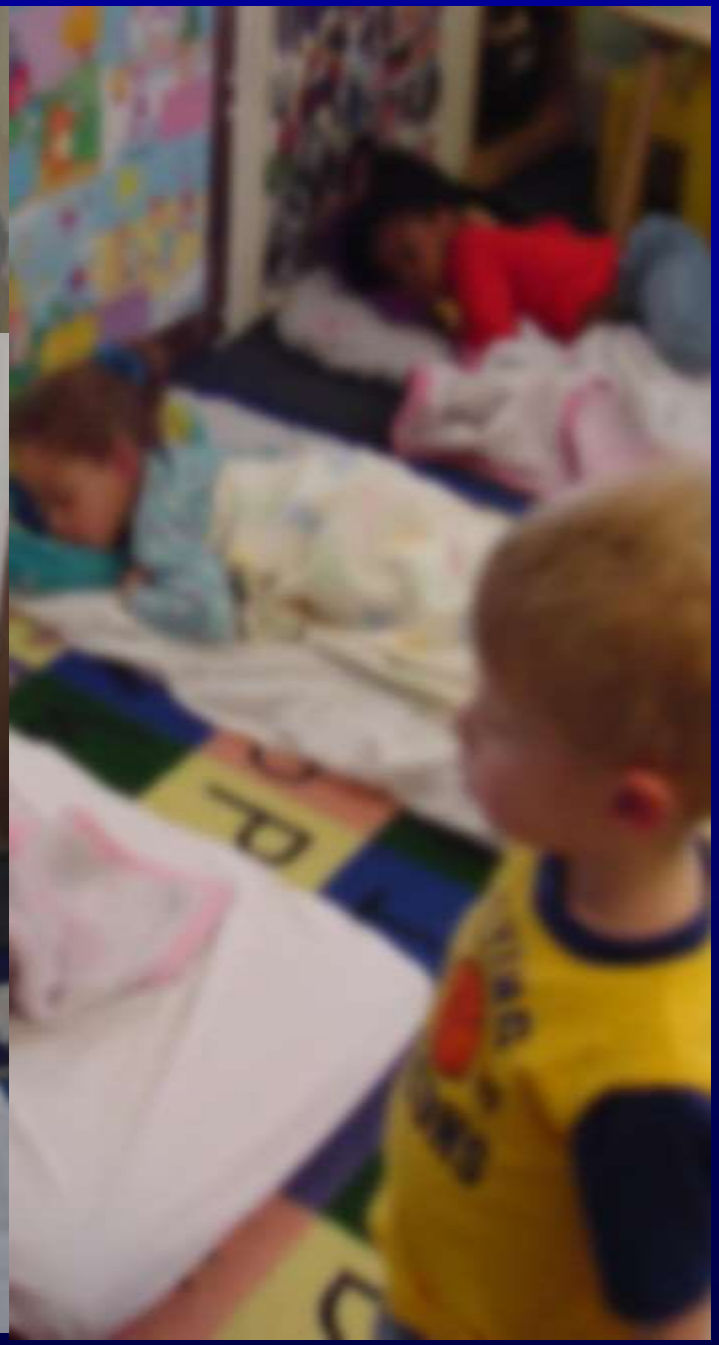
(see reading packet on Durham)

My work demonstrated these instructions could make even a hazardous lead tap, test under 15 ppb



Day care






ENVIRONMENTAL HEALTH


COUNTY

Enough lead behind this aerator to poison 5000 kids

(@ CPSC 175 ug Pb acute health risk and 25% bioavailability)

After cleaning aerator water tested "safe" 6 hours later

Lesson 1: Stop cleaning aerators the night before LCR sampling

Lesson 2: Miss Lead Hazards When Sampling, Endanger Public Health

Example: DC WASA 2005-2008

Consumers instructed to pre-flush pipes **10 minutes** the night before LCR sampling to barely meet EPA AL

3 independent entities sampling tap water at this time found very high lead, and a coalition vehemently protested the use of pre-flushing:

EPA RIII/EPA OW allow pre-flushing in DC

CDC (2012) → More lead poisoned kids in DC Homes with LSLs in this time frame

Lesson 1: Stop pre-flushing the night before LCR sampling

Lesson 2: Miss Lead Hazards When Sampling, Endanger Public Health

Many utility sampling instructions have (d)evolved to avoid finding particulate or LSL Pb, in the name of "reducing variability," "homogeneous sampling," and other pseudo-scientific goals

SPECIAL SAMPLING PROCEDURE FOR LEAD AND COPPER FIRST DRAW SAMPLES

Note: The First Draw sample may be taken at any time after a minimum of 6 hours of non-use. It is important to collect the sample as soon as possible after six (6) hours.

Reduce stagnation time

1. A minimum of six (6) hours before the sampling (or the evening before if sample is collected first thing in the morning), remove screen aerator as well as any other faucet attachments.

Remove and clean aerator

2. With your index finger, probe the mouth of the faucet to reveal and remove any particulate matter.

Preflush

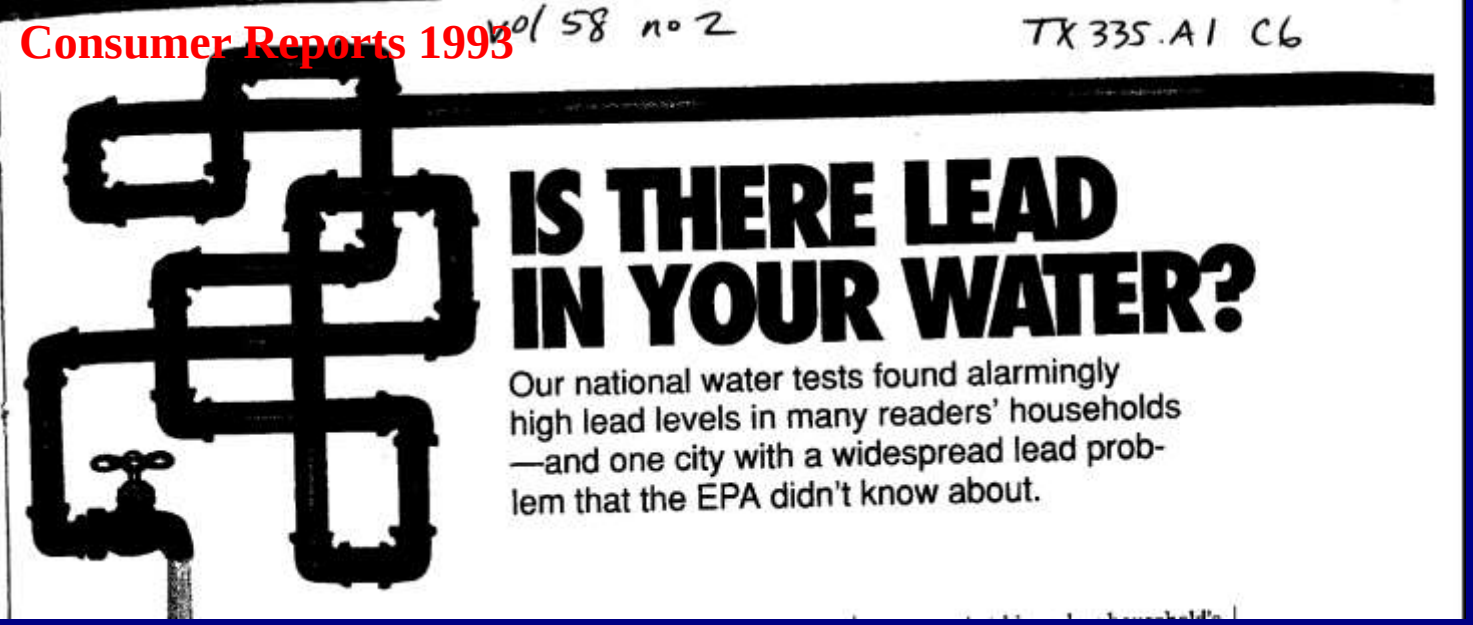
3. Flush cold water faucet for 5 or 6 minutes

6. Sample cold water as it is first drawn from the faucet (open valves slowly to low/medium flow during sampling). Do not use fast, rushing water.

Low flow

Above protocol was used in the US city with the greatest number of lead pipes and lead poisoned children.

Consumer Reports 1993



2013 EPA Study Also Found High LSL Lead in This Water

<City> Water Commissioner ..would like to set the record straight regarding Chicago's drinking water. 9/27/2013.

"**<City> water is absolutely safe to drink** and meets or exceeds all standards set by the U.S Environmental Protection Agency….<City> has had no actionable levels of lead in the water since instituting a "corrosion control" program in the early 1990's…. Since lead only leaches while water is stagnant, a practice of flushing for a few minutes eliminates even the possibility of lead consumption by our customers."

Effect of Bottle Type

Tall Bottles

Doesn’t fit under
many bathroom taps

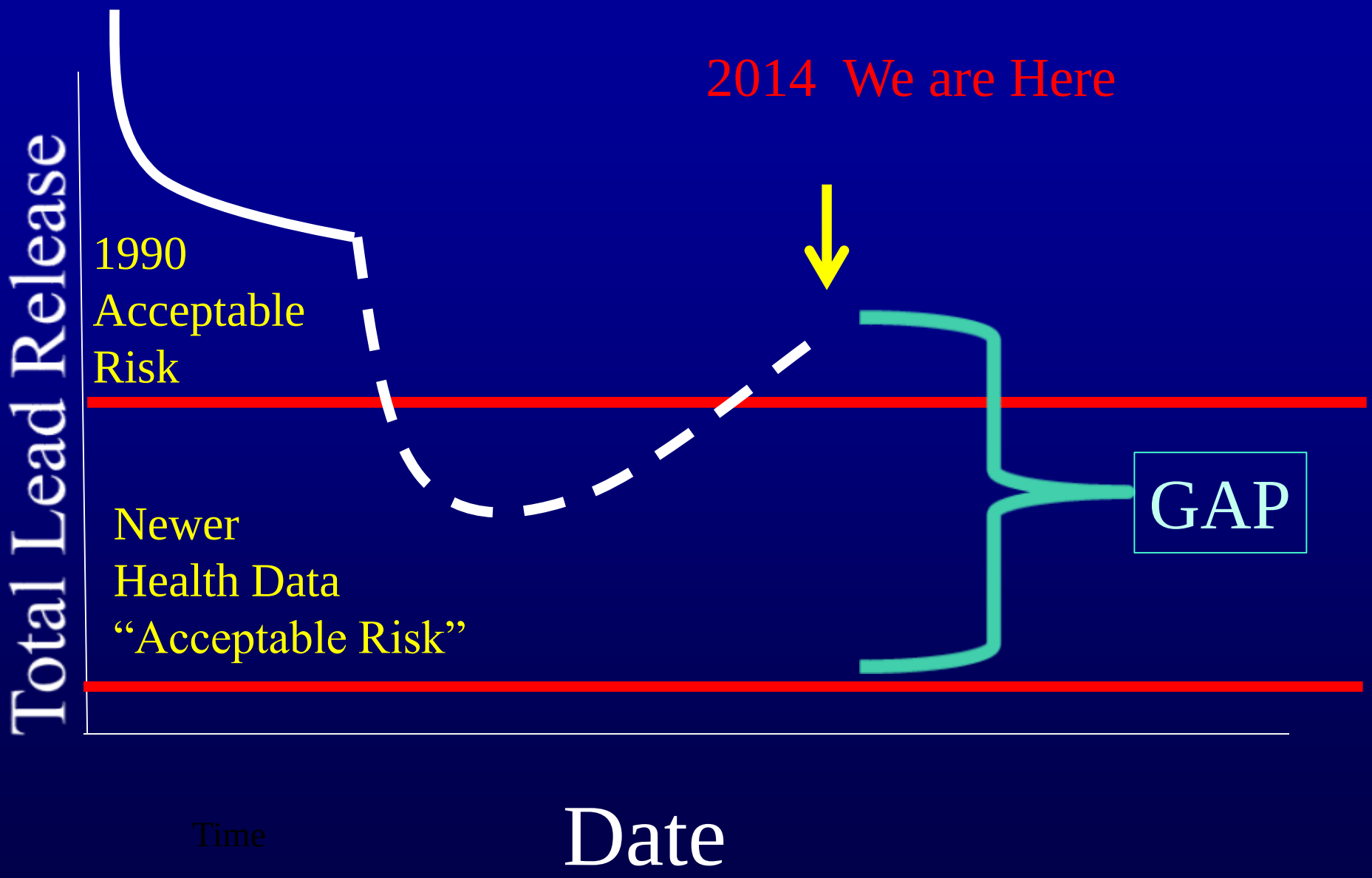
Can’t use higher flow rates

DC Lead Crisis 2000-2004

- Worst example of water lead contamination in modern US history
- Higher fetal deaths, higher miscarriage rates, and high incidence of childhood lead poisoning associated with water lead exposure (as predicted)

→ If 10 minutes pre-flushing was allowed, aerator pre-cleaning and LSL homes were selected to be those of least risk, DC could have easily met the 1st draw EPA AL without any problems

Conceptualization of LCR for Lead Pipe



Recent Pb Health Data And Human Exposure Considerations

Lead and Adverse Pregnancy Outcomes Miscarriages/Fetal Death

*Read before the Yorkshire Branch of the British Medical Association at Bradford, January, 1905.

THE INCREASING USE OF LEAD AS AN ABORTIFACIENT;

A SERIES OF THIRTY CASES OF PLUMBISM.*

By ARTHUR HALL, M.A., M.D.Cantab., F.R.C.P.,
Professor of Pathology, University College, Sheffield; Physician, Sheffield Royal Hospital

NOV. 13, 1926] [THE BRITISH MEDICAL JOURNAL

LEAD AS AN ABORTIFACIENT.

SIR,—Some time ago, in country practice, I had a message from a neighbour asking me to see with him a case of acute abdominal disease. The history was this: A robust young woman (married three months) had had pain in the stomach a few days previously, and again on the day before, when she was first seen. On inquiry her doctor was

1900s Lead abortion pill dose exceeded by normal consumption of water in 15% of DC homes with lead pipe in 2003

Dose was probably worse in 2000 to late 2002 when utility met LCR and said water was “safe”

Fetal Death and Reduced Birth Rates Associated with Exposure to Lead-Contaminated Drinking Water *ES&T* 2013

Trends in DC birth rate (miscarriages) and fetal death rates were consistent with prior work indicating that each 5 ug/dL increase in maternal blood lead doubles miscarriage risk. Fetal death rates correlated to water lead levels and measures of lead pipe occurrence.

ICRP Adult Blood Lead Model

0 → 5 ug/dL in Maternal Blood Lead ≈ 60 ppb water Pb

Lead Doses from Potable Drinking Water Routinely Exceed Standards and Recommendations for Toys, Playground Equipment Set to Avoid Childhood Lead Poisoning (10 ug/dL*)

CPSC Recommendation

CPSC (2005): Toy poses an acute health risk if ingestion could cause a 1 time dose of 175 ug/L

CPSC (1990): Lead dose to children should not exceed 15 ug for 15 days

Representative Equivalent Water Exposure

"Thomas' Train Recall

June 14, 2007

Consumer Product Safety Commission

If the CPSC standards trigger fines and recalls for products not designed for consumption….how can similar doses from potable water be acceptable?

Lead Doses from Potable Drinking Water Routinely Exceed Standards and Recommendations for Toys, Playground Equipment Set to Avoid Childhood Lead Poisoning (10 ug/dL*)

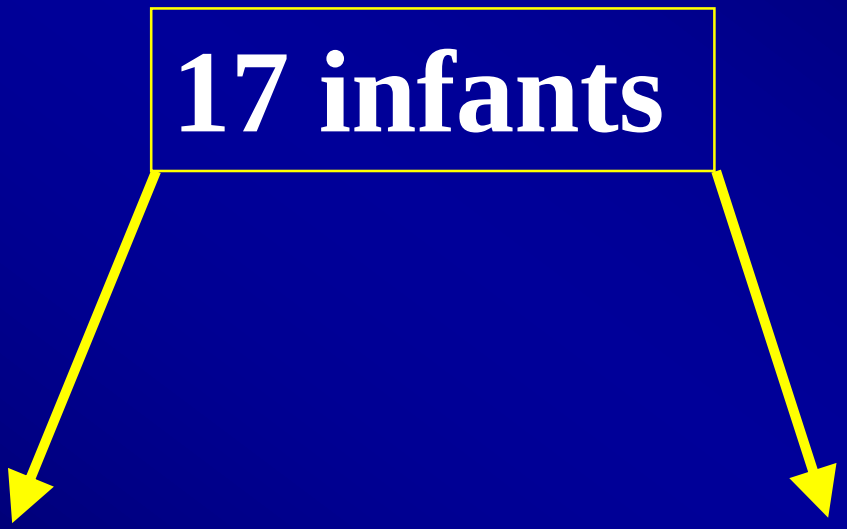
CPSC Recommendation	Representative Equivalent Water Exposure
CPSC (2005): Toy poses an acute health risk if ingestion could cause a 1 time dose of 175 ug/L	1 day of reconstituted infant formula made with water at 145 ppb lead
CPSC (1990): Lead dose to children should not exceed 15 ug for 15 days	15 days reconstituted formula made with water at 12.5 ppb lead

Representative Exposures of Concern for Lower Blood Lead Levels

Group	Increased BLL of Concern	Water Lead
Formula Fed Infants	0 → 1 ug/dL for 50% of those exposed	**3.5 ppb**
Formula Fed Infants	0 → 1 ug/L for 10% of those exposed	**2 ppb**
Formula Fed Infants	0 → 5 ug/dL for 10% of those exposed	**11 ppb**

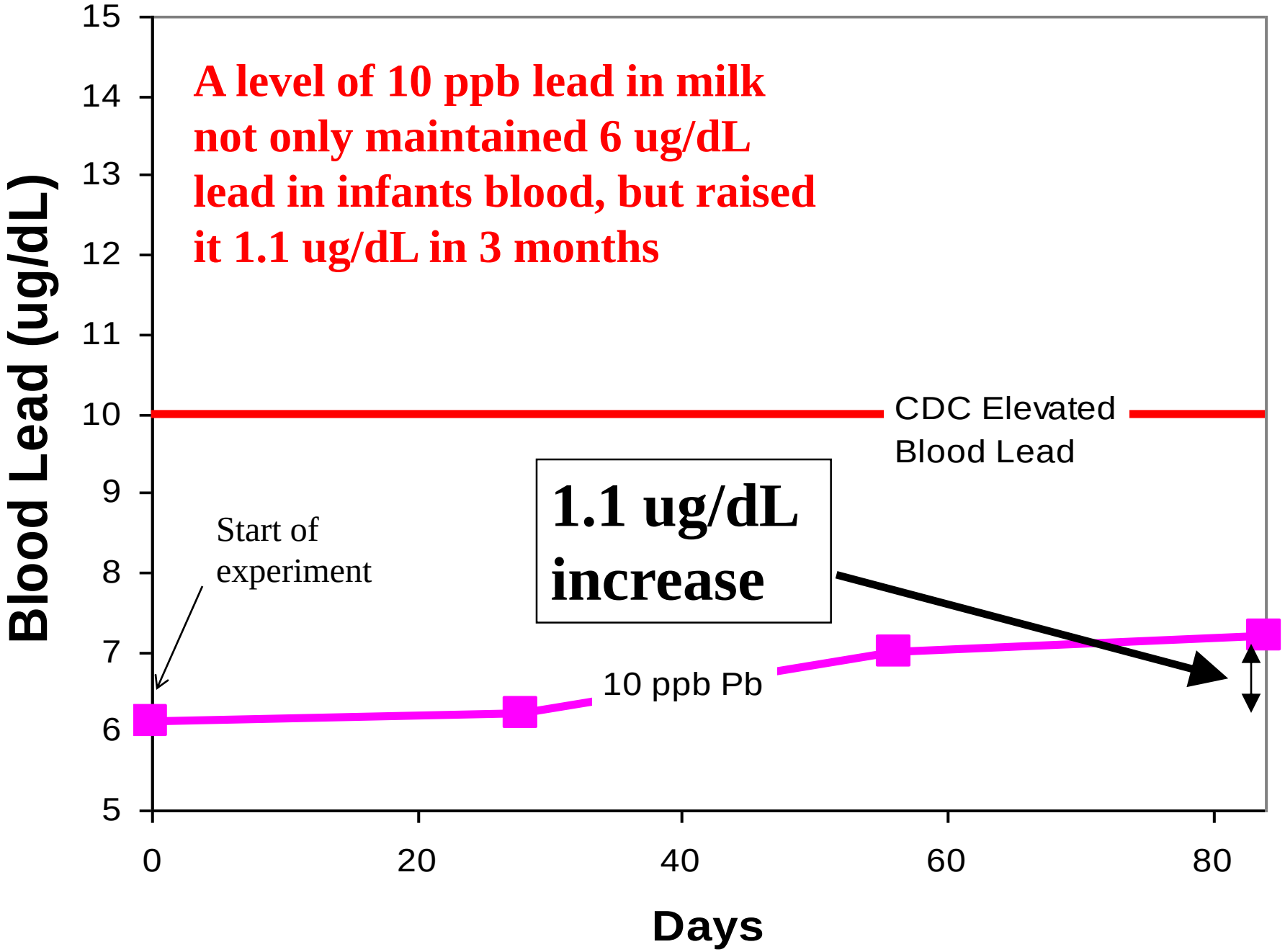
Triantafyllidou, S., Gallagher. D. and Edwards, M. Assessing risk with increasingly stringent public health goals: the case of water lead and blood lead in children. Journal of Water and Health. doi: 10.2166/wh.2013.067 58-68 (2014).

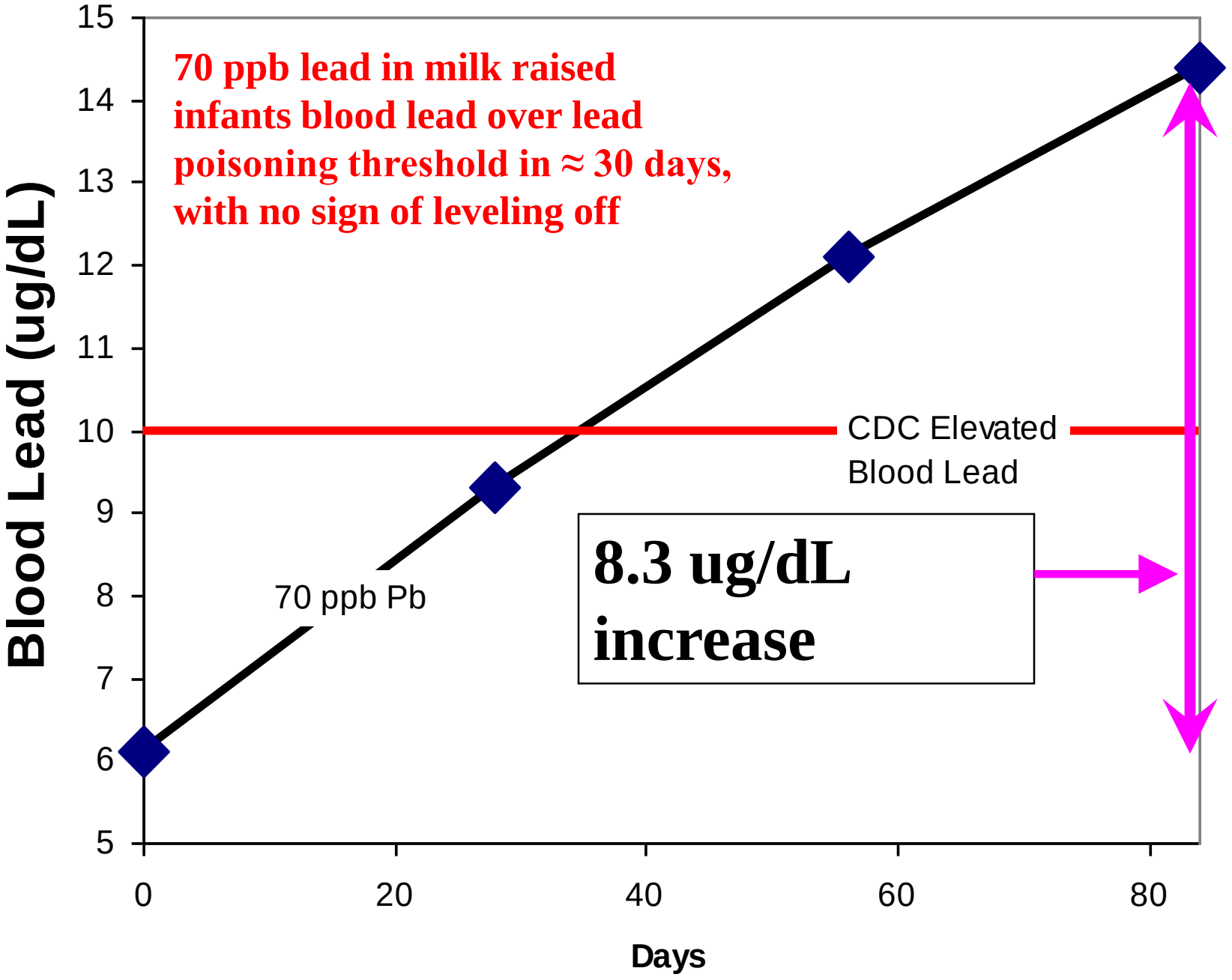
Ryu et al (1983)
Fed leaded milk to infants in US
All dietary Pb intakes accounted for



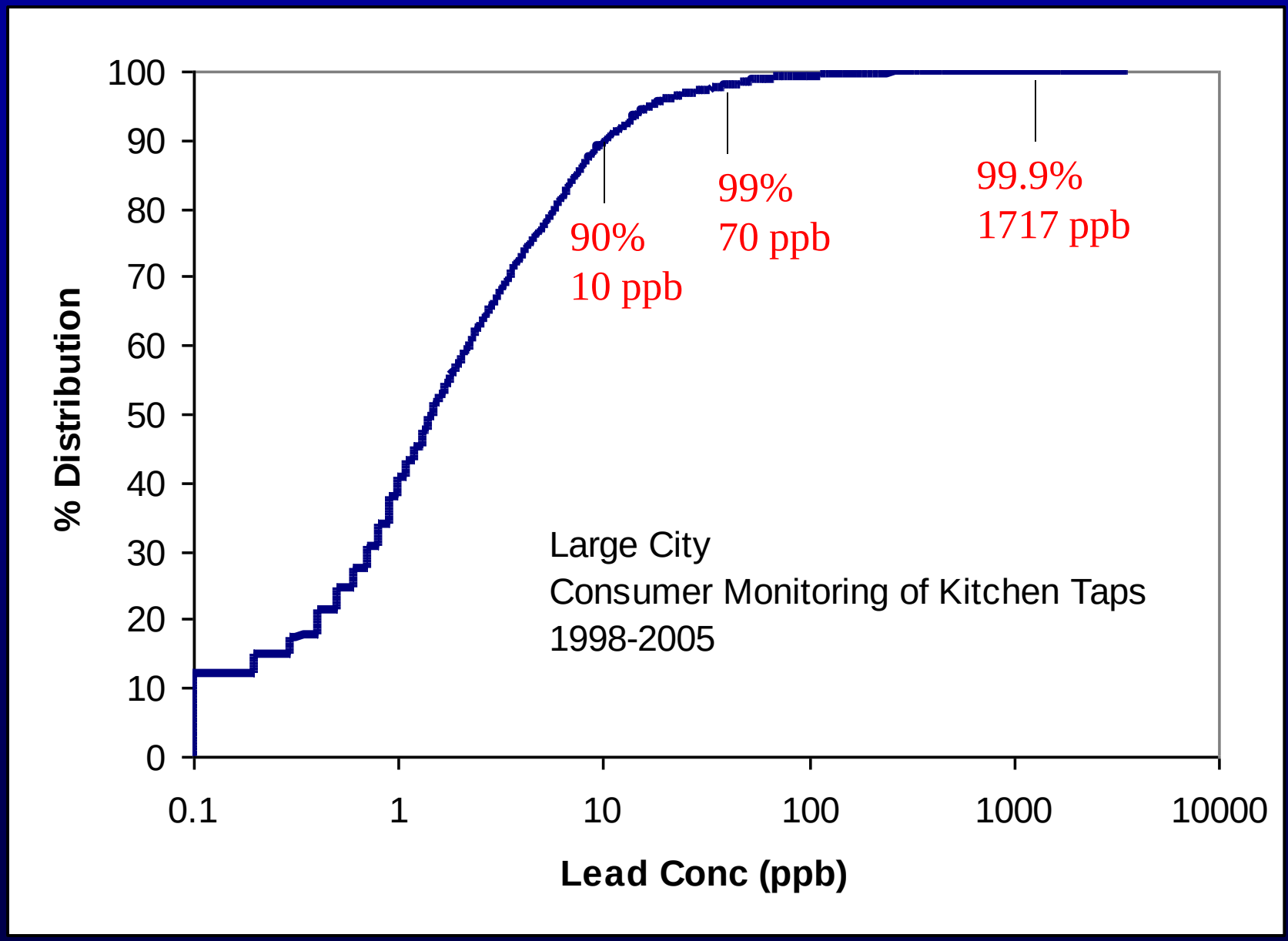
10 fed milk with avg. 10 ppb Pb

7 fed milk with avg. 70 ppb Pb


A level of 10 ppb lead in milk
not only maintained 6 ug/dL
lead in infants blood, but raised
it 1.1 ug/dL in 3 months
Blood Lead (ug/dL)
15
14
13
12
11
10
9
8
7
6
5
CDC Elevated
Blood Lead
1.1 ug/dL
increase
Start of
experiment
10 ppb Pb
0
20
40
60
80
Days


70 ppb lead in milk raised infants blood lead over lead poisoning threshold in ≈ 30 days, with no sign of leveling off
Blood Lead (ug/dL)
15
14
13
12
11
10
9
8
7
6
5
0
20
40
60
80
Days
CDC Elevated Blood Lead
70 ppb Pb
8.3 ug/dL increase

What do lead levels look like for a large US city currently meeting the AL, based on thousands of data points, and how does that translate to EBL?


100
90
80
70
60
50
40
30
20
10
0
% Distribution
0.1
1
10
100
1000
10000
Lead Conc (ppb)
90%
10 ppb
99%
70 ppb
99.9%
1717 ppb
Large City
Consumer Monitoring of Kitchen Taps
1998-2005

≈1% of children in this city predicted to have elevated blood lead (> 10 ug/dL) from tap water consumption alone (> 70 ppb)

in a city with 100,000 children that would be 1000 cases of childhood lead poisoning

Milwaukee and New York City HUD study (2006)

"…the total amount of tap water or tap water-based drinks that were consumed per day by the child was significantly related to the child's blood lead status (p=0.04). …The more glasses of water consumed, the higher the chance of an elevated blood lead level."

Consuming two 8 oz glasses of tap water per day = 50% chance of EBL

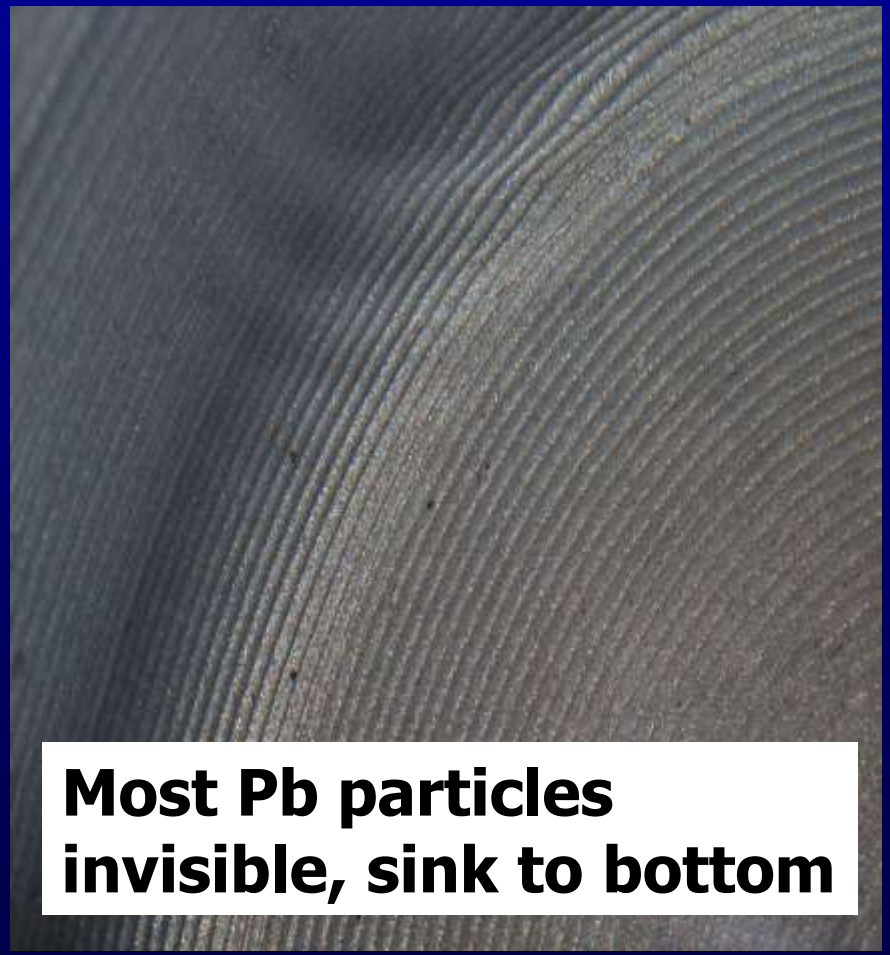
Water lead and LSLs in Europe also consistently and significantly correlated to blood lead

- 63-76% of mothers with blood lead concentrations of 10 μg/dl or above were attributable to tap water lead (Watt et al., 2000)
- Lead in water > 5 ppb significantly increased blood lead ($p > 0.001$) in young women, and intervention excluding tap water a few months dropped blood lead 37% (Fertmann et al., 2004)
- Children in France (6 months-6 years) had 50% higher geometric mean blood lead if they consumed tap water and had an LSL, and the 95%'ile blood lead level for this group was increased by 256% (Etchevers et al., 2014)

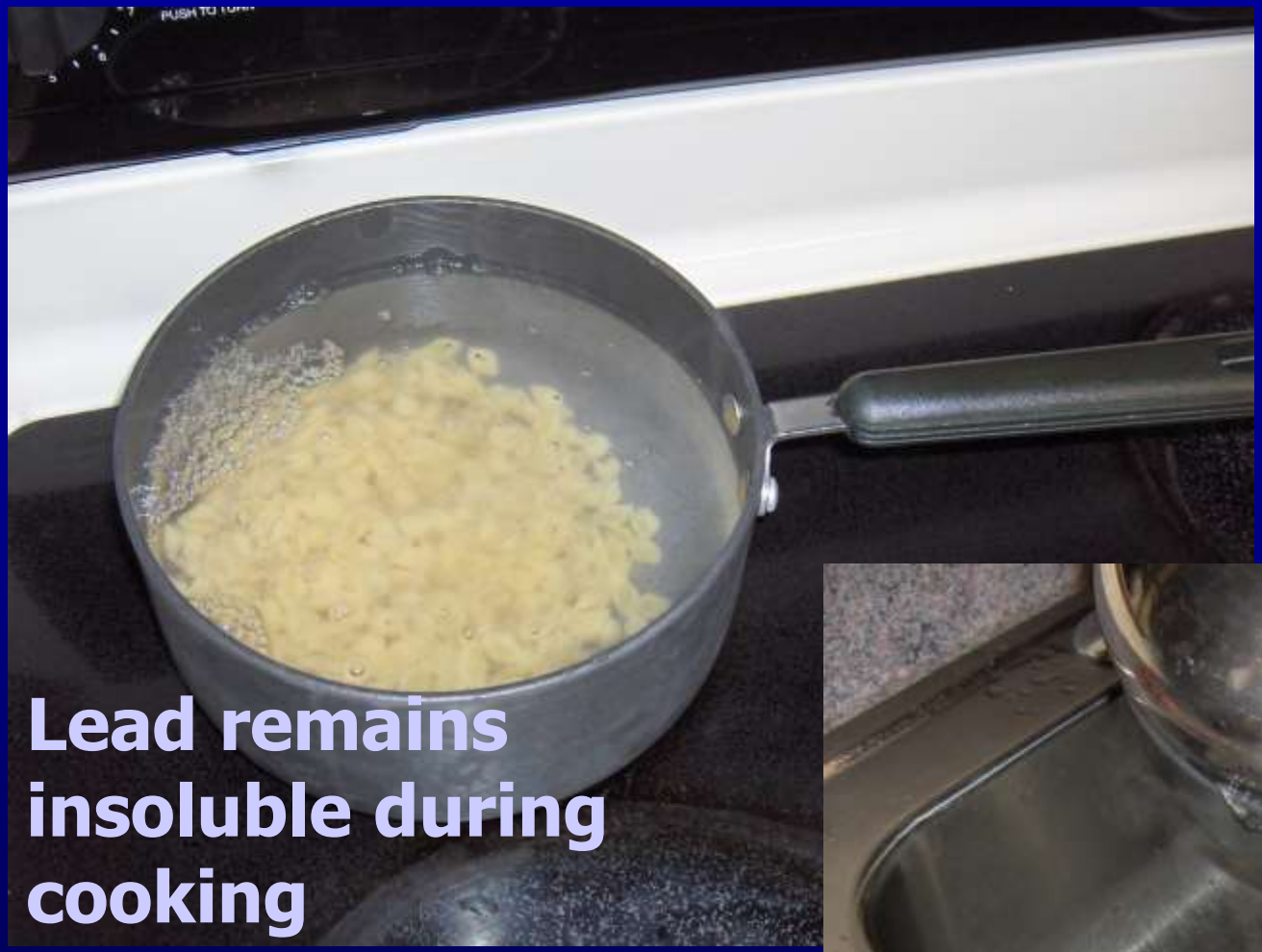
You do not even have to drink tap water to be exposed.

Water collected @ highest flow from faucet of poisoned child

1.5 liters at 535 ppb lead



Most Pb particles invisible, sink to bottom


Lead remains insoluble during cooking


< 5% particulate lead poured off

381 ug Pb 310 ug Pb

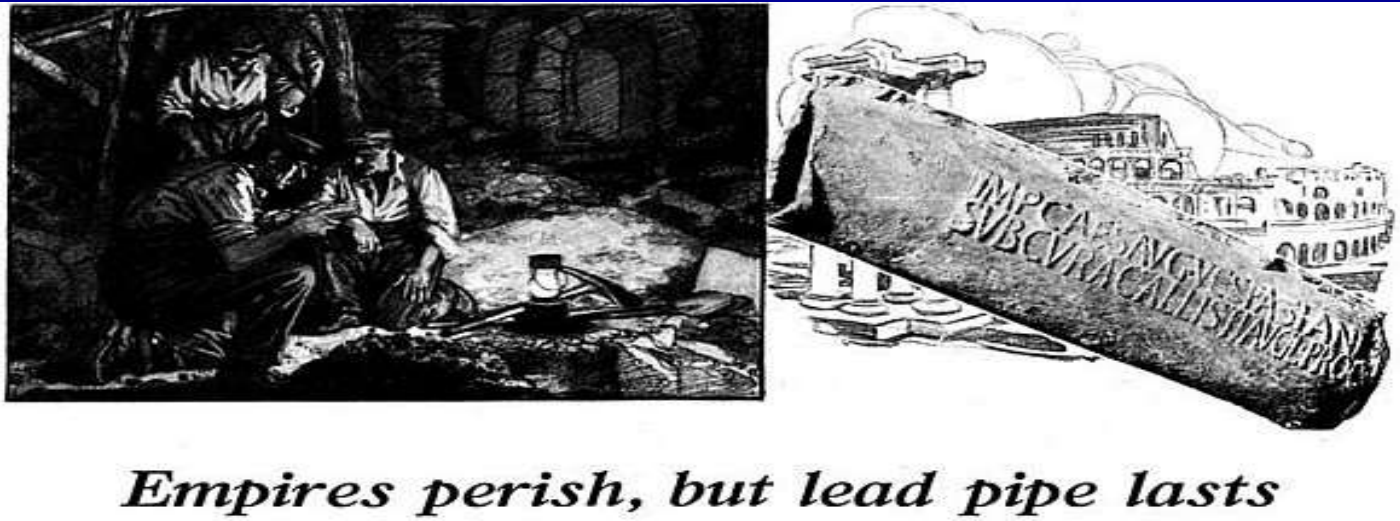
One serving of pasta prepared from tapwater in home of lead poisoned child had more lead than eating a dime size paint chip @ 1% lead.

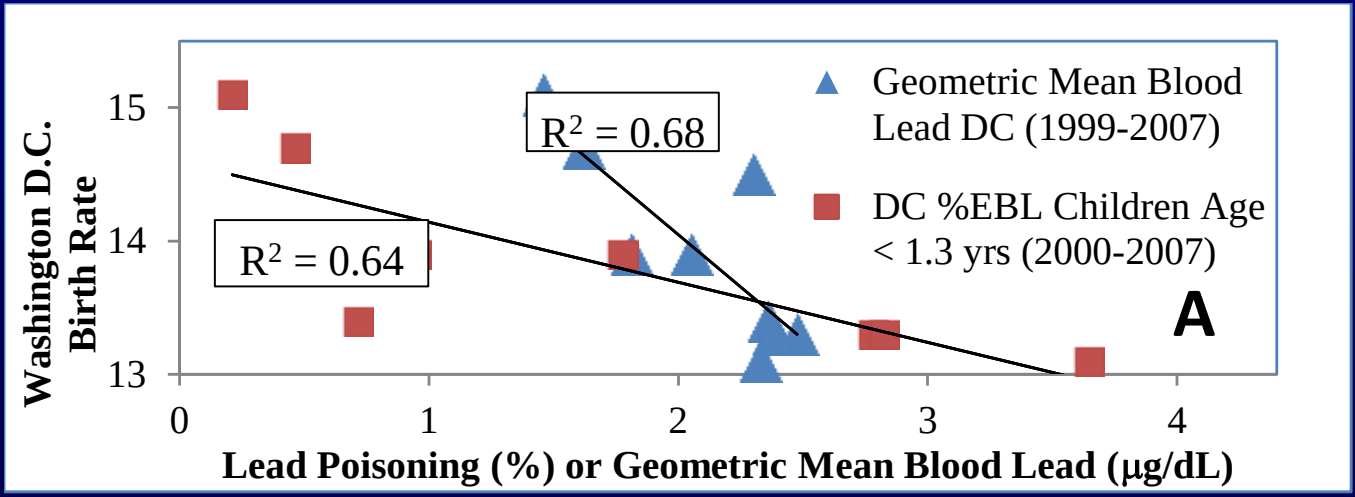
A Revised LCR Needs-Pb

- public education that stops telling consumers with lead services/plumbing that **THEIR WATER IS SAFE***
- an attitude at EPA OW that acknowledges serious water lead health risks, emphasizes important DIRECT links between the LCR and public health, and stops "anything goes" messaging to utilities
- motivated utilities attempting to find high lead in water risks, and the will/means to punish bad actors– or else take LCR sampling completely out of utilities hands
- a plan for complete removal of all lead service lines

***unless it is not safe, in which case we told you so in fine print somewhere**

This NDWAC is making historic decisions.





Edwards ES&T, 2014

Marc Edwards received his bachelor's degree in Bio-Physics from SUNY Buffalo and an MS/PhD in Environmental Engineering from the University of Washington. In 2004, Time Magazine dubbed Dr. Edwards "The Plumbing Professor" and listed him amongst the 4 most important "Innovators" in water from around the world. The White House awarded him a Presidential Faculty Fellowship in 1996 and he was named a MacArthur Fellow in 2008.

He has received 6 outstanding research publication awards from peer reviewed journals, the Huber Research Prize from the American Society of Civil Engineers (2003), and the National Association of Corrosion Engineers Technical Achievement Award (2008). Volunteer (unfunded) research by Edwards and colleagues on health effects from lead in drinking water documented numerous cases of fetal death and childhood lead poisoning associated with lead in tap water nationwide, including those associated with the 2000-2004 Washington D.C. "Lead Crisis." That effort culminated in a Congressional Investigation of CDC, an Outstanding Paper Award in ES&T, a Praxis Award in Professional Ethics from Villanova University and the IEEE Barus Award for Defending the Public Interest.

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