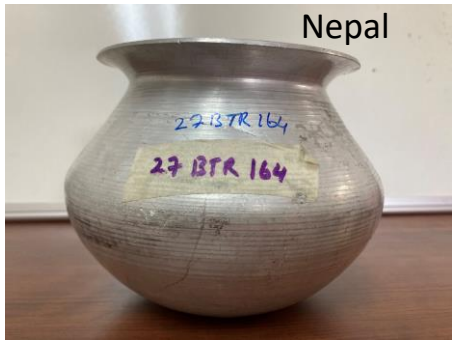
# Understanding Leachability of Lead from Aluminum Pots

Gordon Binkhorst, Pure Earth

Center for Global Development's
Research Conference on Global Lead Exposure









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# Potential lead exposure from aluminum cooking pots in lower and middle-income countries

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## LEAD IN CONSUMER GOODS:

### A 25-COUNTRY ANALYSIS OF LEAD (PB) LEVELS IN 5,000+ PRODUCTS AND FOODS

# Rapid Market Screening

- Largest international assessment of lead contaminated products
- **100 markets in 25 countries**
- **5,000+ products and foods**
- **518 Metallic Foodware Items**
  - **All screened for total lead with an XRF.**
  - **100 aluminum pots selected for leachability testing**

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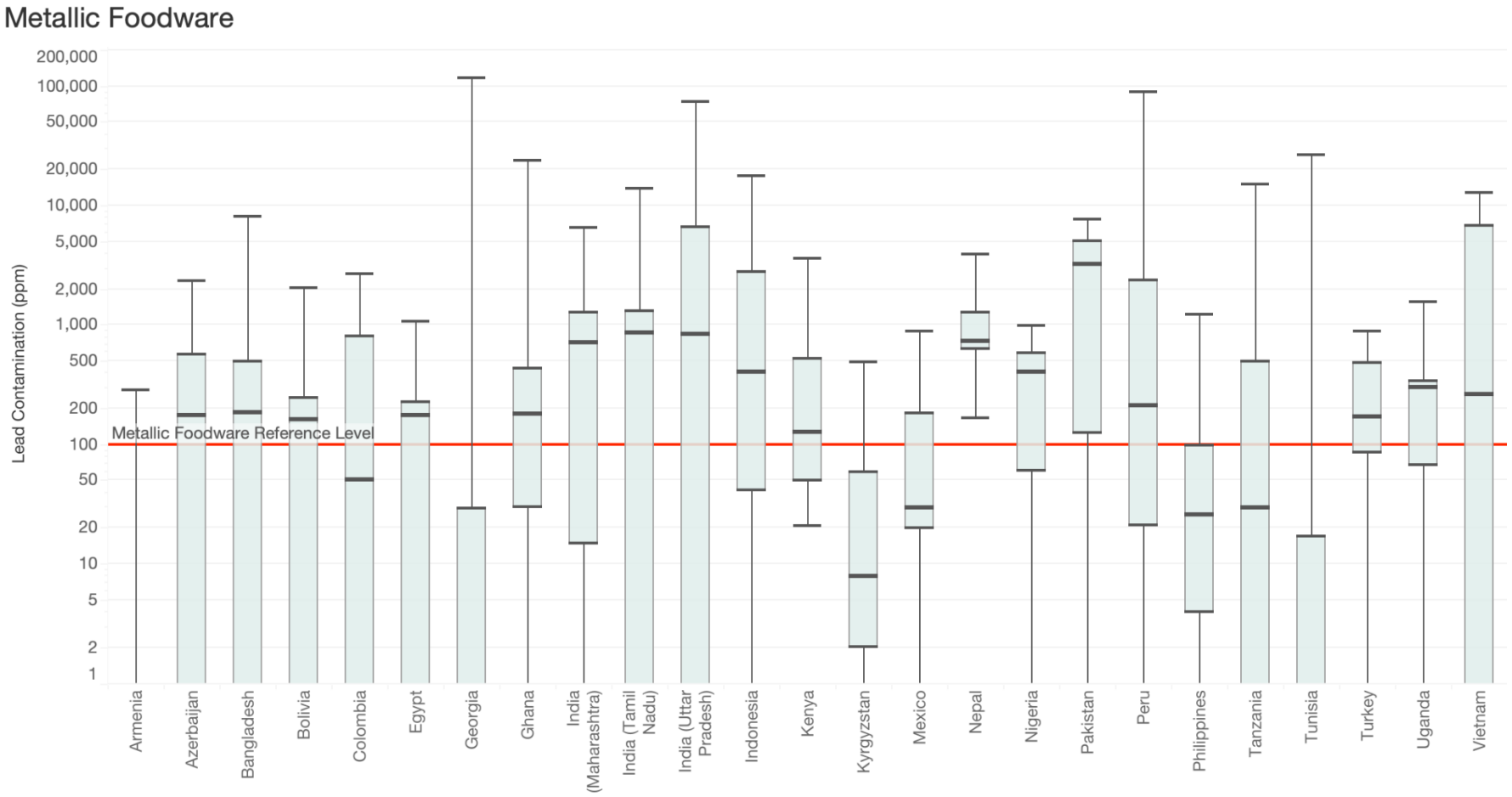
Distribution of Total Lead in Metal Foodware Sampling Results by Quartile

# ALL RMS COOKWARE




- Out of 518 samples of metallic foodware items, 52% exceeded our reference level of 100 ppm. High of over 100,000 ppm or 10% lead.


**Figure 1.** Source materials used to produce the cookware used in this study. (a) Small mixed metals. (b) Plastic-coated blister foils. (c) Aluminum cans. (d) Workers removing aluminum air conditioner fins. (e) Engine block. (f) Auto radiators.

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# Metal exposures from source materials for artisanal aluminum cookware

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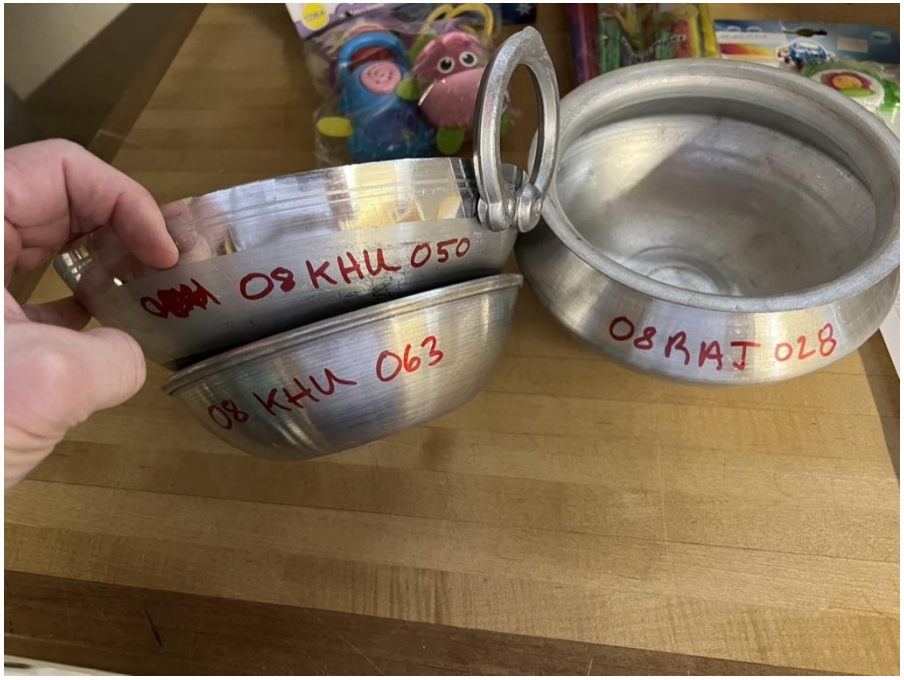
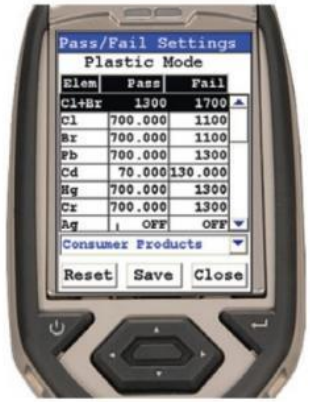
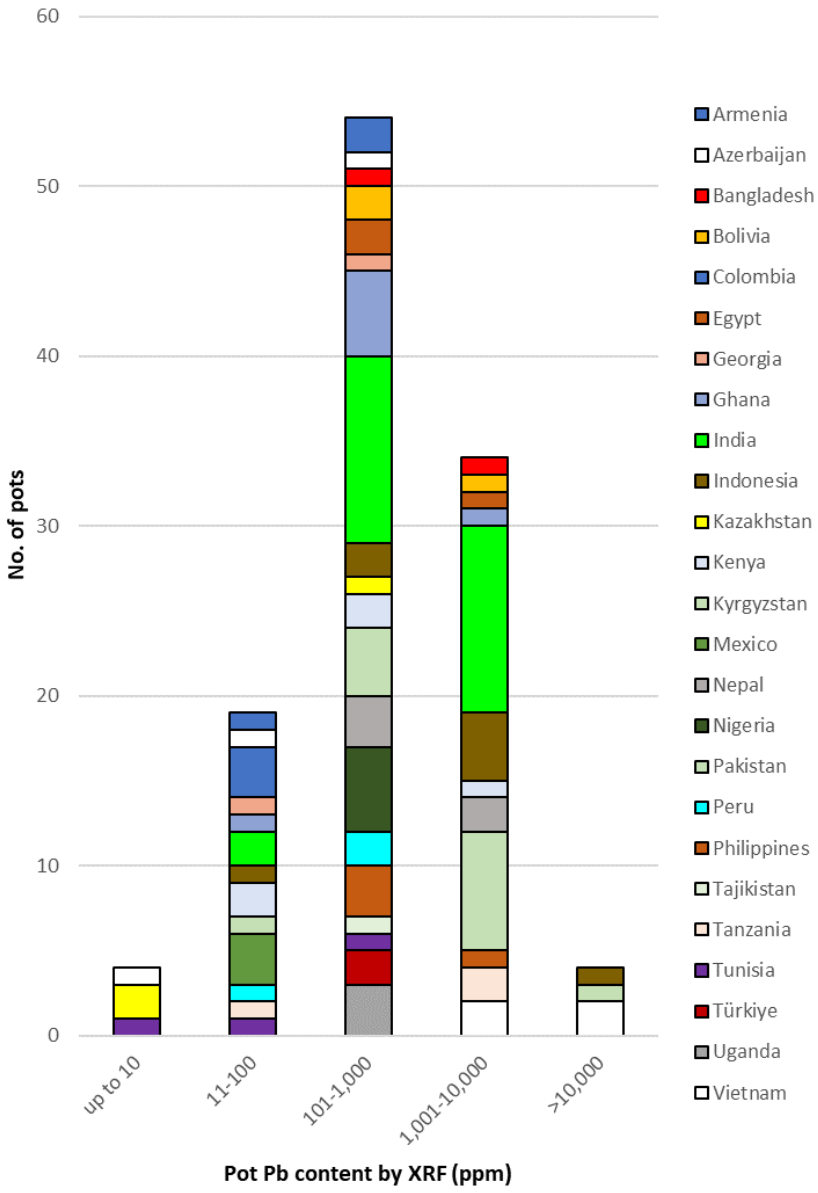
07 MED 040
07 SUR 063
07 SUR 067
Indonesia
Baby Rattle


08 KHU 050
08 KHU 063
08 RAJ 028


01KUM042
01KOF009
01 KUM 001
01KUM011

# Range of total Pb concentrations measured by XRF for 115 Al pots sourced from 25 LMIC countries used in the various leaching experiments




UBIQUITOUS...

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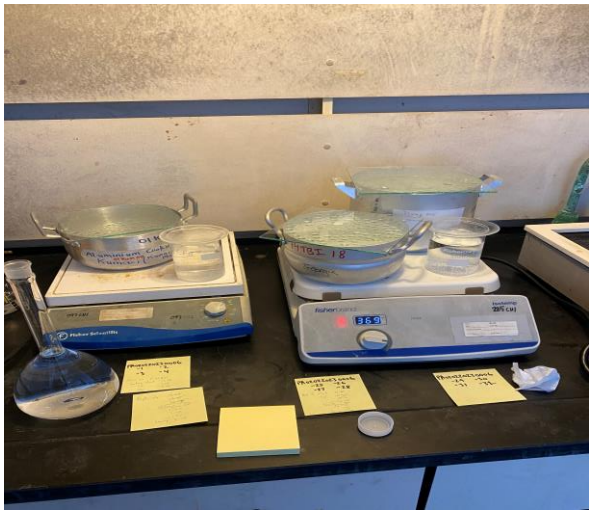
# Total versus Leachable Lead

- High total lead, but what is the exposure potential?
- Leachate studies needed to quantify how much lead may be leaching from these pots

- **Total Lead = 912 ppm**
- **Leachable Lead = 59.4 ug/L**

# Leaching Methodologies

Leachate testing to estimate actual exposure.

- Real food (e.g., rice vs. tomato sauce) vs. simulated (e.g., acetic acid/vinegar). Advantages and disadvantages to both…

Considering simulated leaching, they are many variations

- Leaching medium (e.g., water, palm oil, vinegar/acetic acid)
- Heated vs. unheated
- Salt vs. no salt
- Cooking timeframe
- Old vs. new pots

- All of the above (simulated or real) will affect lead leachate concentrations!  Safety versus exposure…

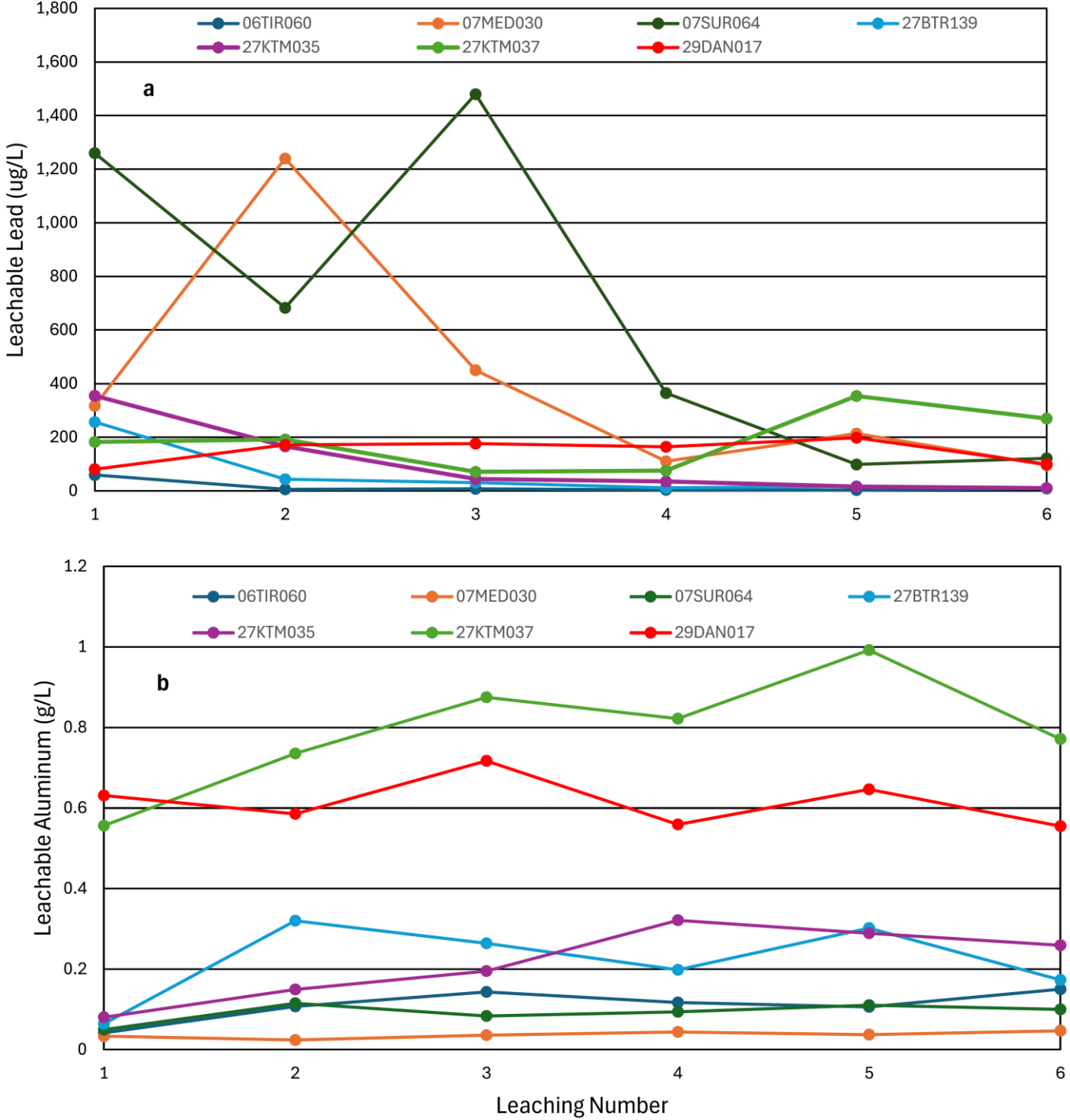
# Leaching Methodologies

Several leaching variables were evaluated:

- Heated versus unheated
  - 2 to 3 orders of magnitude higher
  - 10–30 µg/L range unheated to 200–20,000 µg/L range for heated
- Replicability
  - Not great…but instructive

# Replicability

## Consecutive Repeat Boils



# Several leaching variables were evaluated (cont.):

- Old versus new pots
  - Old leached less than new pots relative to total lead concentrations

- Salt vs no salt
  - Addition of salt marginally increase leachable aluminum and decreased leachable lead.

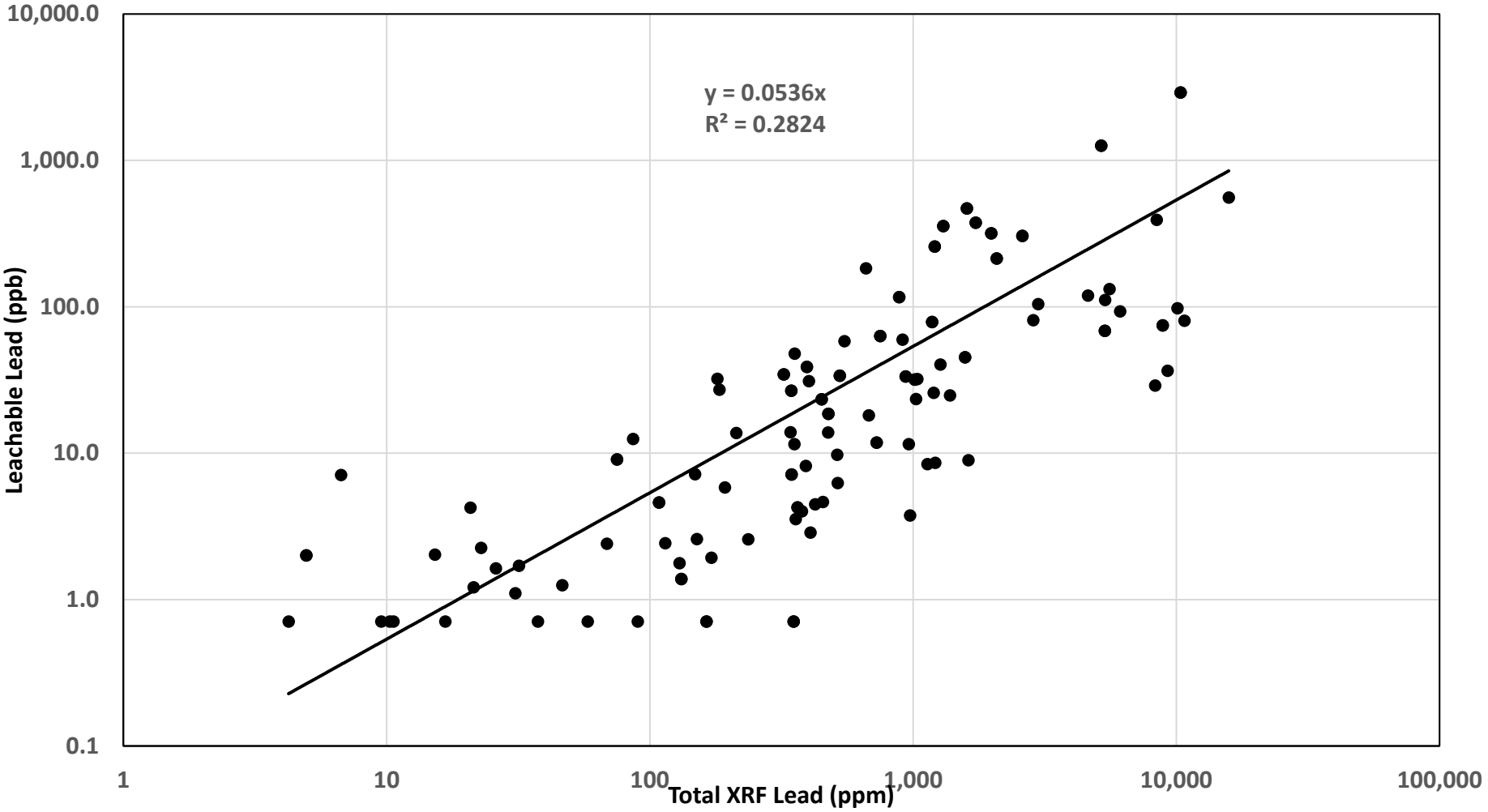
# Methodology

**For the  100 pots selected for leaching.**

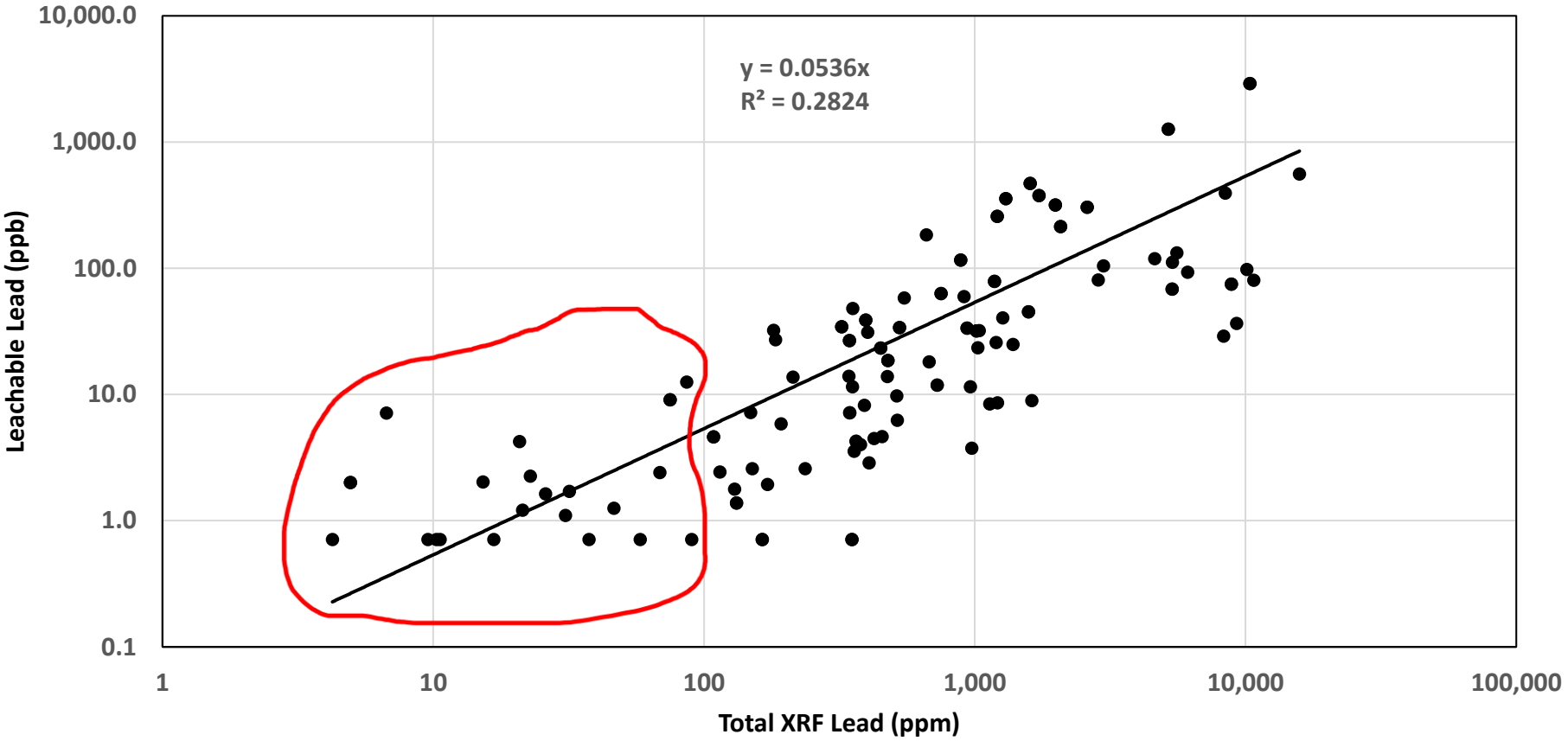
- Pots were filled to 80% capacity with 4% acetic acid (vinegar) and boiled for 2 hours to simulate cooking. Topped off periodically (evaporative losses).
- Samples collected while hot and digested.
- The leachate was analyzed for total Pb and total Al.

- Total versus leachable lead results…

# Leaching Results (n=100)

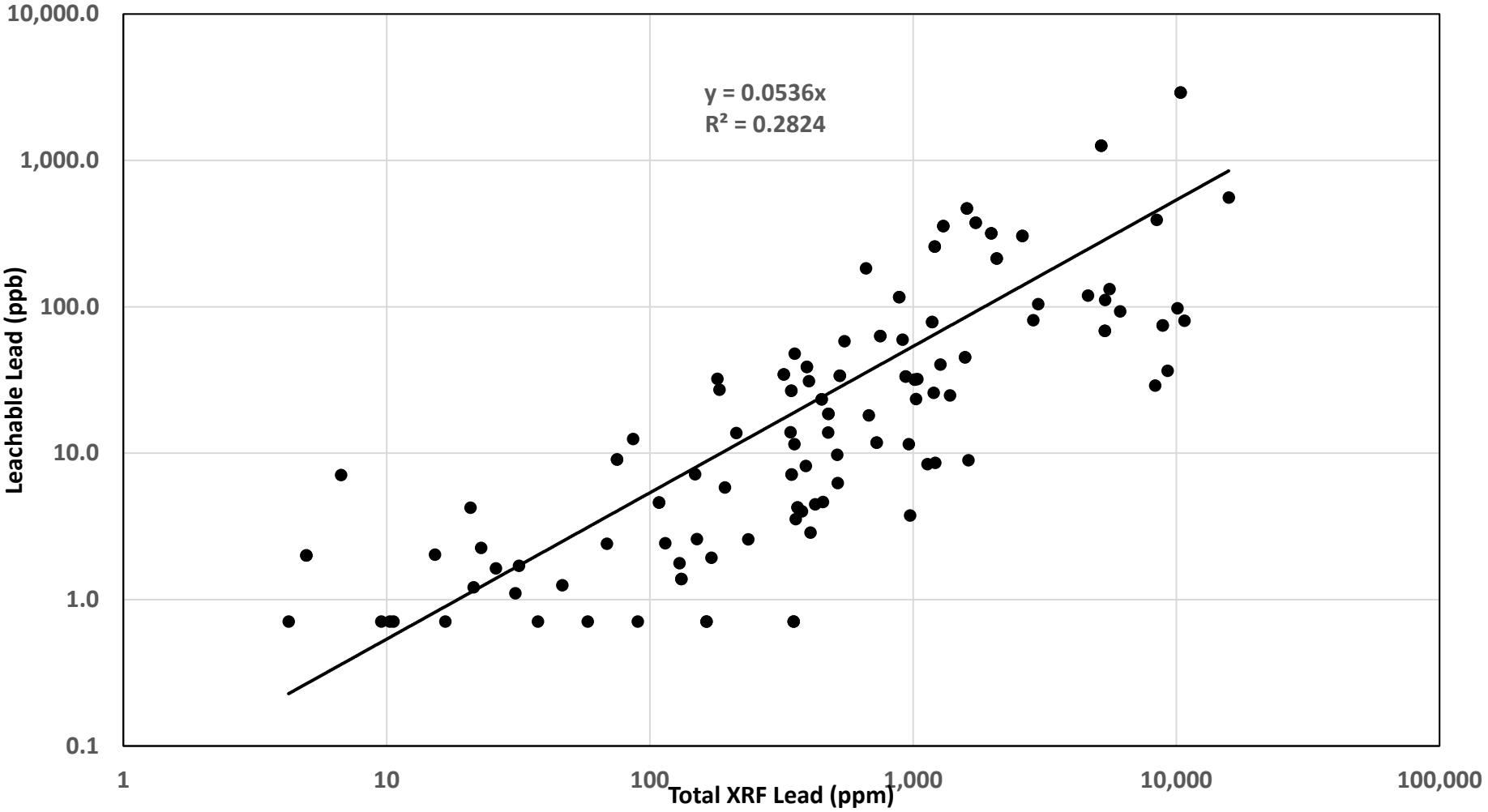


# Leaching Results (n=100)

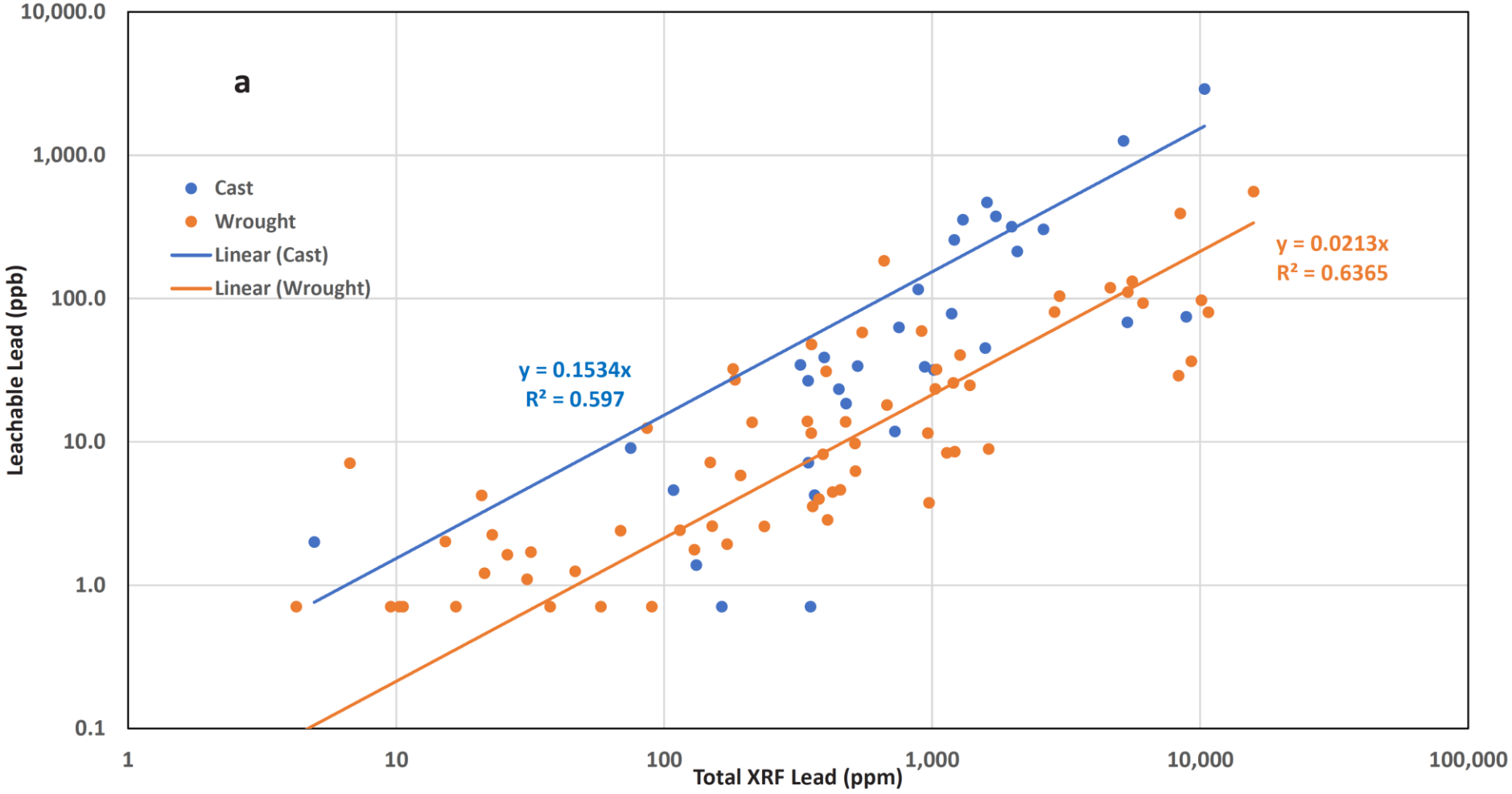



| Total XRF Lead | Number of Samples with Pb in Leachate <10 µg/L | Number of Samples with Pb in Leachate >10 µg/L |
|---|---|---|
| XRF >100 ppm (81 total) | 13 | 68 |
| XRF <100 ppm (20 total) | 19 | 1 |

# Leaching Results (n=100)



# Leaching Results

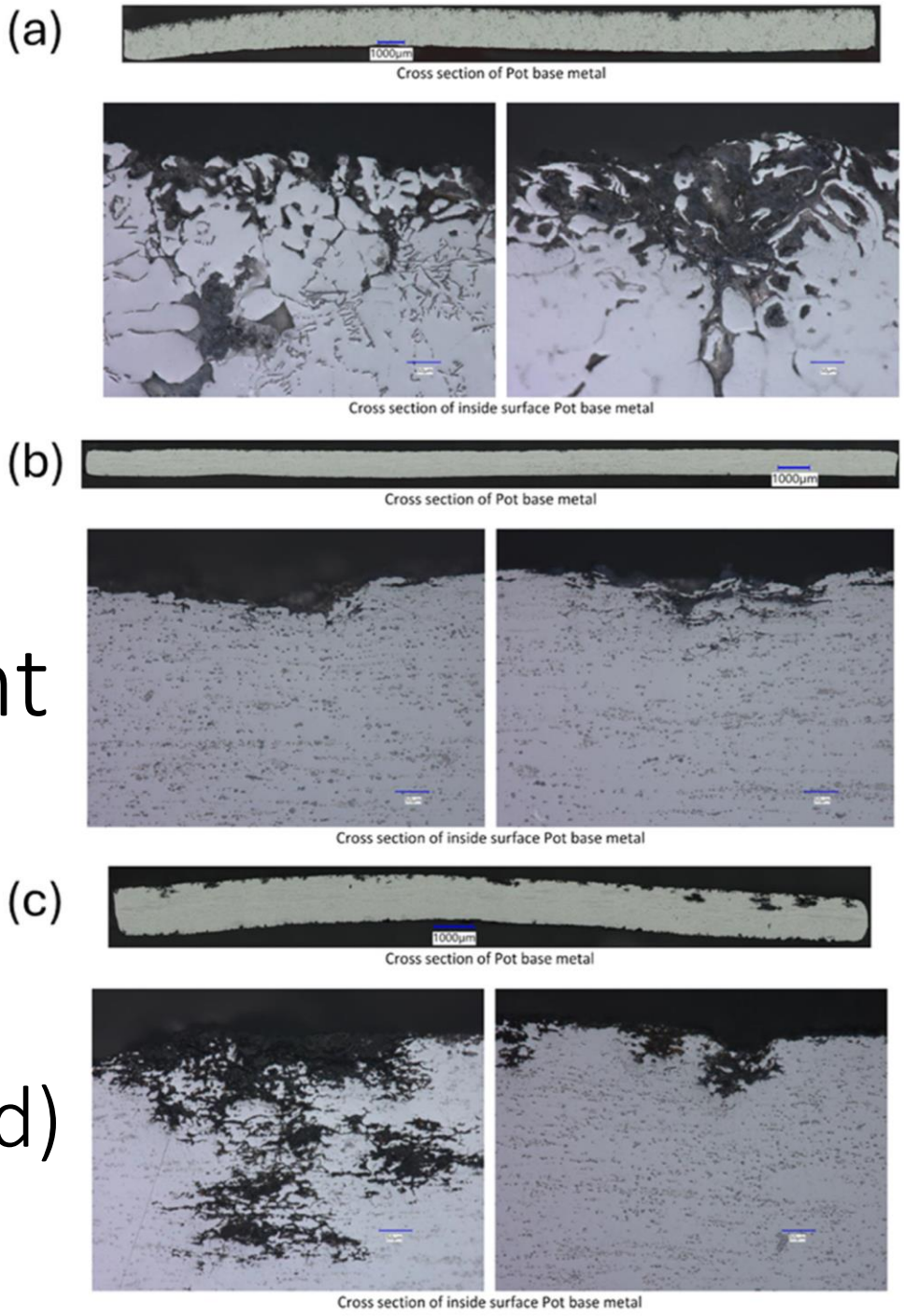


**SEM/EDS**

Cast

Wrought

Wrought (old)




Optical and scanning electron microscopy/energy dispersive spectroscopy

Wrought

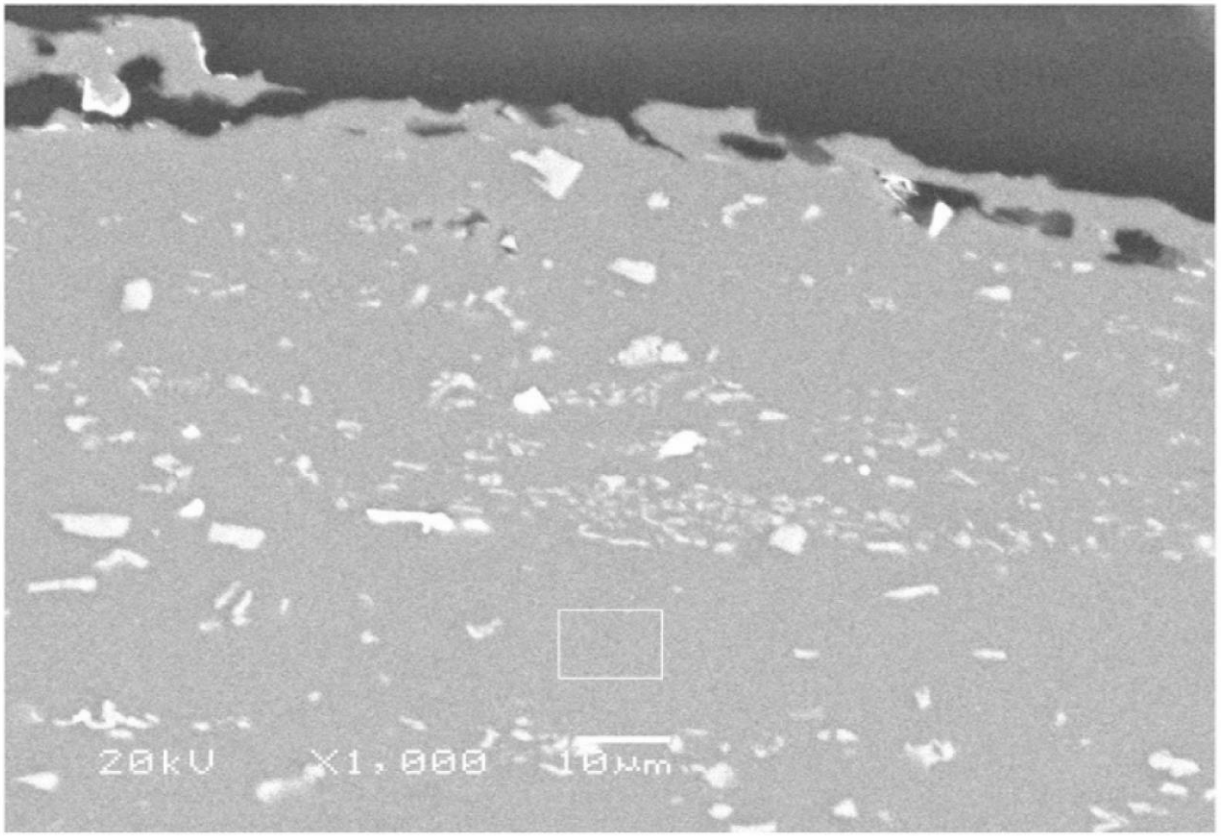



**Fig. 7.** Electron micrograph of the wrought pot from Vietnam (also shown in Fig. 6b), with Pb depicted as the brightest features, and other constituent phases (e.g., silicates, iron bearing components) delineated as light gray.

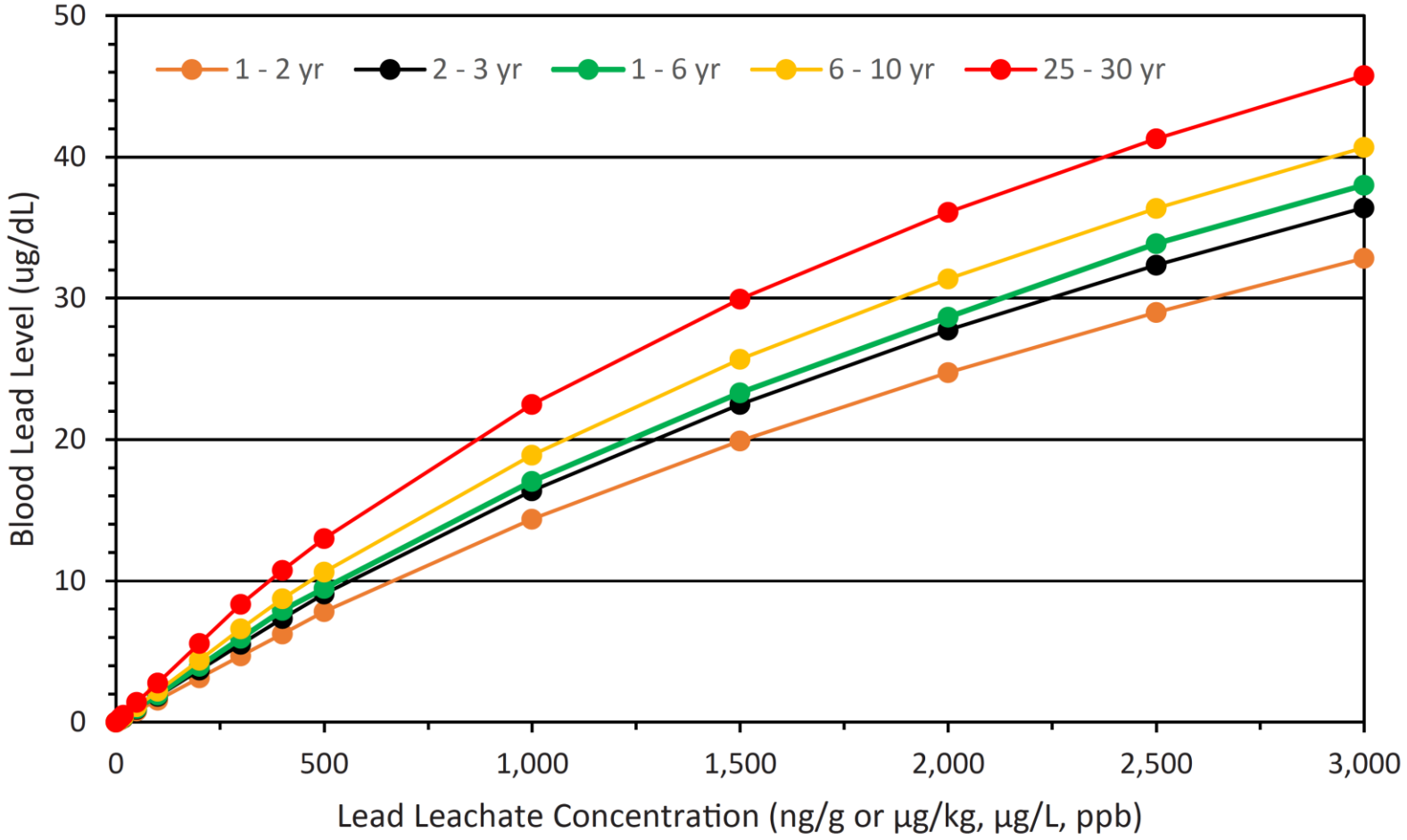
# Blood Lead Levels

What does this all mean in terms of Blood lead Levels (BLLs)???

- Study used the US EPA's All Ages Lead Model (AALM) to estimate BLLs for children and women of child bearing age from daily ingestion of food represented by the lead leachate concentrations found in this study, with a high of 3000 µg/L (300 times the drinking water standard).

- The AALM simulations incorporated decreasing gastrointestinal absorption of Pb and increasing food consumption with age, while holding food consumption constant for adults greater than 20 years old.

# Blood Lead Levels



# Blood Lead Levels

- Leachable Pb in the range of 200–300 µg/L, found in 11 % of the pots tested in this study could result in BLLs exceeding the level of 5 µg/dL at which WHO recommends investigation of potential sources of exposure.

- Limitation: Assumes daily ingestion of foods represented by boiled acetic acid leachate, which is relatively aggressive.
  - Not representative of bulk of foods consumed, e.g., rice, corn and cassava
  - Study in new pots, which leach proportionally more
  - Shorter cooking times, different pot usage, scale buildup etc. etc.

# Summary

- Leachable lead in acetic acid boiled for 2 hrs was 2 to 3 orders of magnitude higher than room temperature acetic acid left in the pots for several days
- 100 ppm total lead appears to be a good reference value for the potential to leach above a 10 ug/L drinking water standard (based on boiled acetic acid, which is conservative)
- Higher total lead yielded higher leachable lead, but a lot of scatter due to a variety of factors including manufacturing technique.
- Cast pots leached more than wrought pots.
- New pots leach proportionally more than old pots.

# Summary

- Replicate leaching tests using 4% acetic acid yielded variable results, often lower lead with relatively consistent aluminum concentrations.
- Poor correlation between leaching aluminum and leachable lead concentrations
- SEM/EDS work sheds light of mechanical aspects controlling leaching, including a layered microstructure in wrought pots, and the environmental accessibility of lead inclusions at pitting progresses.
- BLL modeling based on boiled 4% acetic acid may overestimate actual exposure relative to actual foods consumed.
- Boiled acetic acid may be a good test for certifying cookware as “safe” under most cooking conditions BUT may be overly aggressive with respect to actual exposure.

# Acknowledgments

Thank you for my colleagues named on this paper, as well as the Pure Earth staff who collected, catalogues and XRF'd all the pots and pans from 25 different countries.

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# Thank You!

PURE EARTH 25 YEARS