

BLOOD SPOT METAL ASSESSMENT USING X-RAY FLUORESCENCE

AARON SPECHT

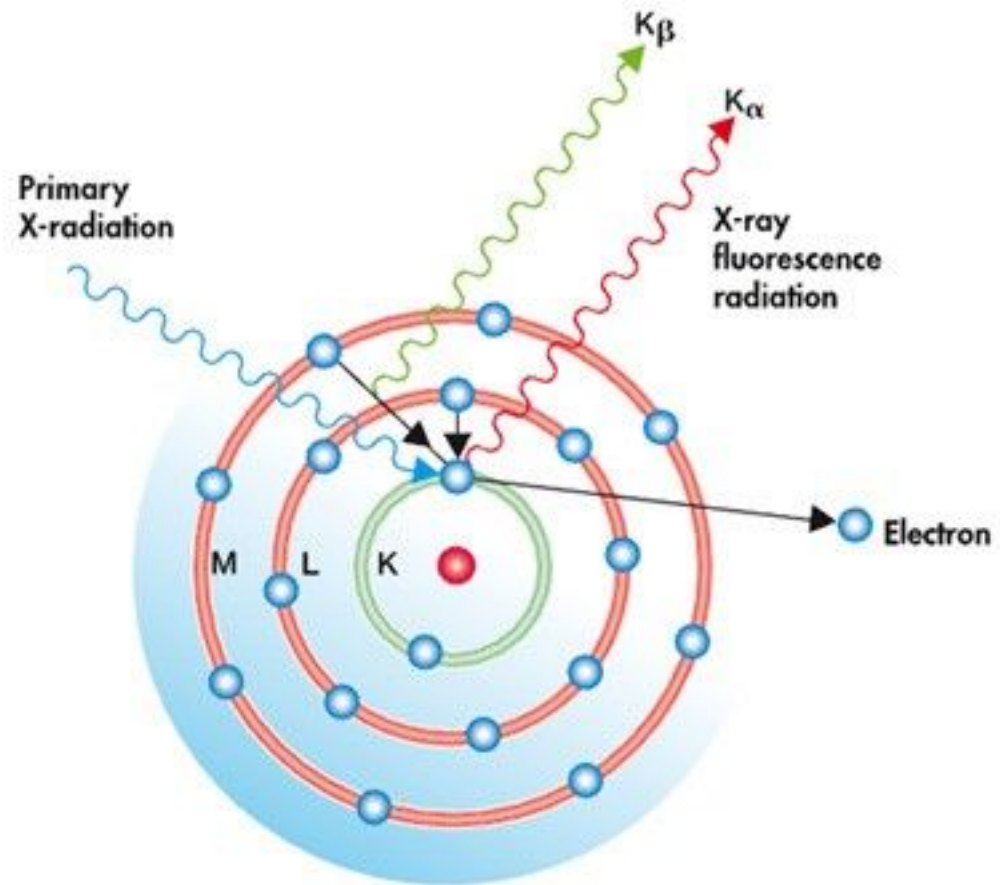


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OUTLINE

- **What is XRF?**
- **Blood spots with XRF**
- **Lead, Cadmium, Mercury, and Arsenic in Blood Spots**





WHAT CAN WE MEASURE?

Thermo Scientific X-RAY ENERGY REFERENCE

Key to Energy Values

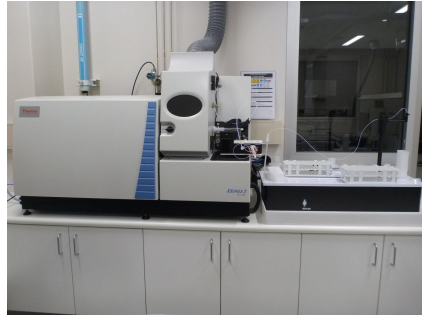
K_{α}^{-1}	K_{β}^{-1}
Ag	
L_{α}^{-1}	L_{β}^{-1}

The chart displays the periodic table with X-ray energy values for various elements. A red box highlights the following elements and their values:

B	C	N	O	F	Ne												
Boron 5	Carbon 6	Nitrogen 7	Oxygen 8	Fluorine 9	Neon 10												
Al	Si	P	S	Cl	Ar												
Aluminum 13	Silicon 14	Phosphorus 15	Sulfur 16	Chlorine 17	Argon 18												
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Potassium 19	Calcium 20	Scandium 21	Titanium 22	Vanadium 23	Chromium 24	Manganese 25	Iron 26	Cobalt 27	Nickel 28	Copper 29	Zinc 30	Gallium 31	Germanium 32	Arsenic 33	Selenium 34	Bromine 35	Krypton 36
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Rubidium 37	Strontium 38	Yttrium 39	Zirconium 40	Niobium 41	Molybdenum 42	Technetium 43	Ruthenium 44	Rhodium 45	Palladium 46	Silver 47	Cadmium 48	Indium 49	Tin 50	Antimony 51	Tellurium 52	Iodine 53	Xenon 54
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Cesium 55	Barium 56		Hafnium 72	Tantalum 73	Tungsten 74	Rhenium 75	Osmium 76	Iridium 77	Platinum 78	Gold 79	Mercury 80	Thallium 81	Lead 82	Bismuth 83	Polonium 84	Astatine 85	Radon 86
Fr	Ra	57-71															
Francium 87	Radium 88		La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
12.03 14.77	12.34 15.23		Lanthanum 57	Cerium 58	Praseodymium 59	Neodymium 60	Promethium 61	Samarium 62	Europium 63	Gadolinium 64	Terbium 65	Dysprosium 66	Holmium 67	Erbium 68	Thulium 69	Ytterbium 70	Lutetium 71
		89-103															
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
			Actinium 89	Thorium 90	Protactinium 91	Uranium 92	Neptunium 93	Plutonium 94	Americium 95	Curium 96	Berkelium 97	Californium 98	Einsteinium 99	Fermium 100	Mendelevium 101	Nobelium 102	Lawrencium 103

STANDARD INSTRUMENTATION FOR METALS

Inductively Coupled Plasma Mass Spectrometry



- Twice the cost of typical XRF systems (excluding maintenance and supplies...)
- Requires sample acid digestion
- Highly trained lab technicians
- Parts per trillion level detection limits

X-ray Fluorescence



- Cheaper to purchase and maintain
- Non-destructive analysis
- Easy to use with less risk of critical failure

BENCHTOP XRF A NEW PARADIGM

X-ray
Fluorescence

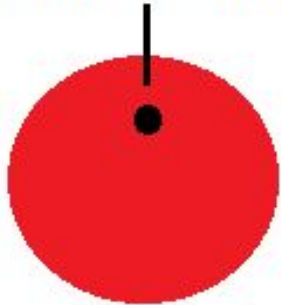


- We can measure almost anything with this at PPB level detection limits
- Let's look at blood spots

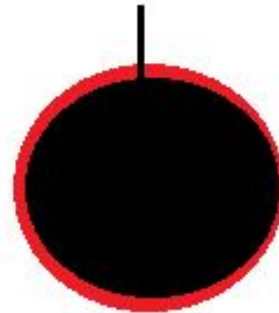
OVERCOMING PROBLEMS WITH BLOOD SPOTS

- The drying process (ring size, volume of blood, hematocrit) can have the potential for influencing measurements of punches or small samples.
- With the XRF we can sample from the full spot size (removes most of these issues)

Standard Sampling
Area for Punch ICP-MS



Sampling Area for XRF



BLOOD SPOTS CALIBRATION AND LIMITATIONS

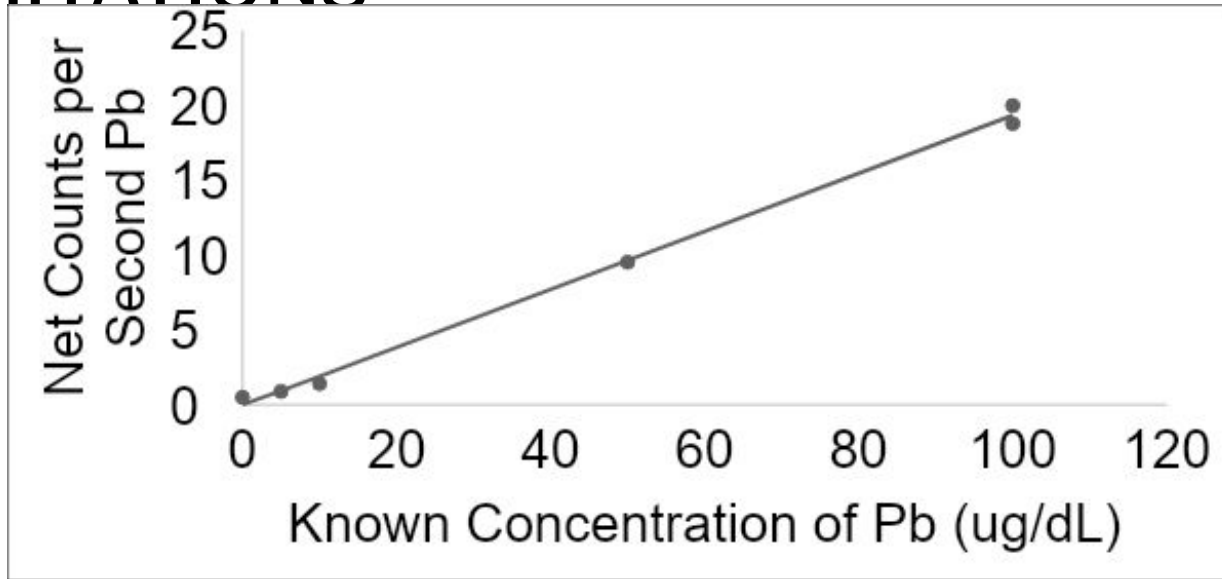


Table 1.
Distribution of repeated 30-minute measurements of blood spots.

Sample	Number of Measurements	Concentration (ug/dL)	Coefficient of Variation	MDL (ug/dL)
Blood Spot Standard	22	10	0.05	1.0
Blood Spot 1 (150 uL)	20	5.5	0.09	1.0
Blood Spot 2 (300uL)	30	7.1	0.23	3.2

VOLUME AND PROCEDURAL DEPENDENCIES

Procedural Repeatability
Test

Sample	Number of Samples	ICP-MS (ug/dL)	Mean (ug/dL)	Coefficient of Variation	Standard Deviation (ug/dL)
Blood 1 (300 uL)	4	7.1	5.1	0.27	1.36
Blood 2 (150 uL)	6	8.8	9.1	0.08	0.74

The deviation is less than or the same as our recorded detection limit. This means we have eliminated most error derived from the preparation of the sample.

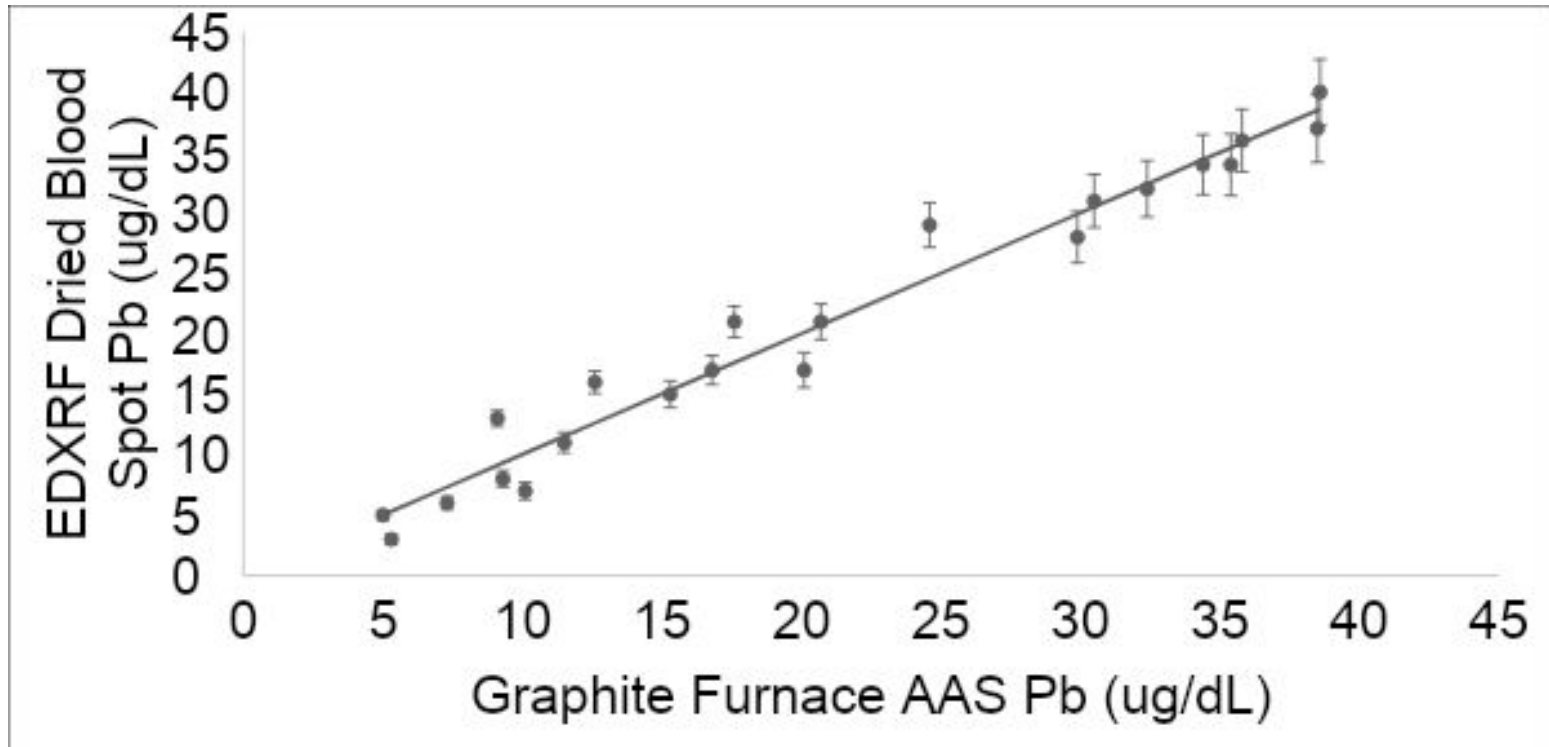
DOES IT WORK IN PRACTICE?

Venous blood from Boston Children's Hospital

NIST 955c Capillary Blood

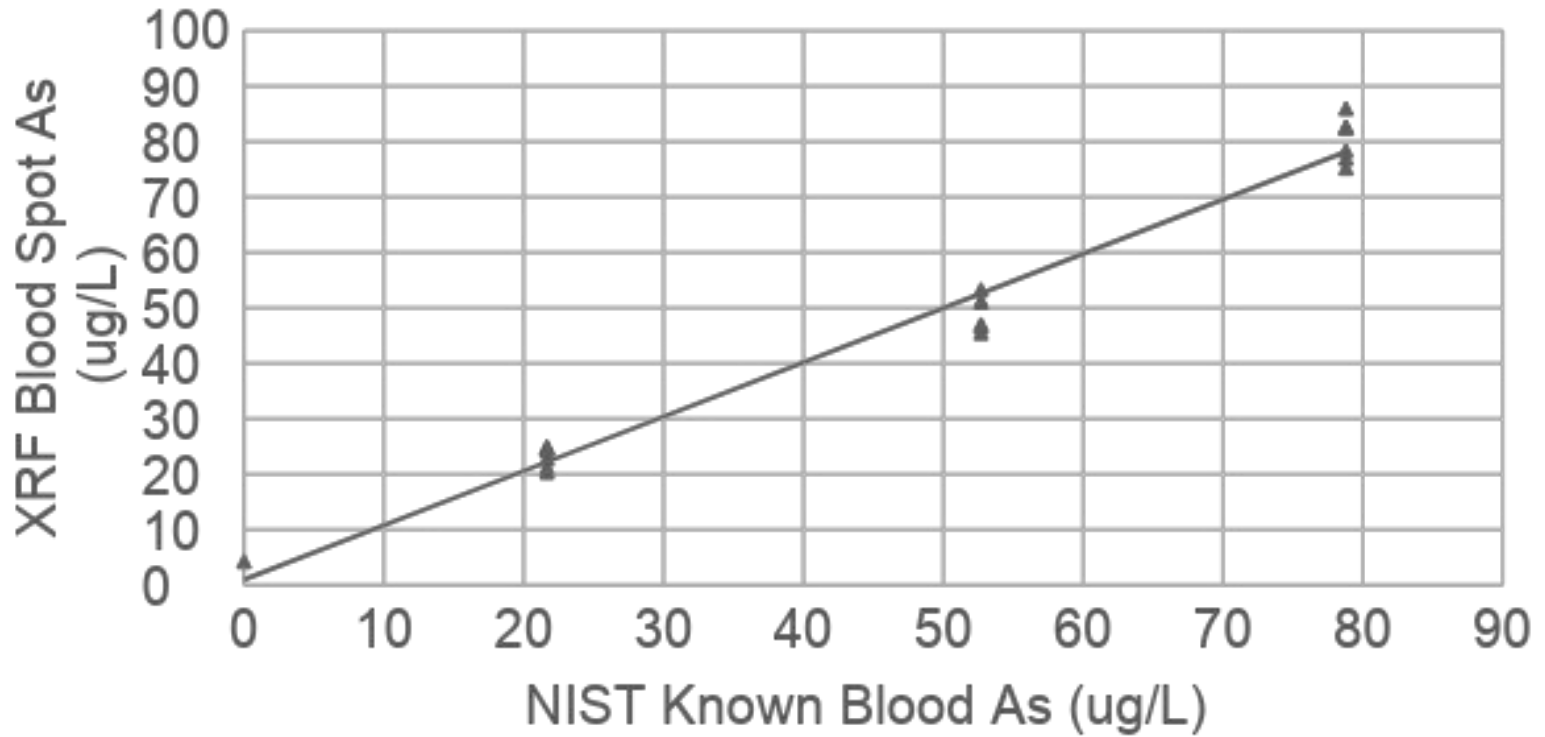
- **Validated known metal concentrations**
 - Arsenic from 0-80 ug/L
 - Mercury from 0-35 ug/L
 - Lead from 0-45 ug/dL
 - Cadmium from 0-10 ug/L

DOES IT WORK IN PRACTICE?

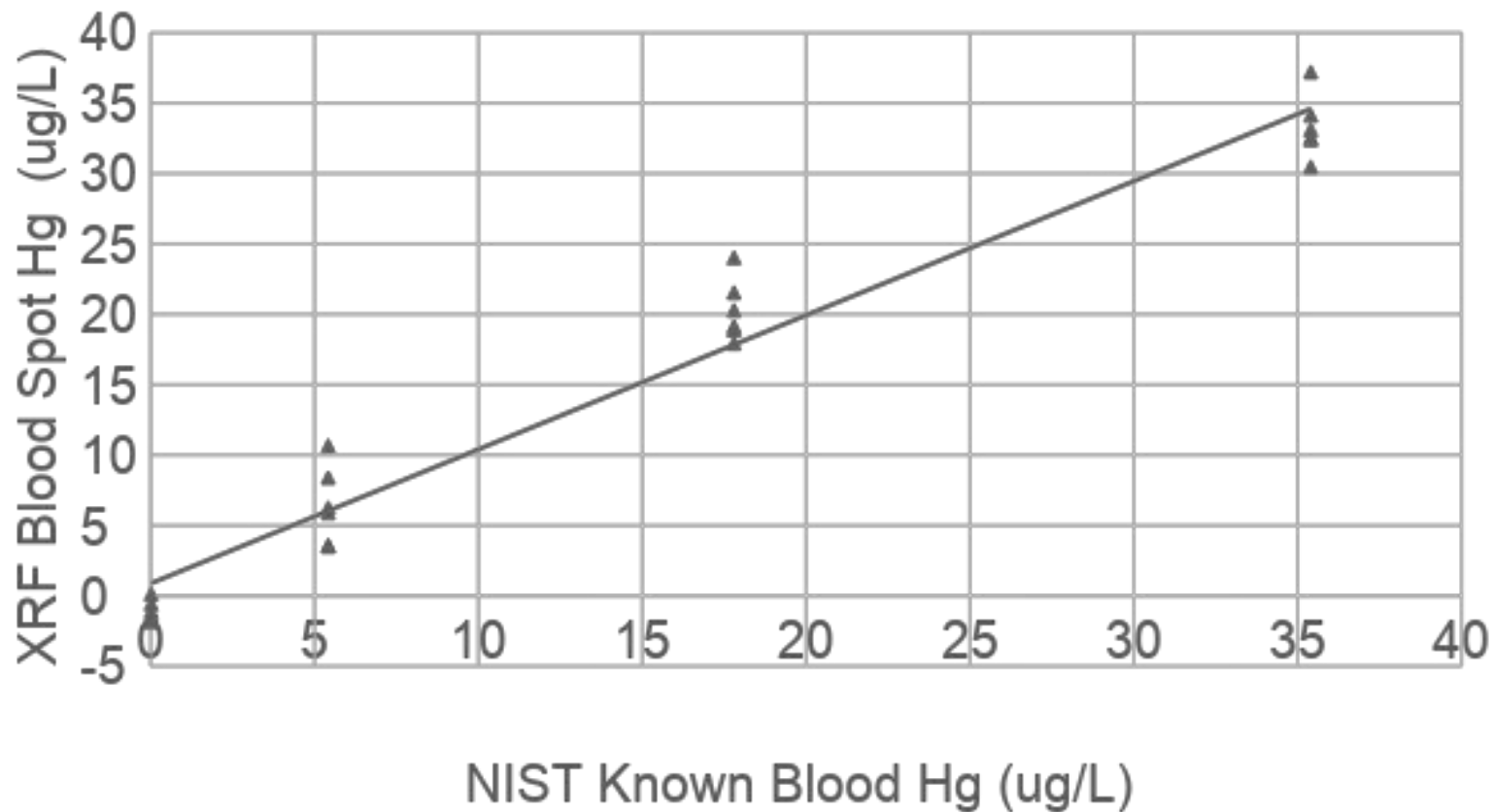


Boston Children's Hospital Blood Samples
Specht et al. 2021, Environmental Science and
Technology

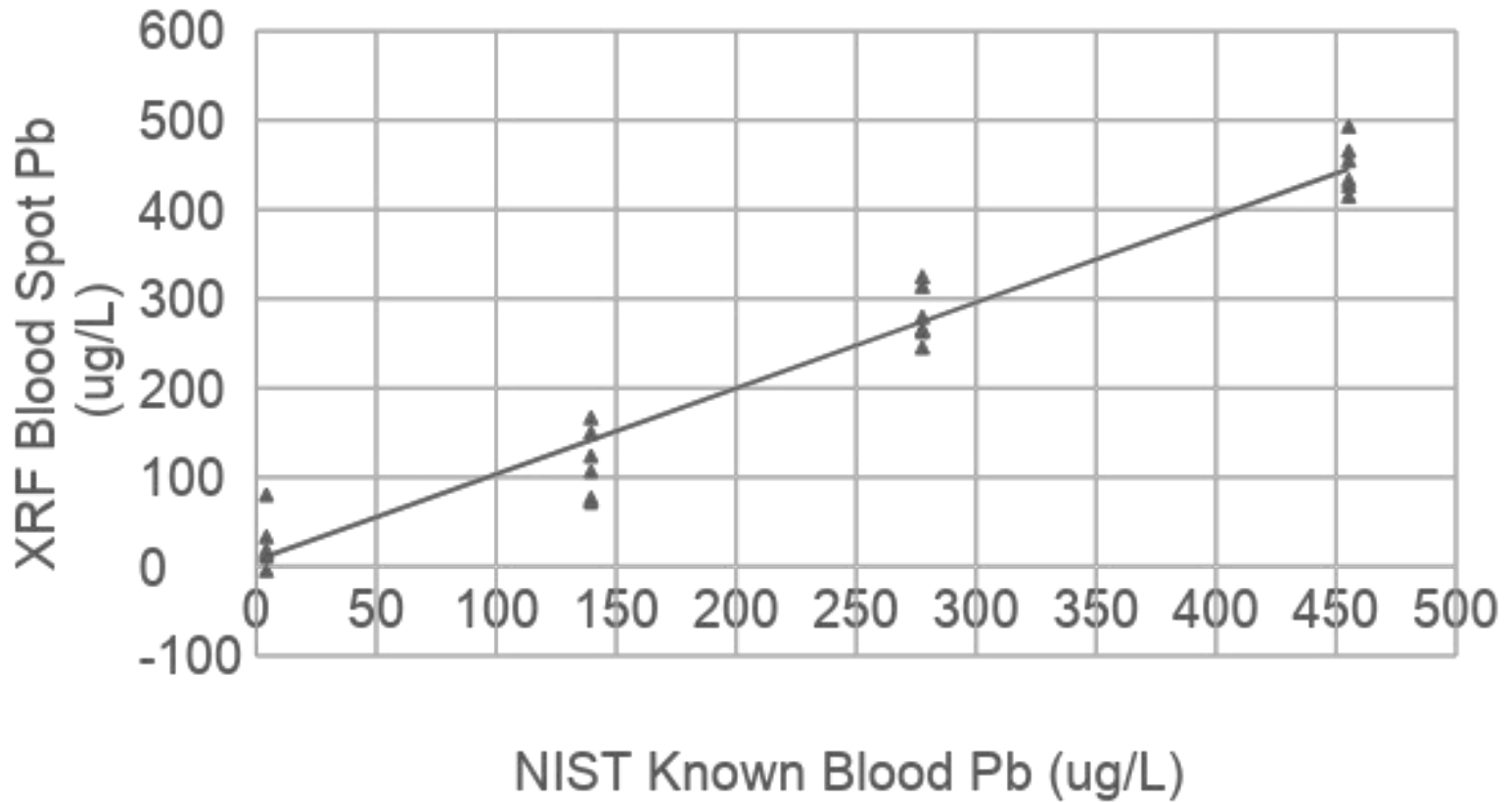
NIST 955C SAMPLE TESTING



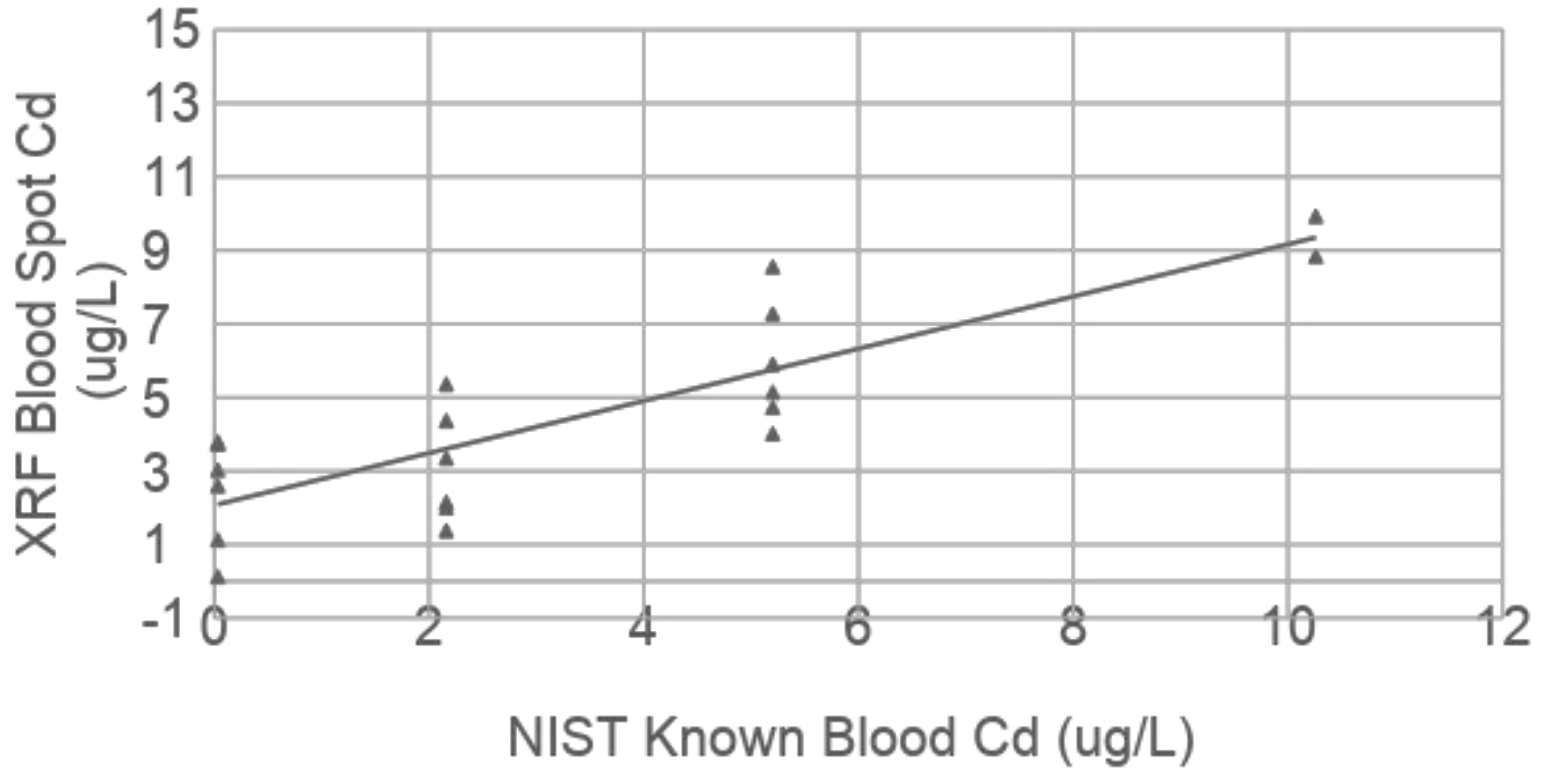
NIST 955C SAMPLE TESTING



NIST 955C SAMPLE TESTING



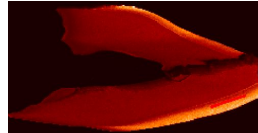
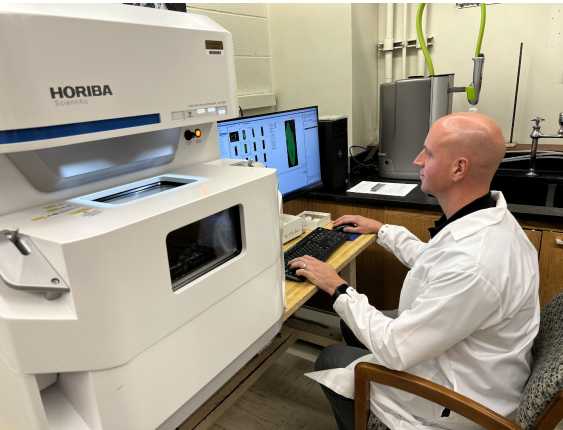
NIST 955C SAMPLE TESTING



CONCLUSIONS

- **Dried blood spots are able to be measured for Pb, Hg, As, and Cd using x-ray fluorescence**
- **Method can be used to get more elements and metals that should also be relevant to health**
- **Some metals have better detection capabilities than others in DBS**

ACKNOWLEDGMENTS



Collaborators on this

Marc Weisskopf, Maitreyi Mazumdar, Jessica Faul, Kelly Bakulski, Everyone in HRS!

Health and Retirement Study (SUBK00018927)

National Institute for Occupational Safety and Health (NIOSH) K01 OH011648

Facility Access Funds (FAF) from the Harvard-NIEHS Center for Environmental Health

(P205600002) Malvern Panalytical for working with me on method development