

# Evaluating Mercury's Impact on the Food Chain Across Six Mining Regions in Ghana

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# Organization

- Pure Earth is a non-profit organization founded in New York in 1999.
- Pure Earth specializes in the identification and management of toxic sites in low- and middle-income (LMIC) countries, with implications on human health.
- Working out of regional offices around the world, Pure Earth's global team of nearly 100 professionals has completed projects in more than 50 LMIC countries.





Credit: Larry Price

# Global Mercury Program Strategy

## Peru

- Restoration of Degraded Areas
- Mercury-Free Technologies
- Mercury-Free Gold Supply  BRILLIANT EARTH
- Peru Mining Women's Network

## Colombia

- Tailings Management
- Mercury Storage Unit
- Contaminated Site Assessment



## Indonesia

- Empowering Women Gold Miners
- Contaminated Site Assessment

## Philippines

- Contaminated Site Assessment

## Mongolia

- "Gold Ninja" - Mercury-Free For Children

# Evaluating Mercury's Impact on the Food Chain Across Six Mining Regions in Ghana



# Study's Goals and Objectives

## General Objective:

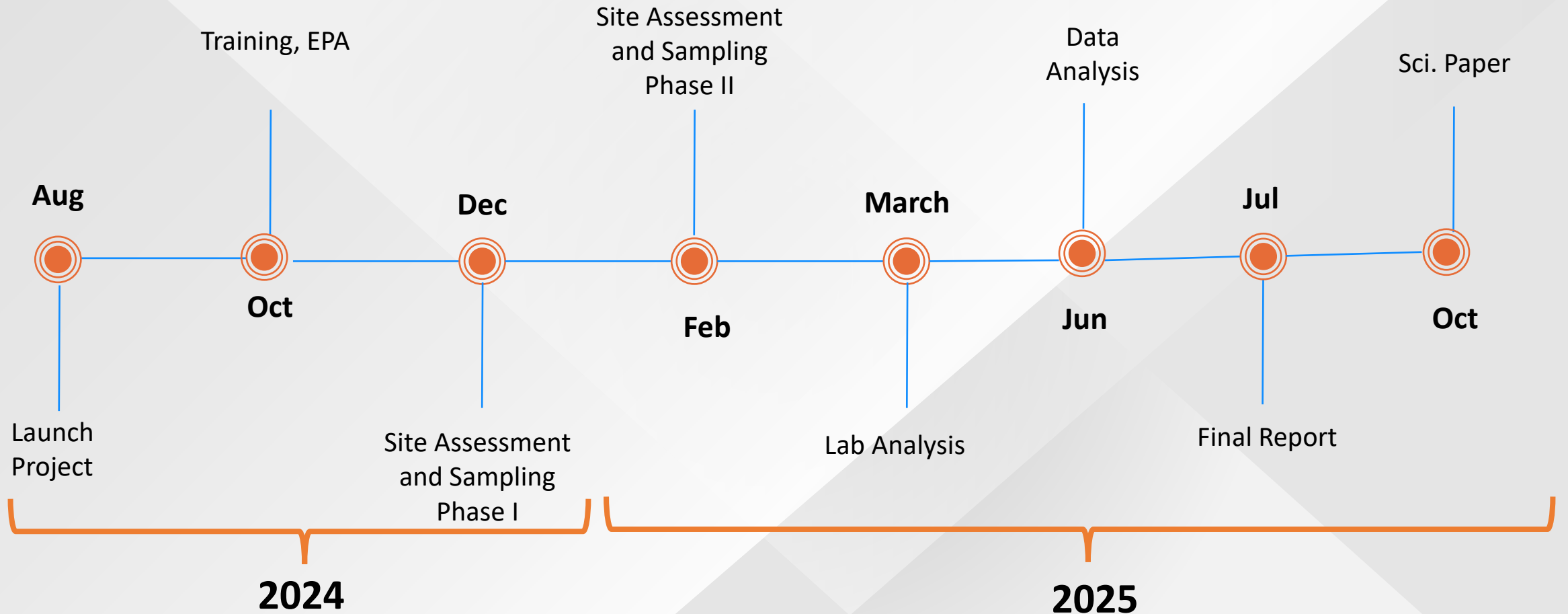
- Assess mercury pollution into the food chain and environment in selected ASGM sites across six regions in Ghana.

## Specific Objectives:

- Delimit and evaluate mercury contamination in various environmental matrices.
- Determine mercury levels in soil, water, crops, and fish.
- Understand mercury's interaction with the food system.



# Project Timeline



# Project Launch



# Context – Mining Activity in Ghana

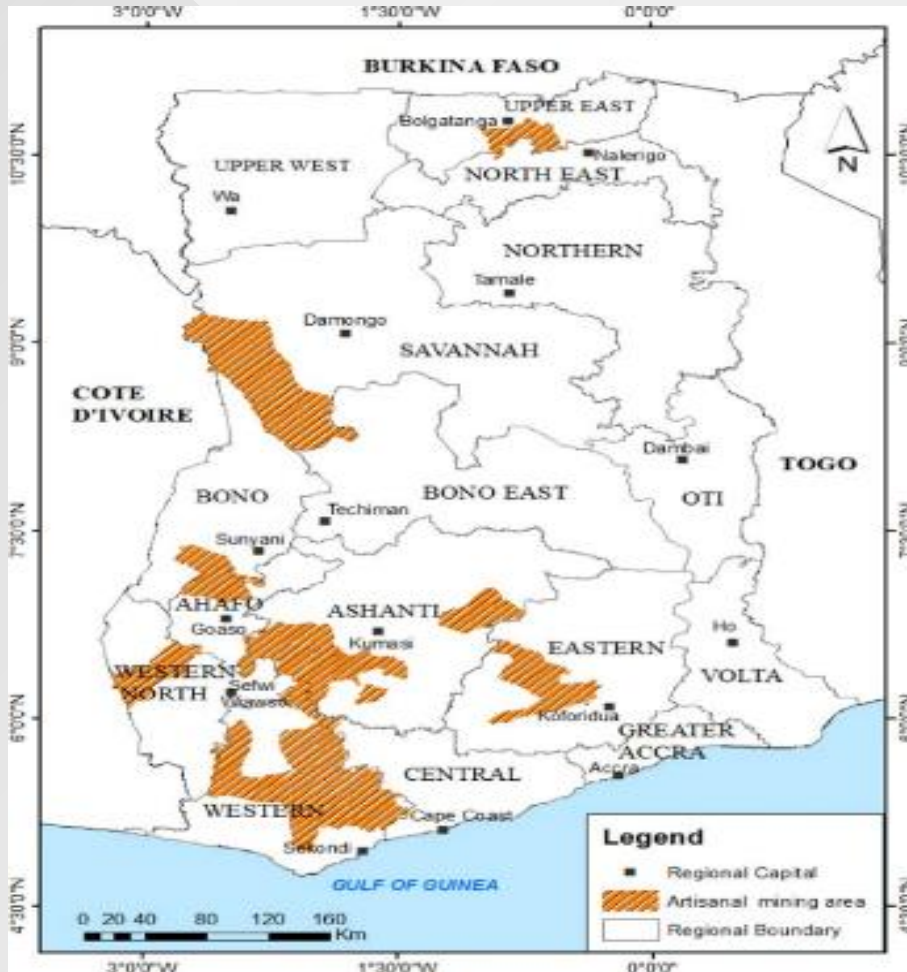


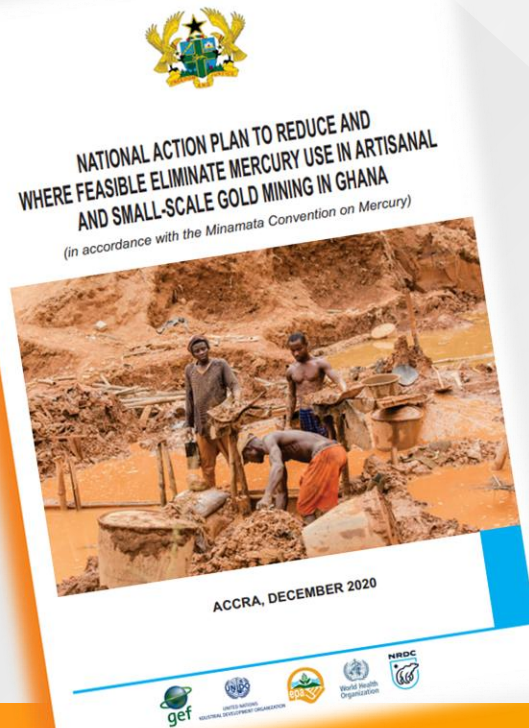
Figure from Takyi et al., 2021

- ASGM is a key economic activity, providing livelihoods and contributing significantly to Ghana's gold output, especially in rural areas.
- Unregulated mining by ASGM actors has significantly caused soil degradation, deforestation and the pollution of water bodies.
- Mercury use in gold extraction leads to severe health and environmental risks, including neurotoxicity and air/water contamination.
- ASGM also mobilizes Pb, and As, which accumulate in soils, rivers, and food crops, posing chronic health hazards.
- Heavy-metal pollution threatens biodiversity, agriculture, and food security, with long-lasting ecological effects.
- Despite Ghana's commitment to the Minamata Convention, data gaps and weak regulation persist—highlighting the need for coordinated mitigation and sustainable mining practices.

# Current Status – Mercury & Minamata Convention

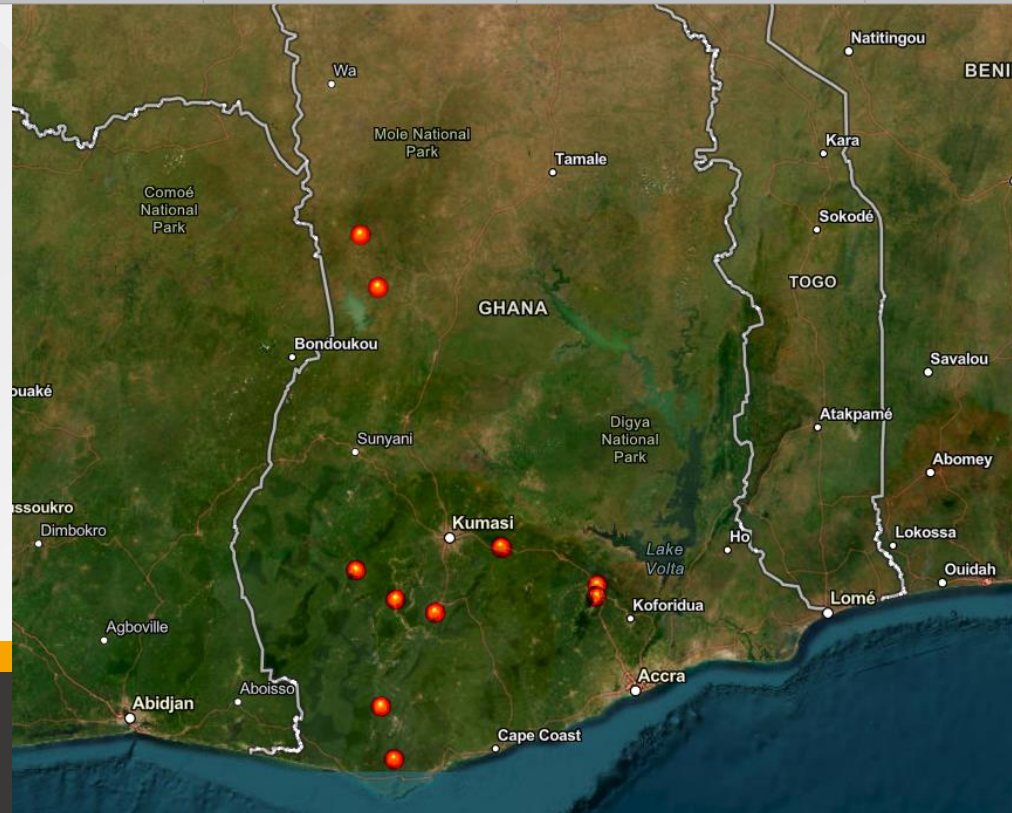
This project is part of the activities identified in the country's NAP to comply with the Minamata Convention. Some aspects are:

- Conduct baseline **mercury inventories** and site **assessments at artisanal mining areas** to determine current levels of mercury use.
- Monitor **soil**, sediment, **water**, and tailings in and around mining sites for mercury and other heavy metals.
- Assess bioaccumulation **in crops, fish**, and foodstuffs in communities near mining zones.
- Establish an environmental monitoring network and sampling **protocols** for ongoing surveillance of mercury in ecosystems.
- Use collected data to map hotspots of contamination and identify priority areas for remediation and intervention.



# Site Selection

Ashanti (AR)	Central (CR)	Eastern (ER)	Savannah (SR)	Western (WR)	Western North (WNR)
Konongo Odumase (KO)	Akwaboso (AK)	Asiakwa (AS)	Dakrupe (DA)	Wassa Keyianko (WK)	Lake Amponsah (LA)
Konongo Zongo (KZ)		Osino (OS)	Tinga (TA)	Ankobra Community (AC)	
Nyamebekyere (NY)					



# Training

- EPA Officials & Technical Personnel



# Methodology and Results

# Methodology

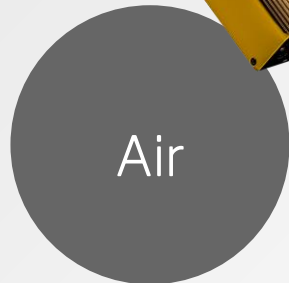
## Toxic Site Investigation Program - TSIP

The primary purpose of the TSIP program is to generate reliable information that 1) pinpoints the location of toxic sites and 2) assesses their severity.



Soil

XRF



Air

JEROME



Water



Food  
Crops



Fish

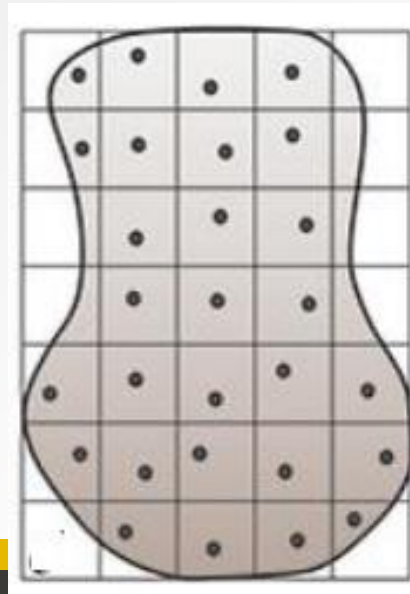
LAB ANALYSIS

# Sampling Strategy and Data Collection

## Toxic Site Investigation Program - TSIP

1. Site identification / Accessibility
2. Geographical delimitation
3. Confirmation of the sampling strategy
4. Data Collection (Environmental Socio- Economic)

Order	Type	Method	Number Samples
1	Soil (In Situ)	XRF	~100
2	Air	Jerome	Unlimited
3	Soil - Simple	Bag (@250 g)	10
4	Crops/ Vegetables	Bag	10
5	Water	Bottle (200 ml)	15
6	Fish	Bag (50 g)	7



# Data Collection & Samples Transportation



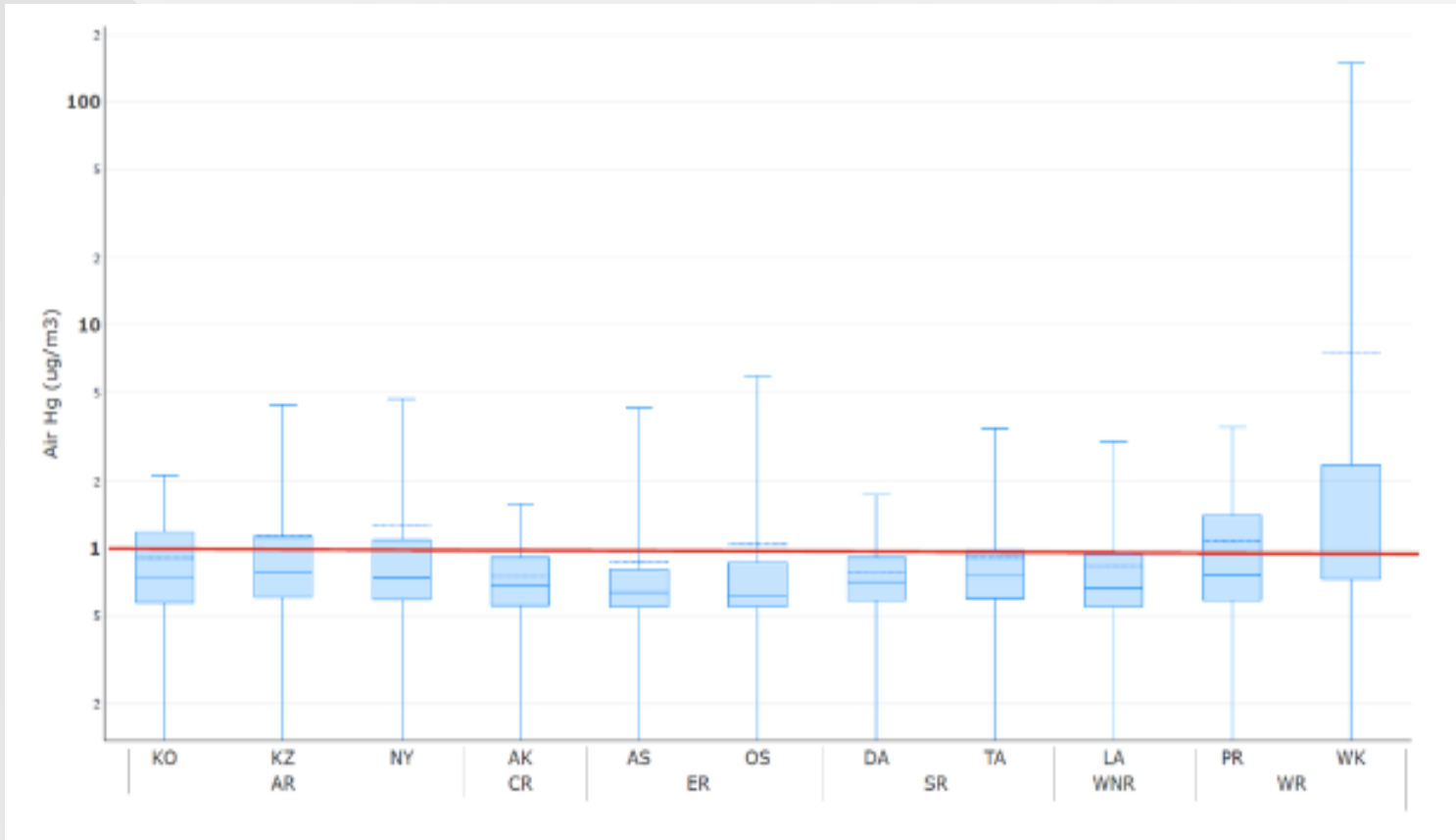
# Reference Values

	Air	Water (mg/L)	Water (mg/L)	Soil for residential areas (ppm)	Soil for housing areas (ppm)	Soil for playgrounds (ppm)
	Ghana	Ghana	FAO & WHO	US EPA	Germany	Germany
<b>Arsenic</b>	15 (ng/m <sup>3</sup> )	0.01	0.01	35	50	25
<b>Cadmium</b>	3 (ng/m <sup>3</sup> )	0.003	0.003	7.1	20	10
<b>Lead</b>	0.5 (ug/m <sup>3</sup> )	0.01	0.01	200	400	200
<b>Mercury</b>	15 ng/m <sup>3</sup> for 24 hrs averaging 1 ug/m <sup>3</sup>	0.001	0.001	7.1	20	10

	Fish (mg/kg)	Fruit (mg/kg)	Tuber (mg/kg)	Vegetable (mg/kg)	Cereal (mg/kg)	Legume (mg/kg)	Rice mg/kg	Cacao powder mg/kg
	WHO/FAO (+), EU Commission (**), China Standards (###)							
<b>Arsenic</b>	0.1###			0.5###	0.5###		0.2–0.35 <sup>+</sup>	0.5###
<b>Cadmium</b>	0.05 <sup>**</sup>	0.1 <sup>+</sup>	0.1 <sup>+</sup>	0.05–0.2 <sup>+</sup>	0.1 <sup>+</sup>	0.1 <sup>+</sup>	0.4 <sup>+</sup>	2.0 <sup>+</sup>
<b>Lead</b>	0.3 <sup>+</sup>	0.1 <sup>+</sup>	0.1 <sup>+</sup>	0.05–0.3 <sup>+</sup>	0.2 <sup>+</sup>	0.1 <sup>**</sup>	0.5###	0.5###
<b>Mercury</b>	0.5 <sup>**</sup>			0.01###	0.02###		0.02###	

*For arsenic, WHO/FAO and EU Commission give limits for inorganic arsenic only.*

# Air – Results



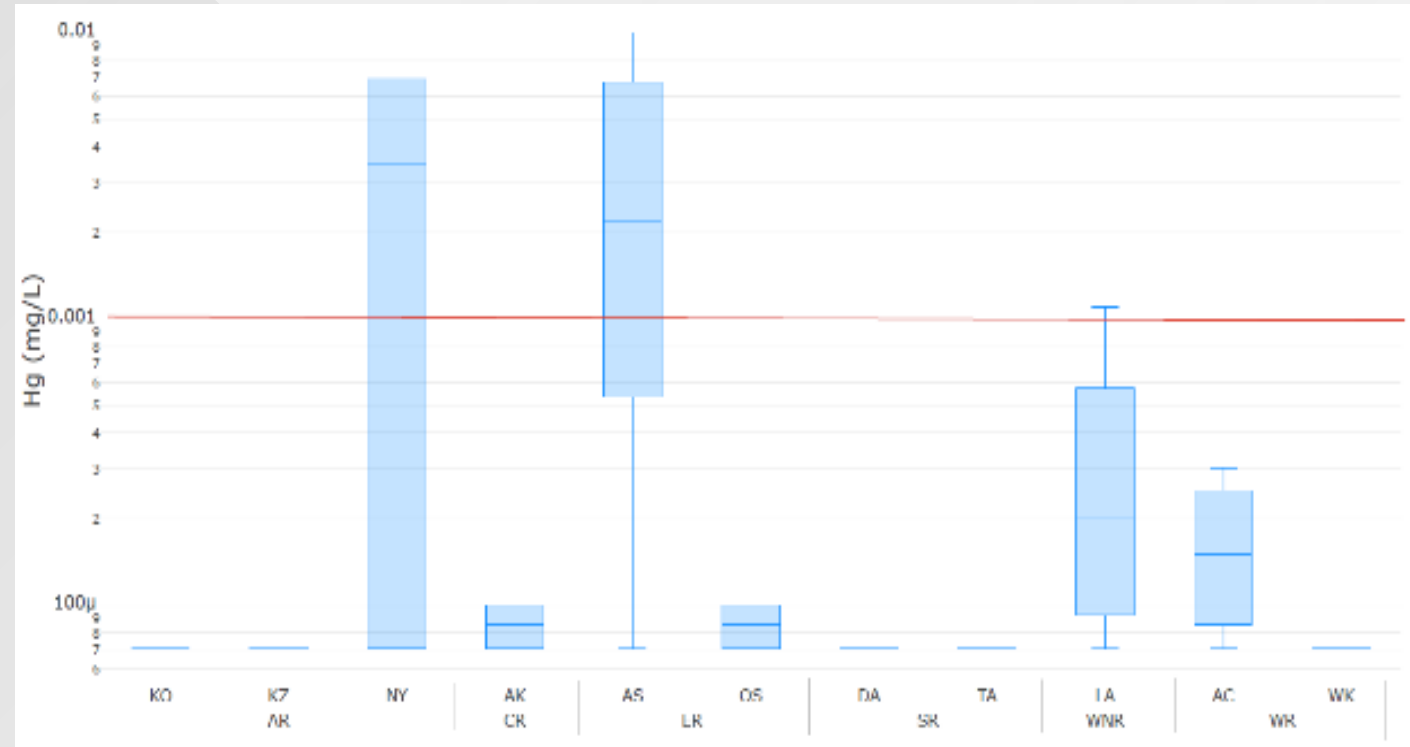
Region	Site	Number of Samples	Mean	Max	Min	SD
AR	KO	60	0.30	2.11	<RL	0.52
	KZ	100	0.49	4.39	<RL	0.78
	NY	90	0.39	4.70	<RL	0.85
CR	AK	100	0.29	1.58	<RL	0.39
ER	AS	83	0.26	4.24	<RL	0.55
	OS	110	0.34	5.87	<RL	0.72
SR	DA	106	0.36	1.73	<RL	0.42
	TA	140	0.46	3.44	<RL	0.52
WNR	LA	80	0.33	3.01	<RL	0.49
WR	PR	76	0.42	3.46	<RL	0.67
	WK	100	1.84	150.20	<RL	15.00

In air, mercury vapor concentrations were generally below Ghana’s permissible limit of  $1 \mu\text{g}/\text{m}^3$ , except at **Wassa Kanyanko (WK)**

# Distribution of Air Hg Concentration in Wassa Kayianko



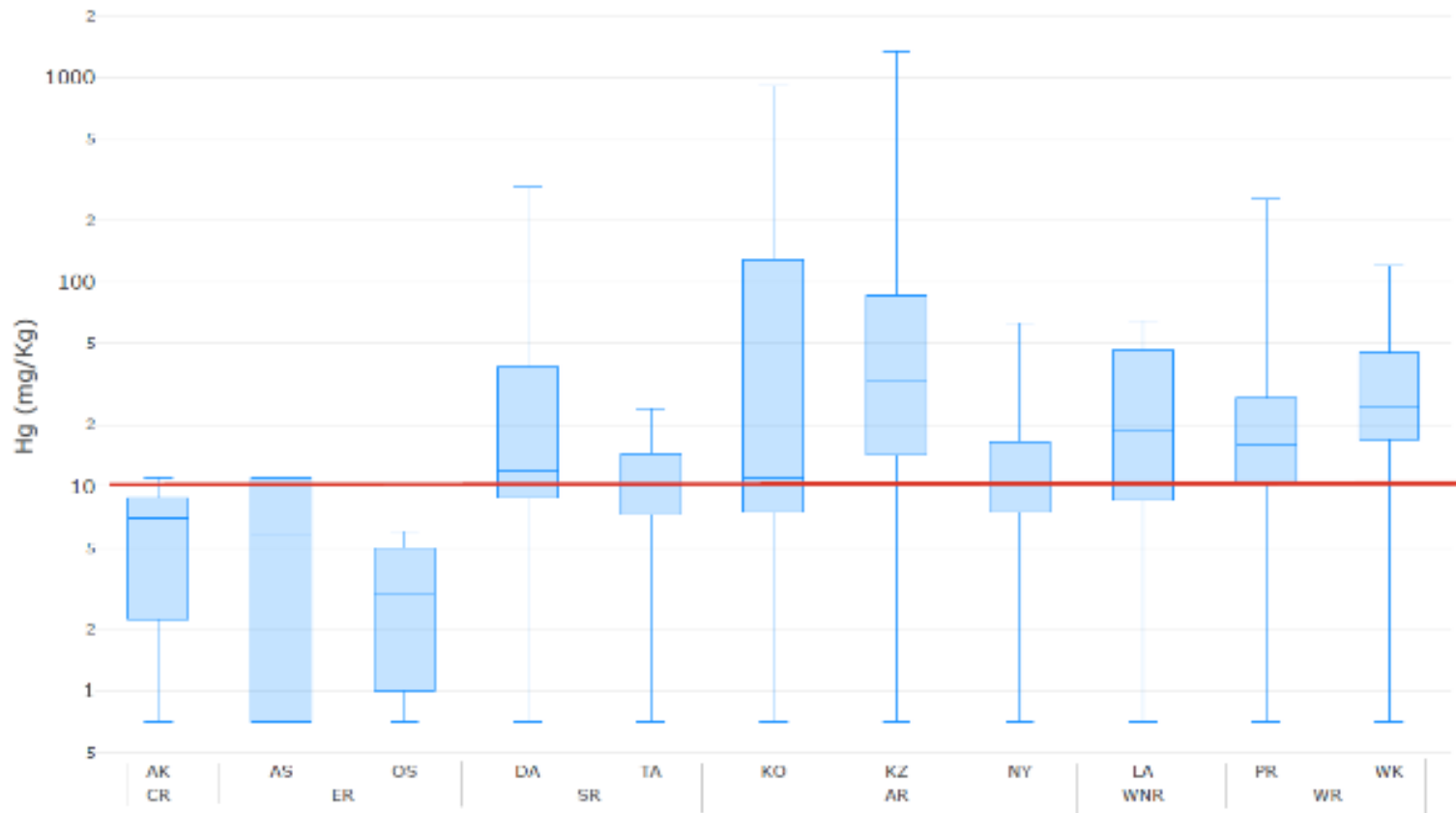
# Water – Results



Region	Site	# Samples	Av	Max	Min	SD
AR	KO	2	<RL	<RL	<RL	<RL
	KZ	3	<RL	<RL	<RL	<RL
	NY	8	0.0009	0.0069	<RL	0.0024
CR	AK	4	<RL	0.0001	<RL	0.0001
ER	AS	7	0.0021	0.0100	<RL	0.0037
	OS	10	<RL	0.0001	<RL	<RL
SR	DA	10	<RL	<RL	<RL	<RL
	TA	5	<RL	<RL	<RL	<RL
WNR	LA	11	0.0002	0.0011	<RL	0.0003
WR	AC	4	0.0002	0.0003	<RL	0.0001
	WK	5	<RL	<RL	<RL	<RL

Mercury levels exceeded the permissible limits in multiple water samples. The concentrations of mercury in these samples exceeded the national threshold of 0.001 mg/L, with a maximum concentration of 0.01 mg/L.

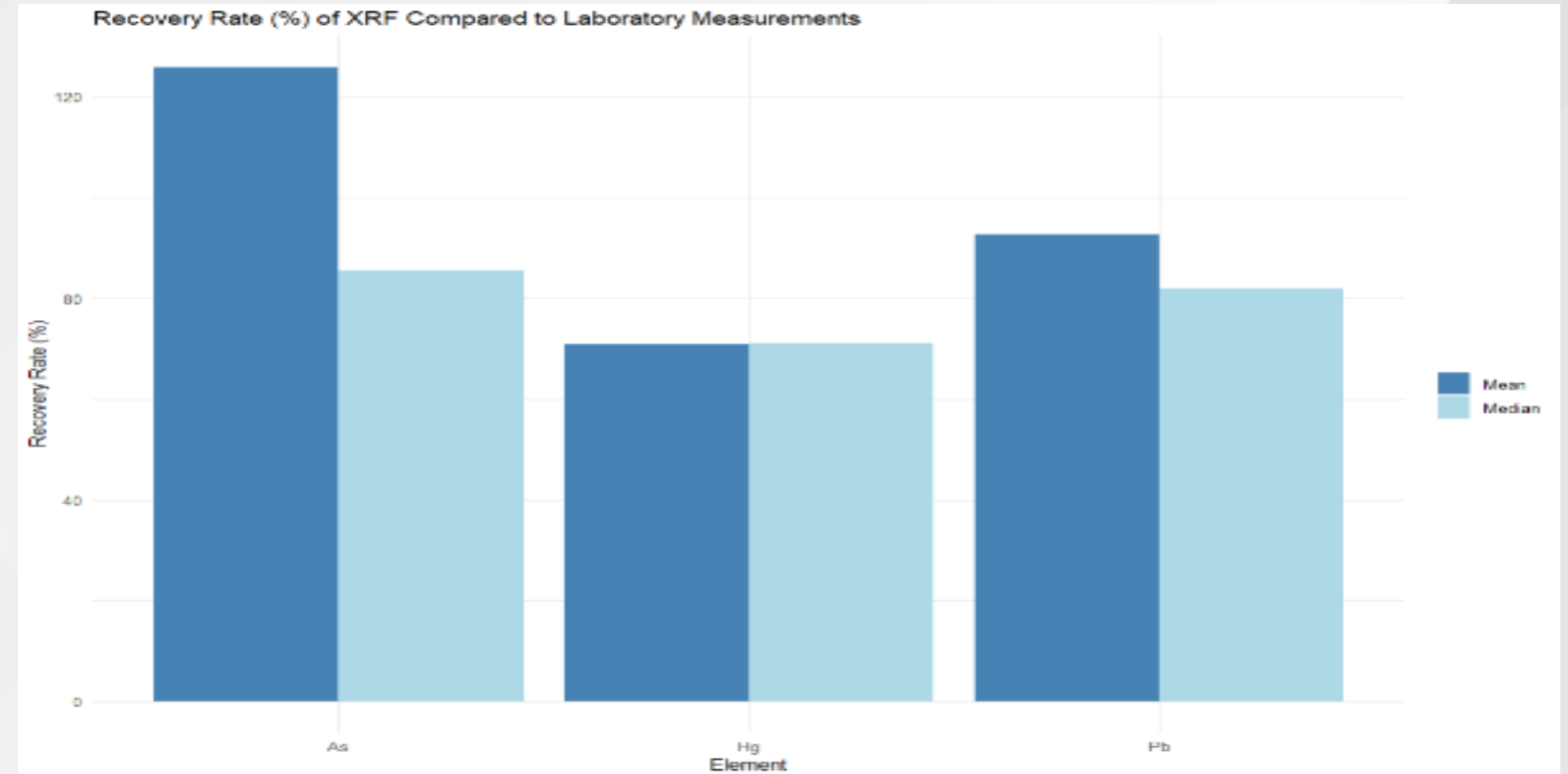
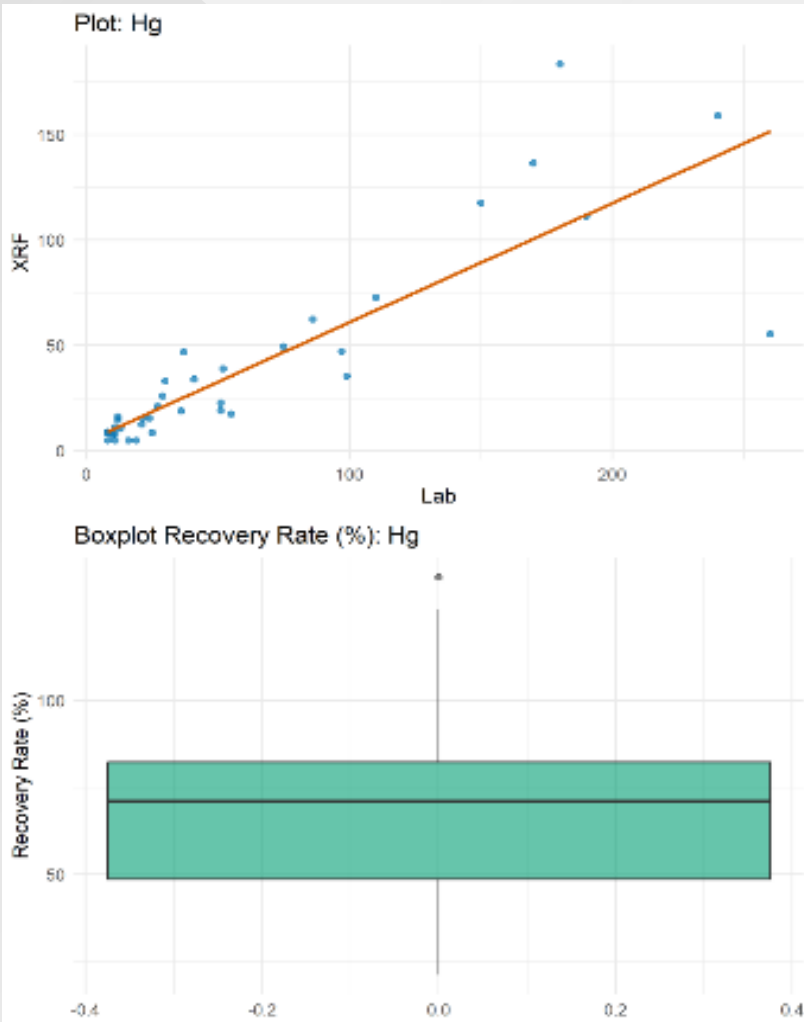
# Soil – Results



Region	Site	Samp	Mean	Max	Min	SD
AR	KO	37	31.01	909	<RL	150.84
	KZ	63	56.40	1342	<RL	187.72
	NY	144	2.74	63	<RL	6.56
CR	AK	100	2.00	11	<RL	2.82
ER	AS	105	0.81	11	<RL	1.00
	OS	107	0.92	6	<RL	0.94
SR	DA	110	6.60	291	<RL	30.68
	TA	100	2.27	24	<RL	4.16
WNR	LA	89	6.21	65	<RL	13.23
WR	PR	82	11.73	254	<RL	30.40
	WK	103	7.09	120	<RL	20.00

A total of 1040 readings were taken with XRF analyzers across all sites to determine the concentration of metals in soil. The highest mean mercury (Hg) concentration is 56 ppm in **Konongo Zongo (KZ)**, mean levels of concern were also observed in **Konongo Odumase (KO)** with 11.7 ppm and in **Prestea (PR)** with 31.0 ppm.

# Soil Samples Correlation



The correlation between portable X-ray fluorescence (XRF) and laboratory-based measurements was high and statistically significant for mercury according to Pearson's correlation coefficients. On the other hand, low recovery rate for mercury (Hg) suggests a potential **underestimation** in field conditions.

# Distribution of Soil Hg Concentration in Konongo Zongo

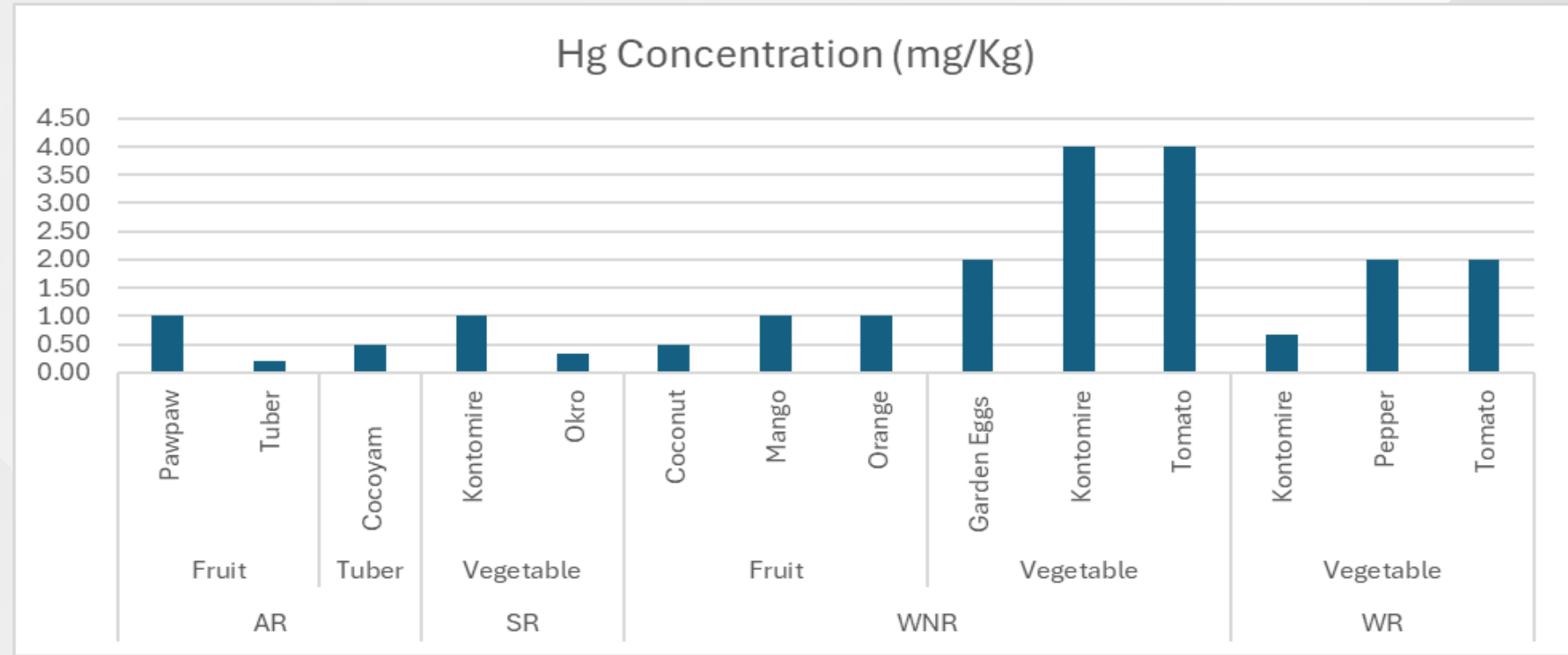


# Distribution Soil Hg Concentration in Lake Amponsah



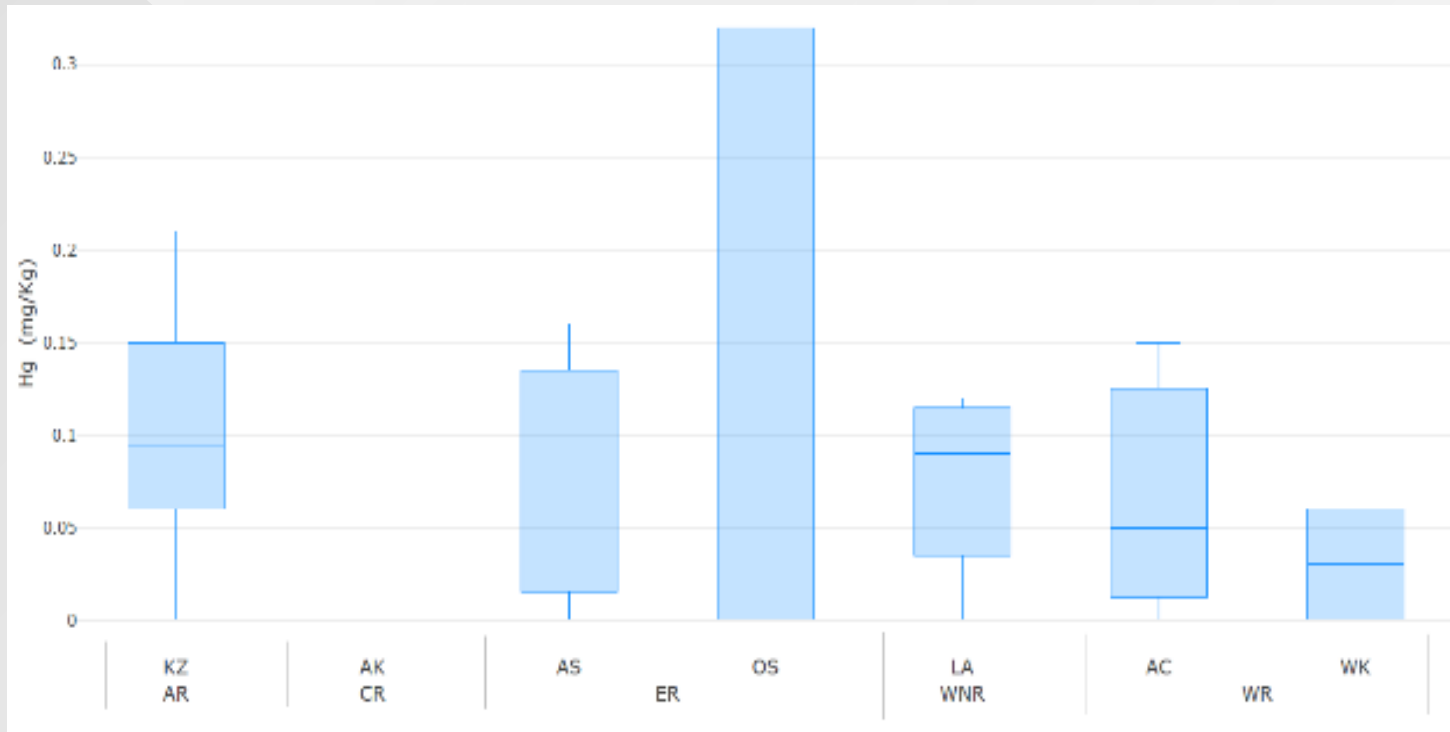
# Food – Results

Food	Region	n	Mercury (Hg)			
			Mean	SD	Median	Max
Cereal	ER	5	<RL	0.000	<RL	<RL
Cereal	SR	2	<RL	0.000	<RL	<RL
Cereal	WNR	2	<RL	0.000	<RL	<RL
Cereal	WR	2	<RL	0.000	<RL	<RL
Fruit	AR	22	0.779	0.280	<RL	2.000
Fruit	CR	2	<RL	0.000	<RL	<RL
Fruit	ER	20	<RL	0.000	<RL	<RL
Fruit	SR	6	<RL	0.000	<RL	<RL
Fruit	WNR	6	0.854	0.160	0.854	1.000
Fruit	WR	11	<RL	0.000	<RL	<RL
Tuber	AR	3	<RL	0.000	<RL	<RL
Tuber	CR	1	<RL		<RL	<RL
Tuber	ER	7	<RL	0.000	<RL	<RL
Tuber	SR	3	<RL	0.000	<RL	<RL
Tuber	WNR	2	<RL	0.000	<RL	<RL
Tuber	WR	5	<RL	0.000	<RL	<RL
Vegetable	AR	8	<RL	0.000	<RL	<RL
Vegetable	CR	2	<RL	0.000	<RL	<RL
Vegetable	ER	10	<RL	0.000	<RL	<RL
Vegetable	SR	12	0.756	0.114	<RL	1.000
Vegetable	WNR	3	3.333	1.155	4.000	4.000
Vegetable	WR	8	1.192	0.669	<RL	2.000



The highest reported mercury concentrations (4 mg/kg) were found in two vegetables in **Western Region (WR)**.

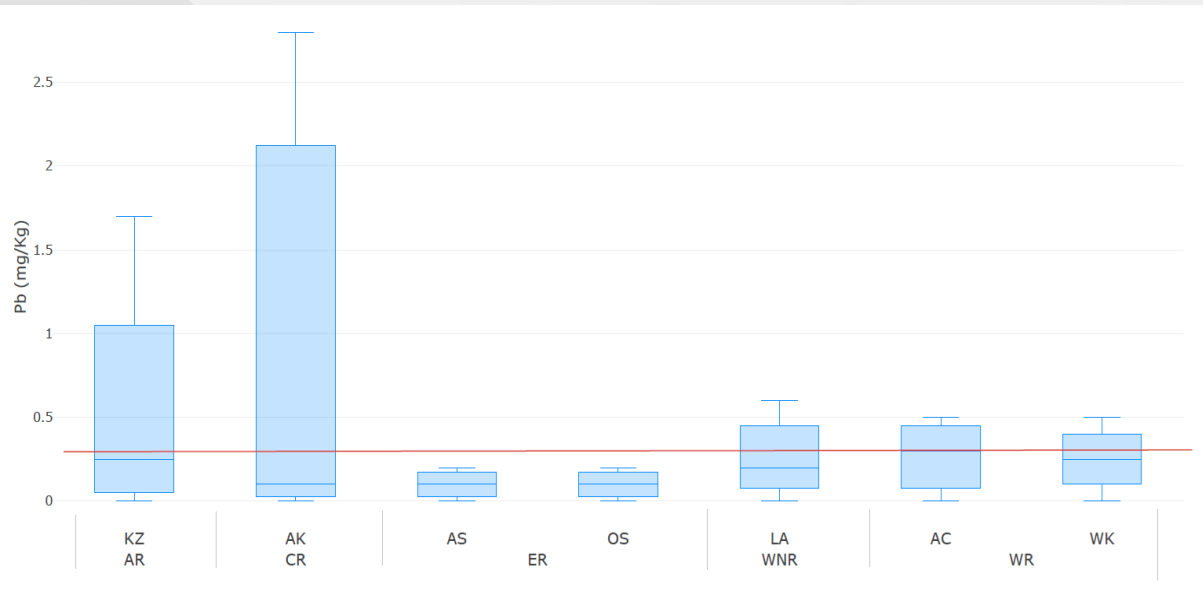
# Fish – Results



Region	Site	#	Hg			
			Av	Max	Min	SD
AR	KZ	7	0.087	0.21	<RL	0.078
CR	AK	7	<RL	<RL	<RL	<RL
ER	AS	4	0.070	0.16	<RL	0.066
	OS	7	0.046	0.32	<RL	0.121
WNR	LA	7	0.043	0.12	<RL	0.056
WR	AC	7	0.029	0.15	<RL	0.057
	WK	7	0.009	0.06	<RL	0.023

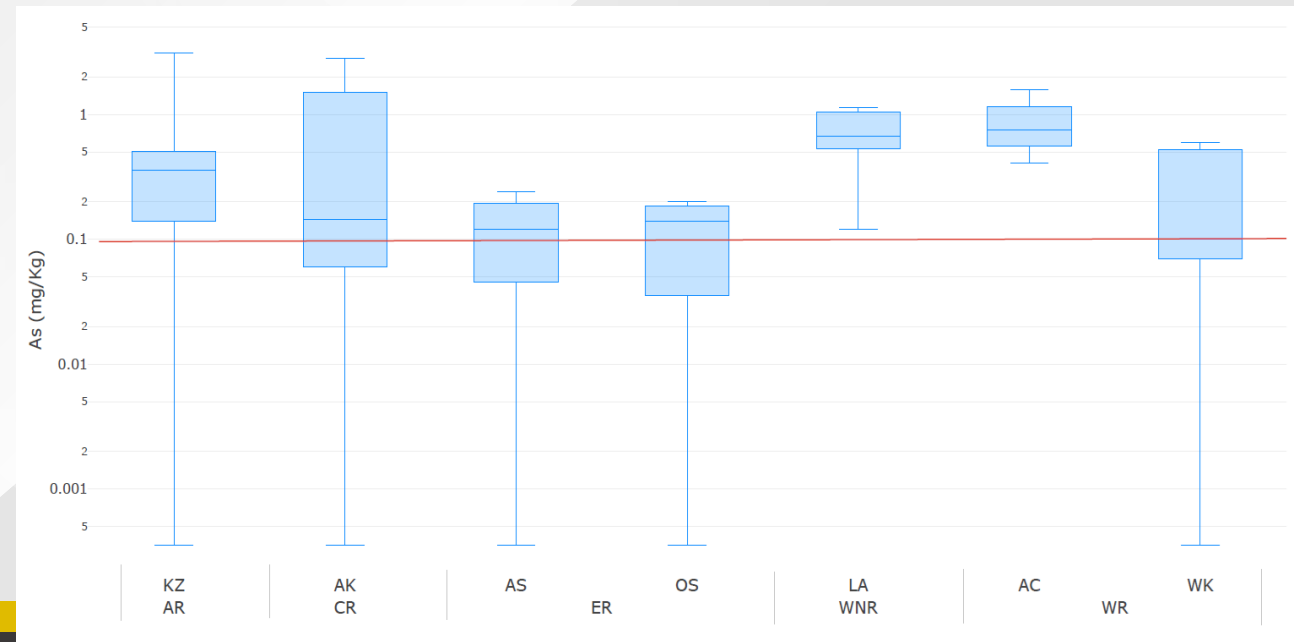
Mercury levels were generally low and below the regulatory maximum of 0.5 mg/kg, with the highest mean of 0.087 mg/kg at **Konongo Zongo (AR)**.

# Fish – Results



Lead Results

## Arsenic Results



# Data Analysis and Comparison with other Toxic Metals

# Regional Trends in Toxic Metal Concentrations

Assess regional differences in Hg, Pb, and As concentrations across environmental media

Method: Jonckheere–Terpstra (JT) trend tests treating regions as an ordered factor (geographic progression)

**Soil samples:** Significant ordinal trends for **Hg, Pb, and As**

Indicates systematic regional variation in soil contamination in ASGM areas of Ghana

*Implication: Strong regional gradients reflect spatially structured contamination patterns*

# Regional Trends in Toxic Metal Concentrations

## Water samples:

- No significant regional trends for Hg or Pb
- **As**: marginally non-significant trend (approaching significance)

## Air samples:

No significant trend for **Hg** concentrations

## Overall interpretation:

*Soil shows the clearest spatial differentiation*

Water and air contamination appear less regionally structured

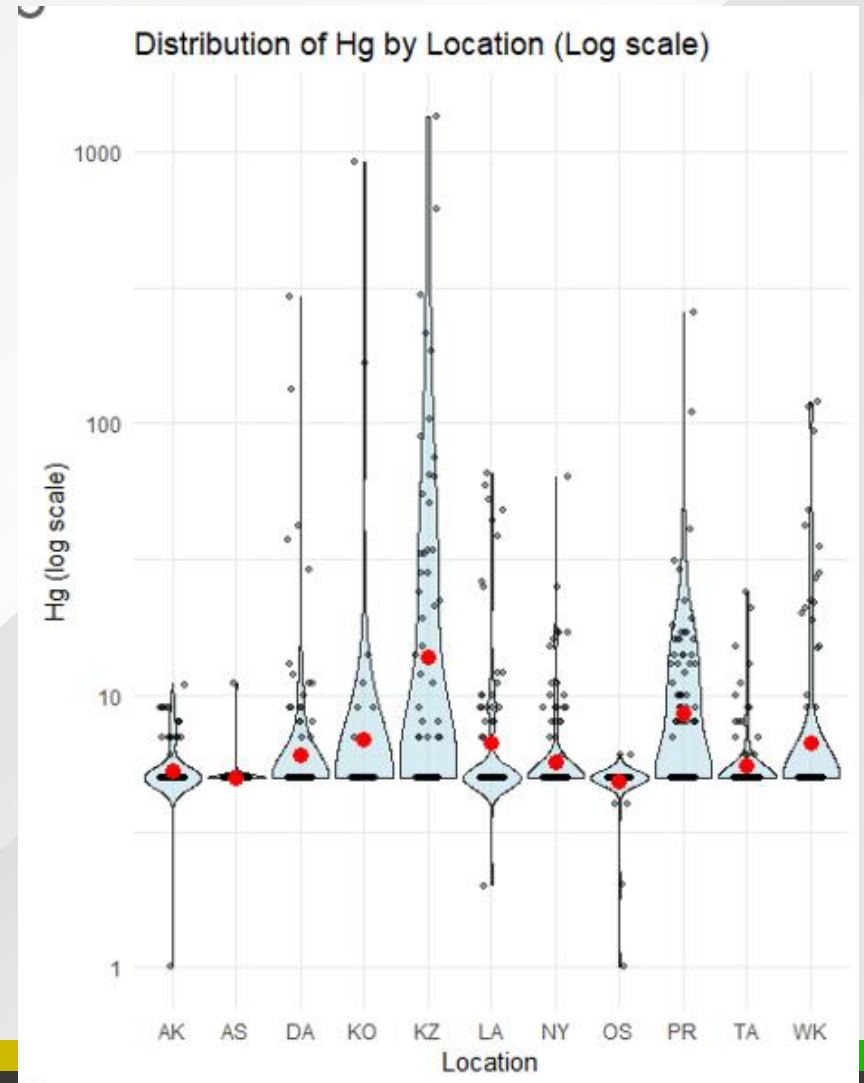
# Regional Variability in Soil Contamination

- High spatial variability in toxic metal concentrations across sampled sites
- Several locations exceeded international reference values
- Confirms contamination in ASGM-affected regions of Ghana
- Most impacted regions: Ashanti and Western Regions
- *Highlights the need for region-specific risk assessment and targeted remediation*

# Elevated Concentrations of Hg, Pb, and As in Soil

## Mercury (Hg):

- Highest in Konongo Zongo (mean 56.4 ppm; max 1,342 ppm)
- Exceeds German threshold of 10 ppm (BMUV, 2021)



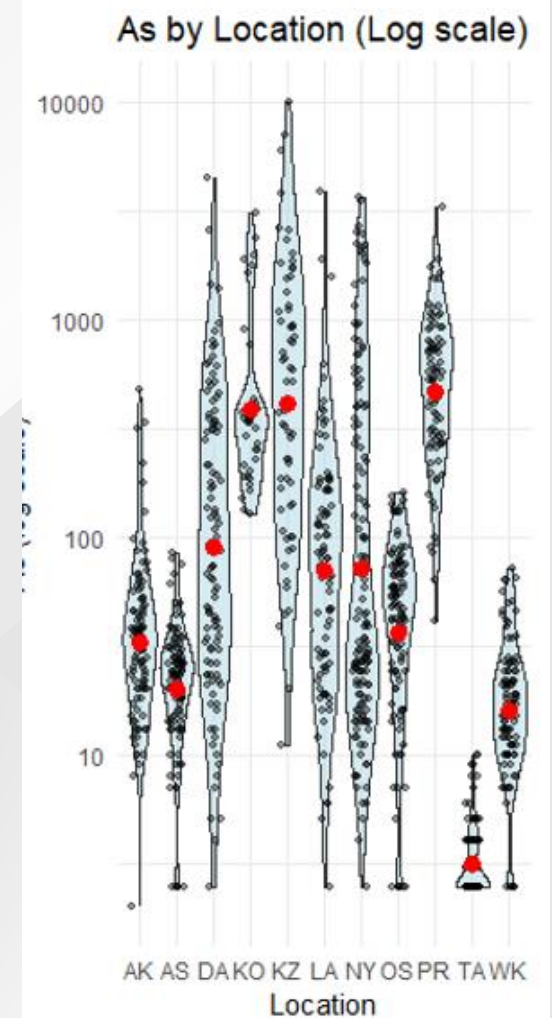
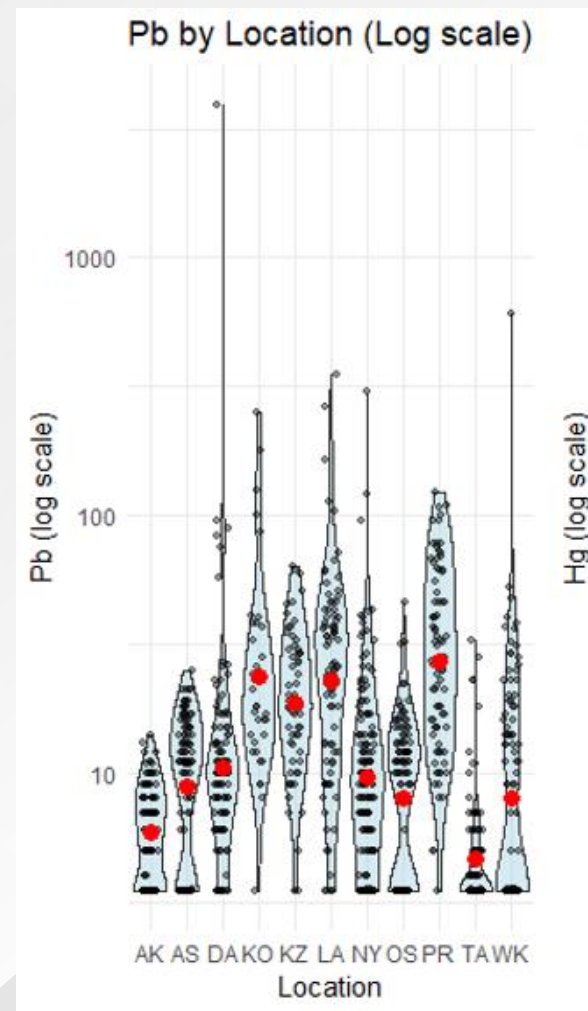
# Elevated Concentrations of Hg, Pb, and As in Soil

## Lead (Pb):

- Highest in Dakrupe, Savannah Region (mean 48.8 ppm; max 3,899 ppm)
- Above US EPA residential guidance value of 200 ppm

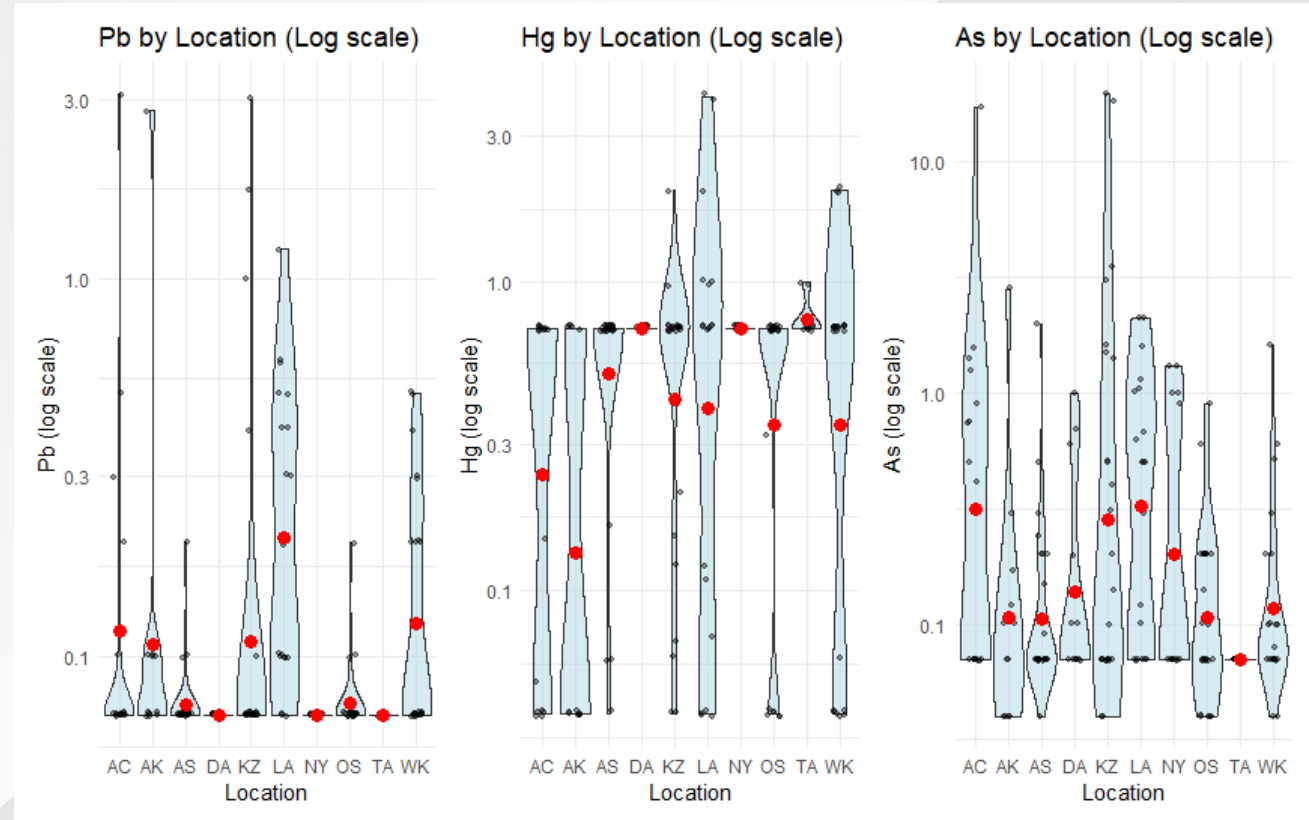
## Arsenic (As):

- Extremely high in Konongo Zongo (mean 1,066 ppm; max 10,060 ppm)
- Indicates severe contamination hotspots



# Mercury in Food Crops – Regional Overview

- No clear regional pattern observed in Hg concentrations
- Mean values remain low and stable across regions
- Median values vary due to occasional high outlier samples
- High within-region variability, suggesting localized contamination events
- *Results imply diffuse exposure sources rather than regional clustering*



# Widespread Contamination and Exposure Pathways

- **Toxic metals detected:** Arsenic (As), Lead (Pb), Mercury (Hg), and Cadmium (Cd)
- **Exposure pathways:** Soil, water, fish, and food crops in ASGM-affected areas
- **Findings:** Concentrations frequently **exceed international safety thresholds**
- **Health concern:** Mixed exposure environment poses **serious chronic public health risks**
- **Community context:**
  - Long-term residents dependent on **farming and artisanal mining**
  - **Low educational access** and reliance on local food sources heighten vulnerability

# Health Impacts of Toxic Metal Exposure

- **Arsenic (As):** Skin lesions, cancers, cardiovascular and nervous system disorders, gangrene, erectile dysfunction
- **Lead (Pb):**
- **Children:** Impaired brain development, lower IQ, behavioral issues
- **Pregnancy:** Placental transfer → adverse birth outcomes
- **Adults:** Kidney, cardiovascular, reproductive, and immune system damage

# Health Impacts of Toxic Metal Exposure

- **Cadmium (Cd):** Kidney failure, osteoporosis, lung cancer, cardiovascular disease
- **Mercury (Hg):**
  - **Elemental:** Inhaled by miners → neurological and renal damage
  - **Methylmercury:** Bioaccumulates in fish → neurodevelopmental toxicity
- Classified as **carcinogenic (Group 2B)**

# Study Limitations and Future Directions

- **Temporal limitations:**

- Air mercury (Hg) concentrations vary with **time and temperature**
- Sampling restricted to **specific periods**; peak values may reflect **local smelting events** rather than average exposure

- **Spatial heterogeneity:**

- High variability in contamination across sites
- Uneven sampling density—>**1,000 soil vs. only 69 water samples**
- Extreme outliers (e.g., **As = 10,060 ppm in Konongo Zongo**) not representative of wider trends

# Study Limitations and Future Directions

- **Analytical constraints:**
- **No speciation** of Hg or As →  
total concentrations may **over- or underestimate toxicity**
- **Limited crop data** and absence of **national food standards**
- **No bioavailability/ exposure pathway analysis**, limiting health risk interpretation
- **Future research needs:**
- Broader, more **representative sampling**
- **Metal speciation** and **temporal monitoring**
- Integration of **biomonitoring** for human exposure assessment

# Governance

- Weak governance fuels ASGM environmental and health risks
- Fragmented institutions hinder monitoring and enforcement efforts
- Complex licensing drives miners into informal operations
- Limited education reduces compliance and safe practices.

# Community vulnerability and patterns of environmental injustice

- Miners face extreme exposure to mercury and silica dust
- Women and children experience chronic, intergenerational toxic risks
- Contaminated crops and fish heighten community-wide health threats
- Livelihood diversification essential for safer, sustainable alternatives

# Solutions and Policy

- ASGM regulation fragmented across multiple institutions and sectors.
- Act 703 defines small-scale mining but lacks policy coherence.
- Enforcement gaps and political influence weaken oversight.
- Stronger cross-sector coordination essential for sustainable reform.

# Conclusions

- **Regional trends:** Significant soil contamination in ASGM areas, especially in the **Ashanti** and **Western Regions**.
- **Soil risk levels:** Several samples exceeded **EPA and international thresholds** for mercury (Hg), lead (Pb), and arsenic (As).
- **Pathways of exposure:** Soil identified as the **primary exposure route**; water, air, and food showed limited or inconsistent trends.
- **Food contamination:** Generally lower metal levels, but **elevated As** and occasional high Hg and Pb in vegetables from the Western Region.

# Conclusions

- **Analytical validation: Strong correlations** between XRF and ICP-MS results ( $r = 0.85\text{--}0.94$ ), confirming XRF's reliability for **rapid field assessment**.
- **Policy implications:** Findings call for **targeted remediation, integrated governance, and community-based action** in Ghana's ASGM sector.
- **Next steps:** Urgent need for **human biomonitoring, public health interventions, and sustainable mining alternatives**.

THANK YOU

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