



## Namibian Environment & Wildlife Society (NEWS)

25<sup>th</sup> April 2024 (Namibia Scientific Society, Windhoek, Namibia)

Pollution from lead mines - Kabwe (Zambia) and mining towns in Namibia

Yabe John

Team Leader - KAMPAI Group 2

Nakayama S, Yohannes YB, Nakata H, Toyomaki H, Muzandu K, Kataba A, Zyambo G, Moonga G, Munyinda NS, Mufune T, Liazambi A, Chawinga K, Sakala D, Ikenaka Y, Choongo K, Ishizuka M

# What are toxic metals?

- The most toxic metals include lead (Pb), cadmium (Cd), mercury (Hg) and arsenic (As)
- Characteristics of toxic metals
  - They have no known biological function in the body
  - They are **toxic at low concentrations**
  - They target essential organs namely kidney (**nephrotoxicity**), liver (**hepatotoxicity**), and brain (**neurotoxicity**), etc.
  - They can be carcinogenic, mutagenic or teratogenic
- They are **priority metals** that are of great **public health concern**.



# Can essential metals be toxic?

- Essential metals include iron (Fe), cobalt (Co), copper (Cu), manganese (Mn), and zinc (Zn)
  - They are **necessary** for biological functions
  - They can be **toxic at higher concentrations**.
- The toxicity of heavy metals are **dose-dependent**.



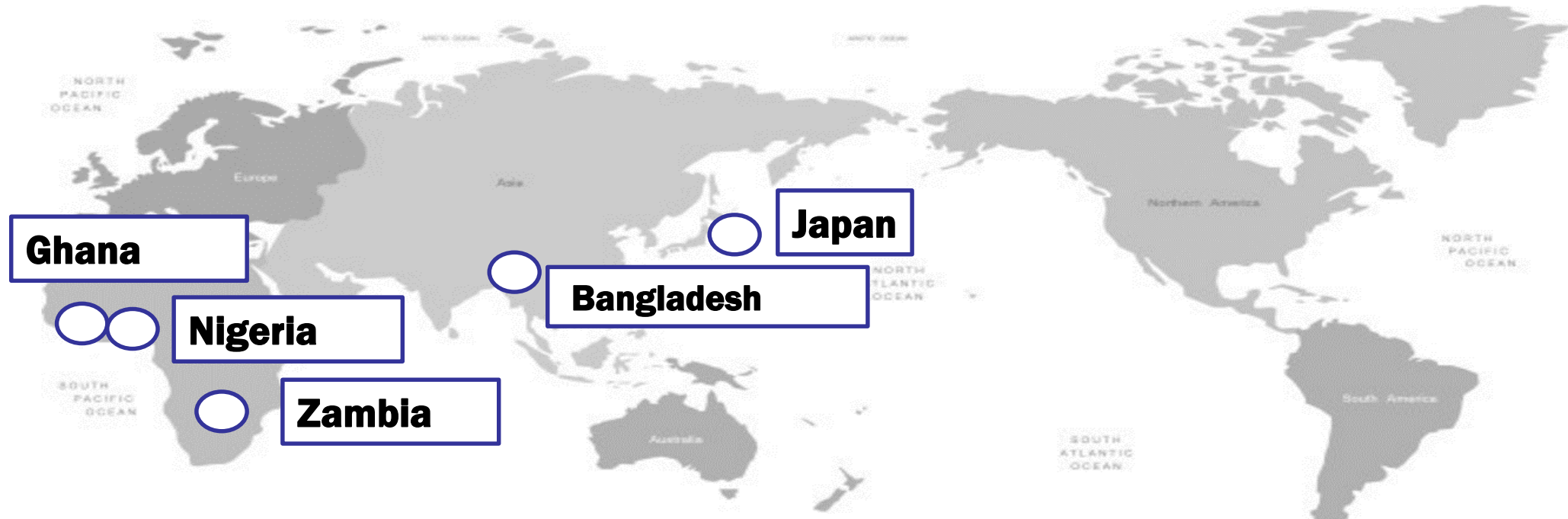
## THE DOSE MAKES THE POISON

***“All substances are poisons; there is none that is not a poison. The right dose differentiates a poison and a remedy.”***



*Paracelsus (1493 - 1541) - The Founding Father of Toxicology.*

# Examples of World Heavy Metal Disasters (Pb, Hg, Cd, As)



- **Cadmium (Cd)** toxicity (>100 deaths) - *Itai itai* disease (Japan, 1967)
- **Methylmercury (Hg)** toxicity (>1000 deaths) - *Minamata* disease (Japan, 1956)
- **Lead (Pb)** toxicity (>400 children died) - Nigeria (2010)
- **Arsenic (As)** toxicity (>1000 deaths) - Bangladesh (1970-)

# National Institute for Minamata Disease – Minamata Bay, Japan (2011)

4



国立水俣病総合研究センター  
NATIONAL INSTITUTE FOR MINAMATA DISEASE

## Lead Toxicity

- Lead (Pb) is a soft, gray to black metal.
- It is malleable, ductile, and dense and is a poor conductor of electricity.
- It is **ubiquitous** in the environment
- It has **no known biological role** in humans or animals
- Serious problem in developing countries (extractive industries)
- **Anthropogenic activities** are the main **sources** of exposure



Lead acid battery



Toys



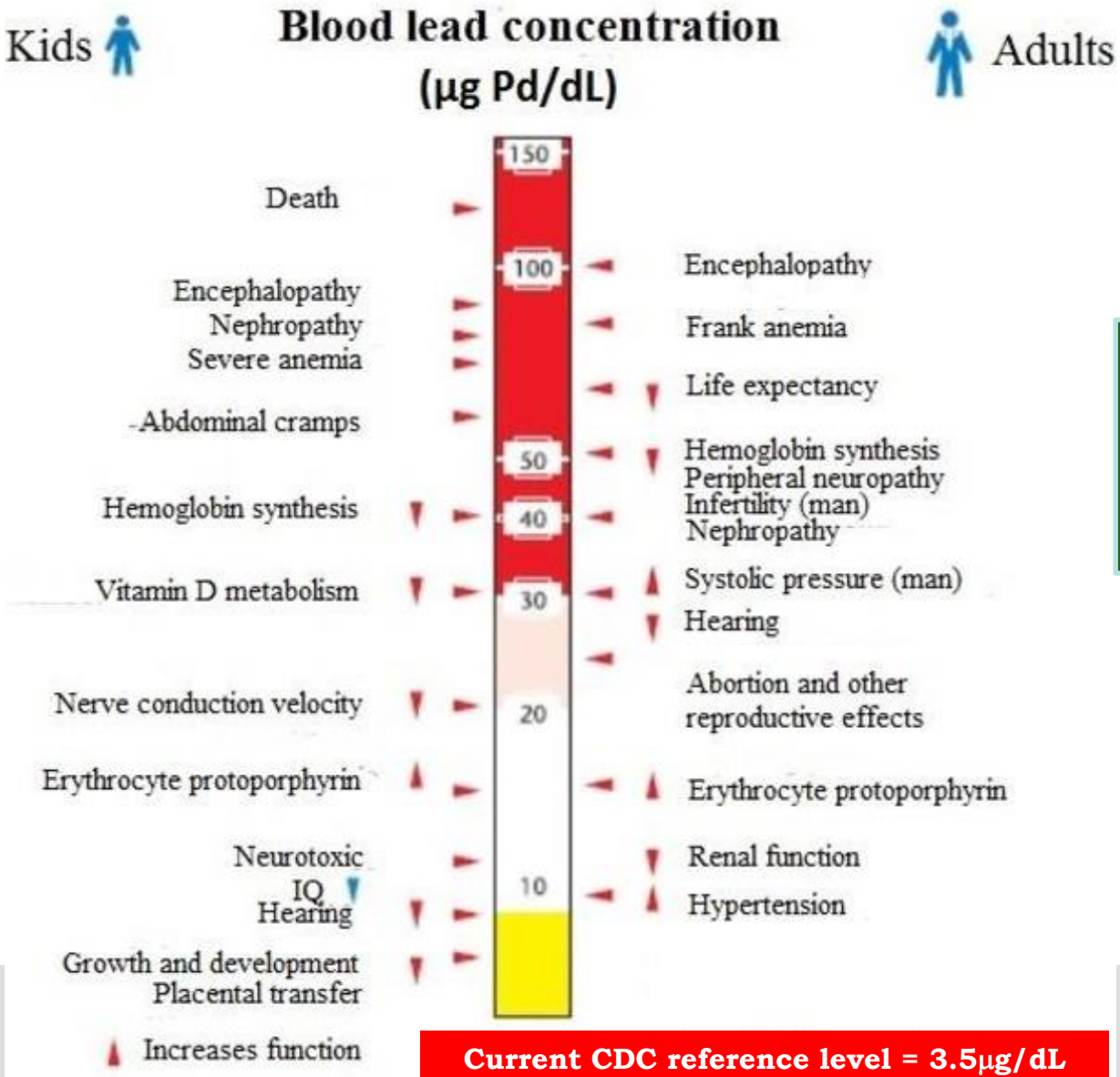
Water pipes



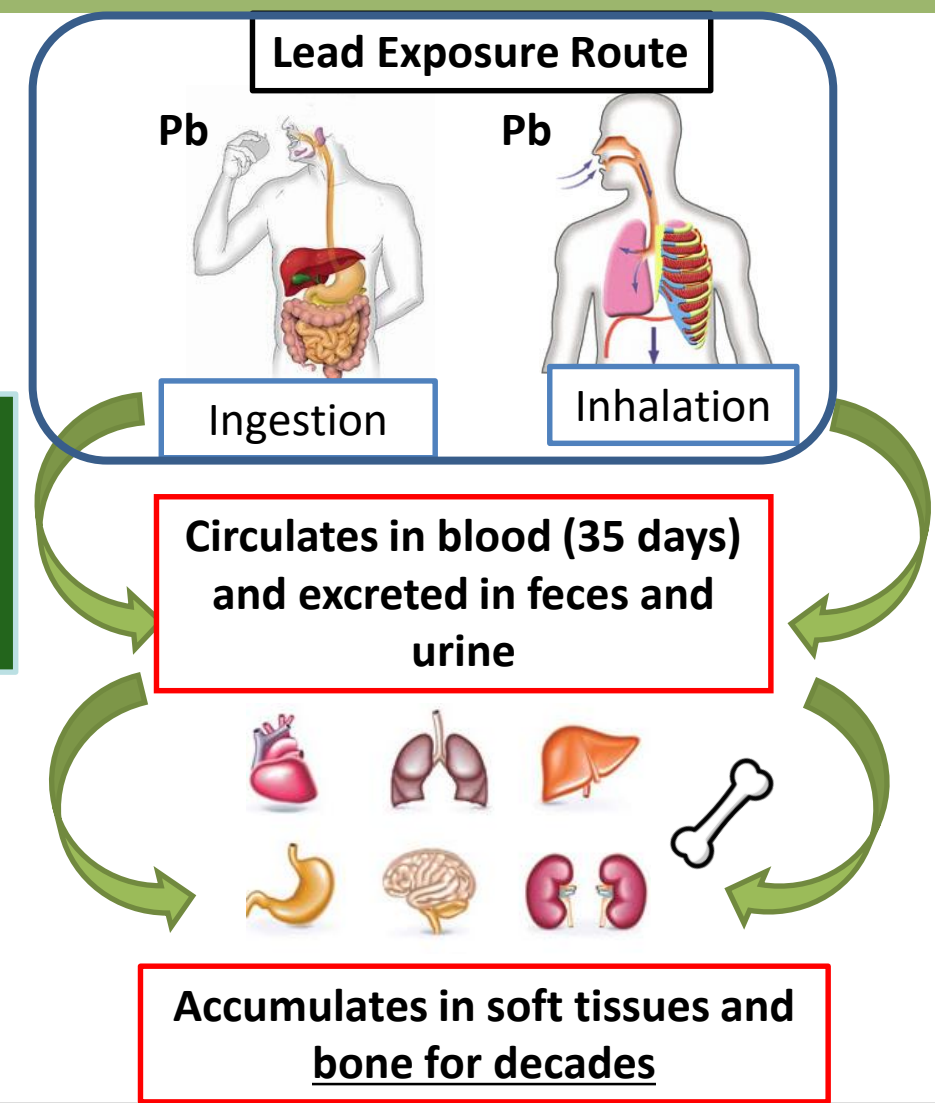
Lead bullets



# Lead clinical manifestations



Fe and Zn deficiency enhances intestinal Pb absorption and therefore toxicity



[Environ Health Perspect.](#) 2009 Oct; 117(10): 1535–1540.  
Published online 2009 May 14. doi: [10.1289/ehp.0900696](https://doi.org/10.1289/ehp.0900696)

PMCID: PMC2790507  
PMID: [20019903](https://pubmed.ncbi.nlm.nih.gov/20019903/)

[Environ Health Perspect.](#) 2012 Apr; 120(4): 601–607.  
Published online 2011 Dec 20. doi: [10.1289/ehp.1103965](https://doi.org/10.1289/ehp.1103965)

PMCID: PMC3339453  
PMID: [22186192](https://pubmed.ncbi.nlm.nih.gov/22186192/)

## Mass Lead Intoxication from Informal Used Lead-Acid Battery Recycling in Dakar, Senegal

The blood lead level of the 50 children tested in **Senegal** ranged from **40 to 614**  $\mu\text{g}/\text{dL}$  with a mean of **129.5**  $\mu\text{g}/\text{dL}$  (200).

### Abstract

[Go to:](#) ▶

**Background and objectives** Between November 2007 and March 2008, 18 children died from a rapidly progressive central nervous system disease of unexplained origin in a community involved in the recycling of used lead-acid batteries (ULAB) in the suburbs of Dakar, Senegal. We investigated the cause of these deaths.

**Methods** Because autopsies were not possible, the investigation centered on clinical and laboratory assessments performed on 32 siblings of deceased children and 23 mothers and on 18 children and 8 adults living in the same area, complemented by environmental health investigations.

**Results** All 81 individuals investigated were poisoned with lead, some of them severely. The blood lead level of the 50 children tested ranged from 39.8 to 613.9  $\mu\text{g}/\text{dL}$  with a mean of 129.5  $\mu\text{g}/\text{dL}$ . Seventeen children showed severe neurologic features of toxicity. Homes and soil in surrounding areas were heavily contaminated with lead (indoors, up to 14,000 mg/kg; outdoors, up to 302,000 mg/kg) as a result of informal ULAB recycling.

## Outbreak of Fatal Childhood Lead Poisoning Related to Artisanal Gold Mining in Northwestern Nigeria, 2010

[Carrie A. Dooyema](#),<sup>1,2</sup> [Antonio Neri](#),<sup>1</sup> [Yi-Chun Lo](#),<sup>2</sup> [James Durant](#),<sup>3</sup> [Paul I. Dargan](#),<sup>4</sup> [Todd Swarthout](#),<sup>5</sup> [Oladayo Biya](#),<sup>6</sup> [Saheed O. Gidado](#),<sup>6</sup> [Suleiman Haladu](#),<sup>6</sup> [Nasir Sani-Gwarzo](#),<sup>7</sup> [Patrick M. Nguku](#),<sup>6</sup> [Henry Akpan](#),<sup>8</sup> [Sa'ad Idris](#),<sup>9</sup> [Abdullahi M. Bashir](#),<sup>9</sup> and [Mary Jean Brown](#)<sup>1</sup>

The mean blood lead concentration for children in **Nigeria** was **153**  $\mu\text{g}/\text{dL}$  (range **56 - 445.0**  $\mu\text{g}/\text{dL}$ )

### Abstract

[Go to:](#) ▶

**Background:** In May 2010, a team of national and international organizations was assembled to investigate children's deaths due to lead poisoning in villages in northwestern Nigeria.

**Objectives:** Our goal was to determine the cause of the childhood lead poisoning outbreak, investigate risk factors for child mortality, and identify children < 5 years of age in need of emergency chelation therapy for lead poisoning.

**Results:** We surveyed 119 family compounds. Of 463 children < 5 years of age, 118 (25%) had died in the previous year. We tested 59% (204/345) of children < 5 years of age, and all were lead poisoned ( $\geq 10$   $\mu\text{g}/\text{dL}$ ); 97% (198/204) of children had blood lead levels (BLLs)  $\geq 45$   $\mu\text{g}/\text{dL}$ , the threshold for initiating chelation therapy. Gold ore was processed inside two-thirds of the family compounds surveyed. In multivariate modeling, significant risk factors for death in the previous year from suspected lead poisoning included the age of the child, the mother's work at ore-processing activities, community well as primary water source, and the soil lead concentration in the compound.



# KAMPAI Project Summary and ZA.ZINAMBO Project Plans



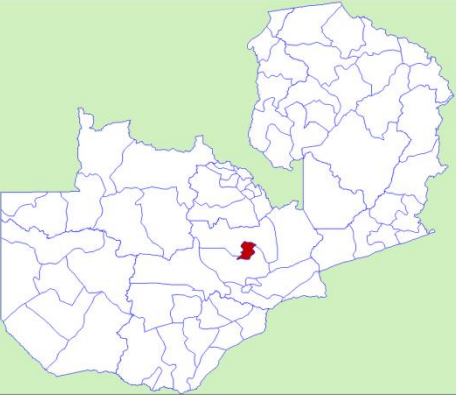
KAMPAI Summary: Lead Poisoning-Kabwe, Zambia



ZA.ZINAMBO Project: Arsenic & Lead Pollution - Tsumeb and Rosh Pinah, Namibia  
Lead exposure from hunting activities?



Namibian Environment & Wildlife Society - April 2024



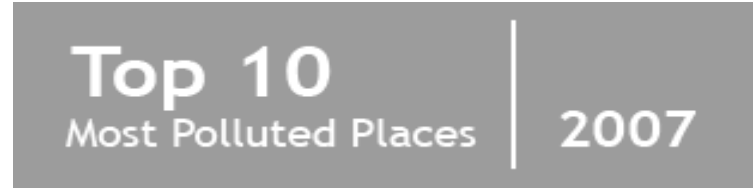
**Kabwe** ➤ Capital of Zambia's Central Province  
 ➤ 230,000 population size

➤ Long history of Pb-Zn mining; **from 1902 to 1994**

**Kabwe town is known as:**



**KABWE IN TOP 10 MOST POLLUTED TOWNS**  
 POST ON: February 12, 2015



[www.worstpolluted.org/projects](http://www.worstpolluted.org/projects)





Scavenging for lead on tailings dump



Children playing on lead contaminated soils



Houses less than 500m away from tailings dump



Women and children crushing stones to sell as gravel



Lead contaminated central canal – annual flooding

> [Environ Toxicol Chem.](#) 2011 Aug;30(8):1892-7. doi: 10.1002/etc.580. Epub 2011 Jun 3.

## Uptake of lead, cadmium, and other metals in the liver and kidneys of cattle near a lead-zinc mine in Kabwe, Zambia

John Yabe <sup>1</sup>, Shouta M M Nakayama, Yoshinori Ikenaka, Kaampwe Muzandu, Mayumi Ishizuka, Takashi Umemura

Affiliations + expand

PMID: 21590713 DOI: [10.1002/etc.580](#)

### Abstract

Concentrations of lead, cadmium, and other metals in the liver and kidneys of cattle near a lead-zinc mine in Kabwe (Zambia), which is ranked among the 10 worst polluted places on earth, were compared with other Zambian towns. Metal concentrations were measured in the liver and kidneys of 51 cattle from Kabwe and other Zambian towns. The maximum metal concentrations, expressed in mg/kg and dry weight, in the liver or kidneys were 398.4 (Cu), 252.6 (Zn), 77.81 (Cr), 19.37 (Cd), 7.57 (Ni), 1.8 (Pb), 1.04 (Co), 0.112 (Hg), and 0.05 (As). Concentrations of Pb and Cd in Kabwe cattle were higher than levels in other Zambian towns. The mean concentration of Cd exceeded benchmark values in offal destined for human consumption. Levels of Ni and Cr may also pose public health concerns. Concentrations of Pb and Cr, Pb and Cu, Cd and Zn, Cd and Hg, Zn and Cu, Cu and Co, as well as Co and Ni were positively correlated. The present study also highlighted the dangers of exposure of animals and humans to a mixture of toxic metals.

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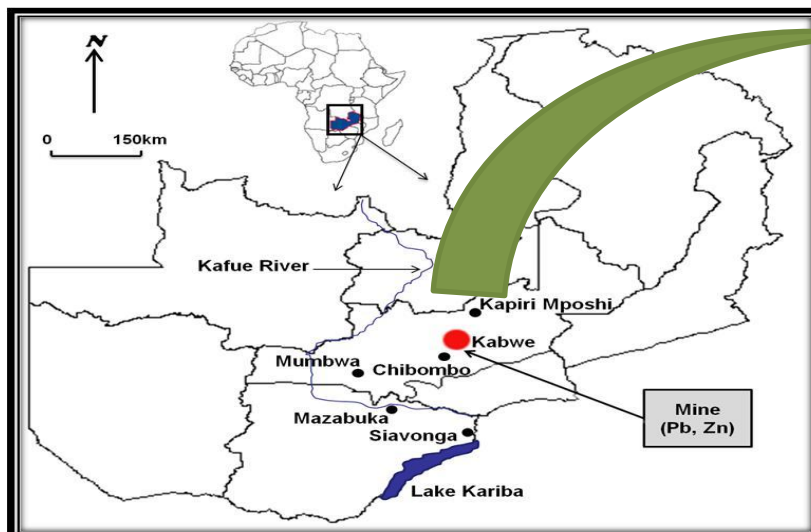
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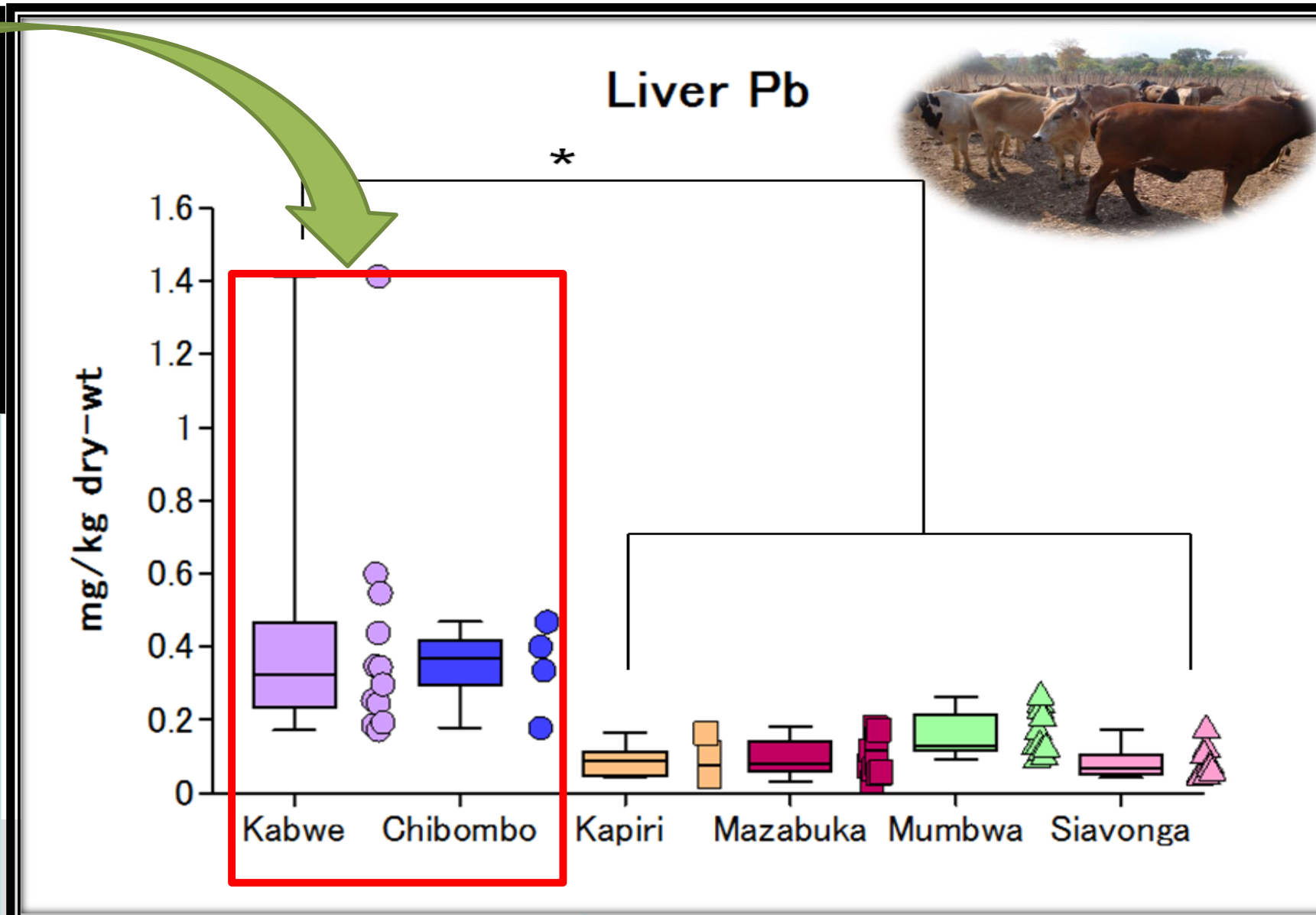
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# Regional difference of Pb in cattle liver in Zambia



- **Kabwe**
  - higher levels of Pb in the liver
- **Chibombo**
  - Pb levels were similar to Kabwe
- **Other towns**
  - Lower Pb levels
- **Asterisk:  $p < 0.001$**





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› [Environ Toxicol Chem.](#) 2013 Jan;32(1):189-92. doi: 10.1002/etc.2029. Epub 2012 Nov 21.

## Metal distribution in tissues of free-range chickens near a lead-zinc mine in Kabwe, Zambia

John Yabe <sup>1</sup>, Shouta M M Nakayama, Yoshinori Ikenaka, Kaampwe Muzandu, Kennedy Choongo, Geoffrey Mainda, Matthew Kabeta, Mayumi Ishizuka, Takashi Umemura

Affiliations + expand

PMID: 23059509 DOI: [10.1002/etc.2029](#)

### Abstract

Concentrations of Pb, Cd, and other metals in tissues of 17 free-range and 32 commercial broiler chickens from the Kabwe mining town in Zambia were determined. Mean concentrations of Pb and Cd exceeded maximum levels for human consumption in some organs including muscle (Pb only) in free-range chickens, in contrast to low levels in broiler chickens. Human consumers in Kabwe could be exposed to Pb and Cd in free-range chickens.

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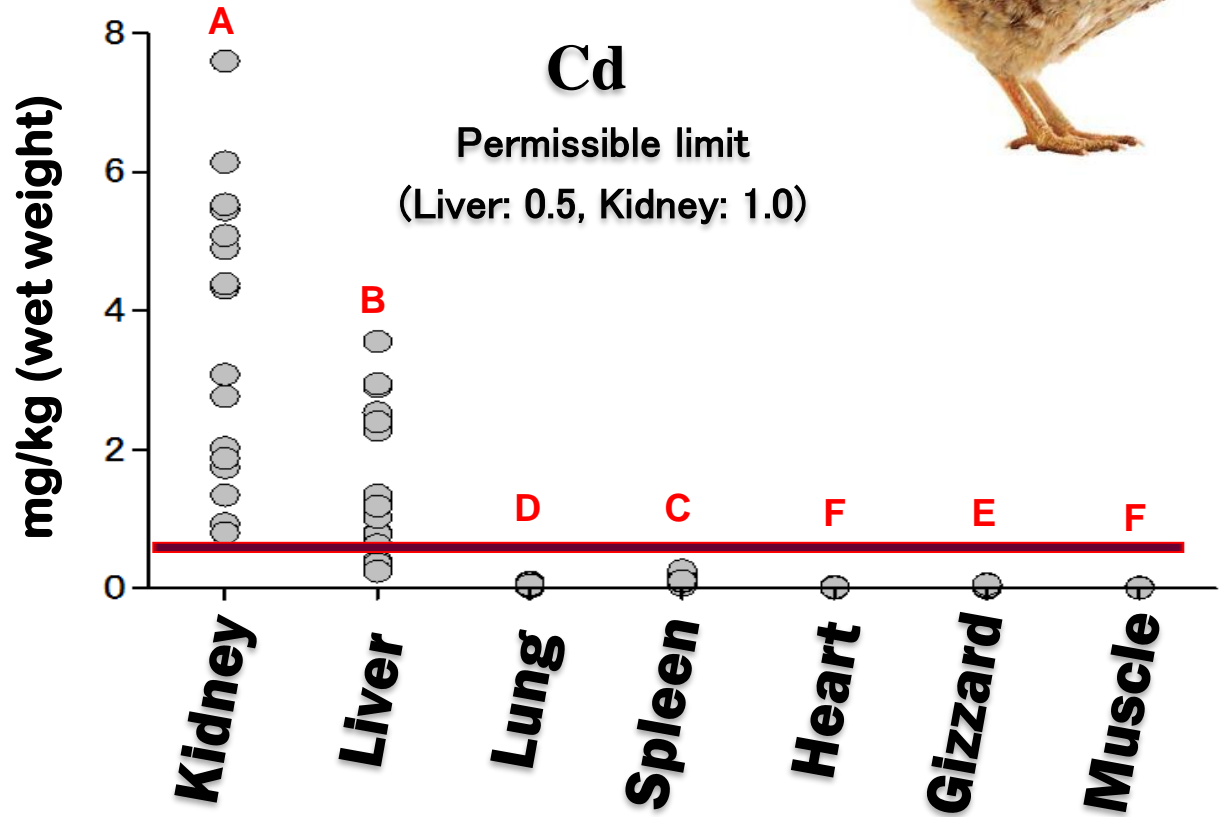
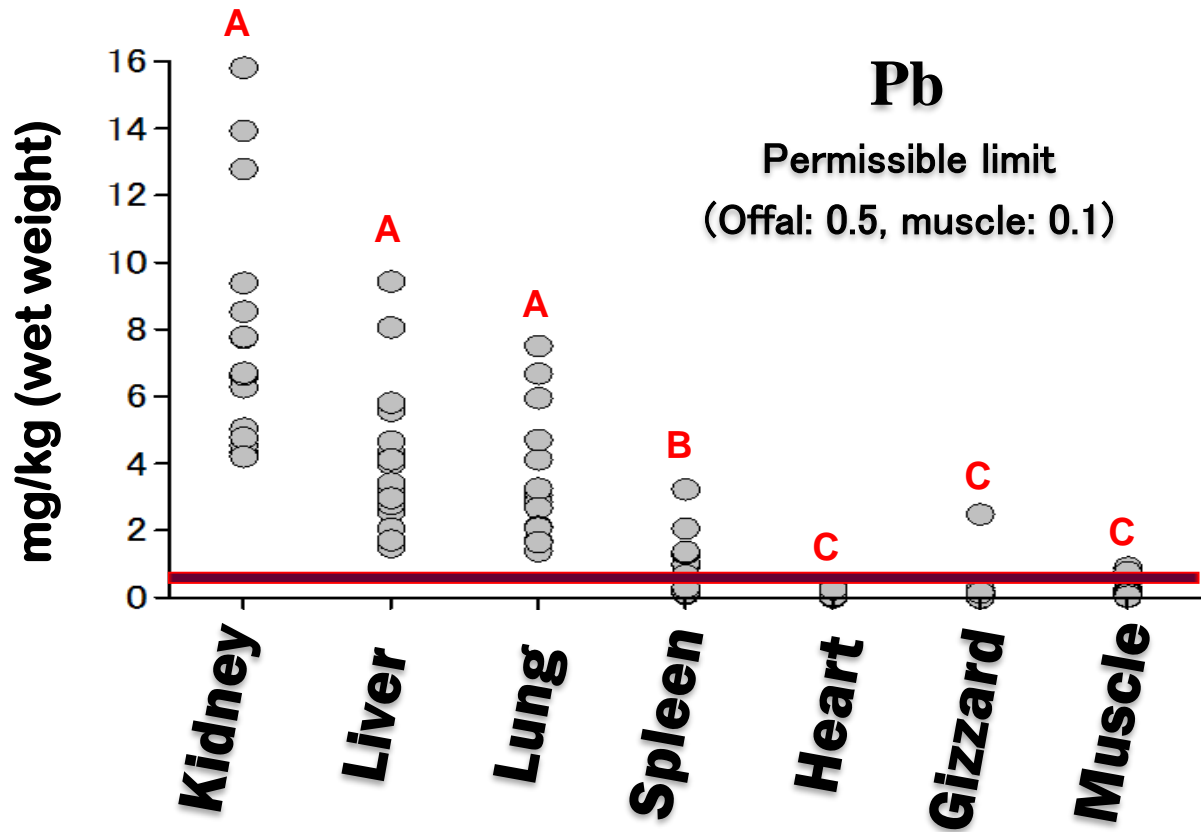
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# High Pb and Cd levels in muscle and offal of Free-range chickens in Kabwe



**Pb and Cd exceeded the permissible limits**

# Pb and Cd comparison in liver of broiler and free-range in Kabwe

**Broiler**

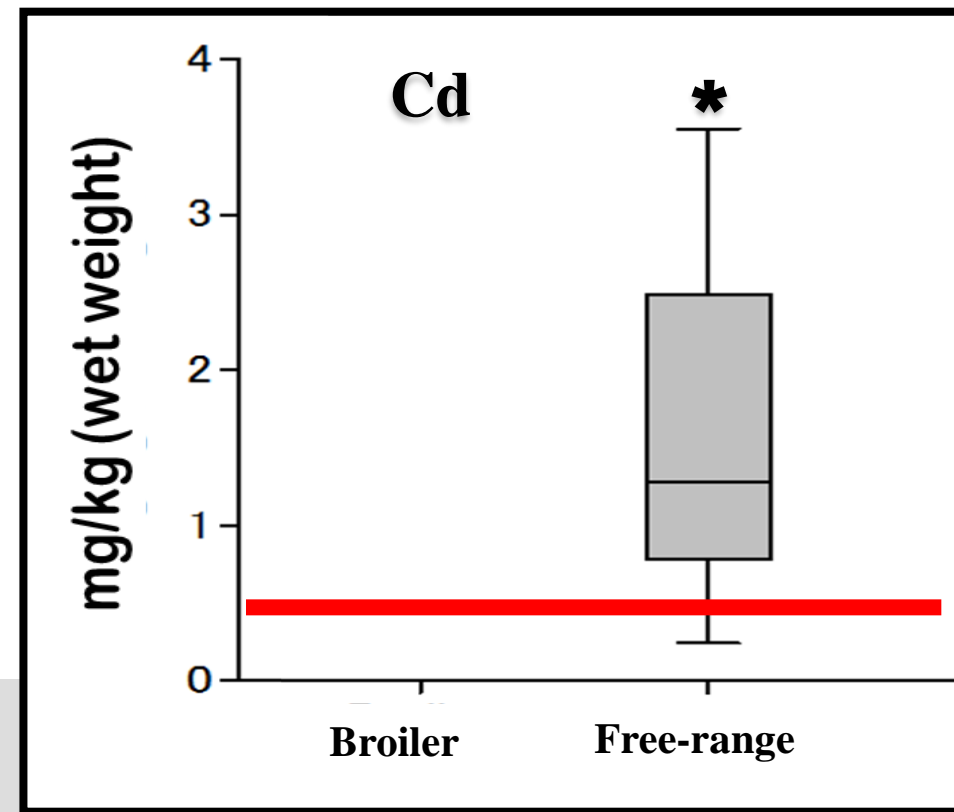
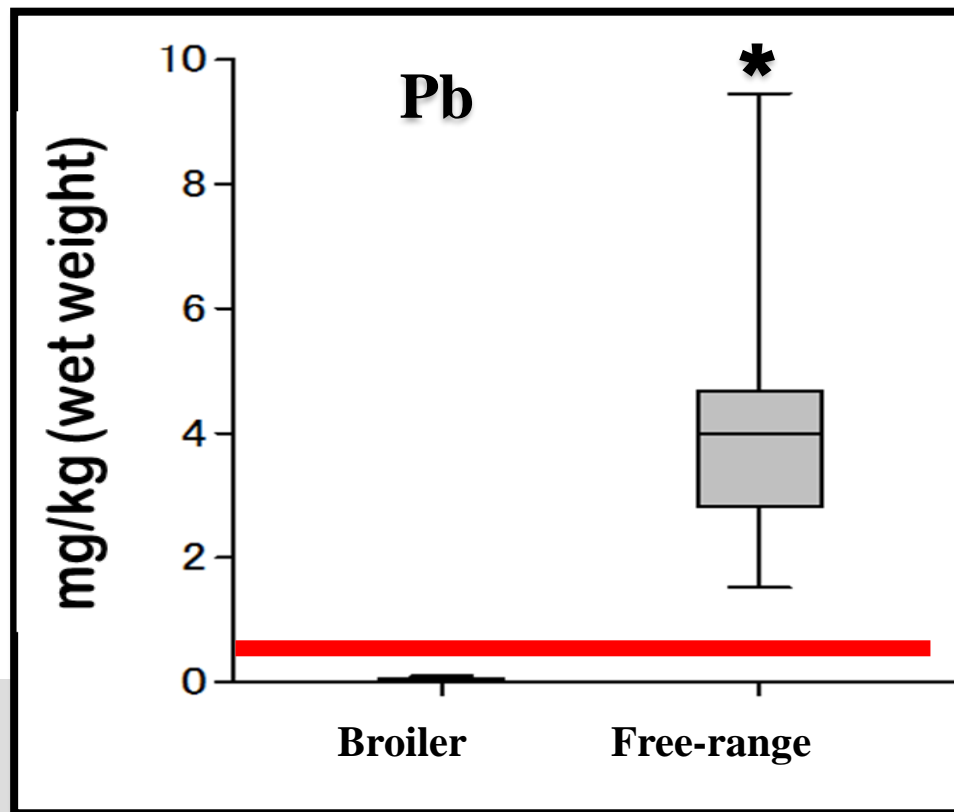


Kept indoors and fed commercial feed

**Free-range**



Roam and scavenge for food in the mine townships





Bookmarks

- Lead poisoning in children from townships in the vicinity of a lead-zinc mine in
  - 1 Introduction
  - 2 Materials and methods
    - 2.1 Sampling sites
    - 2.2 Blood collection
    - 2.3 Sample preparation and metal extraction
    - 2.4 Metal analysis
    - 2.5 Statistical analysis
  - 3 Results
    - 3.1 Blood lead levels (BLLs)
    - 3.2 Blood Pb accumulation

Chemosphere 119 (2015) 941–947

Contents lists available at ScienceDirect

**Chemosphere**

journal homepage: [www.elsevier.com/locate/chemosphere](http://www.elsevier.com/locate/chemosphere)

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## Lead poisoning in children from townships in the vicinity of a lead–zinc mine in Kabwe, Zambia <sup>☆</sup>

John Yabe <sup>a,1</sup>, Shouta M.M. Nakayama <sup>b,1</sup>, Yoshinori Ikenaka <sup>b</sup>, Yared B. Yohannes <sup>b</sup>, Nesta Bortey-Sam <sup>b</sup>, Balazs Oroszlany <sup>b</sup>, Kaampwe Muzandu <sup>a</sup>, Kennedy Choongo <sup>a</sup>, Abel Nketani Kabalo <sup>c</sup>, John Ntapisha <sup>c</sup>, Aaron Mweene <sup>a</sup>, Takashi Umemura <sup>b</sup>, Mayumi Ishizuka <sup>b,\*</sup>

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<sup>b</sup>Laboratory of Toxicology, Department of Environmental Veterinary Sciences, Graduate School of Veterinary Medicine, Hokkaido University, Kita 18, Nishi 9, Kita-ku, Sapporo 060-0818, Japan  
<sup>c</sup>Ministry of Health, District Health Office, P.O. Box 80735, Kabwe, Zambia

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### HIGHLIGHTS

- We measured blood lead levels in children near a Pb–Zn mine in Zambia.
- 100% of the sampled children under 7 years had BLLs > 5 µg dL<sup>-1</sup>.
- Highest BLLs were seen in children around the age of 2 years.
- BLLs > 150 µg dL<sup>-1</sup> were recorded 8 children with a maximum of 427.8 µg dL<sup>-1</sup>.
- The children living around the Pb–Zn mine are at serious risks of Pb poisoning.

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ARTICLE INFO      ABSTRACT

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Yabe et al.... Zambia.pdf

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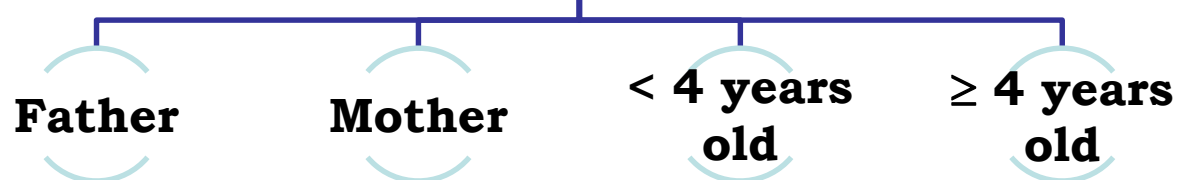
Yabe et al. 2015. Chemosphere: 19, 941–947

- Measured lead contamination among **household members** in Kabwe communities to characterize the town's burden of disease.
- This in turn would help **define interventions** to mitigate Pb exposure and alleviate adverse health outcomes.

## KAMPAI broad surveillance

1000 households

- ◆ Blood
- ◆ Urine
- ◆ Fecal
- ◆ Breast milk



	Father	Mother	< 4 years old	≥ 4 years old
<b>Human Risk assessment</b>	○	○	○	○
<b>Urine and fecal Pb analysis</b>	○	○	○	○
<b>Quality of Life</b>	○	○	○	○
<b>Neurodevelopmental impairment</b>		○	○	
<b>Milk lead levels and correlations</b>		○	○	



# Study sites

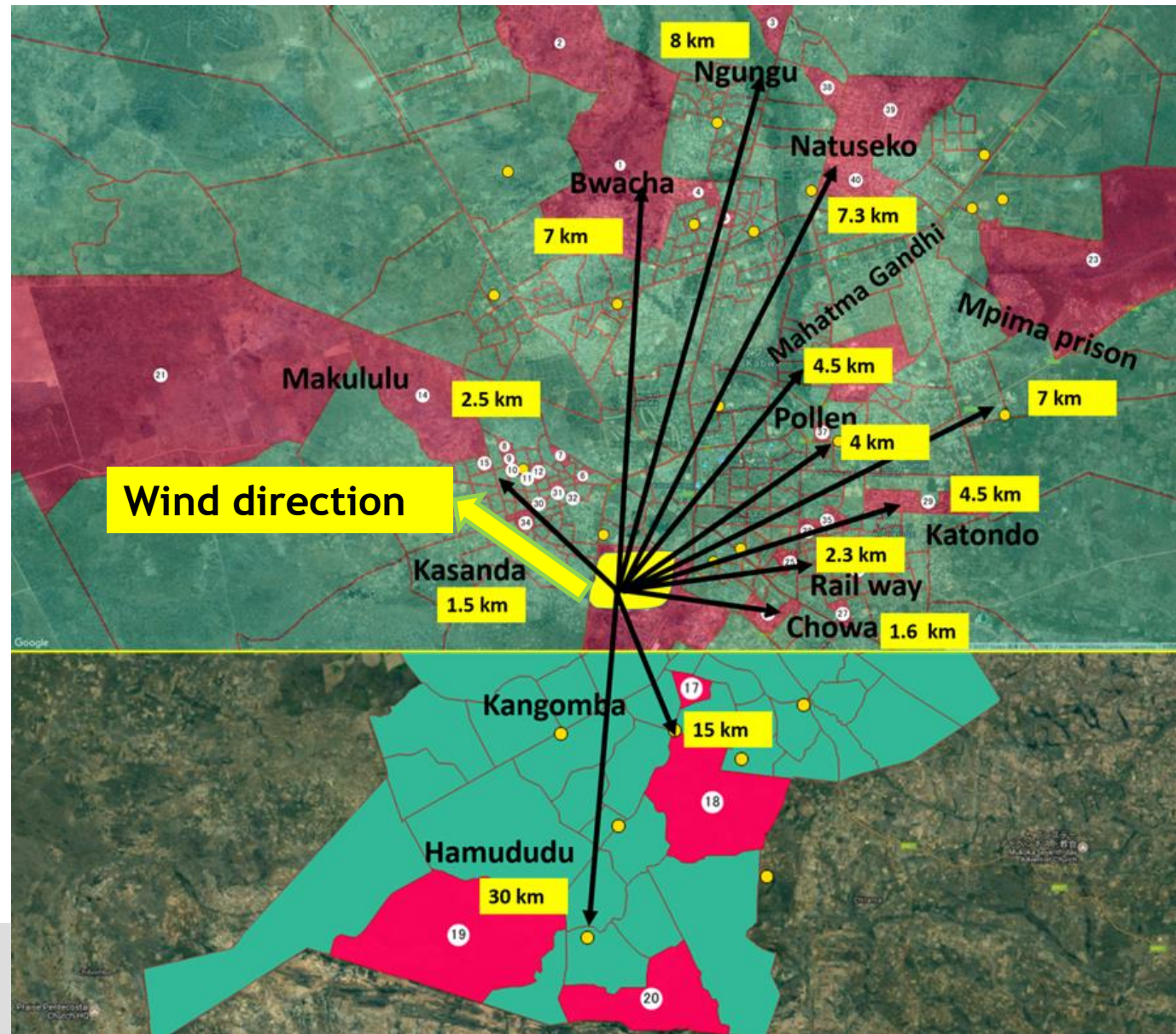
**Blood samples were collected from:**

- ↪ 40 Standard Enumeration Areas (SEAs)
- ↪ 13 clinics
- ↪ About 1250 participants

**Venous blood**

Collected at each health center by  
laboratory technicians and nurses

**Pb analysis**



**Ethical clearance by UNZABREC & MOH**

**Written informed consent obtained from parents**

Bookmarks ×

Current trends of blood lead levels, distribution patterns and exposure variations

1. Introduction

2. Materials and methods

2.1. Sampling sites

2.2. Sample collection

2.3. Blood Pb analysis

2.4. Statistical analysis

3. Results

3.1. Subjects and BLL

3.2. Critical BLL values among household members

3.3. Pb exposure patterns among



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Chemosphere



## Current trends of blood lead levels, distribution patterns and exposure variations among household members in Kabwe, Zambia



John Yabe <sup>a</sup>, Shouta MM. Nakayama <sup>b</sup>, Hokuto Nakata <sup>b</sup>, Haruya Toyomaki <sup>b</sup>, Yared B. Yohannes <sup>b</sup>, Kaampwe Muzandu <sup>a</sup>, Andrew Kataba <sup>a,b</sup>, Golden Zyambo <sup>a</sup>, Masato Hiwatari <sup>c</sup>, Daiju Narita <sup>d</sup>, Daichi Yamada <sup>d</sup>, Peter Hangoma <sup>e</sup>, Nosiku Sipilanyambe Munyinda <sup>e</sup>, Tiza Mufune <sup>f</sup>, Yoshinori Ikenaka <sup>b</sup>, Kennedy Choongo <sup>a</sup>, Mayumi Ishizuka <sup>b,\*</sup>

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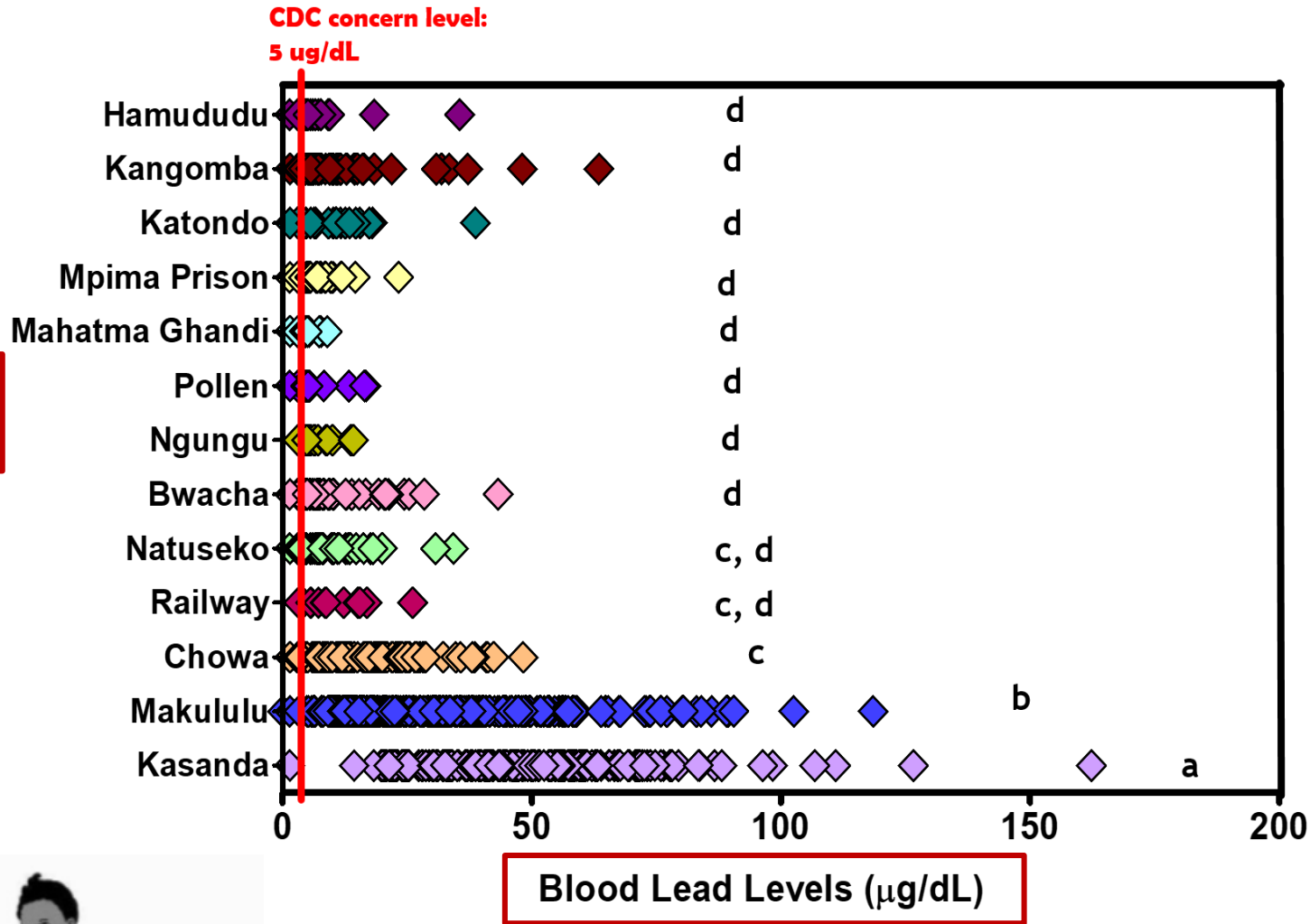
<sup>e</sup> The University of Zambia, School of Public Health, P.O. Box 32379, Lusaka, Zambia

<sup>f</sup> Ministry of Health, District Health Office, P.O. Box 80735, Kabwe, Zambia

### H I G H L I G H T S

- We measured blood lead in household members in Kabwe, which has a history of Pb–Zn mining.
- Blood Lead Levels (BLL) ranged from 1.65 to 162 µg/dL and were highest in children compared to parents.
- LeadCare II analyser provided prompt diagnosis to identify children needing chelation therapy.
- Age, distance from the mine and direction were the main factors influencing Pb exposure.
- Children living near the Pb–Zn mine are at serious risks of Pb and Cd poisoning.

Area



## Summary - Blood Lead Levels (BLLs):

- Ranged from LOD to **162 µg/dL**
- There was significant difference among BLLs based on **area**
- **Distance** from the mine and wind direction were key factors in exposure levels
- Only about **30 % had BLL below** the CDC reference level (current level is 3.5 µg/dL)
- A high peak in children around the **age of 2 years** and lower BLL in older children
- Children were at **higher risk**



Bookmarks ✕

☰ | 📌

- ▼ 📌 Lead concentrations and isotope ratios in blood, breastmilk and feces:
  - 📌 1 Introduction
  - ▼ 📌 2 Materials and methods
    - 📌 2.1 Sampling sites
    - 📌 2.2 Sampling
    - 📌 2.3 Pb and metal concentration analysis
    - 📌 2.4 Calculation of daily intake of Pb in infants through
    - 📌 2.5 Stable Pb isotope analysis
    - 📌 2.6 Plasma biochemical analysis and metallothionei



### Lead concentrations and isotope ratios in blood, breastmilk and feces: contribution of both lactation and soil/dust exposure to infants in a lead mining area, Kabwe, Zambia<sup>☆</sup>

Haruya Toyomaki <sup>a</sup>, John Yabe <sup>b,h</sup>, Shouta M.M. Nakayama <sup>a,\*</sup>, Yared B. Yohannes <sup>a,c</sup>, Kaampwe Muzandu <sup>a,b</sup>, Tiza Mufune <sup>d</sup>, Hokuto Nakata <sup>a</sup>, Yoshinori Ikenaka <sup>a,e,i,j</sup>, Takeshi Kuritani <sup>f</sup>, Mitsuhiro Nakagawa <sup>f</sup>, Kennedy Choongo <sup>b,g</sup>, Mayumi Ishizuka <sup>a</sup>

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- <sup>h</sup> Department of Pathobiology, School of Veterinary Medicine, University of Namibia, Windhoek, Namibia
- <sup>i</sup> Translational Research Unit, Veterinary Teaching Hospital, Faculty of Veterinary Medicine, Hokkaido University, Sapporo, 060-0818, Japan
- <sup>j</sup> One Health Research Center, Hokkaido University, Japan

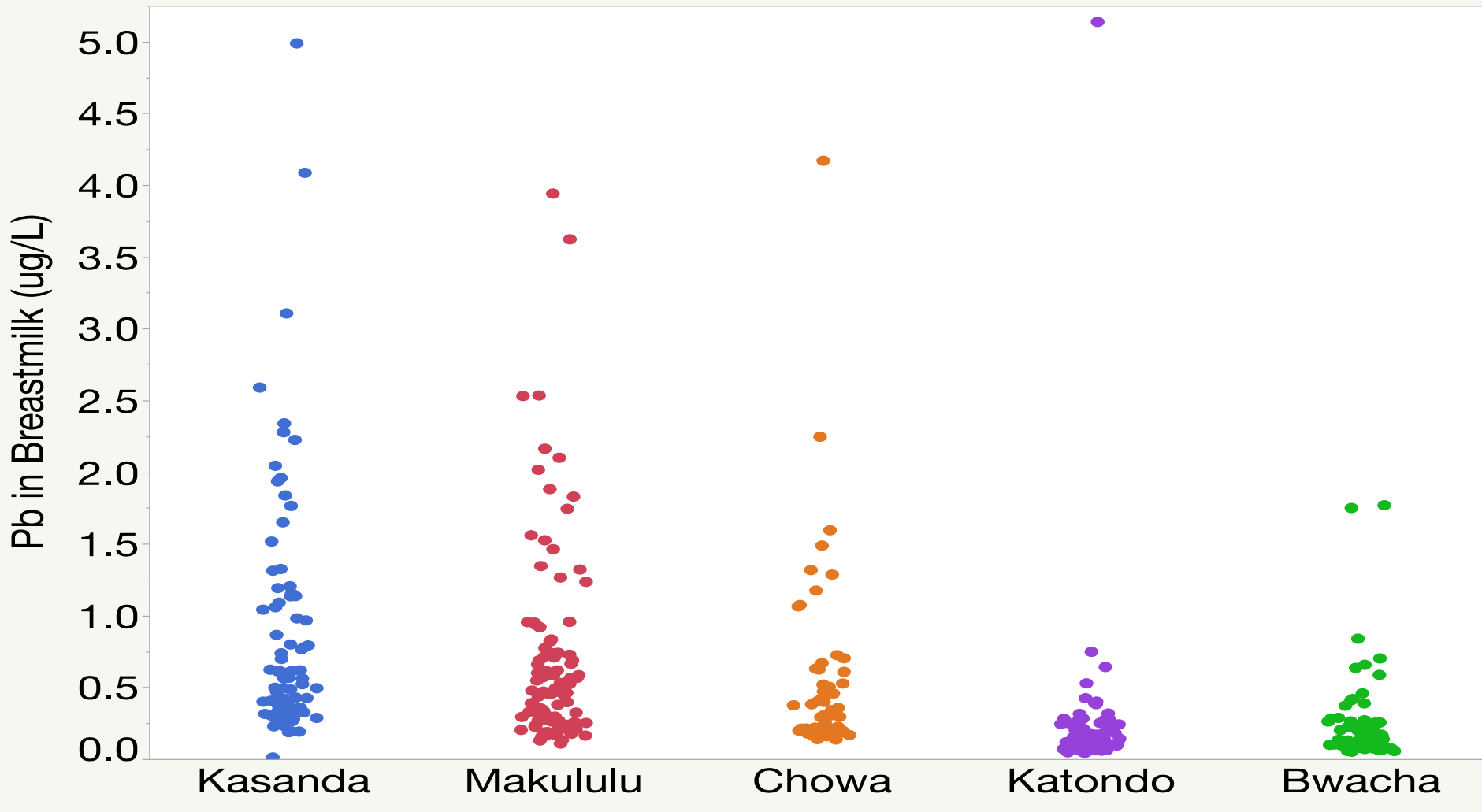
#### ARTICLE INFO

**Keywords:**  
 Lead poisoning  
 Infant  
 Mother  
 Breastmilk  
 Lead stable isotope

#### ABSTRACT

Lead (Pb) poses a serious public health concern. Breastmilk may be a possible source of Pb exposure in infants, as Pb can be transferred from the maternal blood to breastmilk. The present study was undertaken to determine the Pb exposure and the contribution of lactation as one of the exposure pathways to infants in a Pb mining area, Kabwe, Zambia. Blood, breastmilk and infants' feces were collected from 418 pairs of infants and mothers. The Pb concentrations, isotope ratios in the samples, and biochemistry in mothers' plasma were analyzed. The overall mean of blood lead levels (BLLs) in infants and mothers were 18.0 and 11.3 µg/dL, respectively. High Pb concentration in breastmilk (range: 0.4–51.9, mean: 5.3 µg/L) above the WHO acceptable level between 2 and 5 µg/L were found and could be one of the sources of Pb exposure in infants. The Pb isotope ratios in infants' feces were the most similar to Pb ratios in the soil samples. The results suggest that infants are also exposed to Pb from the environment. Pb exposure in infants through breastfeeding and soil ingestion could potentially exceed daily intake of Pb which causes neurodevelopmental toxicity. In contrast to the high BLLs in mothers, the plasma biochemical profiles of most analyzed parameters were interestingly within, or close to, the standard reference values. Our data suggest that environmental remediation is urgently needed to reduce the Pb exposure in infants and mothers from the environment in Kabwe in parallel with chelation therapy.

# Pb Levels in Breast milk Samples – below acceptable limits

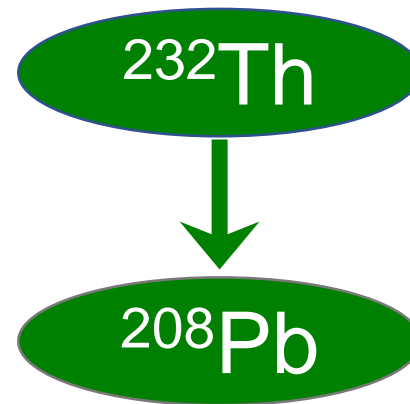
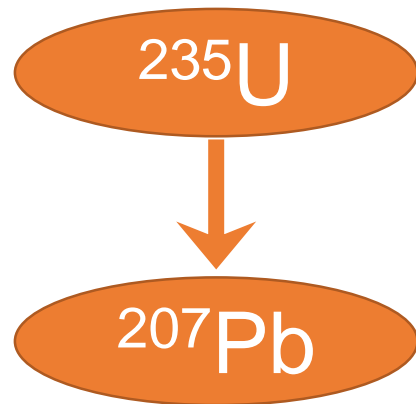
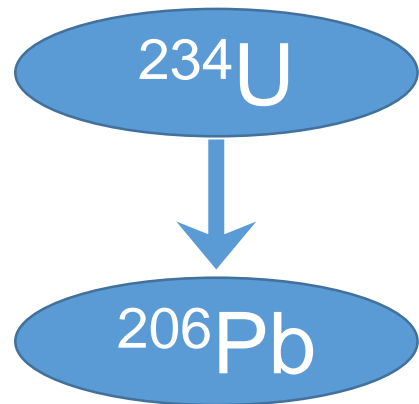


WHO's Acceptable Pb levels in breastmilk: 5 µg/L



Breastmilk	All	Kasanda	Makululu	Chowa	Katondo	Bwacha
Mean (N)	0.51 (417)	0.89 (81)	0.70 (102)	0.55 (57)	0.22 (93)	0.22 (84)
Range	0.01 - 5.1	0.01 - 5.0	0.11 - 3.9	0.14 - 4.2	0.04 - 5.1	0.05 - 1.8

- Lead has four stable, naturally occurring isotopes (Pb-Irs):  $^{204}\text{Pb}$  (1.4%),  $^{206}\text{Pb}$  (24.1%),  $^{207}\text{Pb}$  (22.1%) and  $^{208}\text{Pb}$  (52.4%).
- Pb isotope ratios; ( $^{207}\text{Pb}/^{206}\text{Pb}$ ,  $^{208}\text{Pb}/^{206}\text{Pb}$ ) are not affected to a measurable extent by physico-chemical fractionation processes.
- **Pb-IRs are different depending on Pb source**  
→ Natural tracer of Pb

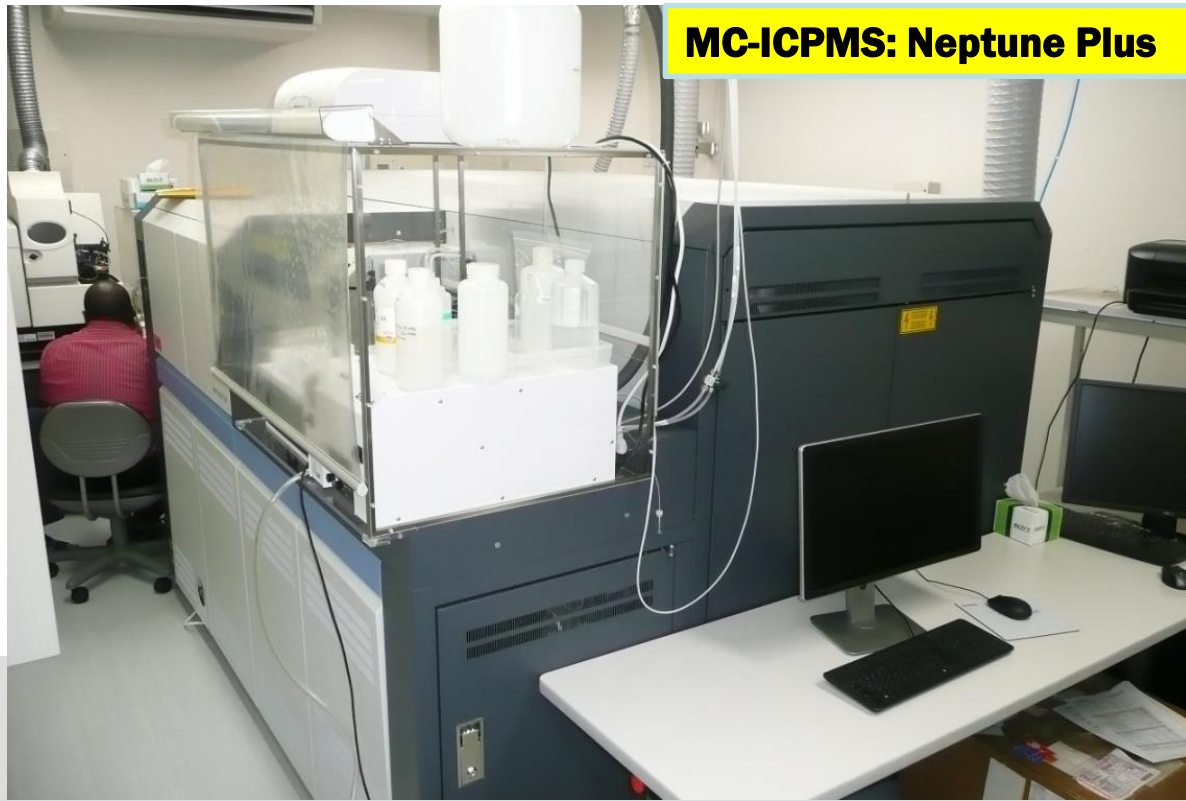


**Similar isotope ratio value → Same Pb source**

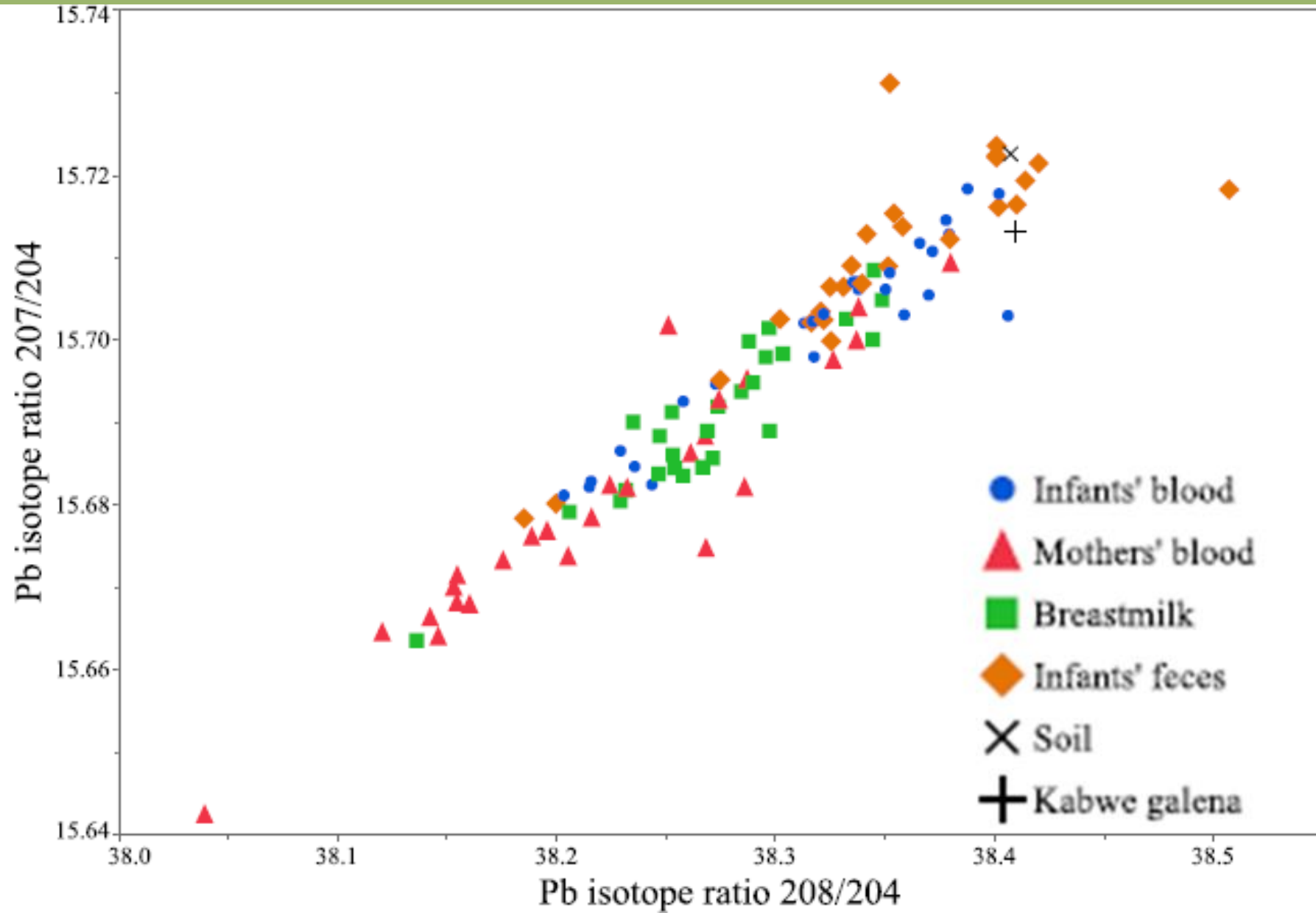


## Stable Pb isotope ratios

- Multi Collector ICP-MS (MC-ICPMS)
- To clarify source of exposure



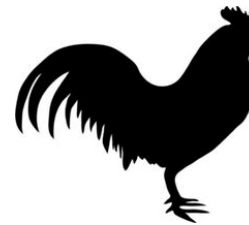
- Pb isotope ratio analysis showed similar trends for **infants blood, feces, soil and Kabwe galena**
- Pb isotope ratios for **mothers' blood and milk** were **distant from the galena and soil** but **closer to infants blood**
- BLLs in infants were higher than mothers
- A positive correlation between BLLs of paired Mothers and Infants ( $p < 0.01, \rho = 0.6$ )





Goat

- G150 (N=5, 150km from mine)
- G30 (N=5, 30km from mine)
- G0 (N=5, around mining area)



Chicken

- BC (N=5, broiler chicken)
  - FRC (N=10, free range chicken)
- (\*both group were from around mining area)

Dissection

Blood, liver, kidney, lung, spleen, brain, bone, feces, stomach/gizzard contents, etc.

can be regarded as the dominant source of Pb

Environmental samples (eg. soil)



Soil

- S150 (N=6, 150km from mine)
- S30 (N=2, 30km from mine)
- S0 (N=19, around mining area)

Drying and Microwave digestion

Analysis of Pb level and Pb-IRs using ICP-MS

00 00

▼ Reliability of stable Pb isotopes to identify Pb sources and verifying biological fractionation of Pb isotopes in goats and chickens ...

1. Introduction
- ▼ 2. Materials and methods
  - 2.1. Sampling of animals and environmental samples
  - 2.2. Sample preparation and analysis of element concentrations
  - 2.3. Analysis of Pb-IRs
  - 2.4. Statistical analysis
- ▼ 3. Results
  - 3.1. Element concentrations in



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## Environmental Pollution

journal homepage: [www.elsevier.com/locate/envpol](http://www.elsevier.com/locate/envpol)

## Reliability of stable Pb isotopes to identify Pb sources and verifying biological fractionation of Pb isotopes in goats and chickens



Hokuto Nakata <sup>a,1</sup>, Shouta M.M. Nakayama <sup>a,1</sup>, John Yabe <sup>b</sup>, Allan Liazambi <sup>c</sup>, Hazuki Mizukawa <sup>d</sup>, Wageh Sobhy Darwish <sup>a,e</sup>, Yoshinori Ikenaka <sup>a,f</sup>, Mayumi Ishizuka <sup>a,\*</sup>

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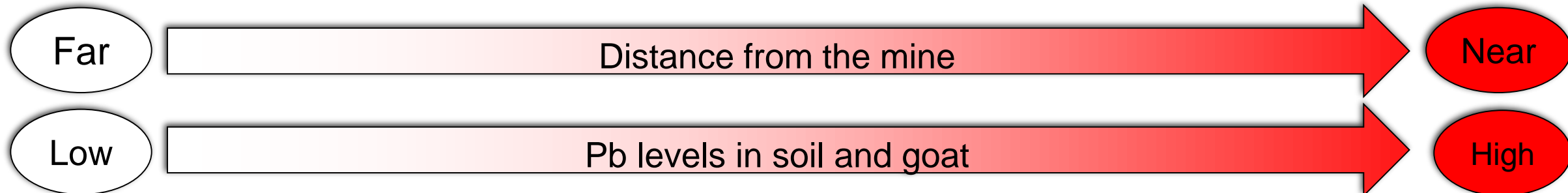
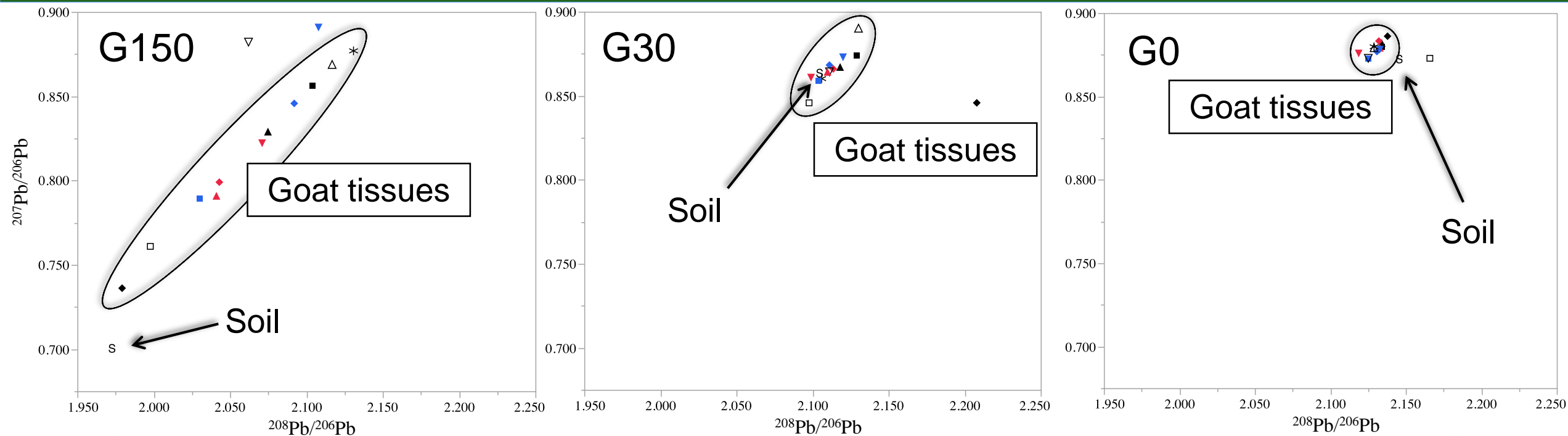
## ABSTRACT

Stable Pb isotope ratios (Pb-IRs) have been recognized as an efficient tool for identifying sources. This study carried out at Kabwe mining area, Zambia, to elucidate the presence or absence of Pb isotope fractionation in goat and chicken, to evaluate the reliability of identifying Pb pollution sources via analysis of Pb-IRs, and to assess whether a threshold for blood Pb levels (Pb-B) for biological fractionation was present. The variation of Pb-IRs in goat decreased with an increase in Pb-B and were fixed at certain values close to those of the dominant source of Pb exposure at Pb-B > 5 µg/dL. However, chickens did not show a clear relationship for Pb-IRs against Pb-B, or a fractionation threshold. Given these, the biological fractionation of Pb isotopes should not occur in chickens but in goats, and the threshold for triggering biological fractionation is at around 5 µg/dL of Pb-B in goats.

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## Highlights

- Presence of Pb isotope fractionation in goat and chicken was studied.
- The variation of Pb-IRs in goat decreased with an increase in Pb-B.
- Chickens did not show a clear relationship for Pb-IRs against Pb-B.
- The biological fractionation of Pb isotopes should not occur in chickens but in goats.
- Threshold for triggering biological fractionation is at 5µg/dL of Pb-B in goats.

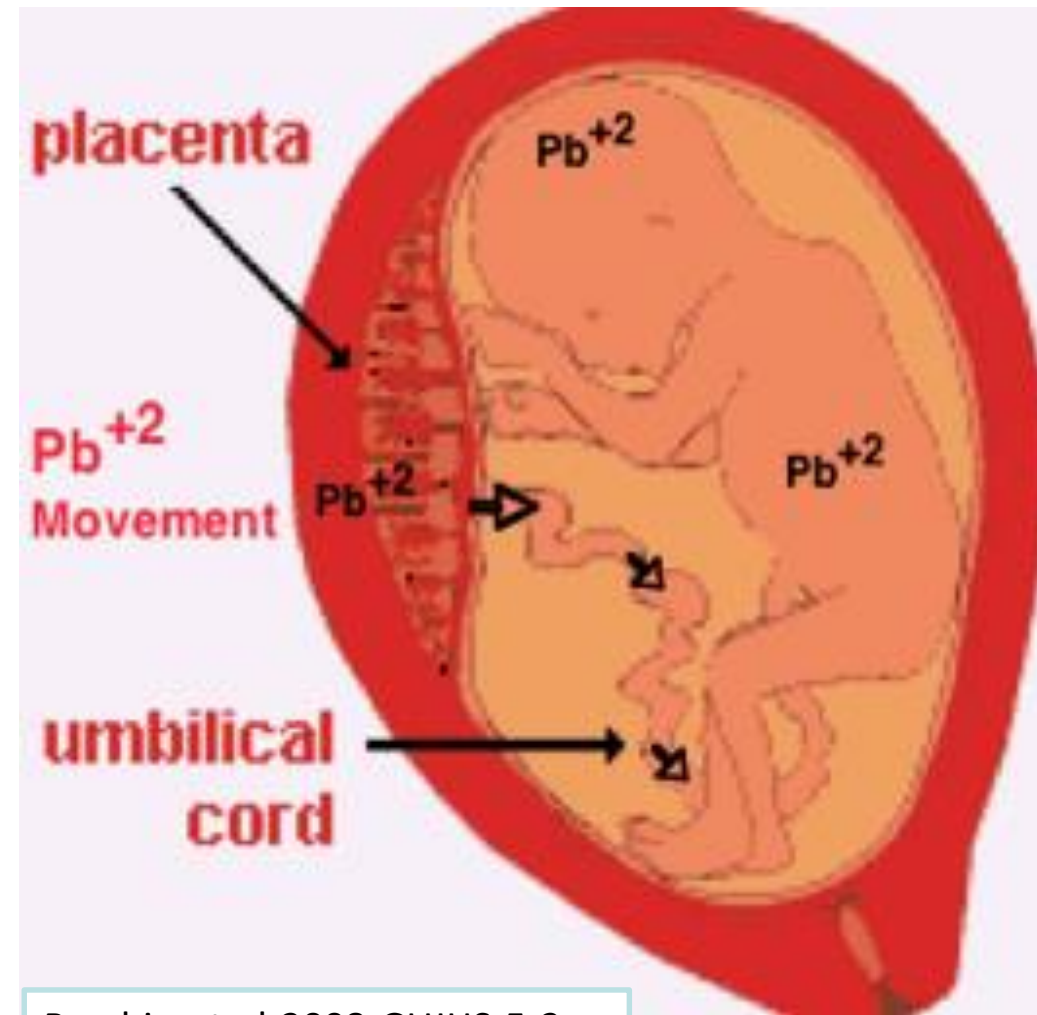


1. The values of Pb-IRs in goat with high Pb level reflected those in soil (pollution source)

# Assessing the Impact of Pb Exposure and Maternal Characteristics on Neurodevelopmental (ND) Outcomes in Children 29

## Background

- Increased mobilization of Pb from bones (**endogenous source**)
  - **Pregnancy, lactation and calcium deficiency**
- **Trans-placental transfer** of Pb is well known
  - through **syncytiotrophoblast**.
- Pb transfer peaks at 12-14 weeks gestation
  - fetal production of **1,25-dihydroxyvitamin D**
- **Pre- and perinatal exposure** results in **higher brain Pb levels** than postnatal exposure.
  - Under-developed **blood-brain barrier** in early life.



Brochin-et-al-2008-GUJHS-5-2

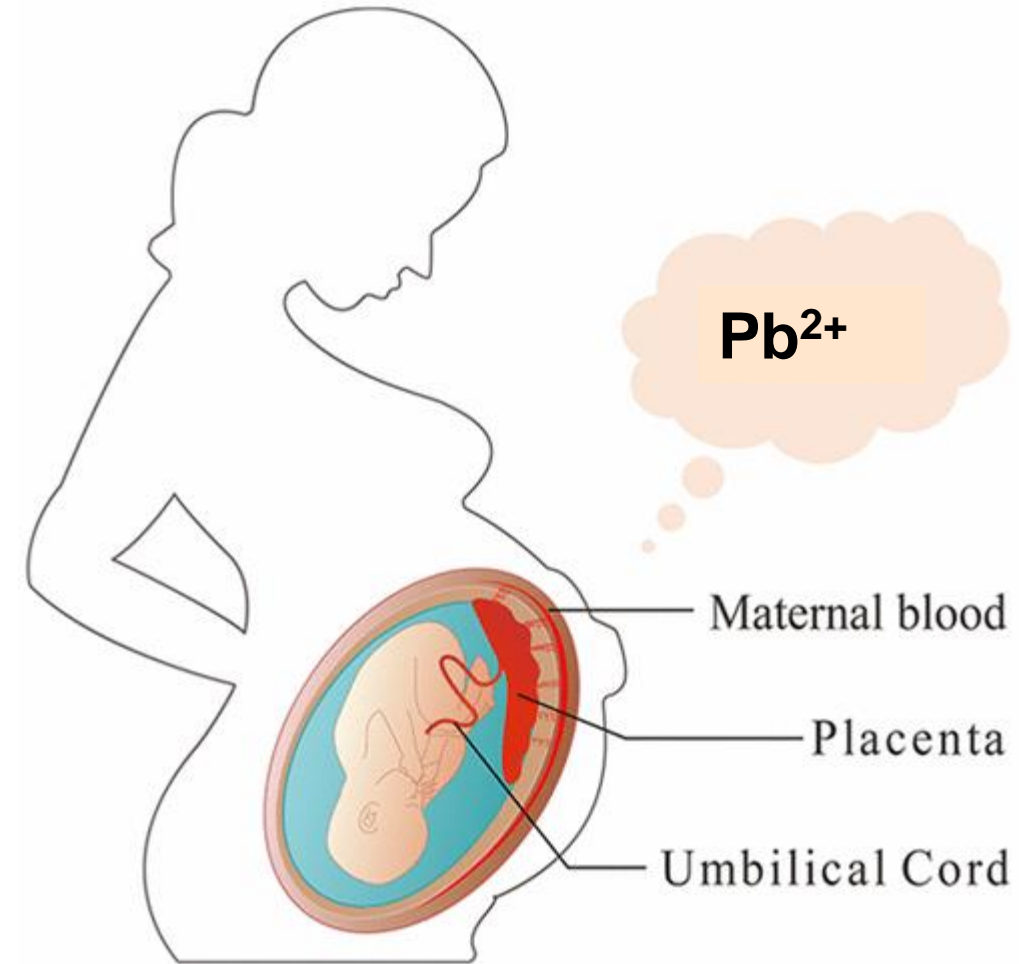
# Assessing the Impact of Pb Exposure and Maternal Characteristics on Neurodevelopmental (ND) Outcomes in Children 30

## Background

- Pb exposure can cause serious **neurocognitive damage**.
- **Maternal, social and environmental factors** can alter susceptibility to the cognitive effects of Pb.

## Objectives

- Assess the impact of **childhood Pb exposure** on neurodevelopmental outcomes.
- Assess the influence of **maternal characteristics** on neurodevelopmental outcomes in selected exposed communities of Kabwe, Zambia



# Assessing the Impact of Pb Exposure and Maternal Characteristics on Neurodevelopmental (ND) Outcomes in Children

## Areas on ASQ<sup>®</sup>-3

The ASQ<sup>®</sup>-3 screens five key areas of development in young children to create a well-rounded snapshot of the child's skills and abilities. This handout lists the areas of development and briefly explains each.

### Communication

Assesses language, both what a child understands and how they follow directions (**receptive**) and how they vocalize, use words, and start to make sentences (**expressive**).

### Gross Motor

Assesses large muscle (body, arms, and legs) movement and coordination.

### Fine Motor

Assesses eye/hand and hand/finger movements and coordination, pre-writing skills.

### Problem Solving

Assesses skills of thinking and learning, how child solves problems, pre-academic skills.

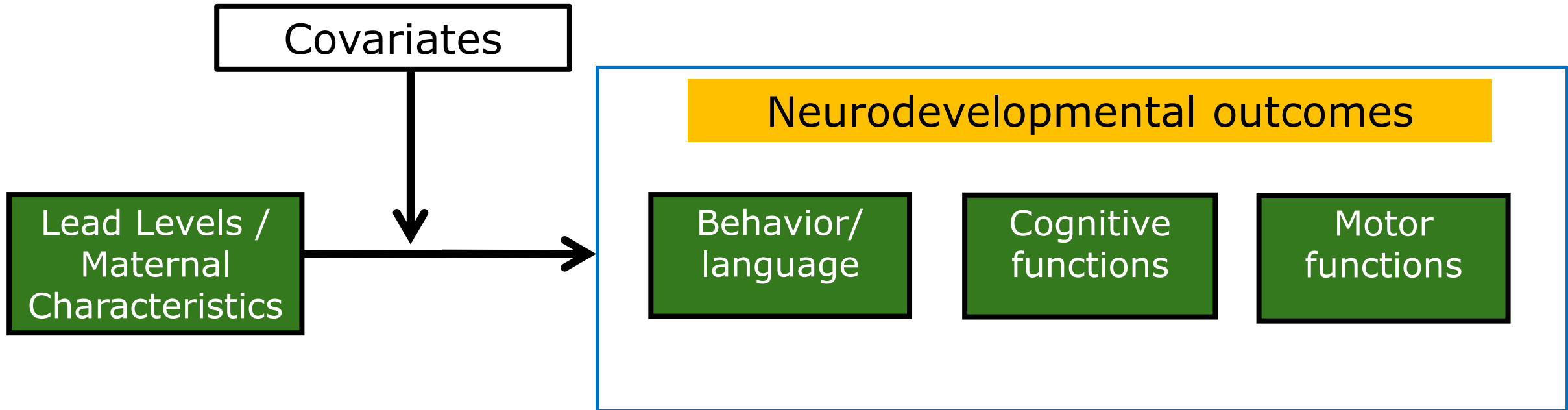
### Personal-Social

Assesses **self-help** skills (e.g., feeding, dressing, toileting) and **social interactions** with others.



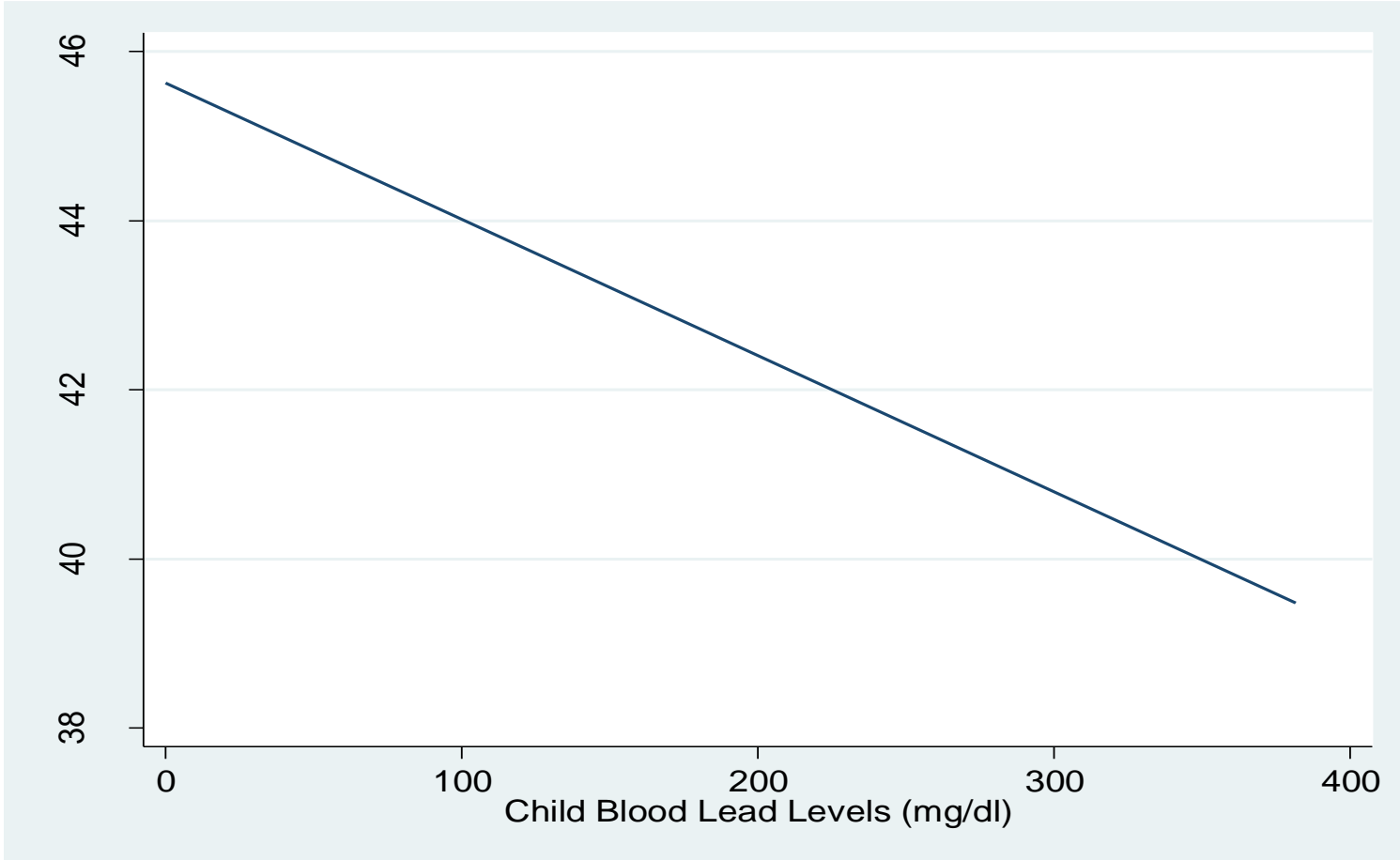


# Assessing the Impact of Pb Exposure and Maternal Characteristics on Neurodevelopmental (ND) Outcomes in Children

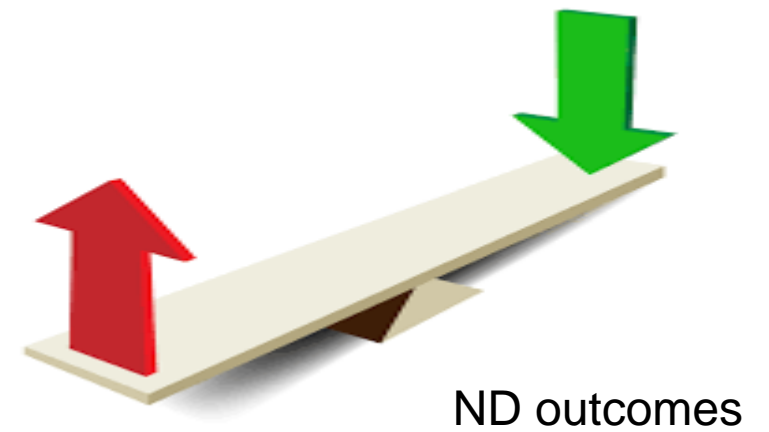


## Maternal Characteristics

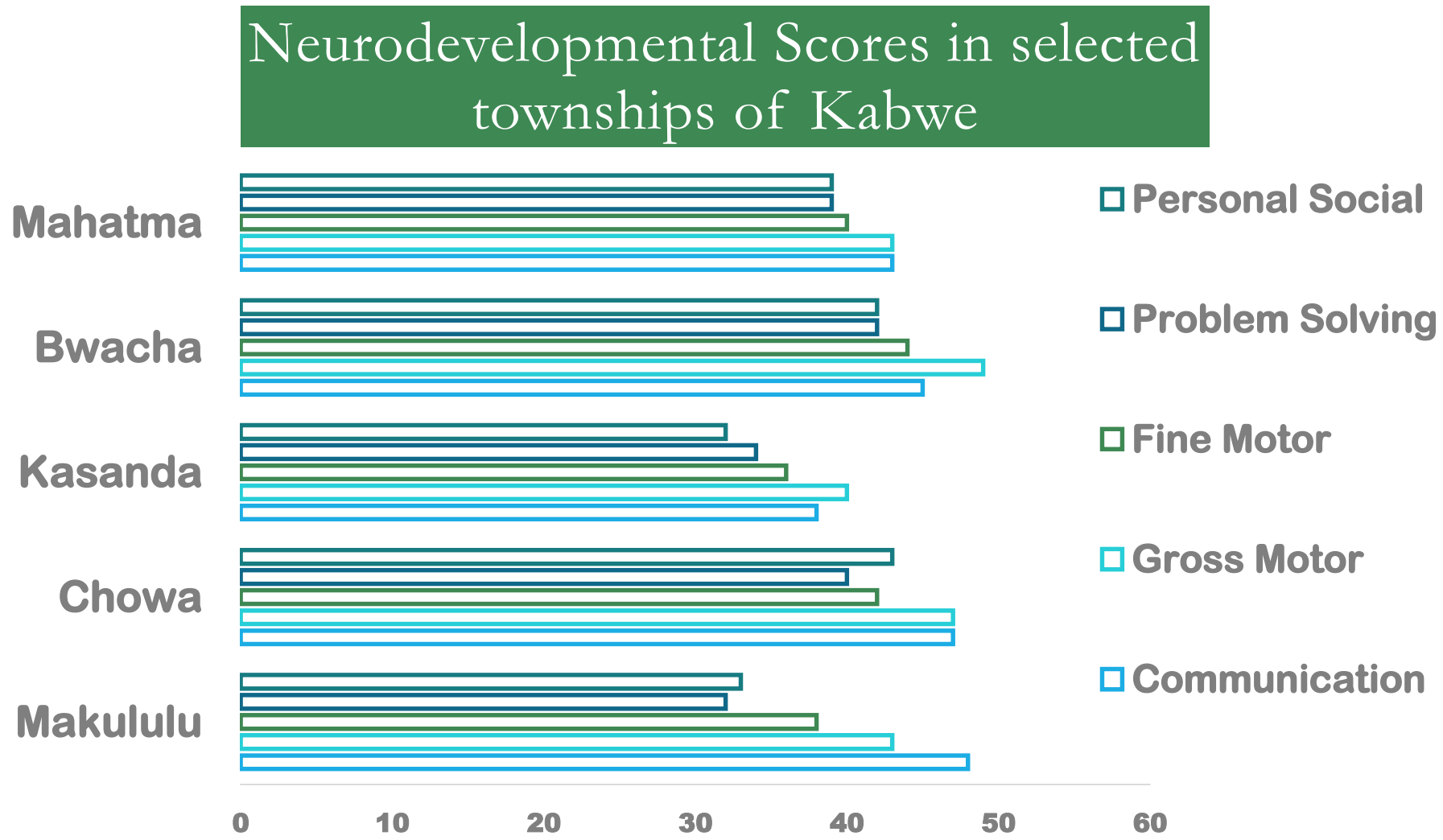
- Age
- Marital status
- Education level
- Income level
- Breast feeding duration



Blood lead levels and ND scores



There was a negative correlation between BLLs and ND scores



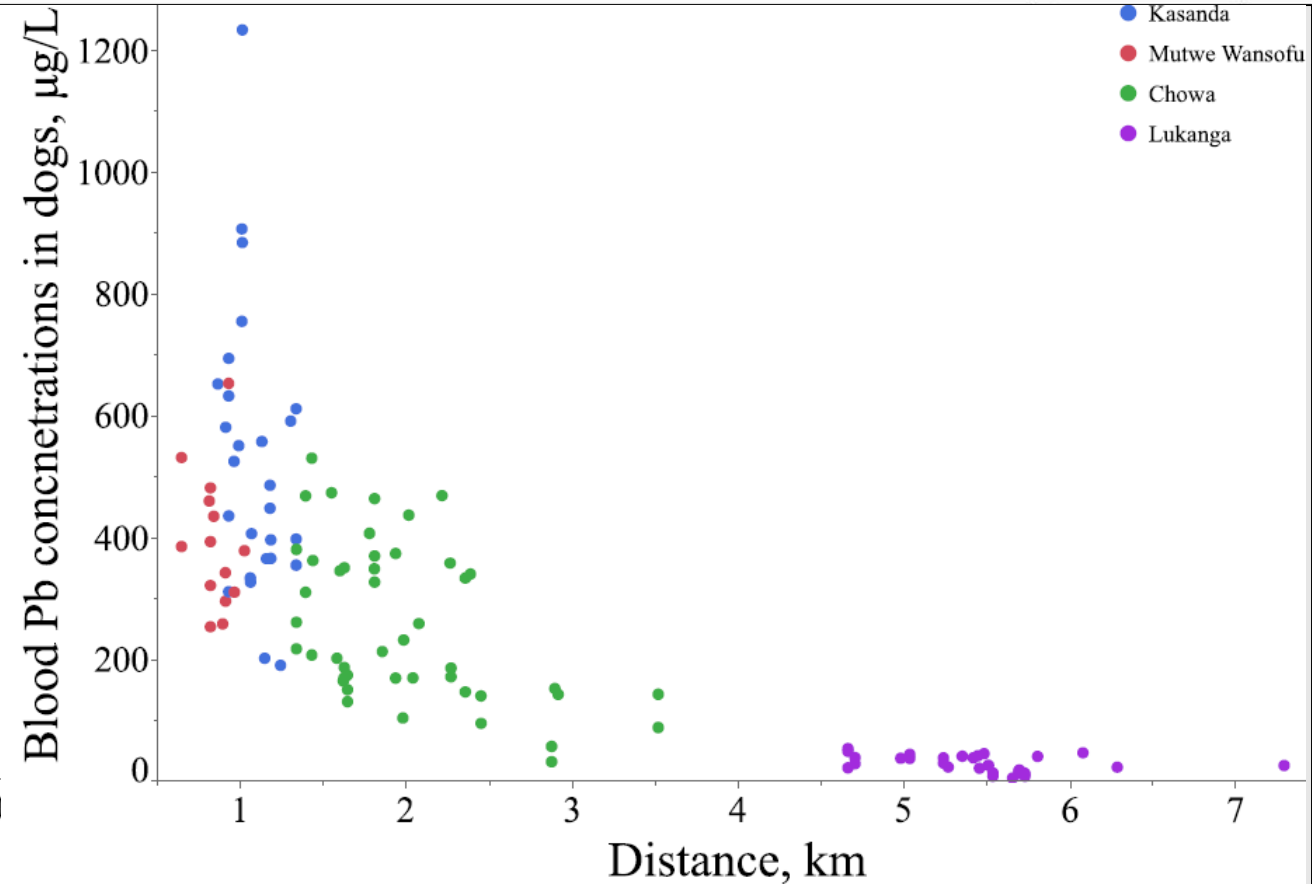
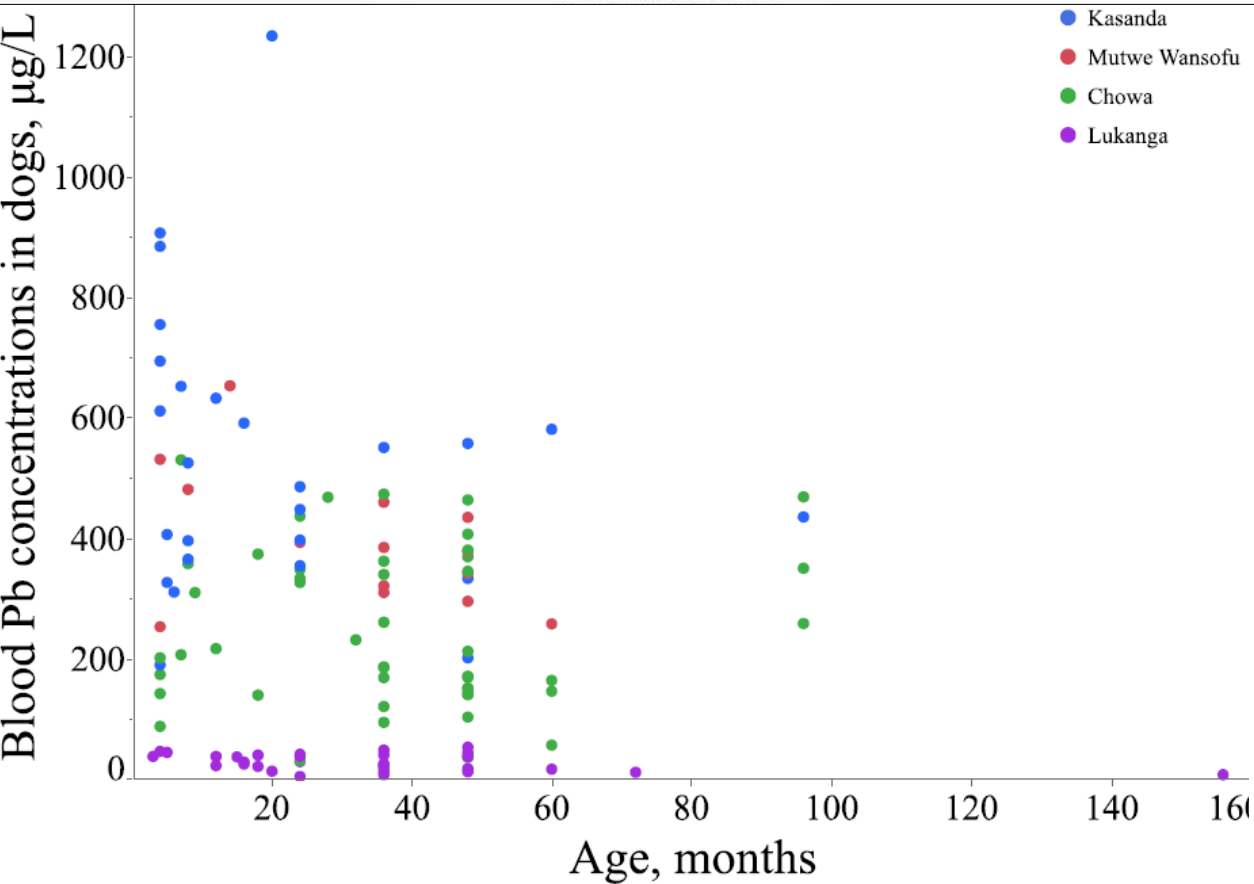
There were significant differences in ND scores by the location.\*except FM domain\*

## Background and Objectives

- Large-scale surveys of humans have serious challenges.
- Ethical clearance for research in humans is difficult to obtain
- Therefore, we assessed the trends of **Pb in domestic dogs** residing in areas around the mine for use as **sentinel animals**.
- Pb **isotope ratios** in the blood were analyzed.
- **Blood biochemical** analysis to evaluate the **health impact** of Pb exposure in dogs.



Free rabies vaccination campaign in Kabwe for dog blood sample collection



## H I G H L I G H T S

- Lead (Pb) levels in blood of 120 dogs around a Pb mining area, Kabwe were measured.
- The overall mean of Pb in dog blood in the present study was 271.6 µg/L.
- Pb levels significantly decreased with increasing age and distance from the mine.
- Pb isotope ratios in blood showed values close to those reported for Kabwe galena.
- Dogs could be useful as a sentinel animal of Pb exposure on human in Kabwe.

# Conclusions, Recommendations and Work in Progress

## Take-home message

- Blood lead levels in communities near the Pb mine in Kabwe are **alarming**
- Lead in levels **in human breast milk are generally low**
- **Free range chickens** could be an important **source** of Pb in Kabwe
- **Children** in Kabwe are mainly exposed to Pb through their **mother's blood and from the soil**
- Pb toxicity in Kabwe affects **liver, kidney, hematopoietic system**
- **Dogs** in Kabwe can be used as **sentinel animals for Pb biomonitoring**
- **Hot spots** that require urgent remediation are **Kasanda, Mutwewansofu and Makululu**

## World Bank funded project (ZMERIP) collaboration

- Treatment of the target children with BLL above **45 µg/dl** is currently underway
- Environmental remediation programs under ZMERIP are already underway

## Further assessments

- Children below the age of 3 years – Neurodevelopmental Impairment Assessment
- School going children above the age of >3 - IQ, ADHD, etc.
- Lead (Pb) exposure and birth outcomes in pregnant mothers (PhD student – in progress)

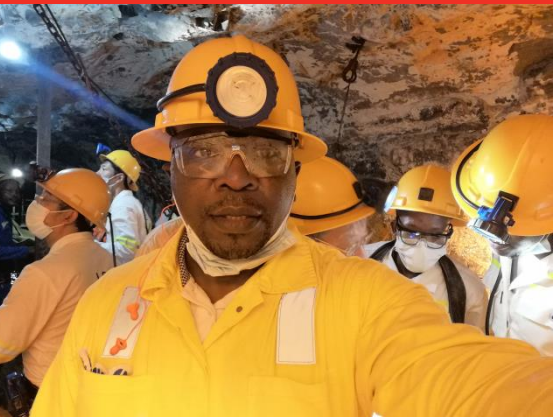




# Impacts of Arsenic and Lead Contamination in Tsumeb and Rosh Pinah, Namibia: a Multidisciplinary and One Health Approach

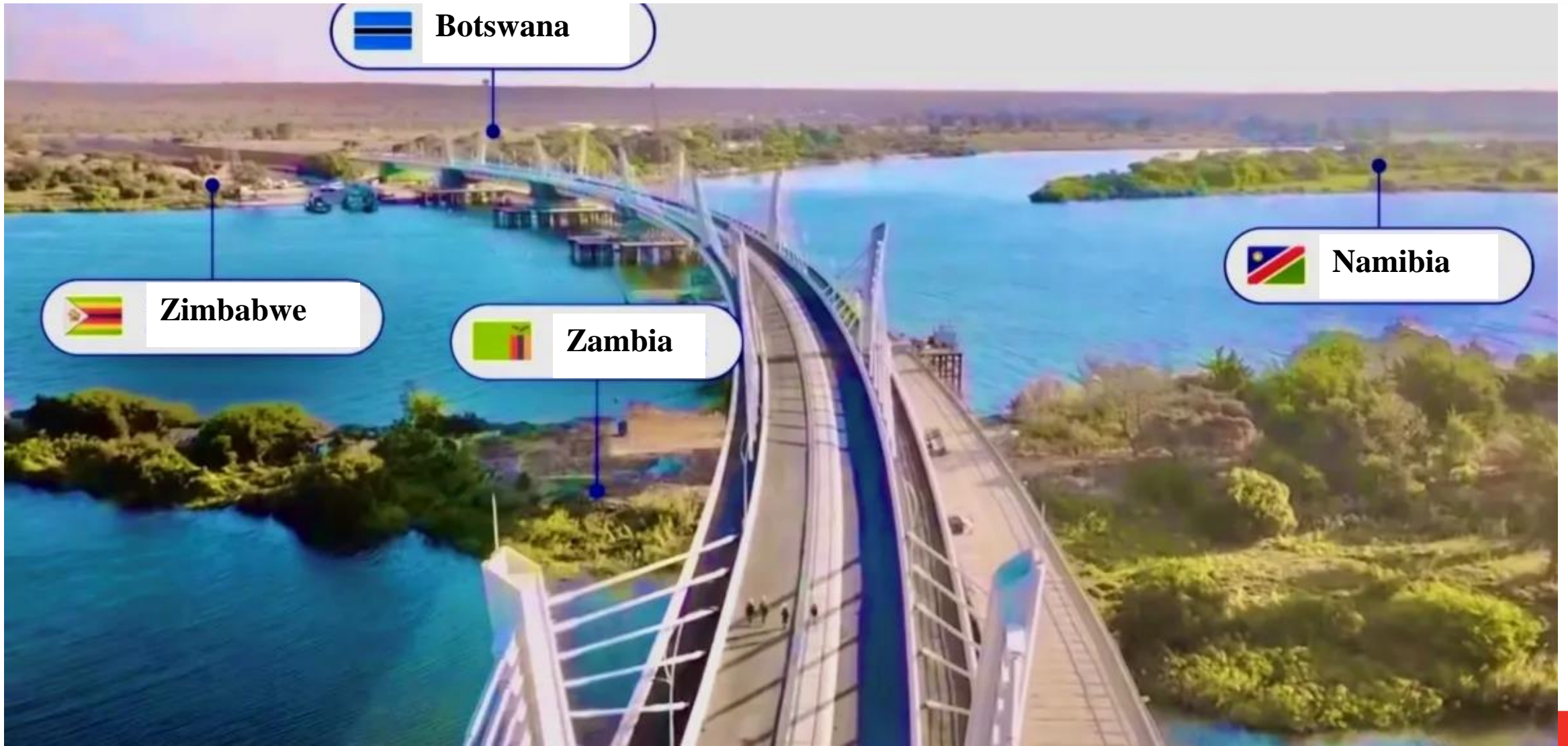
**John Yabe** – University of Namibia; Regional Coordinator (ZA.ZINAMBO Project)

Shouta Nakayama, Yvonne Hemberger, Mark Jago, Gerhard Iputa, Johnson Oluwagbenga, Simon Angombe, Tuyenikelao Nekwaya, Moshood Onifade, Silas Hango, Victoria Ndeshimona, Mayumi Ito, Anna Marais, Mayumi Ishizuka





# ZA.ZINAMBO PROJECT (Zambia – Zimbabwe – Namibia – Botswana) + Japan



# ZA.ZINAMBO PROJECT (ZAMBIA – ZIMBABWE – NAMIBIA – BOTSWANA)

## Sub-Saharan Africa and Japan

- Promote Region collaboration
- Hokkaido University, Japan (facilitate)

## ❖ One Health Concept

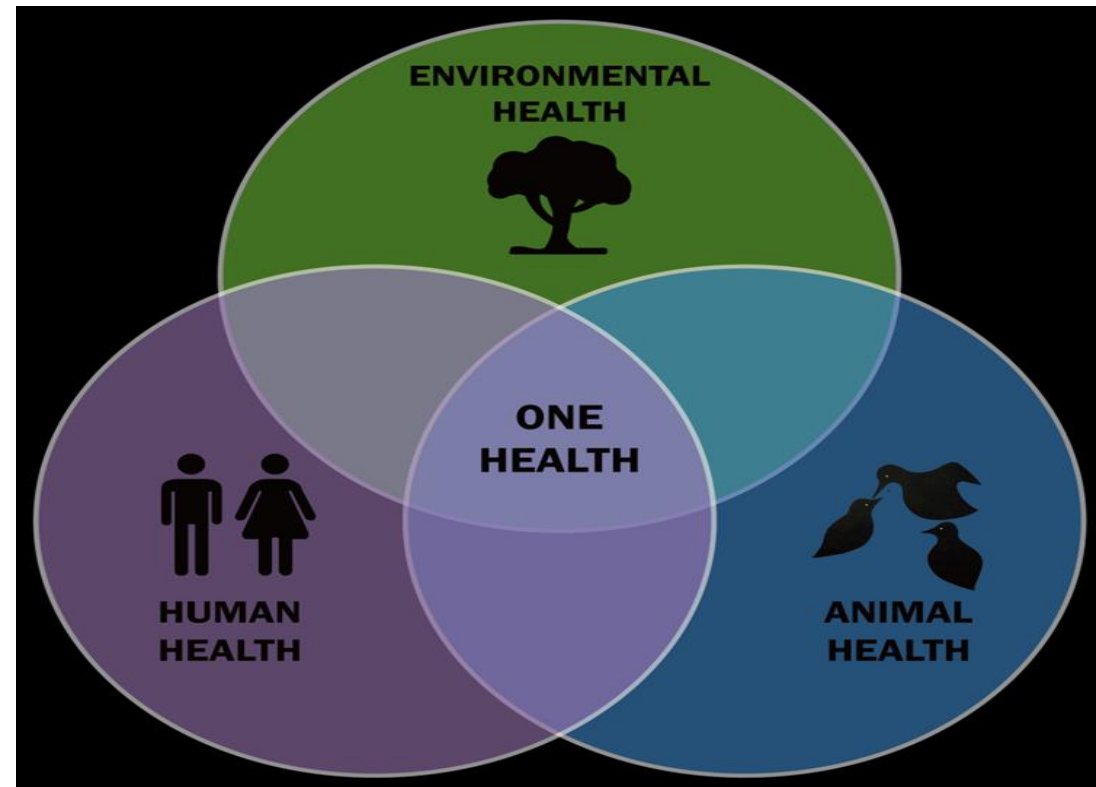
- Environment – Animal Health – Human Health

## ❖ Metal Contamination and Remediation

- Lead, Arsenic, Mercury, Cadmium, etc.

## ❖ Funding

- Japan International Cooperation Agency (JICA)
- Japan Science and Technology Agency (JST)



# Research Site Identification – Why Tsumeb?

## Location

- North-central, about 440 km, north of Windhoek

## ❖ Population

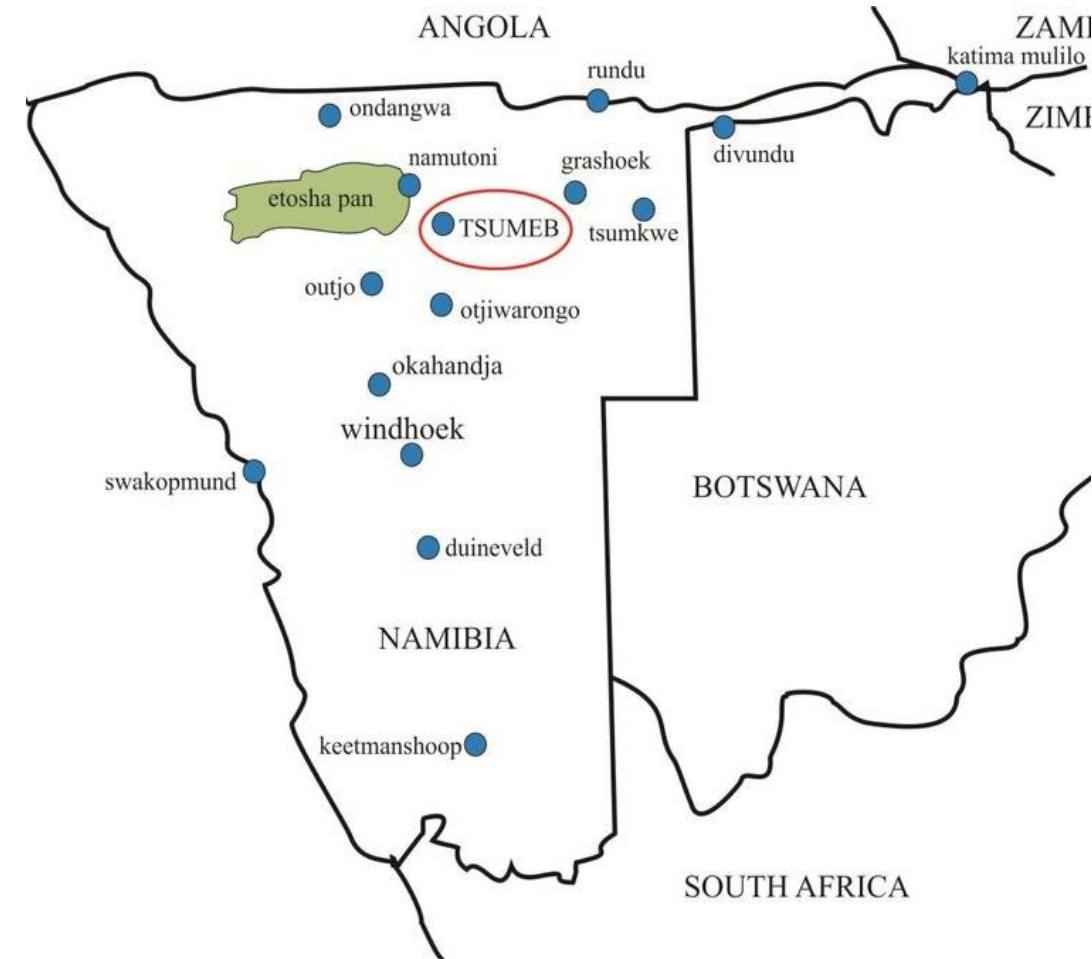
- About 19,000 residents (unverified)

## ❖ Mining / smelting history

- Mining - Anglo-German company (1903)
- Tsumeb smelter – processes **copper** from Tsumeb and **other mines** (DPM)
- **Lead and Copper** (Arsenic as byproduct)

## ❖ Important Agricultural Region

- High annual rainfalls (> 550 ml annually)
- Intensive agriculture (maize, fruits, vegetables)
- Part of the "Golden Triangle", or "Maize Triangle"



# Why are we interested in Arsenic (and Lead)?



UNAM  
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## Arsenic Toxicity

- ❖ **Arsenic is toxic** - Acute poisoning causes nausea, vomiting, abdominal pain, and diarrhea
- ❖ Chronic exposure affects the skin
  - Hyperpigmentation, hyperkeratosis e.g., in the hands and feet
- ❖ **Arsenic is a carcinogen** - affects numerous organs
  - Workers and residents in the vicinity of smelters are most vulnerable
  - Lung, urinary tract and skin cancer are reported at levels in drinking water around and above 50  $\mu\text{g}/\text{L}$
- ❖ Encephalopathy and peripheral neuropathy may occur.



Int J Environ Health Res. 2007 Apr;17(2):141-9. doi: 10.1080/09603120701219154. PMID: 17616870.

# Does Arsenic Pollution occur in Tsumeb?

- ❖ The **Namibia Custom Smelter** (NCS or the Tsumeb smelter) processes complex Cu concentrates from Bulgaria and Peru
  - These are contaminated with **As**
- ❖ Drop in As demand - produced **As is stored on-site**
- ❖ Environmental contamination (**Pb, Cd & As**) reported
- ❖ **Soil contamination** - over **13,000 mg/kg** were recorded in the vicinity of the smelter
- ❖ **Plant contamination** - As, Pb and Cd exceeded WHO limits in marula fruits, pumpkins, chilies and tomatoes
- ❖ **NO scientific data for Animal and Human exposure.**
- ❖ Conflicting reports of As exposure in Tsumeb



2013 – dumping (Tsumeb, Namibia)

<https://bankwatch.org/blog/health-reports-confirmed-widespread-over-exposure-to-toxic-arsenic-at-tsumeb-smelter-in-namibia>

# Arsenic and Lead in Tsumeb and Rosh Pinah - Media Reports

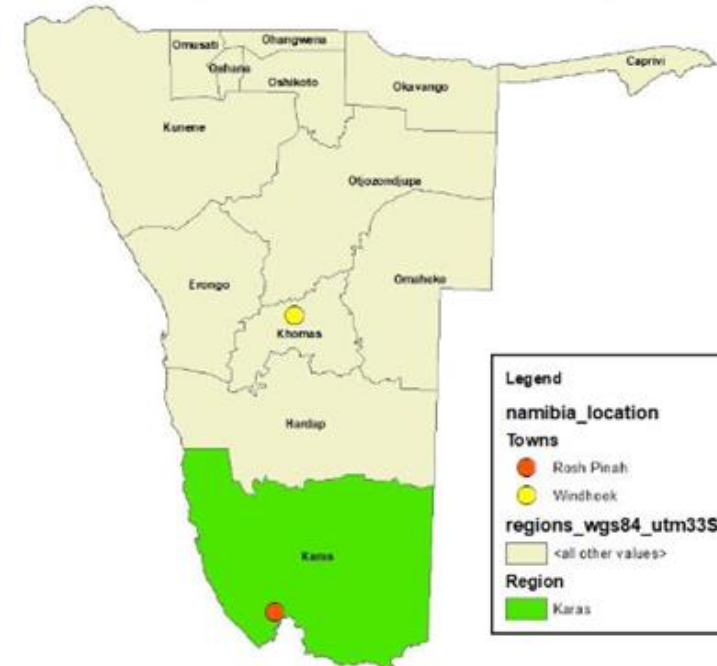
- ❖ <https://bankwatch.org/blog/health-reports-confirmed-widespread-over-exposure-to-toxic-arsenic-at-tsumeb-smelter-in-namibia> (22 December 2015)
- ❖ <http://www.thevillager.com.na/articles/93/-Tsumeb-copper-miners--suffer-from-arsenic--effects/> (2017?)
- ❖ <https://ww2.namibian.com.na/tsumeb-residents-demand-compensation-from-dundee-for-alleged-water-contamination/> (24 August 2023)
- ❖ <https://www.namibian.com.na/rosh-pinah-children-suffer-chronic-lead-exposure/> (13 July 2023)
- ❖ <https://www.namibian.com.na/ministry-investigates-lead-exposure-among-rosh-pinah-children/> (25 July 2023)

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3. Daniel Popov, Genady Kondarev, Bertchen Kohrs. 2016. Dirty Precious Metals. Report from a fact finding mission on the Dundee Precious Metals smelter facility in Tsumeb, Namibia. CEE Bankwatch Network, Earthlife Namibia and Za Zemiata – Friends Of The Earth Bulgaria, 2016
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5. Nejeschlebová, L., Sracek, O., Mihaljevič, M., Ettler, V., Kříbek, B., Knésl, I., Vaněk, A., Penížek, V., Dolníček, Z., Mapani, B., Geochemistry and potential environmental impact of the mine tailings at Rosh Pinah, southern Namibia, *African Earth Sciences* (2015)

## LEAD EXPOSURE IN CHILDREN AT ROSH PINAH LABELLED ‘HARMLESS’

 [Josefina Lukas](#)  9 Oct 2023

Locality Map for Rosh Pinah, !Karas Region



<https://www.eaglefm.com.na/news/namibia/lead-exposure-in-children-at-rosh-pinah-labelled-harmless/>

By:Josefina Lukas





# Is there lead exposure from hunting activities in Namibia?

## ❖ Lead exposure

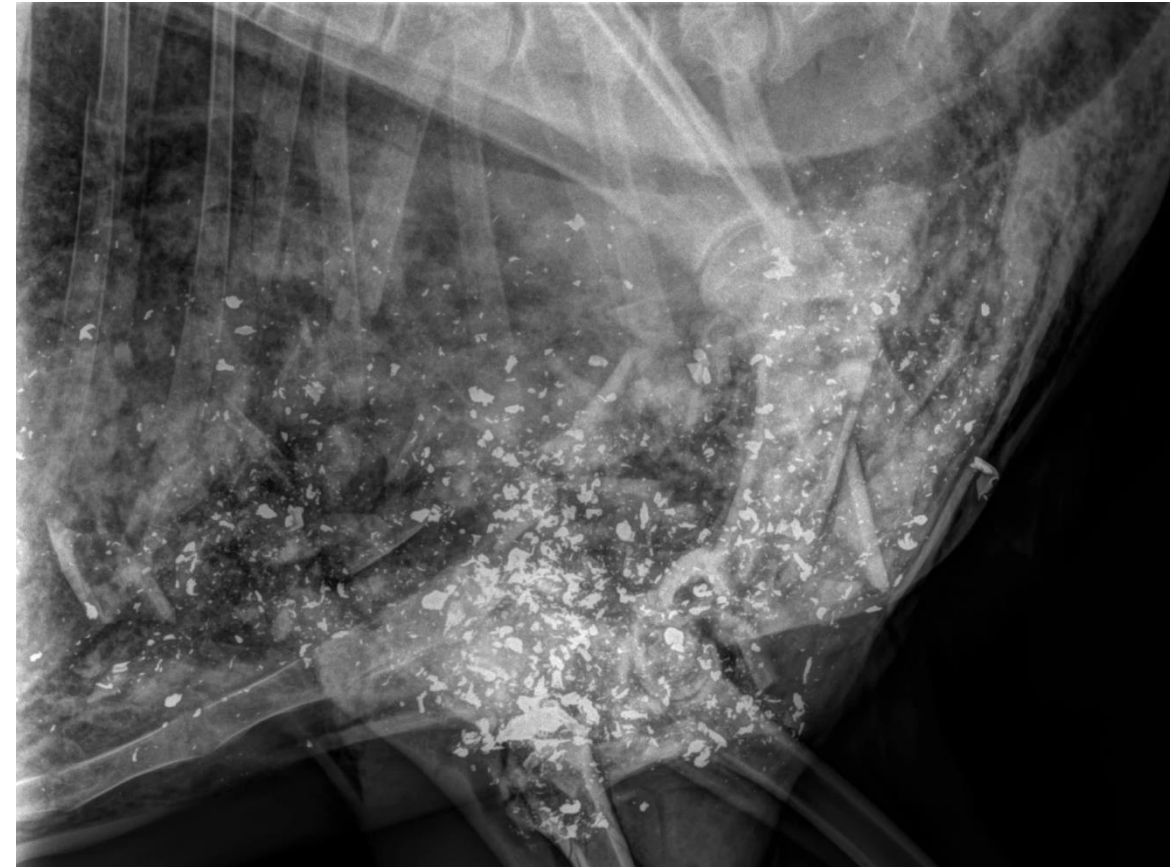
- Meat products from hunted animals
- Hunting dogs
- Hunting communities
- Vultures and scavenging birds
- Carnivorous animals

## ❖ Lead isotope ratio analysis

- Determine source of exposure

## ❖ Change hunting methods?

- Consider replacement of lead ammunition with non-lead ammunition e.g. copper bullets
- Head shots



An X-ray showing tiny lead fragments in the chest of a deer shot with lead bullets. Picture: Jordan Hampton/ University of Melbourne. <https://pursuit.unimelb.edu.au/articles/lead-from-ammunition-is-a-threat-to-everyone-s-health>

# Assembled Research Team (UNAM) - One Health Concept

- ❖ Regional Coordinator (ZAZINAMBO)
  - John Yabe (Veterinary Medicine)
- ❖ National Coordinator (Namibia)
  - Yvonne Hemberger (Public Health, Vet. Med)
- ❖ Veterinary Medicine
  - Toxicology, Wildlife
- ❖ School of Agriculture & Fisheries Science
  - Soil Science, Crop Science
- ❖ School of Science
  - Environmental Science
- ❖ School of Engineering and the Built Environment
  - Mining Engineering, Metallurgical Engineering,
- ❖ **School of Medicine (assembl)**
- ❖ **School of Allied Health Sciences (Not yet engaged)**



# Research Objectives – One Health Concept

- ❖ Identification of the pollution source and exposure pathway to animals and humans
  - Pb and As in air, soil and water
  - Pb and As in agricultural crops
  - Pb and As in food animals
- ❖ Clarification of contamination status and toxic effects in animals and humans
  - Pb concentrations in blood
  - As concentrations in urine
  - Analyze biomarkers of effect
- ❖ Propose environmental remediation methods (locally and to SADC)
  - Phytoremediation, Chemical remediation, etc.
- ❖ Human Capacity Development
  - Staff exchange and training
  - Student training (PG)
  - Laboratory capacity

# Research Facilitation – MOU (UNAM and Hokkaido University)



THANK YOU FOR YOUR ATTENTION

THANK YOU FOR YOUR ATTENTION

