KAMPAI PROJECT - JICA/SATREPS
2016 - 2020

6th December 2016

Visualization of impact of chronic / latent chemical hazard and Geo-Ecological Remediation in Zambia

Collaborative research between the University of Zambia and Hokkaido University

Funding: Japan International Cooperation Agency (JICA) and Japan Science and Technology (JST)

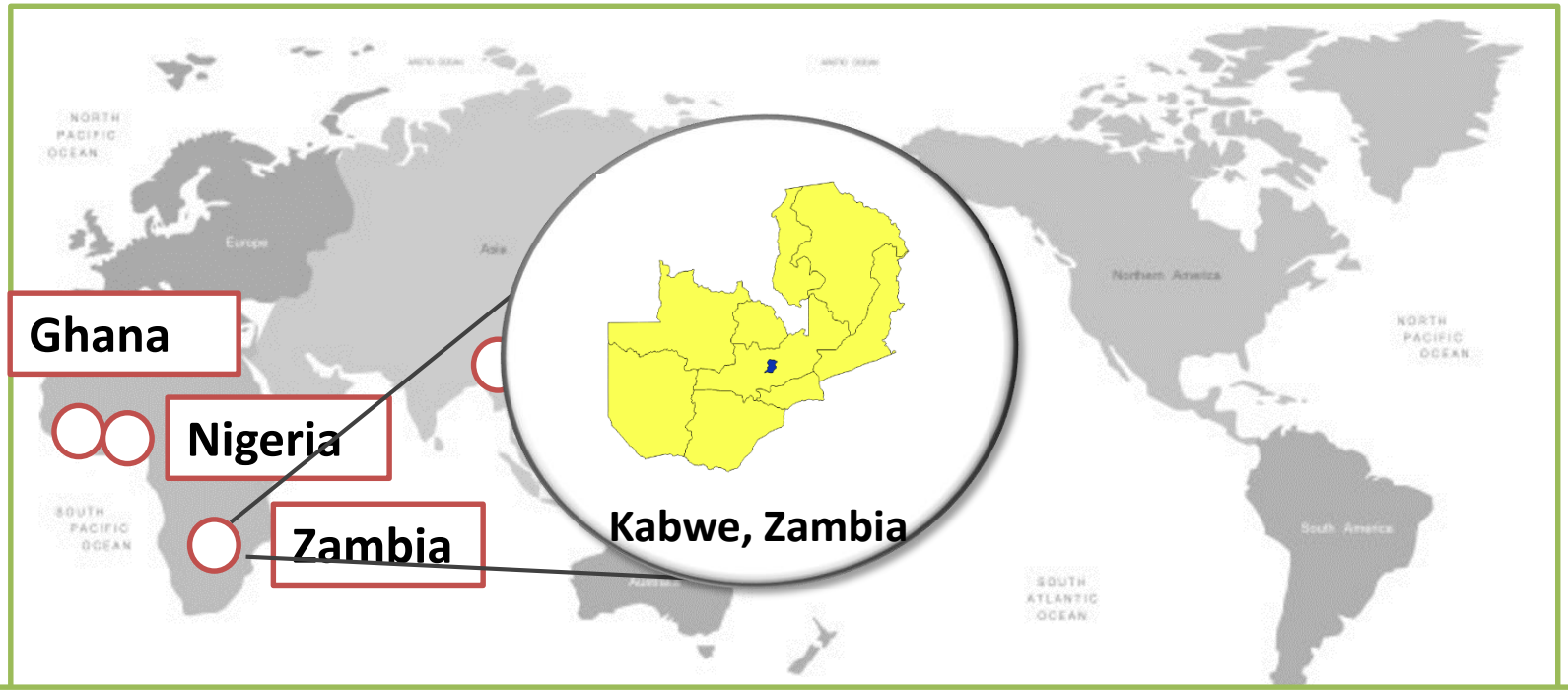
Duration: 2016-2002

Site: Kabwe City, Central Province, Zambia

Project participants from Zambia

1) The University of Zambia
2) Ministry of Higher Education
3) Kabwe Municipal Council (KMC)
4) Ministry of Health (MOH)
5) Ministry of Mines and Minerals Development
6) Ministry of Lands, Natural Resources and Environmental Protection
7) Zambia Environmental Management Agency (ZEMA)
8) National Remote Sensing Centre

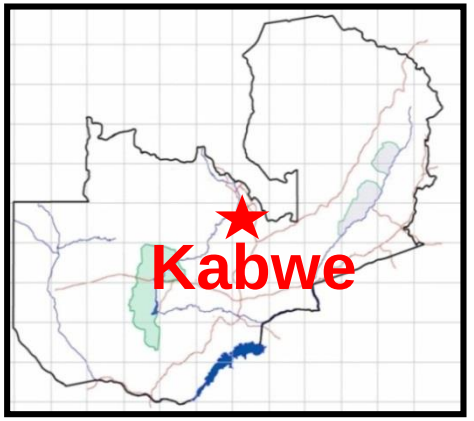
Examples of toxic metal diseases (Pb, Hg, Cd, As)



- **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-)

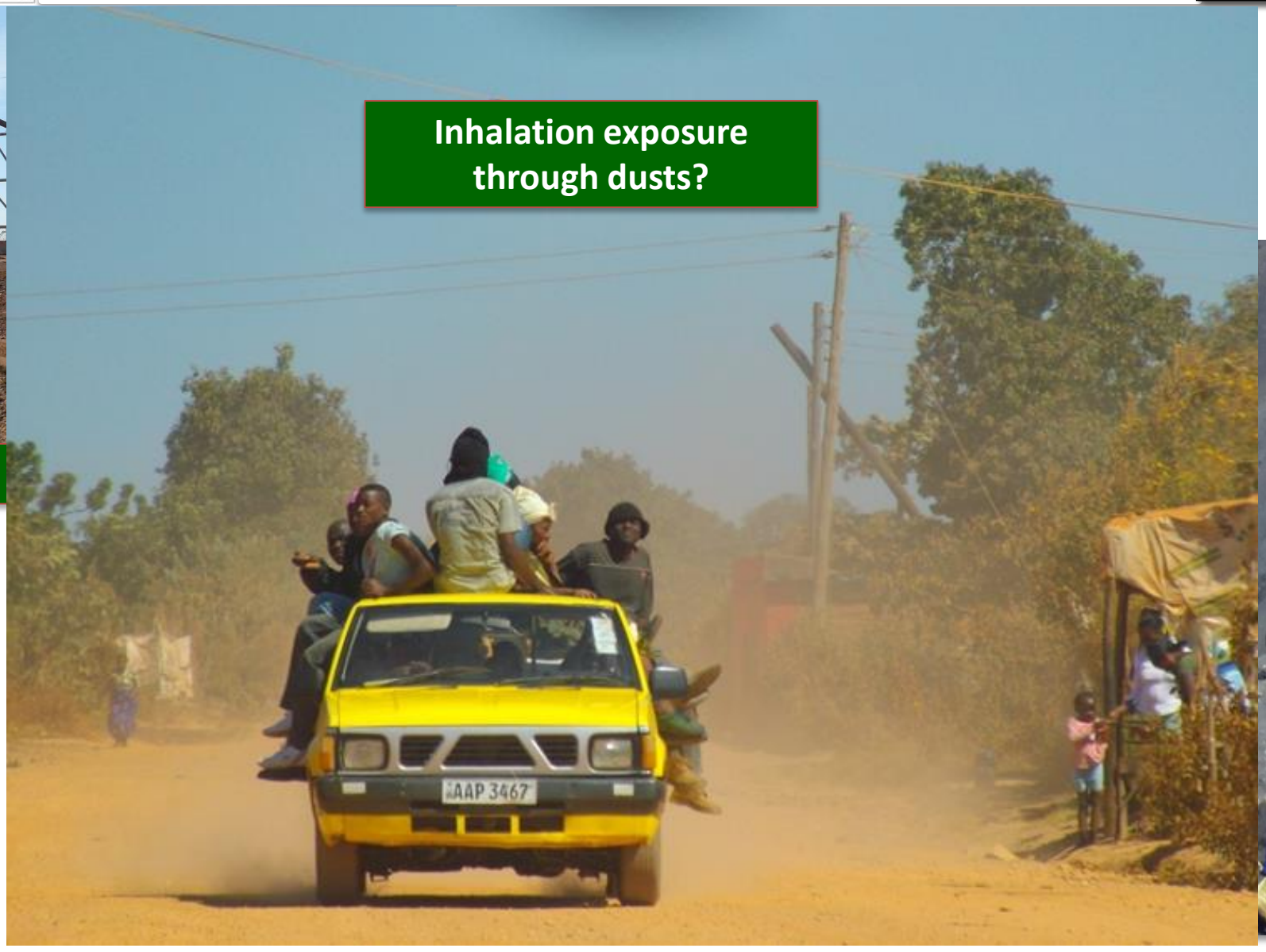
Background - Kabwe City

- Long history of Pb-Zn mining
  - From 1902 to 1994
- Extensive Pb contamination of township soils in the vicinity of the mine
- Kabwe has attracted worldwide attention



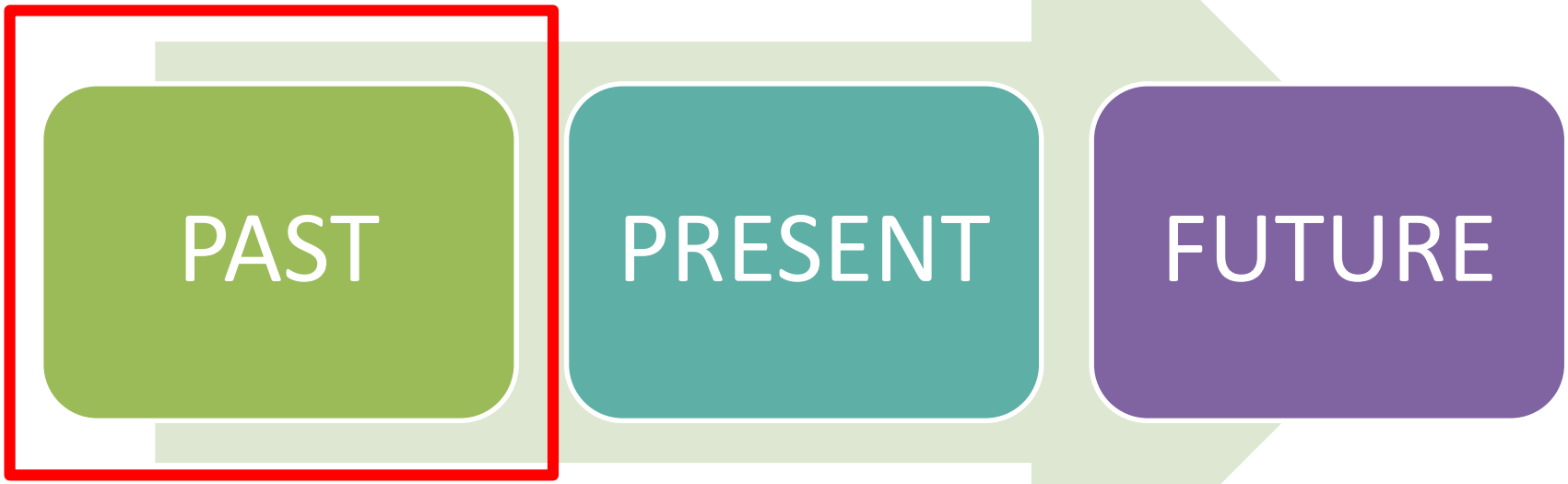
Pb exposure factors

Inhalation exposure through dusts?



Pb exposure factors

Our research activities in Kabwe City



Outline of PAST studies

Pb poisoning in **children?**

2012~

2009~2011

Pb & Cd contamination in **chicken**

goat

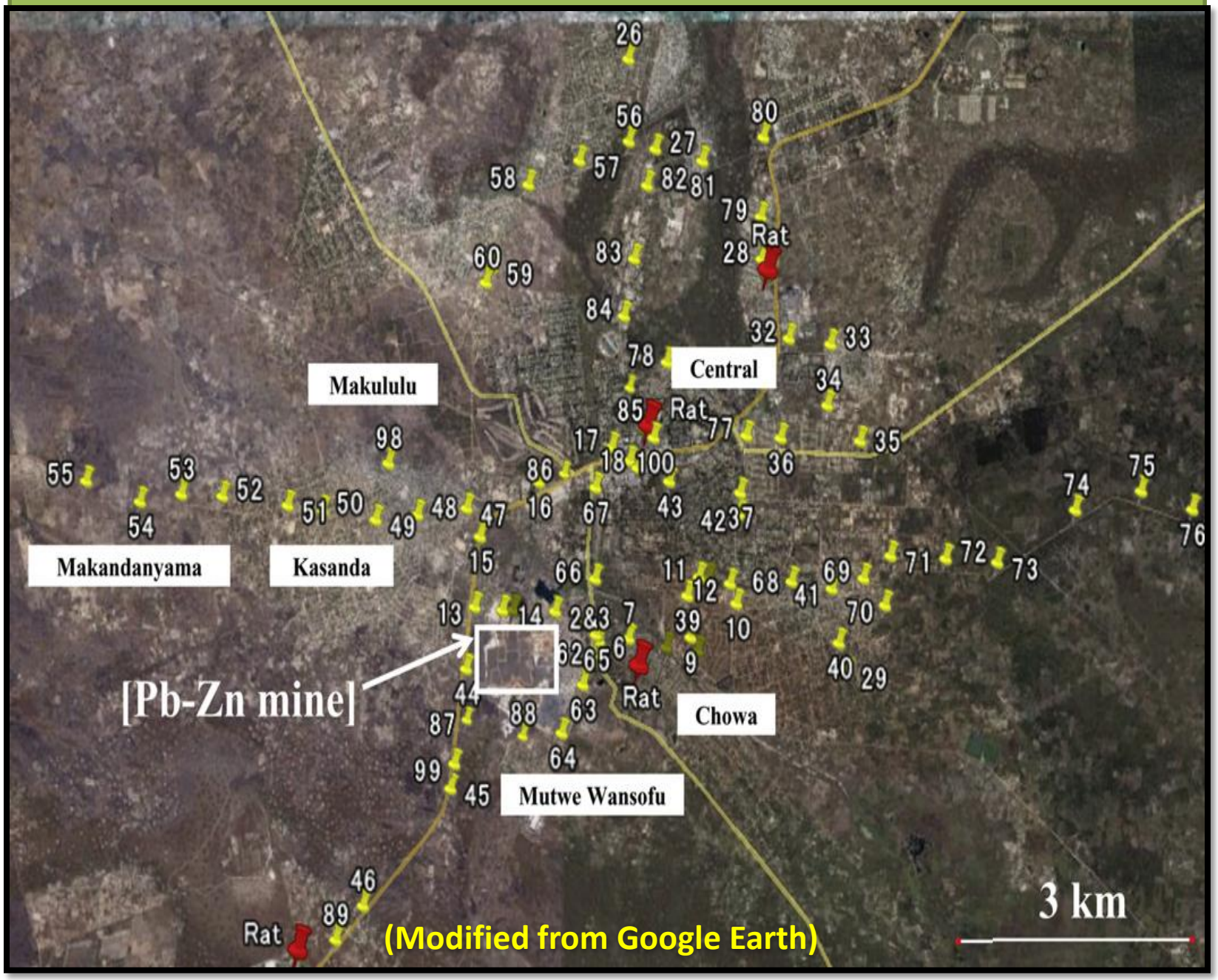
Pb & Cd contamination in **cattle**

Soil contamination and diffusion

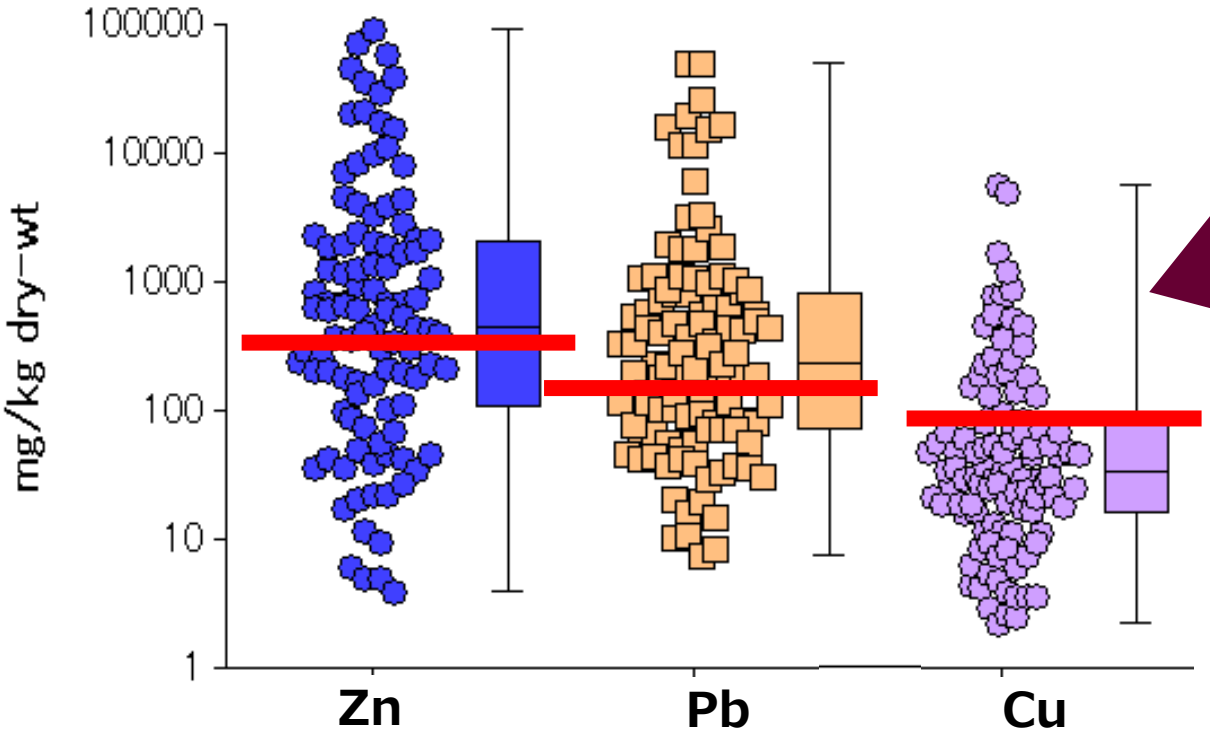
2008~2009

Kabwe Pb & Zn Mining

Soil sampling (n=101, May 2009)



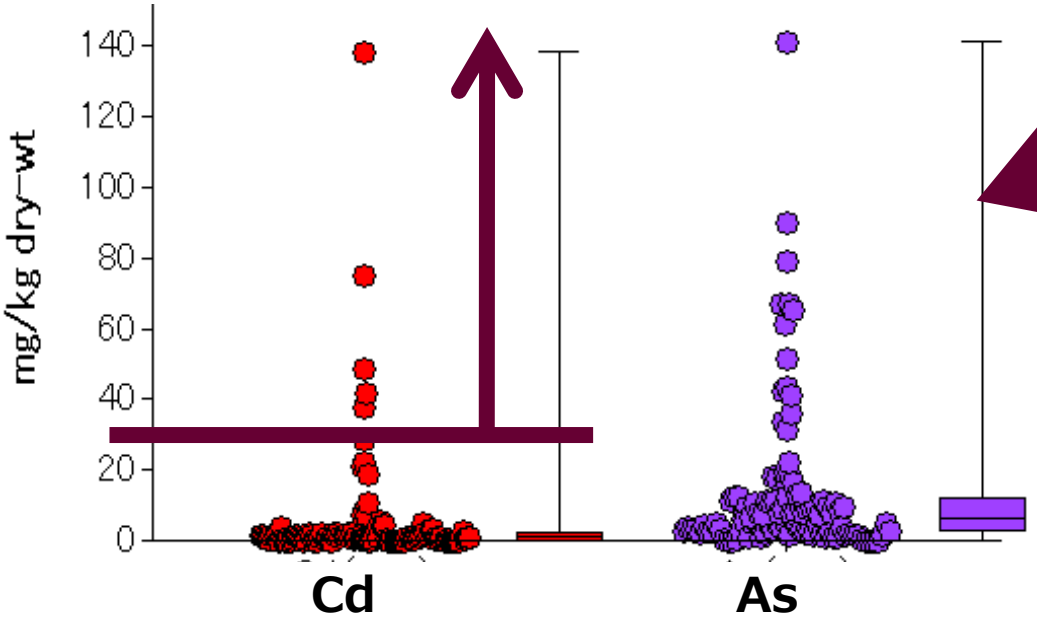
Zn, Pb and Cu concentrations in Kabwe soils



Zn, Cu and Pb concentrations in soil exceeded the FAO Limits.

	Zn	Pb	Cu
Range	5 – 91,000	9 – 51,000	2 – 5,000
Median	610	280	40
FAO Limits	500	150	100

Cd and As in Kabwe soil



Cd and As concentrations also exceed the FAO Limits.

	Cd	As
Range	0.01 - 140	0.04 - 140
Median	1	7
FAO Limits	1.6	18

Pb pollution in children?

Pb & Cd contamination in chicken

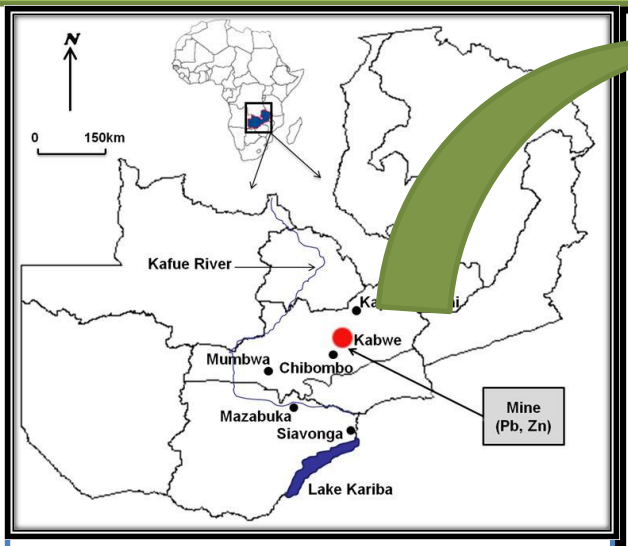
2009~2011

Pb & Cd contamination in cattle

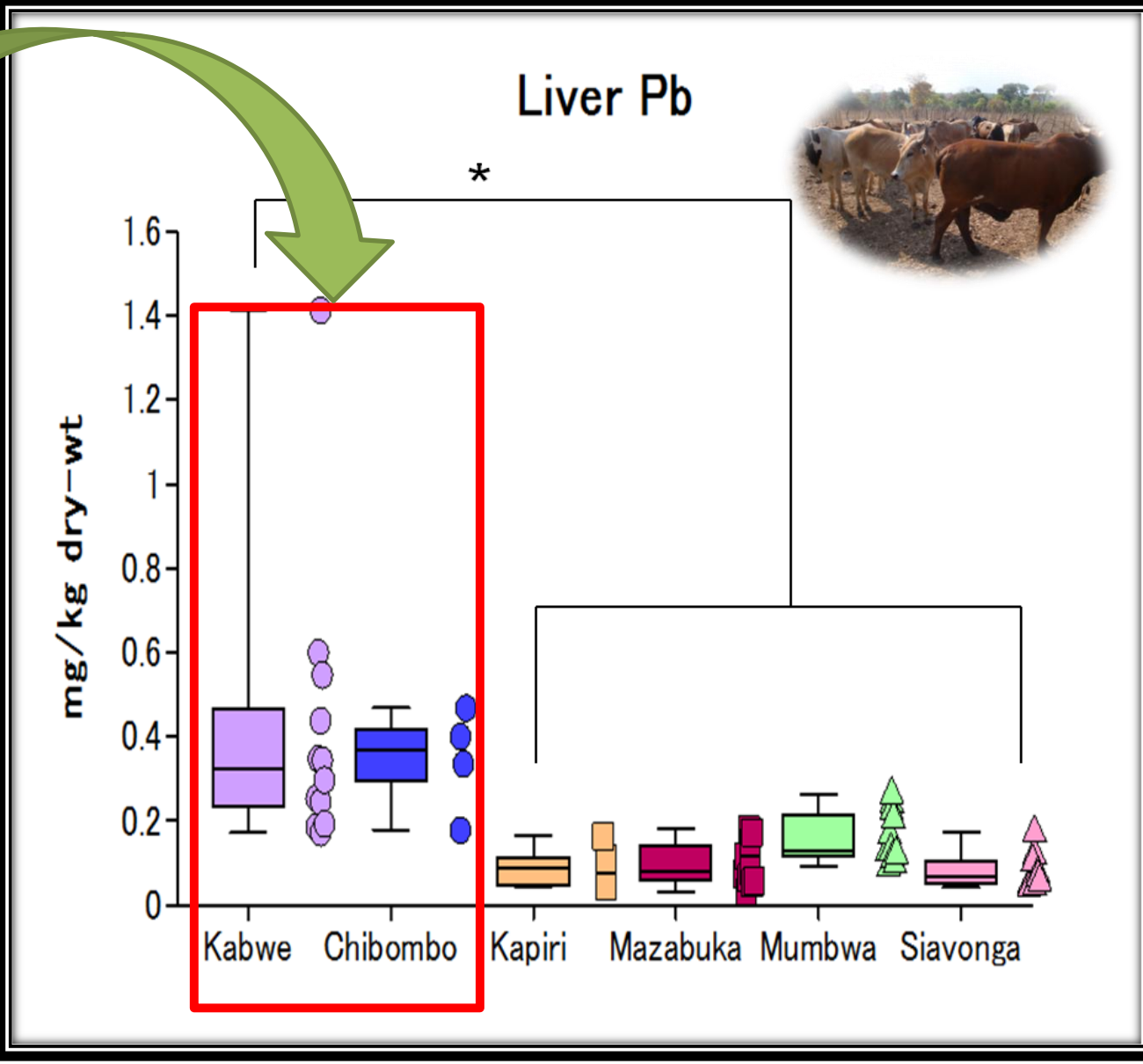
Soil contamination and diffusion

Kabwe Pb & Zn Mining

Regional difference of Pb in cattle liver in Zambia

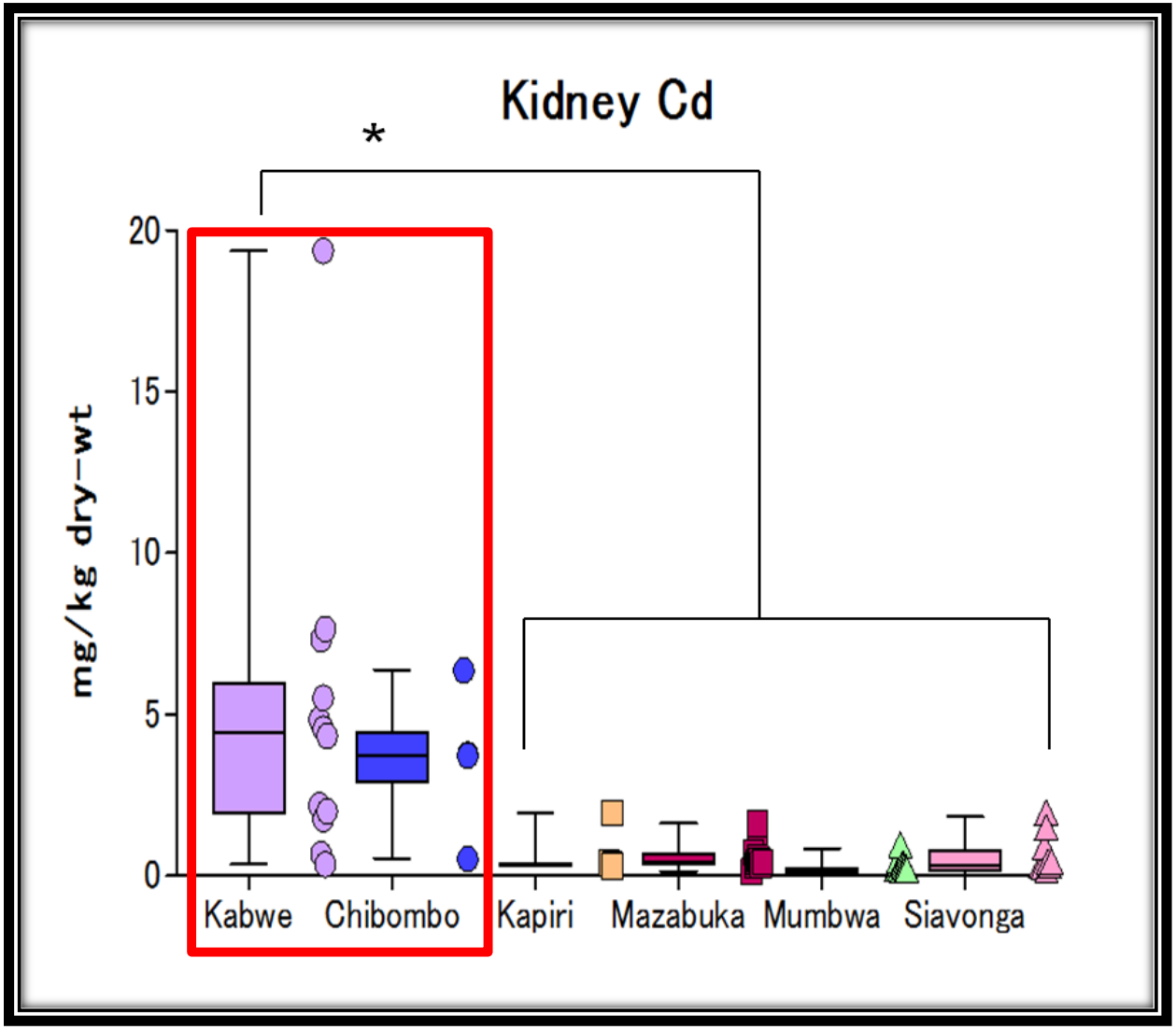


- **Kabwe**
  - **higher levels of Pb in the liver**
- **Chibombo**
  - **Pb levels were similar to Kabwe**
- **Other towns**
  - **Lower Pb levels**
- **Asterisk: $p < 0.001$**

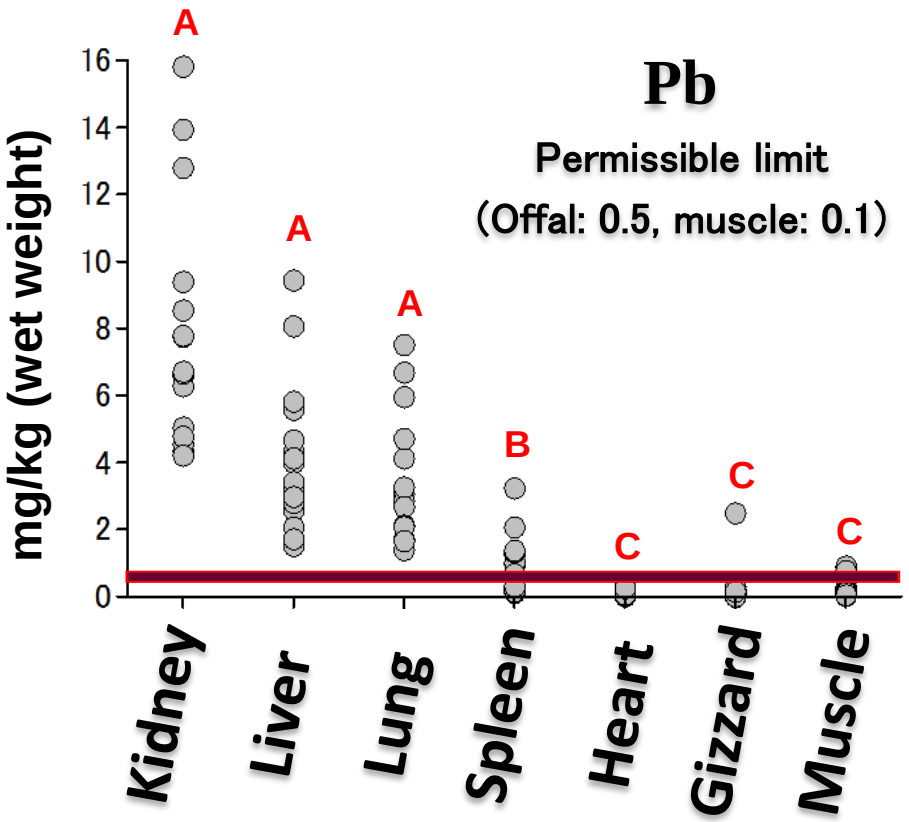


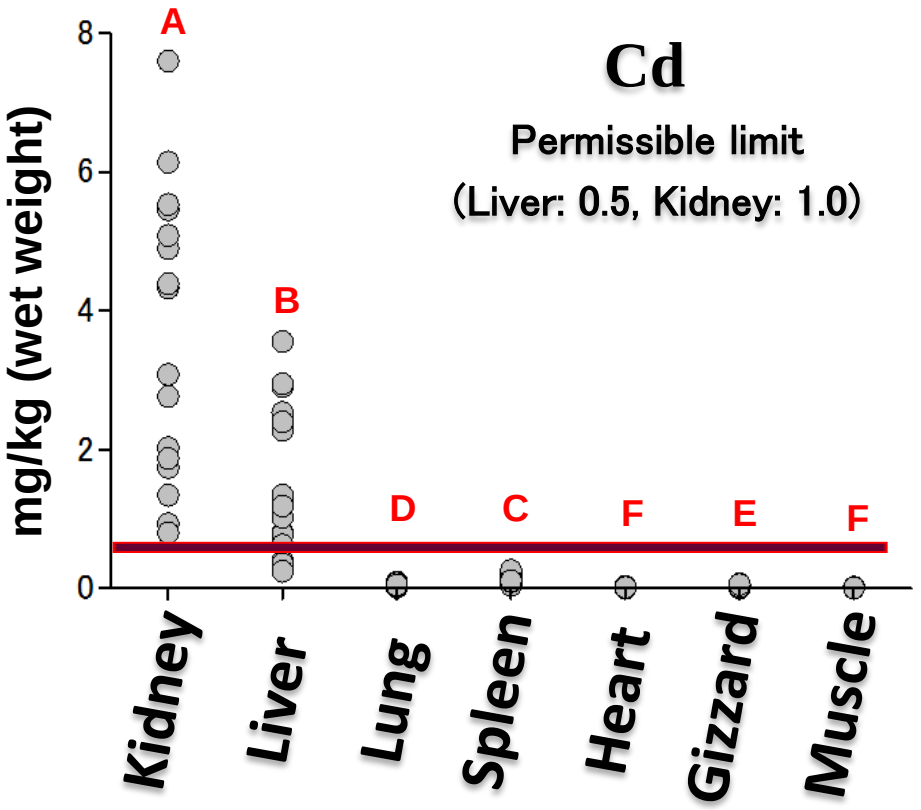
Regional difference of Cd in cattle kidney in Zambia

- **Kabwe**
  - **Higher levels of Cd in kidneys**
- **Chibombo**
  - **Cd levels were similar to Kabwe**
- **Other towns**
  - **Lower Cd levels**
- **Asterisk: $p < 0.001$ (Dunettee test)**



High Pb and Cd levels in muscle and offal of Free-range chickens (n=17) in Kabwe





(Tukey test)

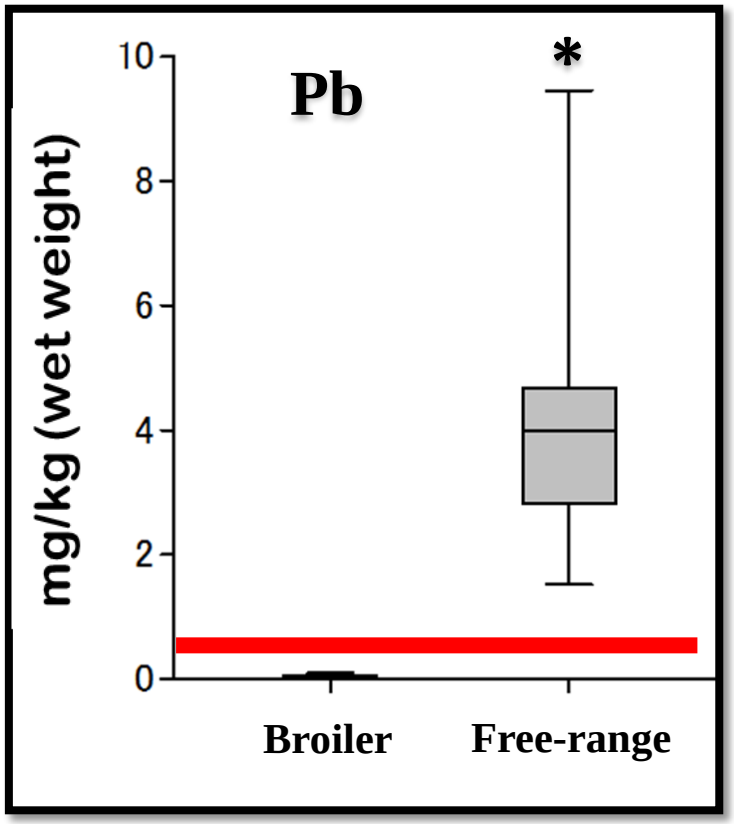
Scavenging Free-range chicken

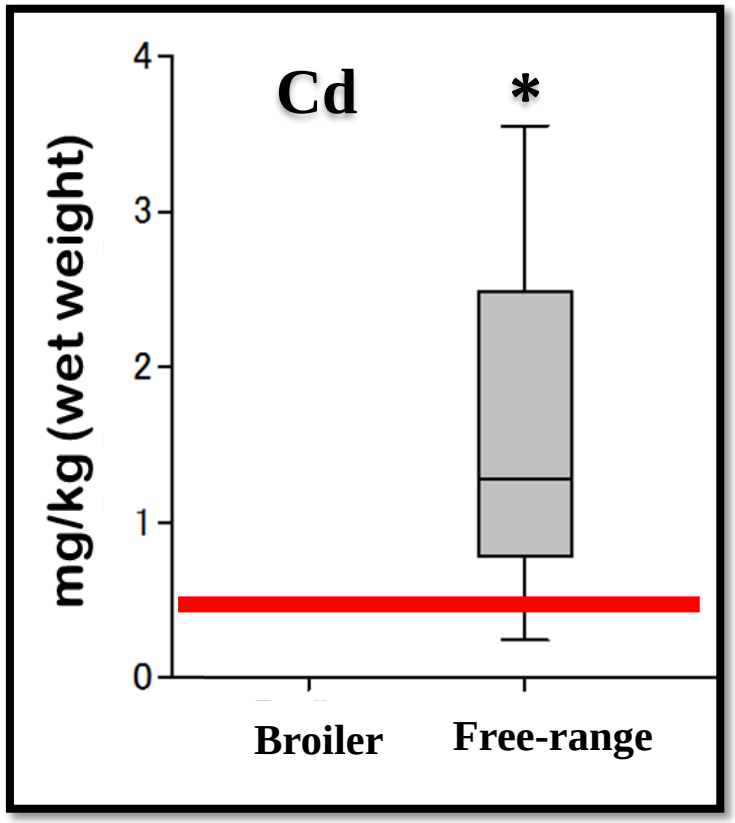
Pb and Cd xceeded the permissible limits

Pb and Cd comparison in liver of Broiler (n=32) and Free-range (n=17) in Kabwe

Broiler  → **Kept indoors and fed commercial feed**

Free-range  → **Roam and scavenge for food in the mine townships**





Outline of PAST studies

Pb poisoning in
children?

Pb & Cd
contamination
in chicken

Soil contamination
and diffusion

Pb & Cd
contamination
in cattle

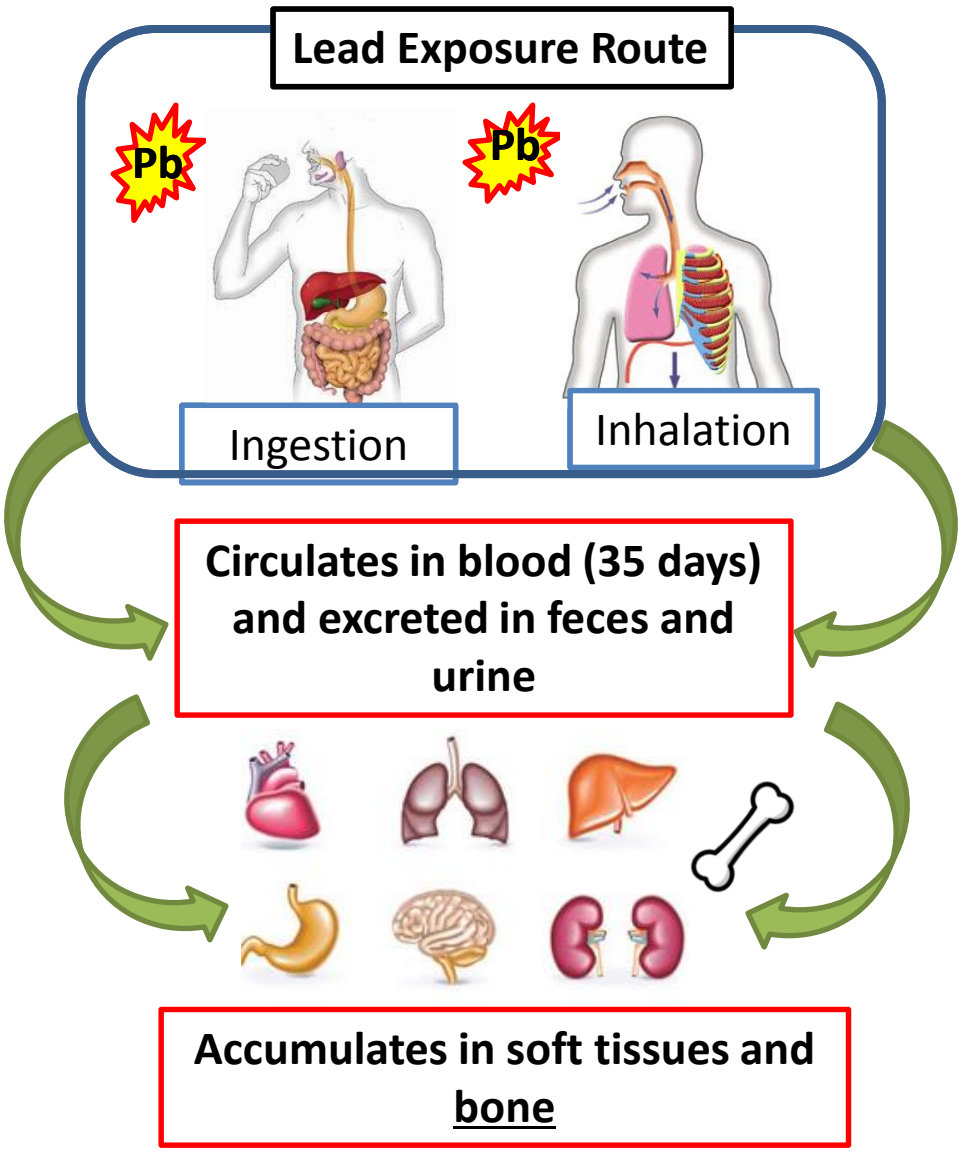
Kabwe Pb & Zn Mining

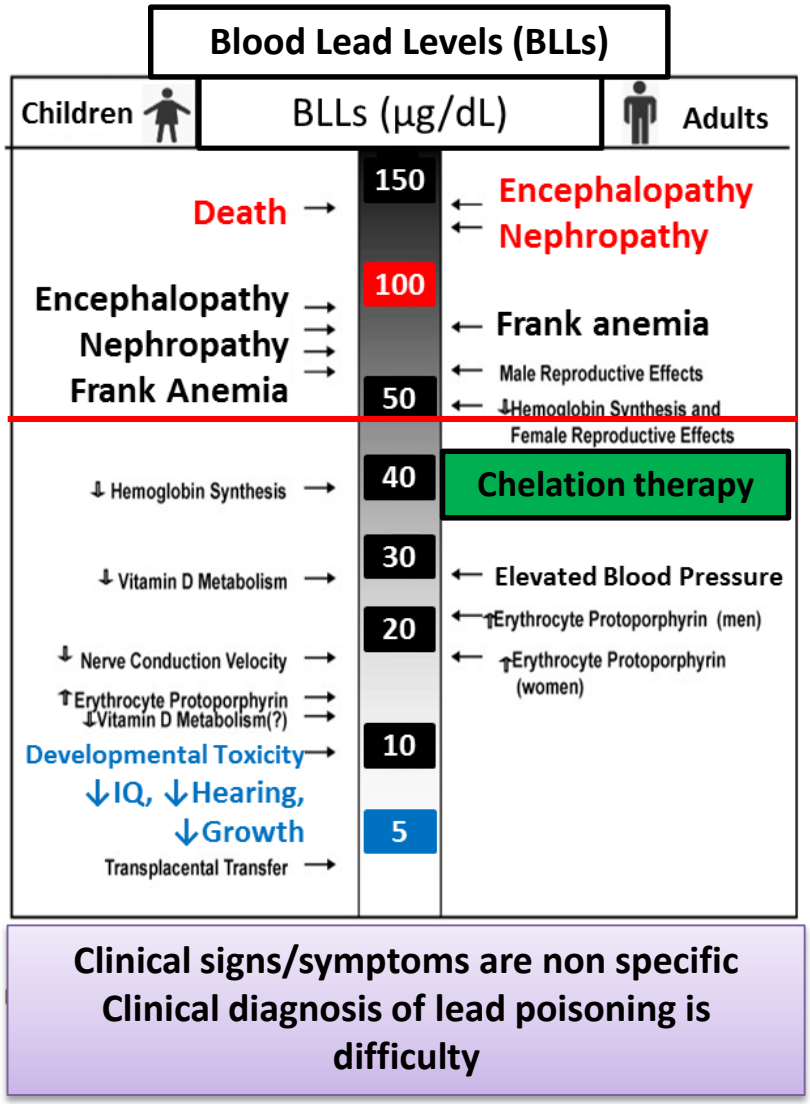
Childhood lead poisoning

- Childhood lead (Pb) poisoning is a serious public health concern
- Toxicity affects multiple organ systems resulting in numerous morphological, biochemical and physiological changes
  - Hematological disorders
  - Nervous system disturbances
  - Impairment of liver and kidney functions

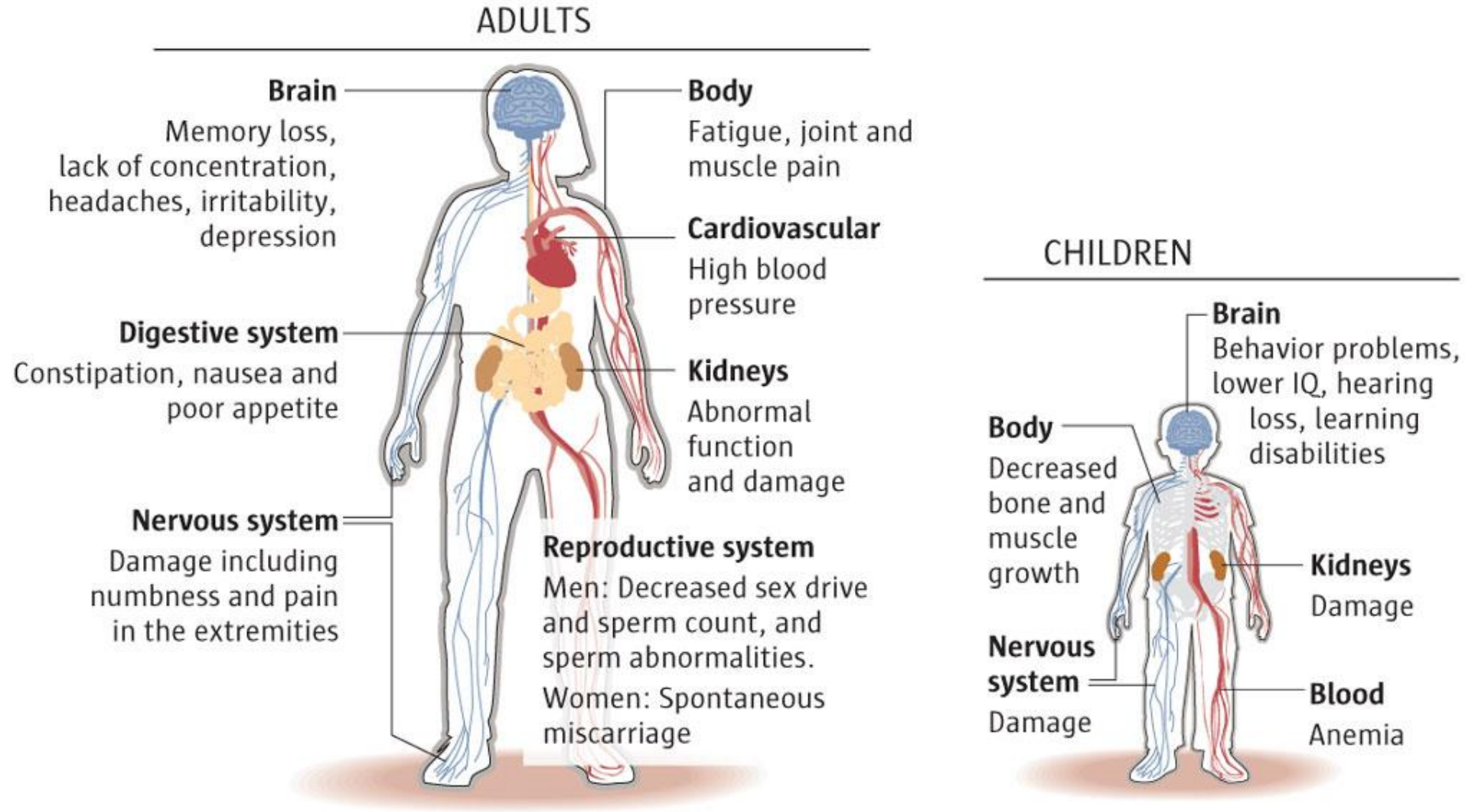
- Young children are vulnerable to Pb poisoning
  - Hand-to-mouth activities
  - Higher gastrointestinal absorption of Pb (40 – 50%)
  - Iron and calcium deficiencies – enhance Pb absorption
  - Only 70% of absorbed Pb is stored in bones and teeth
  - Constant bone remodeling → "Endogenous contamination"
  - Sensitivity of the developing nervous system to Pb toxicity
  - Persistent neurological effects after exposure

Lead exposure and critical BLLS



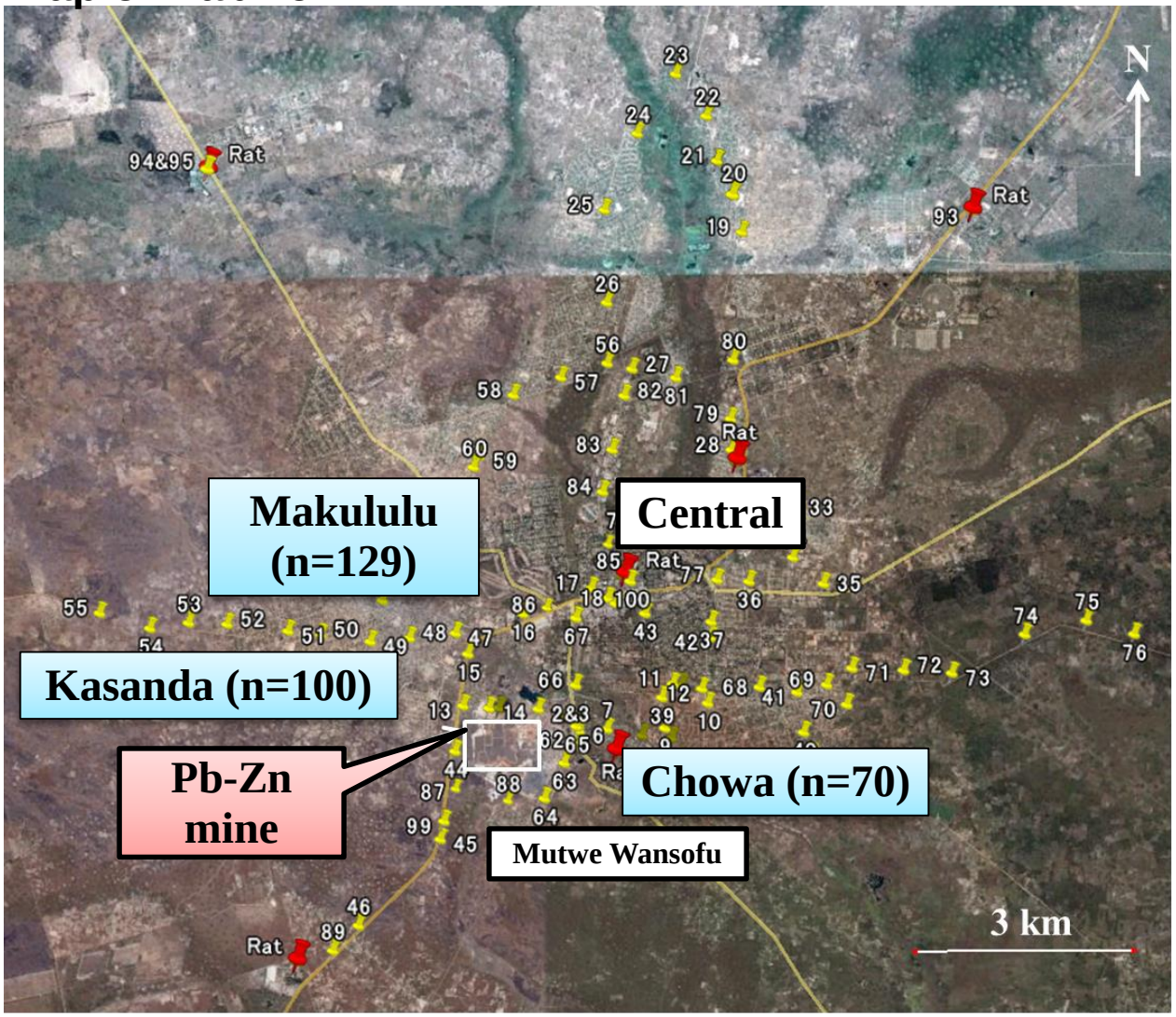


Clinical signs and symptoms



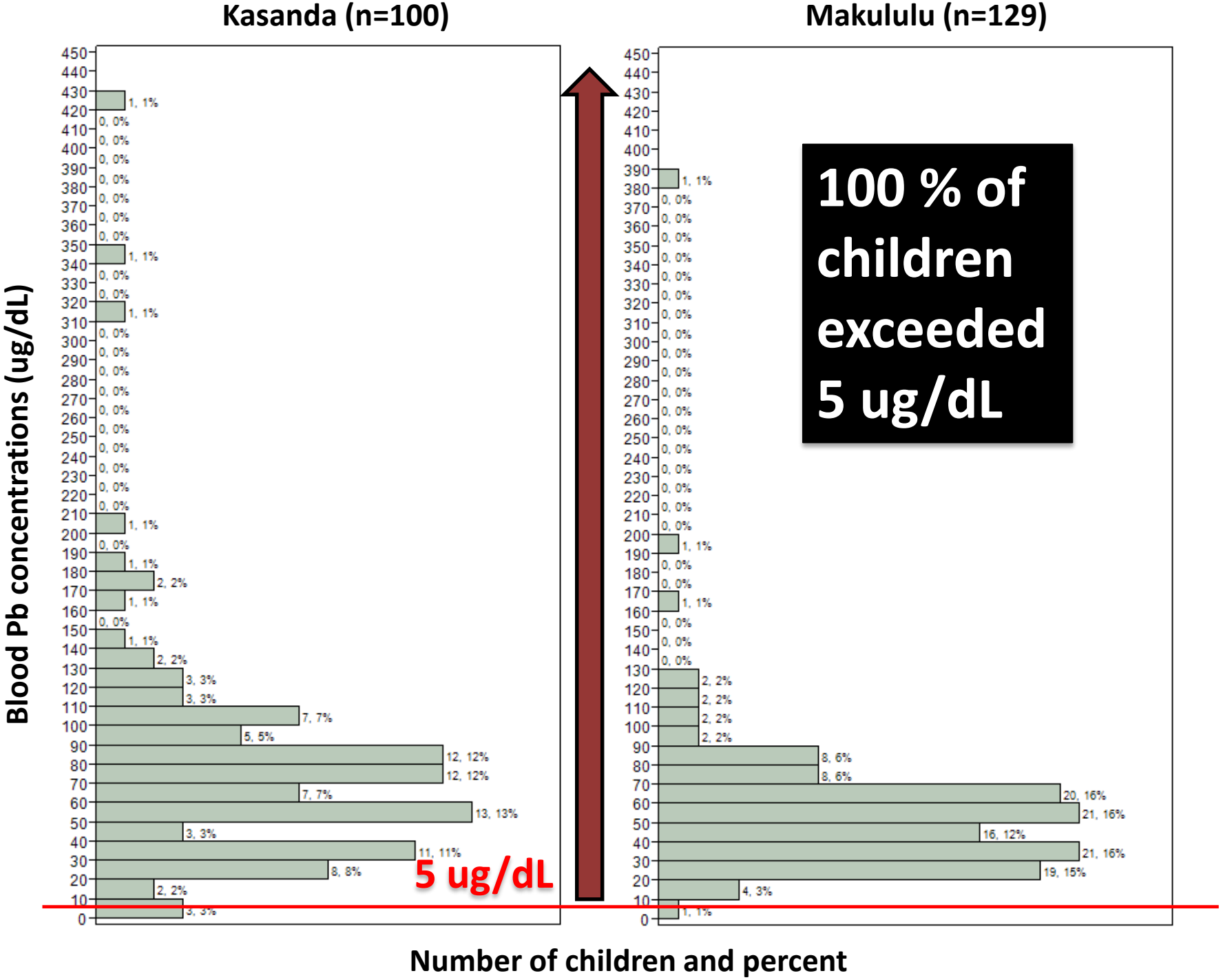
Human sample collection - May 2012

Map of Kabwe

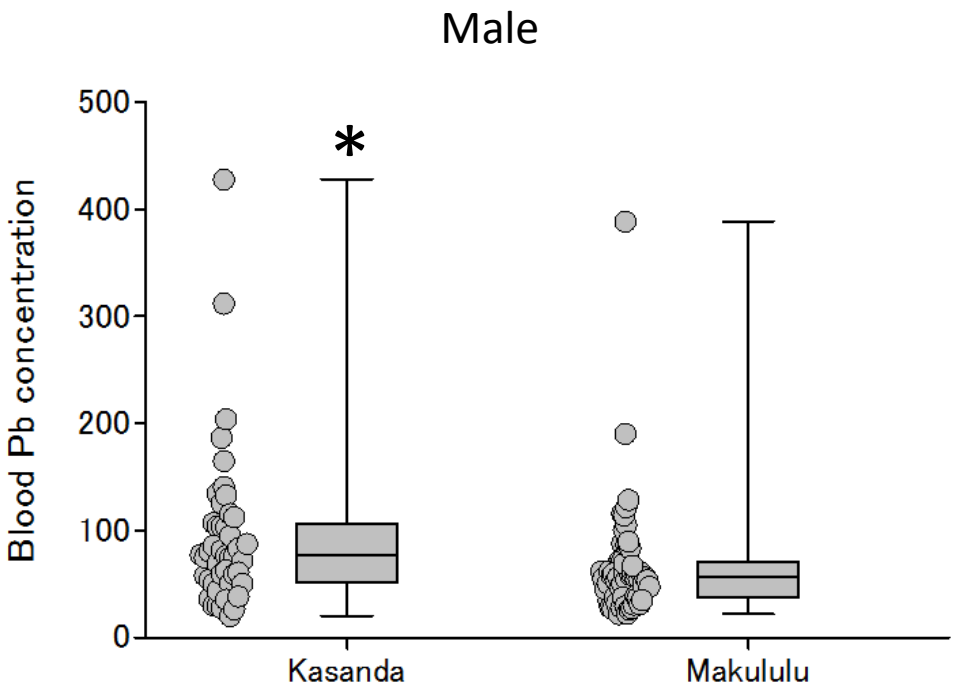


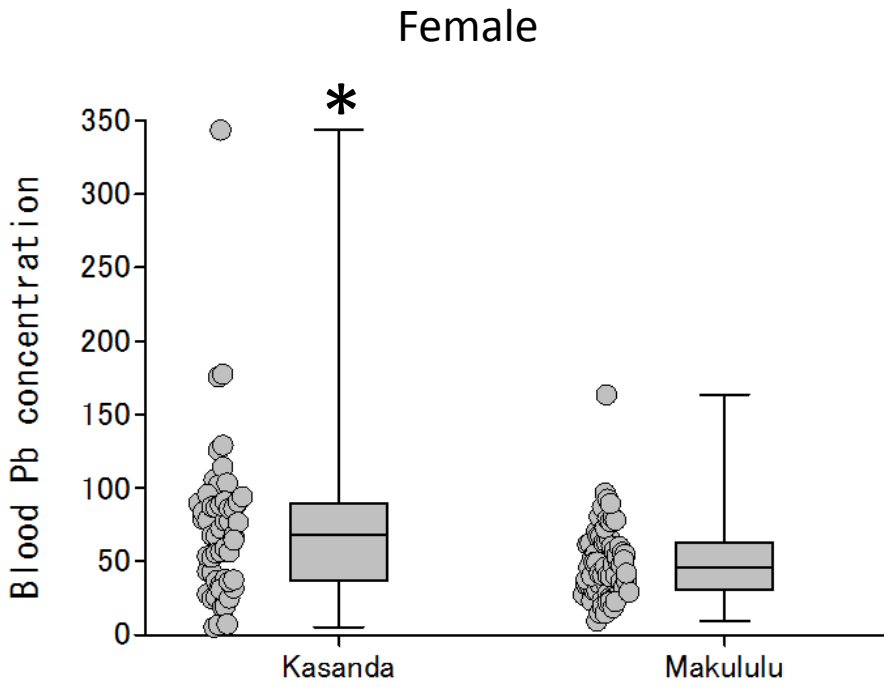
- We collected samples from local communities around Pb-Zn mine.
- 0-7 years old children were main participants.
- 3 Health Centres (Makululu, Kasanda, Chowa area)
- 299 blood
- 250 urine
- 250 feces

(It was difficult to collect urine and fecal samples from all participants)


Kasanda (n=100)
Makululu (n=129)
Blood Pb concentrations (ug/dL)
Number of children and percent
5 ug/dL
100 % of children exceeded 5 ug/dL

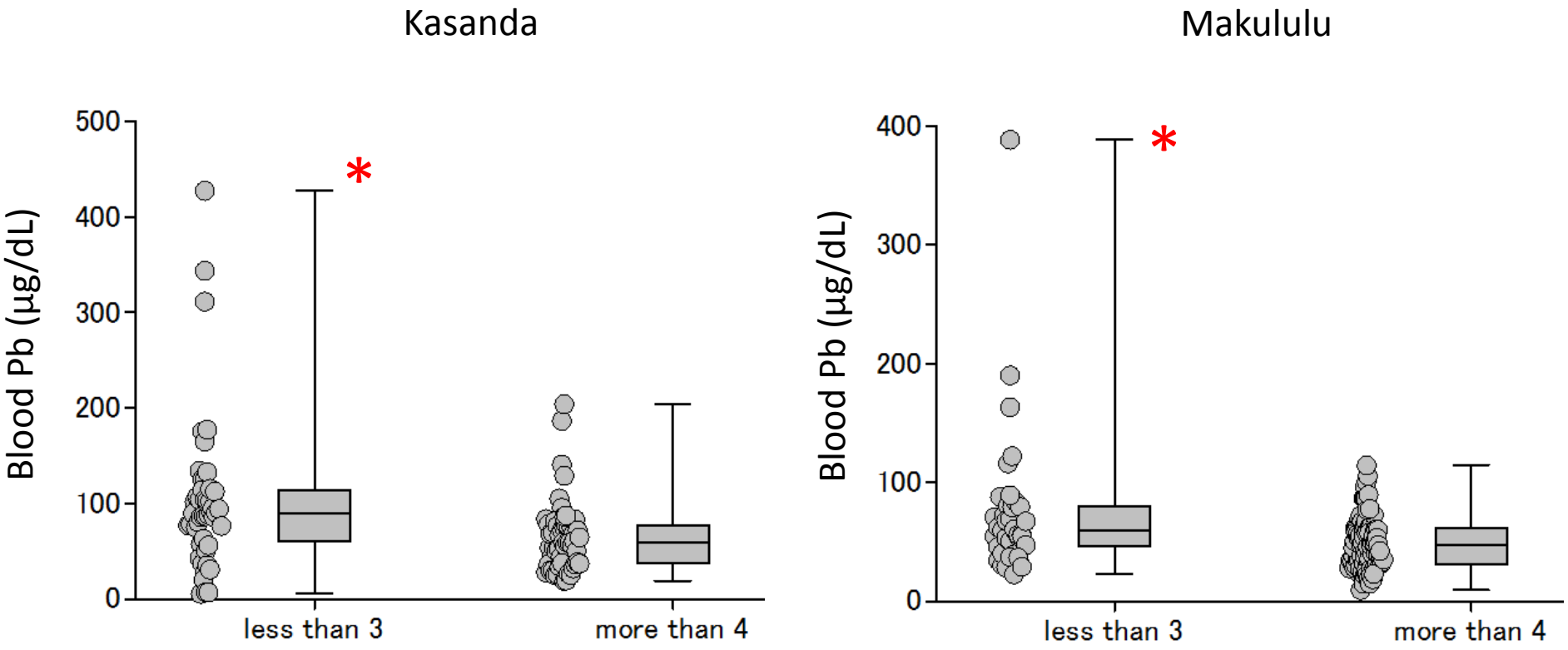
BLL: Kasanda vs Makululu (Boys and girls analyzed separately)





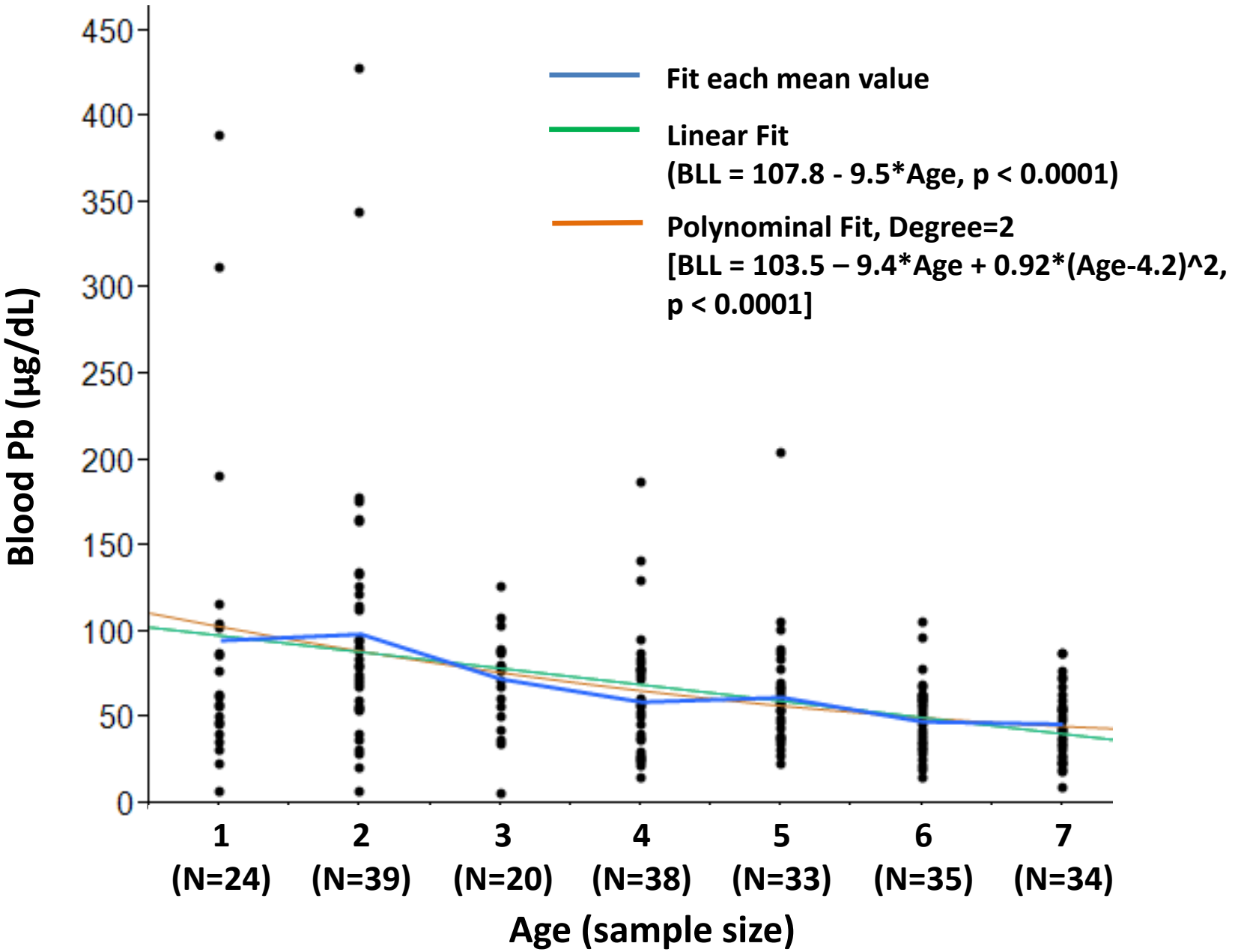
Kasanda was significantly higher in both boys and girls

Age difference (0-3 years vs 4-7 years)



Younger children had significantly higher BLL than older children

Correlation between Age & blood Pb

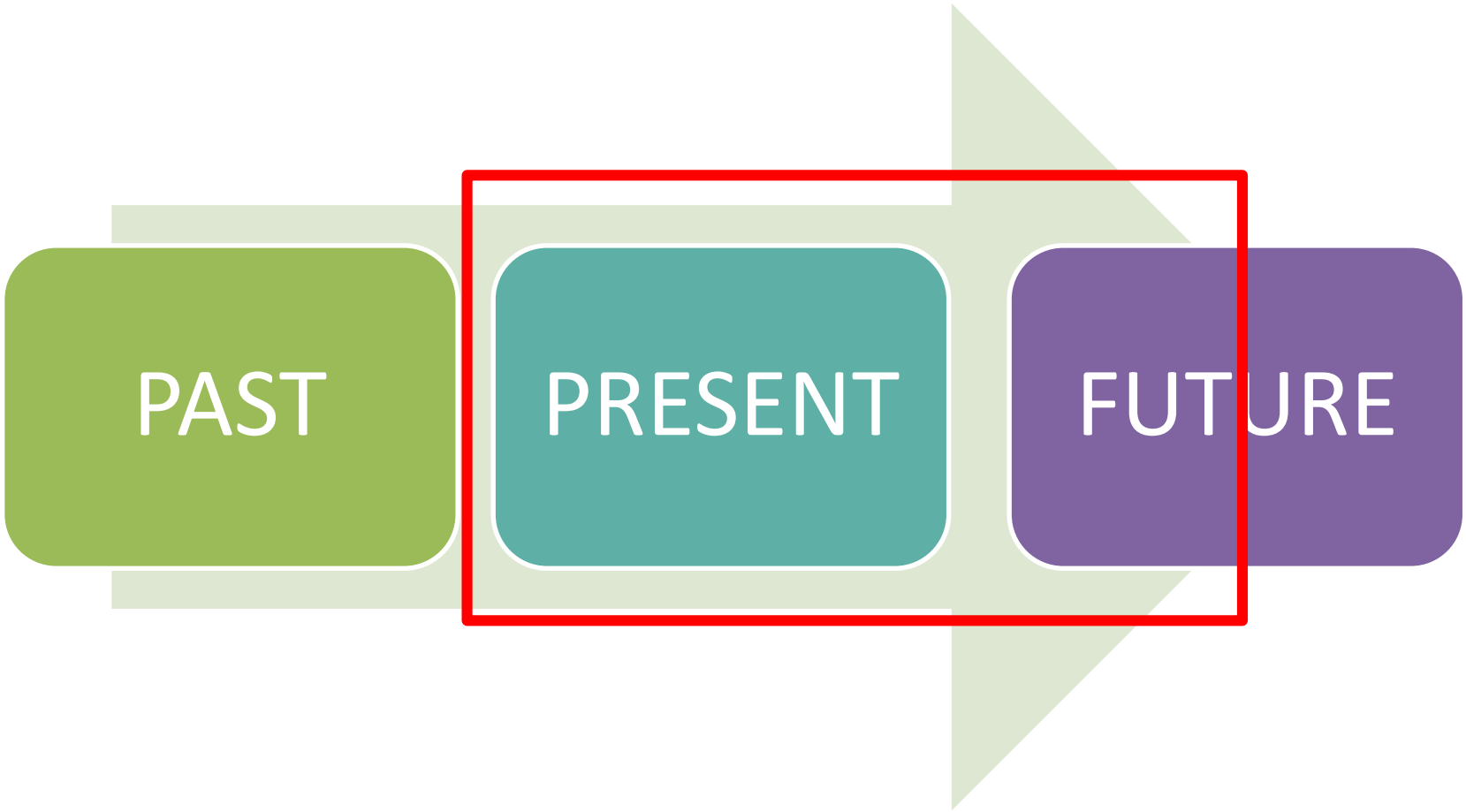


Publications on PAST research

1. **Yabe J** et al. Lead poisoning in children from townships in the vicinity of a lead-zinc mine in Kabwe, Zambia. Chemosphere119:941-7 (2015)
2. **Nakayama SMM**, et al. Accumulation and biological effects of metals in wild rats in mining areas of Zambia. Environmental Monitoring and Assessment 185:4907-4918 (2013)
3. **Yabe J** et al. Metal distribution in tissues of free-range chickens near a lead-zinc mine in Kabwe, Zambia. Environ Toxicol Chem. 2013 Jan;32(1):189-192.
4. **Nakayama SMM**, et al. GIS-based source estimation of Cu pollution in Lake Itezhi-tezhi and metal accumulation profiles in Oreochromis spp. from both field and laboratory studies. Arch Environ Contam Toxicol. 2013 Jan;64(1):119-129.
5. **Nakayama S.M.M**, et al. Metal contaminated soil from mining area caused metal accumulation and biological responses in rats. JJVR, 61:S77-S79 (2013)
6. **Yabe J** et al. Accumulation of metals in the liver and kidneys of cattle from agricultural areas in Lusaka, Zambia. J Vet Med Sci. 2012 Oct;74(10):1345-7.
7. **Nakayama SMM,** et al. Metal and metalloid levels and bio-accumulation characteristics in soil, sediment, land plants and hippopotami (Hippopotamus amphibius L) from the South Luangwa National Park, Zambia. Ecotox Environ Saf. 2012 Jun;80:333-8.
8. **Yabe J** et al. Uptake of lead, cadmium, and other metals in the liver and kidneys of cattle near a lead-zinc mine in Kabwe, Zambia. Environ Toxicol Chem. 2011 Aug;30(8):1892-7.
9. **Nakayama SMM** et al. Metal and metalloid contamination in roadside soil and wild rats around a Pb-Zn mine in Kabwe, Zambia.Environmental Pollution 159 (2011) 175-18.
10. **Yabe J,** et al. Current levels of heavy metal pollution in Africa. J Vet Med Sci. 2010 Oct;72(10):1257-63.
11. **Nakayama** , et al. Heavy metal accumulation in lake sediments, fish (Oreochromis niloticus and Serranochromis thumbergi) and crayfish (Cherax quadricarinatus) in Lake Itezhi-tezhi and Lake Kariba, Zambia. Arch Environ Contam Toxicol. 2010 Aug;59(2):291-300.

Research questions

- Extent of Pb pollution and poisoning in Kabwe?
- Exposure pathways?
- Health impact of Pb poisoning?
- Economic impact of Pb pollution?
- Neurodevelopmental impact of Pb poisoning?
- Suitable remedial measures?


PAST
PRESENT
FUTURE

KAMPAI Project:

KAbwe Mining Pollution Amelioration Initiative

KAMPAI Project

Japanese side:
Hokkaido University

KAbwe Mine Pollution Amelioration Initiative
KAMPAI
ZAMBIA & JAPAN

Zambian side:
University of Zambia and GRZ Ministries

World Bank and Pure Earth (NPO)

KAMPAI Project Outputs

Output 1:
Monitoring and risk assessment in Kabwe mining area (and geo-ecological surveillance of broad areas in Zambia)

→ Faculty of Agriculture Science team:
Measurement of lead in soil and environmental samples in detail

Output 2:
Establishment of economic assessment system for human/animal health and ecosystem and visualization

→ Faculty of Veterinary Medicine, Medice, Education and Economics team:
Risk and economics assessment

Output 3:
Development of geo-ecological database and remediation technology

→ Faculty of engineering team:
New environmental remediation technology of the soil

Output 4: Capacity building

Project preparatory meetings - 2015

Project Output 2 (2016 – 2020)

Specific objectives
• Measure blood Pb concentrations in mother (venous and cord blood) and child pairs in Kabwe
• Measure Pb levels (blood, urine and feces) in children under the age of 7
• Measure Pb concentrations in breast milk
• Measure biomarkers to determine the effects of Pb exposure
• Neurodevelopment assessment of Pb exposure in children
• Assess the socio-economical impact of Pb pollution in Kabwe

Blood Pb concentrations in children, maternal blood and breast milk

❑ Lead crosses the placenta

- ➢ Maternal and umbilical cord blood Pb levels have a strong correlation
- ➢ Blood Pb levels of the infant is similar to that of the mother

❑ Milk Pb levels

- ➢ Pb levels in breast milk increase with levels in maternal blood
- ➢ Concentrations in breast milk indicates postnatal exposure
- Fetuses and infants are at the highest risk of Pb neurotoxicity

Stable Pb isotope ratios and biomarkers

- Stable Pb isotope ratios
  - ICP-MS
  - To clarify source of exposure
- Blood biochemistry
  - COBAS Ready - blood chemical analyser
  - To determine health effects
- Plasma/Urine biomarker
  - HPLC-UV
  - To determine markers of exposure and effect

Neurodevelopment Assessment

- Children under 3 years of age
  - Infants and their mothers will be followed up for a period of 48 months at birth and thereafter every year
  - The Ages and Stages Questionnaire (ASQ) will be used to assess the cognitive, motor, language and behaviour of infants from one to 42 months of age

Neurodevelopment Assessment: 3-10 years old

- Zambia Child Assessment Tool (ZamCAT)
  - For preschool children to assess language, cognition and fine motor skills
- Neuropsychological Assessment Tool (NEPSY)
  - For 3-16 year old to assess subtle central nervous system deficits (social, academic and behavioural difficulties)
- Universal Nonverbal Intelligence Test (UNIT)
  - For 5-17 year old to assess general intelligence using nonverbal means
- Kaufman's Assessment Battery for Children (KABC-II)
  - For 7-18 year old to assess cognitive and mental processes (Sequential Processing, Simultaneous processing, Learning and Planning Ability)

Economic impact assessment

- The impact of lead in Kabwe will be “quantitatively” estimated to establish a model for new assessment system
- No study has compared the Pb exposure of individuals and their socioeconomic conditions for the Kabwe pollution case
- We will investigate the interaction between Pb concentrations of the studied individuals and their socioeconomic characteristics
- We will also investigate the economic consequences of the environmental and health effects in terms of productivity and other related consequences

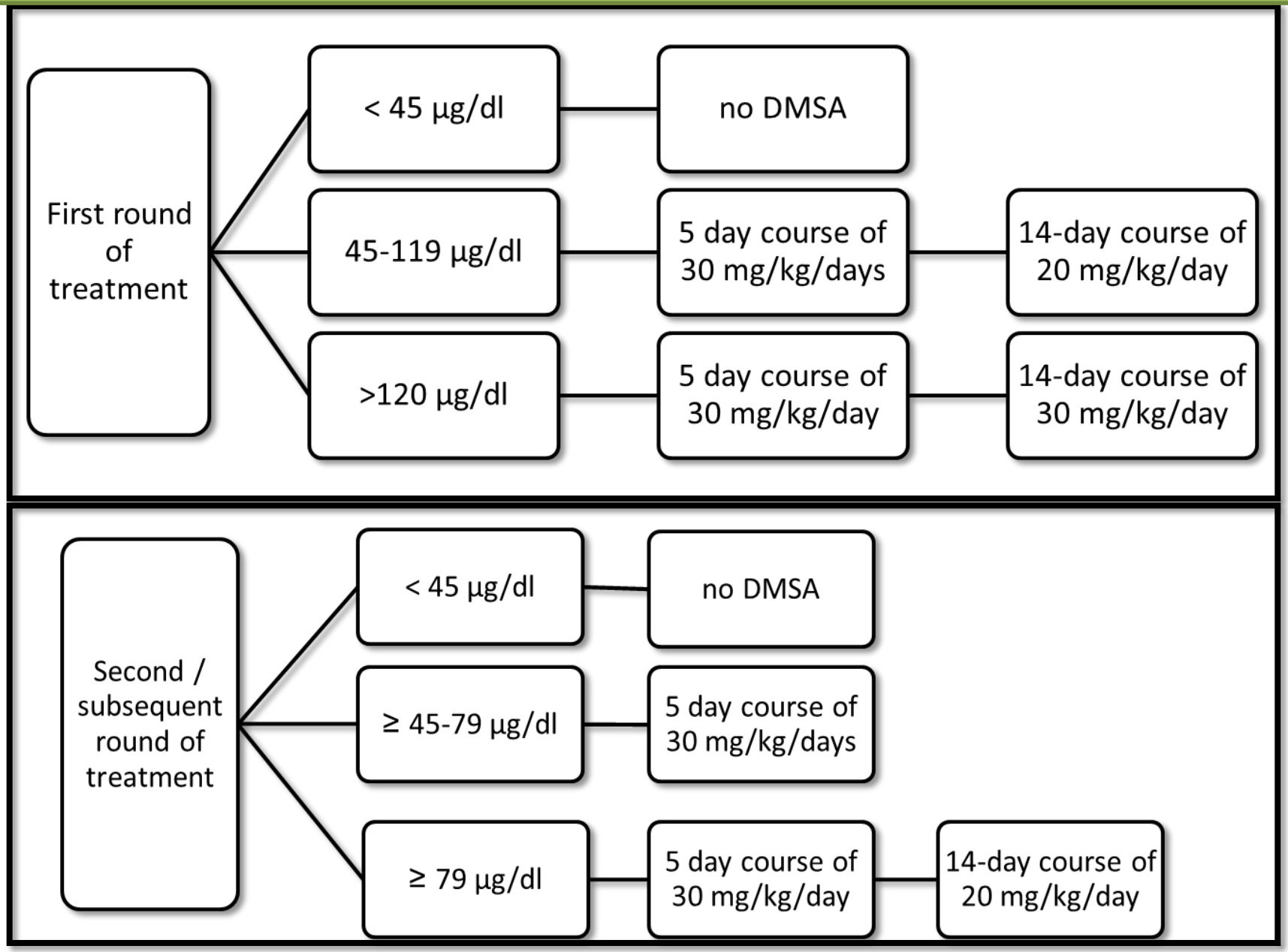
Ethical Considerations

- The following specific standards will be upheld:
  - Ethical clearance already obtained from UNZABREC
  - Clearance already obtained from (NHRA – MOH)
  - Written informed consent will be obtained from parents
  - Minimum risk will be upheld in the drawing of biologic samples by the local medical personnel
  - Samples (cord blood, breast milk, blood, hair and urine) will be disposed off according to stipulated guidelines
  - The presence of the parent/caregiver during the neurodevelopmental testing will also be a requirement
  - Respondents will be assured of confidentiality
  - Parents/guardians of affected children will be referred for further assessment and therapy for the child

Chelation therapy

- Intravenous formulations
  - When clinical symptoms consistent with lead poisoning or when blood lead levels are greater than 70 µg/dL
  - Edetate calcium disodium (CaNa2EDTA) can be used in conjunction with dimercaprol
- Oral formulations
  - Recommended for BLL > 45 µg/dL
  - Dimercaptosuccinic Acid (**DMSA**, Succimer) is the drug most commonly used
  - Other oral agents include DMPS (Unithiol) and penicillamine
  - Zinc can be adversely affected by DMSA

Pb poisoning treatment protocol (DMSA)



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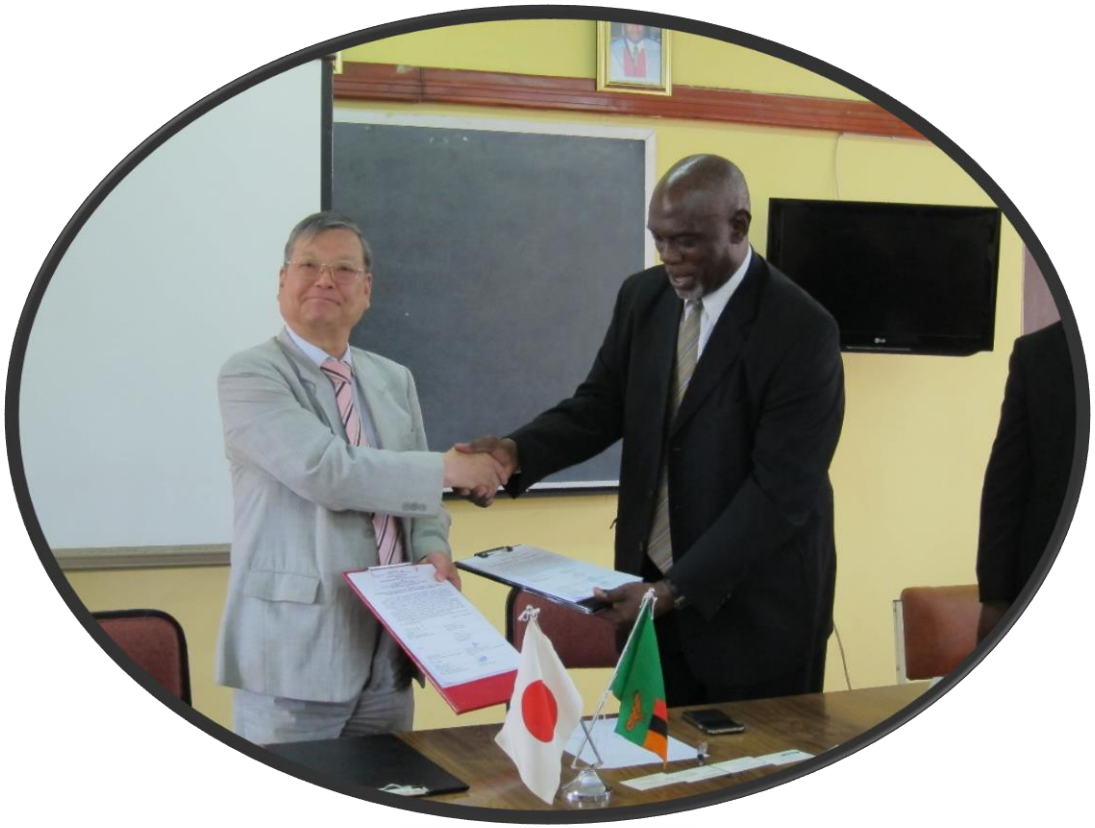

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