Impacts of past mining activities on the Environment in Kabwe Town, Zambia

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IGCP / Sida Projects 594 and 6006 CLOSING WORKSHOP, Praha, Czech Republic

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Outline of Presentation

Background History

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Conclusion

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Background History

Kabwe is capital Central Province of Zambia
Total Population – 250,000

- Lead – Zinc Mine opened in 1904.

- Over the years mining included open cast & underground, mineral processing, smelting and refining with sulphide orebodies, pyrite, sphalerite, galena – minor covellite, chalcopyrite, chalcocite, bornite & tetrahedrite

- Mine officially closed in 1994

- Rehabilitation and Decommissioning Plan in 1995

Substantial informal setting of 35% of Kabwe's total population live in unplanned settlement

Soils

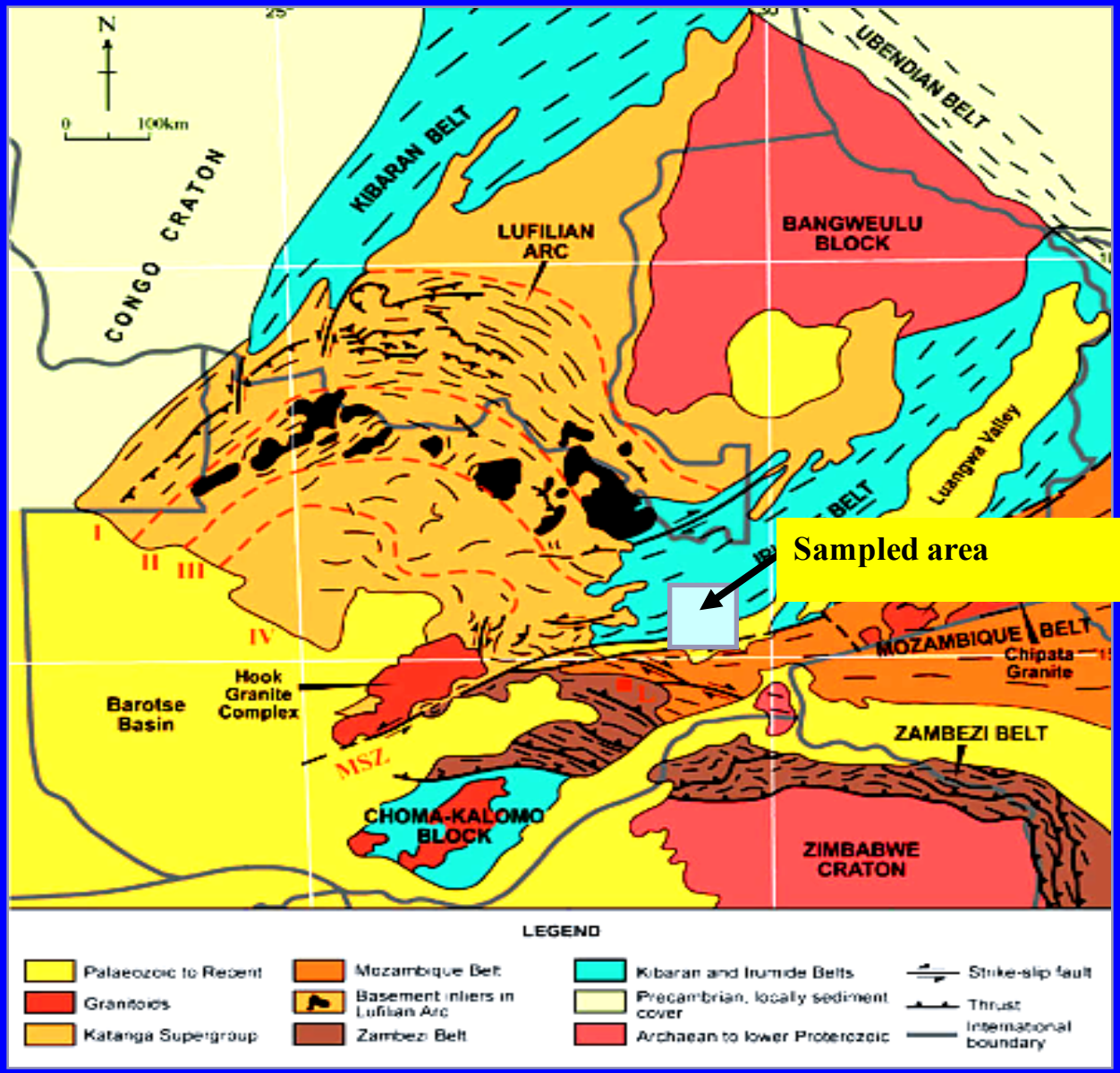
According to the FAO/UNESCO (1997) classification of soils, the acrisols are most abundant in the Kabwe area.

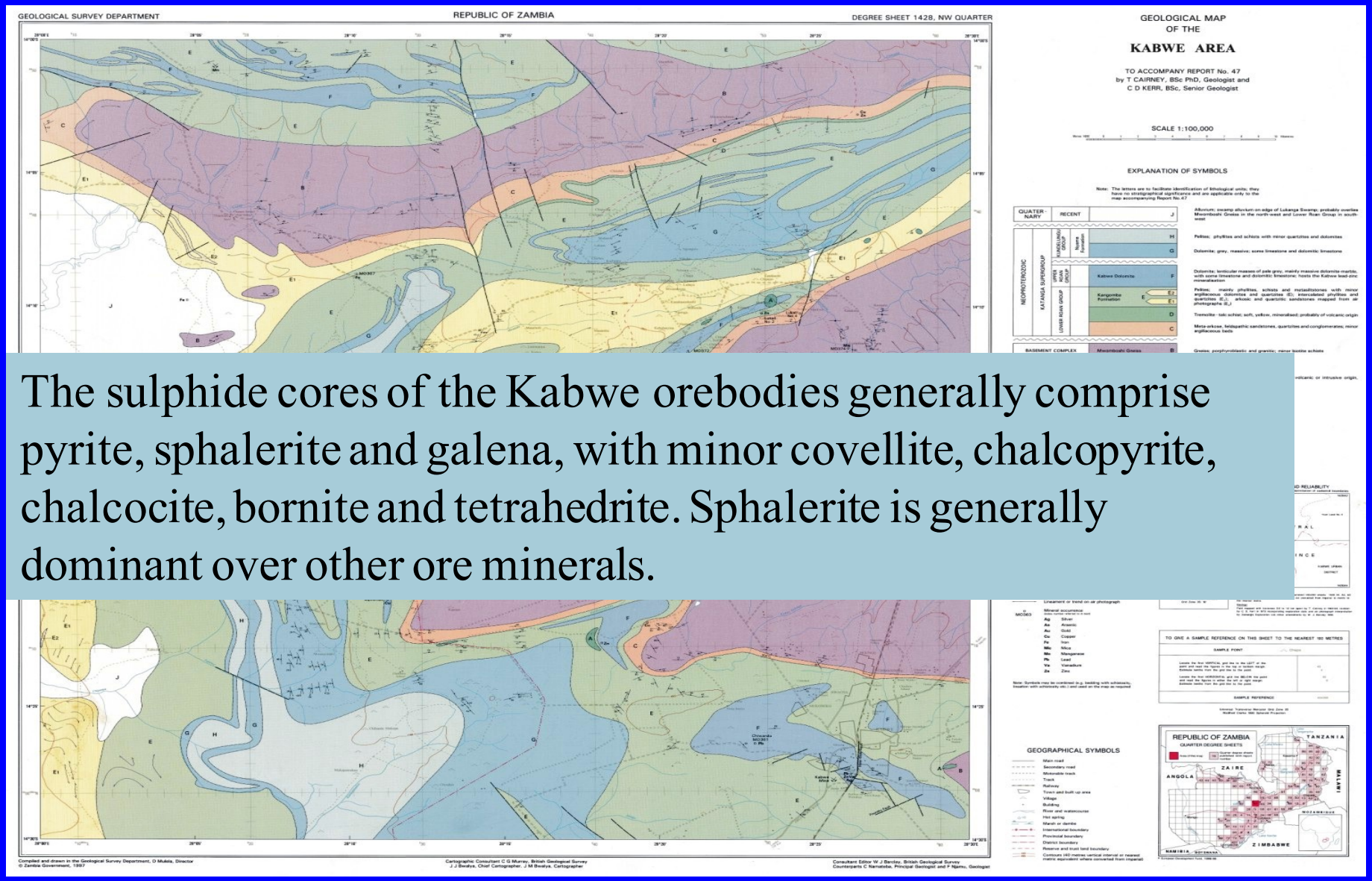
These are Fe-rich tropical soils without development of a cemented horizon. Podsols are less abundant, being formed in areas underlain by shales and quartzites.

Clayey vertisols occur in areas covered by marshes (dambos).

These soils develop a network of cracks on their surface during the dry season (Kříbek et al. 2009).

GEOLOGICAL MAP OF ZAMBIA





The sulphide cores of the Kabwe orebodies generally comprise pyrite, sphalerite and galena, with minor covellite, chalcopyrite, chalcocite, bornite and tetrahedrite. Sphalerite is generally dominant over other ore minerals.

The distributions of the orebodies are strongly fault controlled, and/or controlled by lithological competence barriers between schistose and massive dolomite sectors of the Kabwe Dolomite.

Table 1. Zn and Pb contents of Kabwe orebodies (Water Management Consultants Ltd, 2005)

Orebody	Sulphide ore			Oxidized ore		
	Zn (%)	Pb (%}	Zn/Pb	Zn (%)	Pb (%)	Zn/Pb
1	33.2	24.7	1.2	19.2	14.8	1.3
2	-	-	-	20.7	2.1	9.85
5-6	33.7	14.1	2.39	17.3	6.5	2.0
8	63.4	0.9	70.4	-	-	-
X	33.9	25.0	1.36	20.3	13.4	1.5

Mapping and Assessing the Environmental and Health Impacts of a closed Kabwe Mine, Zambia

The most comprehensive previous work carried out in the area was that edited by Kribek et. al (2008), who mapped and assessed the impacts of mining and mineral processing on the environment and human health in the Kabwe area of Central Province of Zambia under the Project of the Development Co-operation Programme of the Czech Republic No. RP/3/2008 for the years 2008-2010.

Other studies included that of Tembo, Sichilongo and Cernak (2006) who studied the distribution of copper, lead, cadmium and zinc concentrations in soils around Kabwe Town in Zambia

An earlier scoping and design study by Water Management Consultants Ltd (2005) was part of the Copperbelt Environmental Project that was extended to Kabwe Town followed the completion of privatization of the ZCCM in 2000.

The Scoping and Design Study, Phase 1 for Kabwe was therefore undertaken, and from this, ZCCM-IH carried out the cleaning of the Kabwe Town area and pulling down of the mining infrastructure.

Kabwe Old Mine Location

ZCCM –IH 2006-2009

- Kabwe Scoping and Design Study (KSDS);

❖ **Phase 1**
- Determine extent and magnitude of contamination by lead and other toxic substances

❖ **Phase 2**
- Characterize main pathways of lead exposure to residents

❖ **Phase 3**
- A revised closure and rehabilitation plan for the mine site, including measures to reduce human exposure to lead

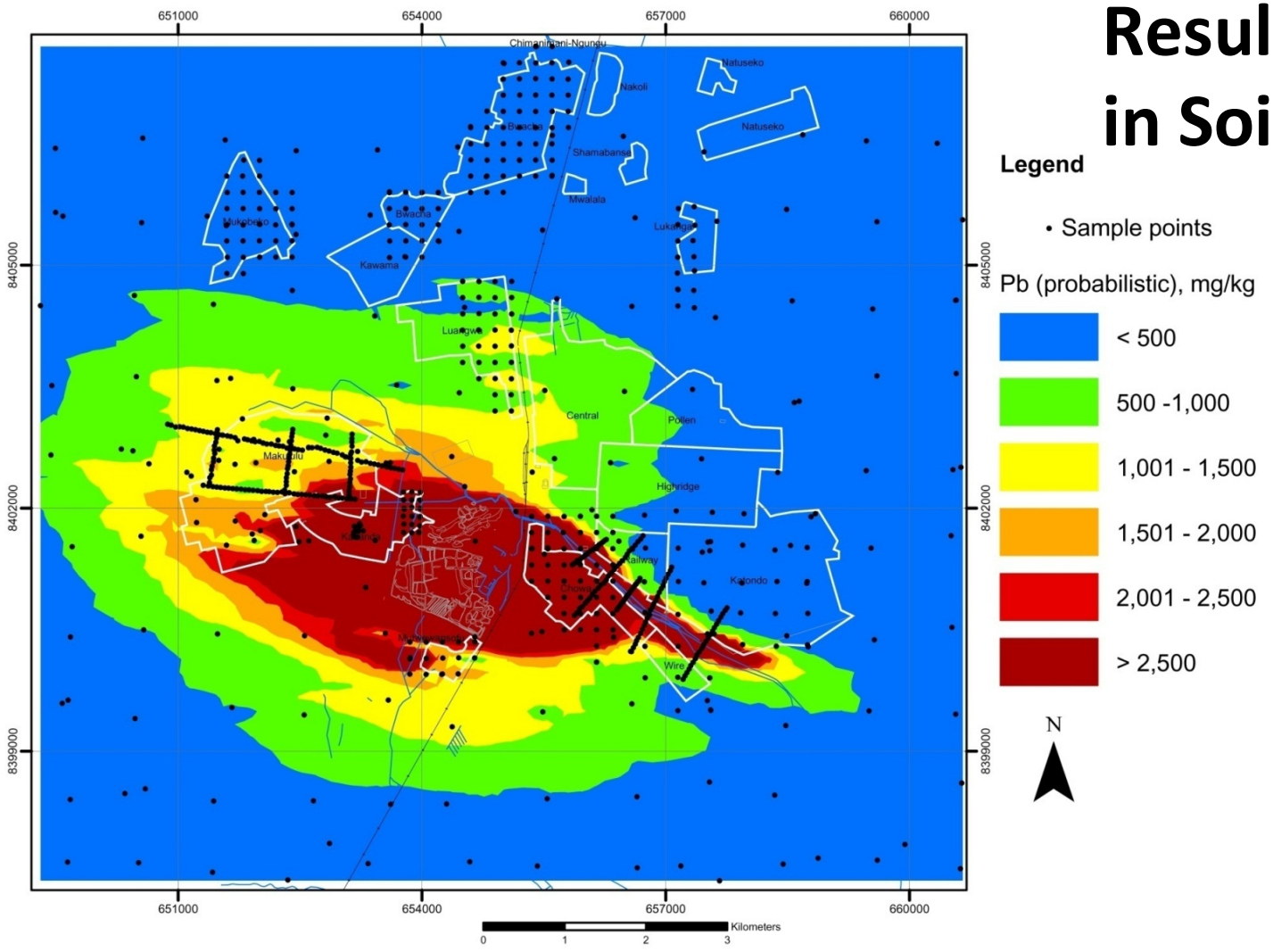
Yoshinori Ikenaka, 2009
Hokkaido University

Effect of mining activity on wild and domestic animals: Case study of lead - zink mining area, Kabwe, Zambia

They collected 101 soil samples and animal samples from blood of cattle, mice and organs of chicken investigate metal pollution of As, Cd, Cr, Cu Co, Ni, Pb and Zn.

ASSESSMENT OF RESULTS

ZCCM –IH 2006-2009 Kabwe Scoping and Design Study



Results of Lead in Soil

Legend

- Sample points

Pb (probabilistic), mg/kg

- < 500
- 500 -1,000
- 1,001 - 1,500
- 1,501 - 2,000
- 2,001 - 2,500
- > 2,500

N

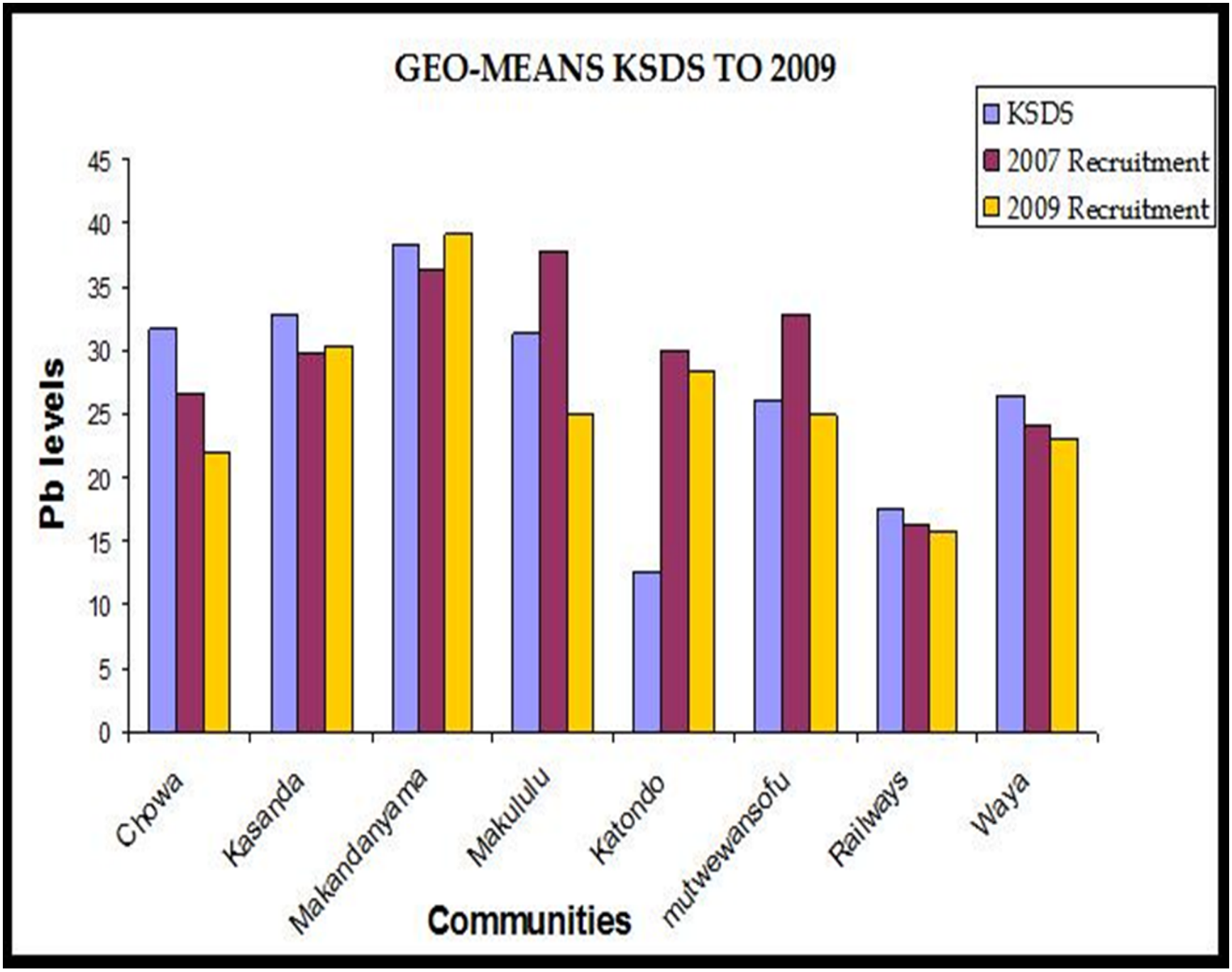
Source of Pollution: KabweMine Plant formed an intense exposure source.

Kabwe Scoping and Design Study after Joseph Makumba, 2013

- KSDS showed high Blood Lead Levels (BLL) above WHO standards (<10 µg/dl), in population living near the former mining area.
- Medically, children between ages 0-7 years arethe most vulnerable to effects of lead exposure.
- BLL are represented in classes of 1 to 5 based on concentration of lead in blood

Classes of Blood Lead Levels

Class	Clinical Picture	BLL
I	Below intervention target	< 10ug/dl
II	Mild	10-19ug/dl
III	Moderate	20-44ug/dl
IV	Severe	45-64ug/dl
V	Emergent	>65ug/dl


GEO-MEANS KSDS TO 2009
KSDS
2007 Recruitment
2009 Recruitment
Pb levels
45
40
35
30
25
20
15
10
5
0
Chowa
Kasanda
Makandanyama
Makululu
Katondo
mutwewansofu
Railways
Waya
Communities

Rehabilitation of Kabwe Mine Plant Area

- All defunct plant infrastructure demolished and cleared.
- Public health hazards the emanation of contamination arising from human access to and/or from Kabwe mine site removed.

- Community water supply improvements
- Establishment of Environmental Public Information Centres
- Incidents of children playing at lead contaminated dumps were prevalent and contributed to elevation of blood lead in children, lead free play parks for children were constructed.
- Greening of households to provide vegetative cover

One of the clinics constructed for lead care support

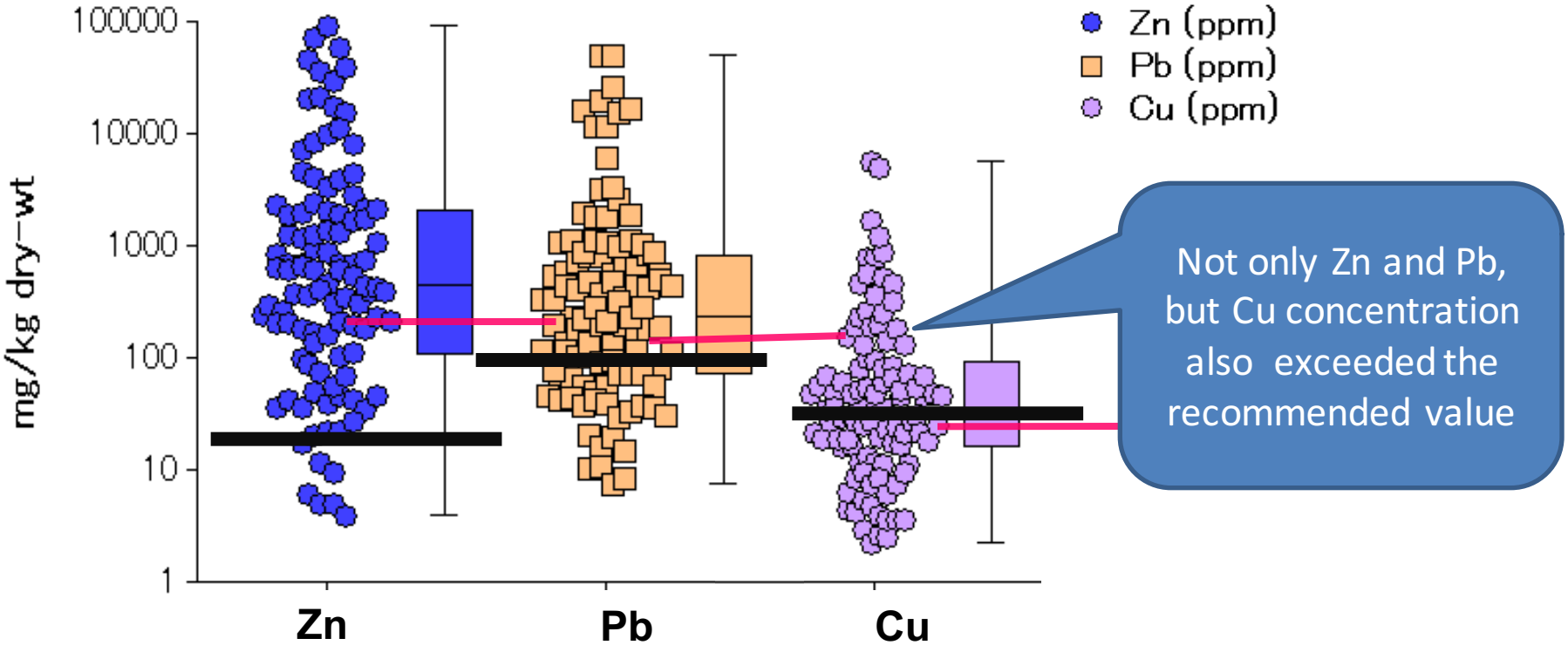
Improved Information on Lead

Sampling points of the soil in Kabwe (n = 101, May 2009)

Yoshinori Ikenaka, 2009
Hokkaido University

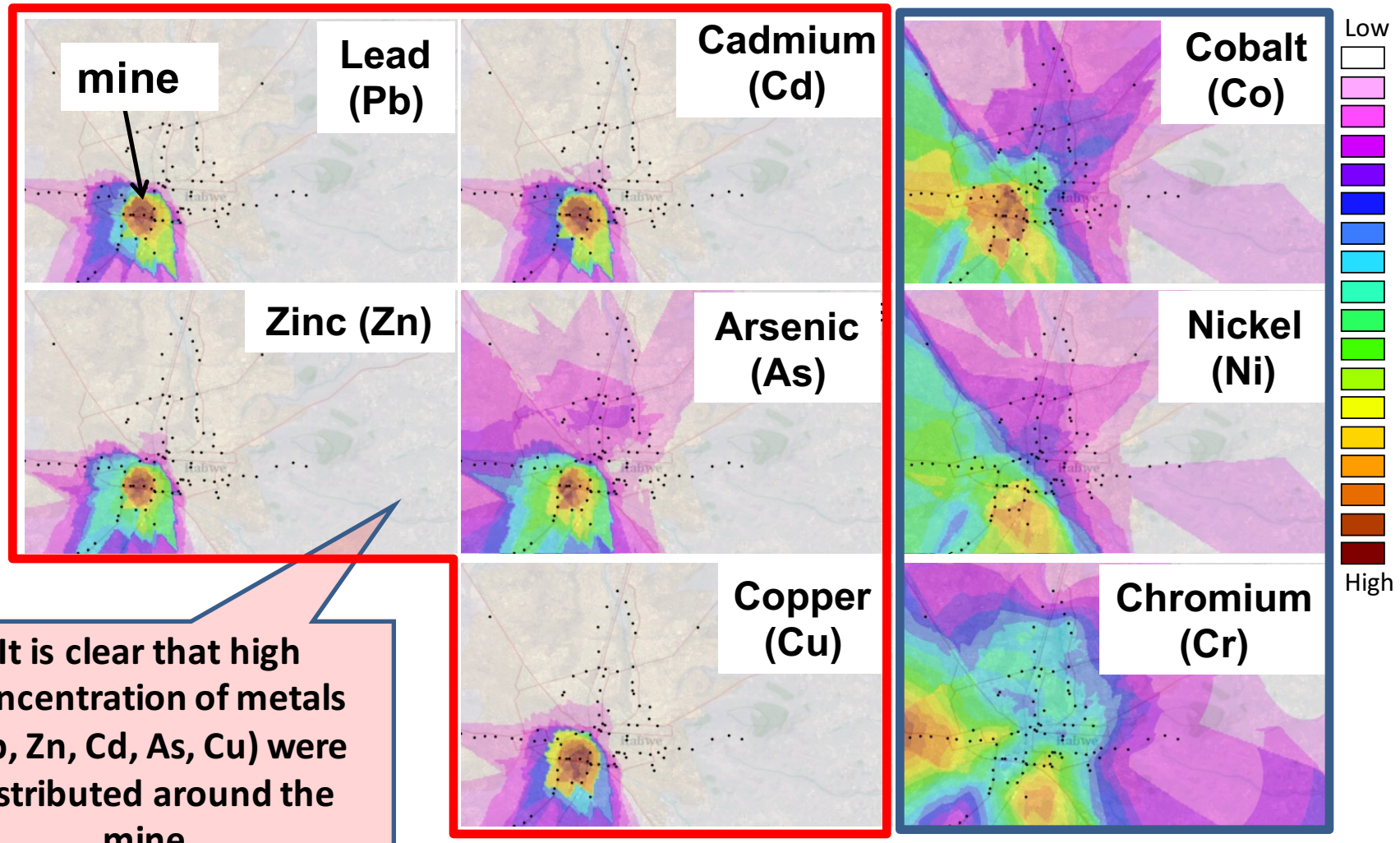
Measured metal concentrations in soil（As, Cd, Co, Cr, Cu, Ni, Pb, Zn）

Zinc (Zn), Lead (Pb) and Copper (Cu) concentrations in Kabwe soils



	Zn	Pb	Cu
Range	5 – 91,000	9 – 51,000	2 – 5,000
Median	610	280	40
Recommended	50-120	120	70

Analysis of metal distributions by GIS

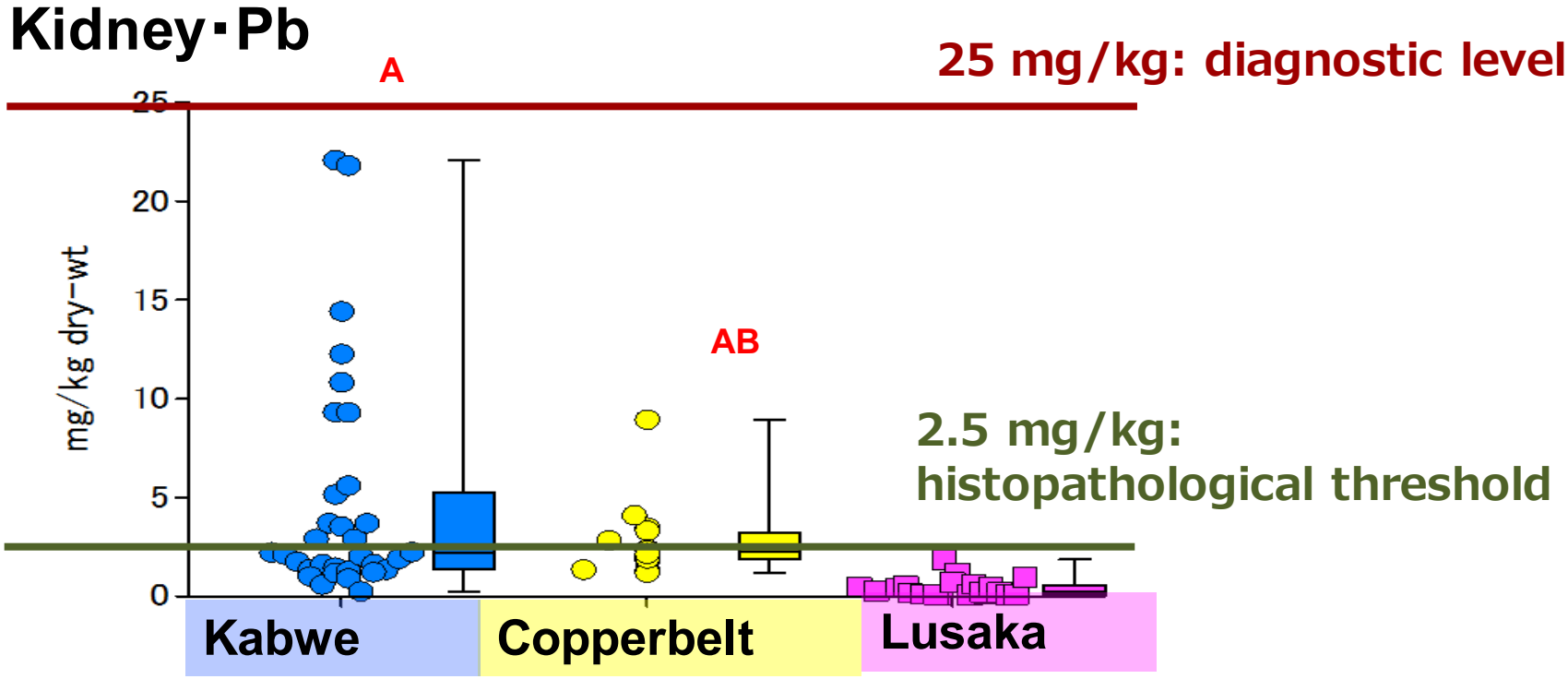


It is clear that high concentration of metals (Pb, Zn, Cd, As, Cu) were distributed around the mine.

These results clearly suggest that not only Pb and Zn, but Cd, As and Cu also originate from mining activity, and are distributed around the mine.

Kidney Pb levels in Kabwe ~Toxicological effects of Pb~

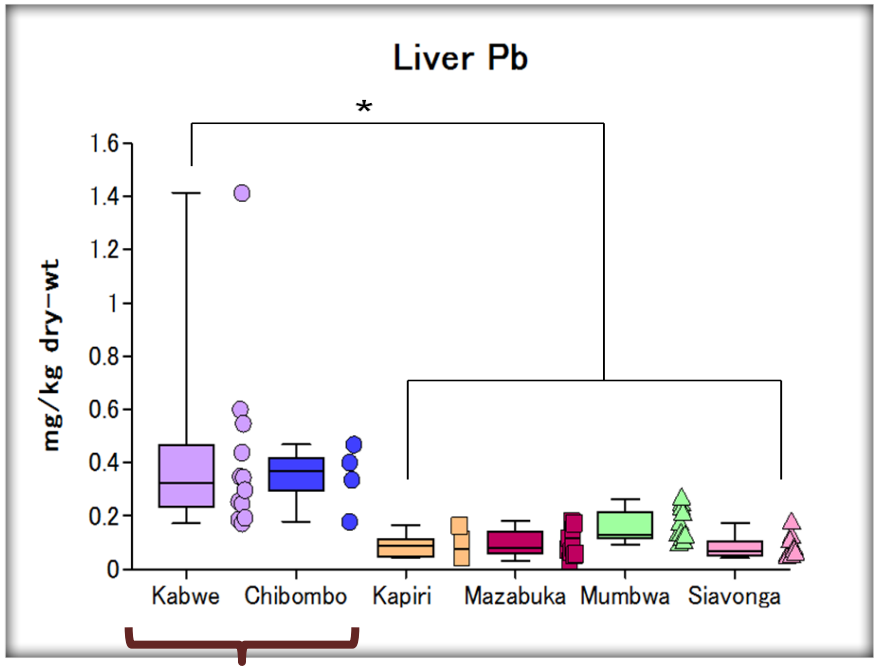
Collected around 100 rats from various area in Zambia include Kabwe



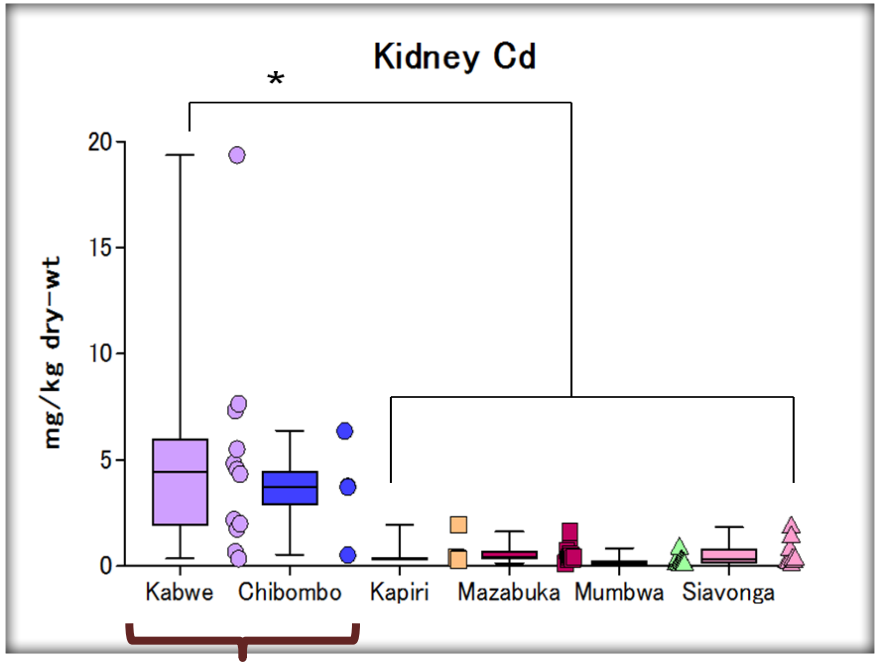
Tukey-Kramer, $P<0.05$

- While non exceeded the diagnostic level (25 mg/kg), several Kabwe rats had Pb levels higher than the histopathological threshold (2.5 mg/kg).

Concentration of Pb and Cd in the tissue of cattle is become high near the mining area



Near the mine



Near the mine

2008 PROJECT OBJECTIVES

Project of the Dev. Assist. Programme of the Czech Republic to the Republic of Zambia for the years 2008-2010

- Determination of the extent and magnitude of contamination by lead and Zinc other metals Kabwe environment
- Evaluation of the gastric availability and plant-accessibility of lead, zinc and cadmium.
- Assessment of harmful properties and ecotoxicity of mining-derived residues.
- Formulation of appropriate measures for the reduction of human health risk.

2013 Study

Assessment of impacts of abandoned mines on the environment and human health in Africa as a follow-up to IGCP/SIDA Projects 594 /606

Worked on Kabwe Old Mine where previous mining activities still exist such as tailings, as well as new activities by undertaking:

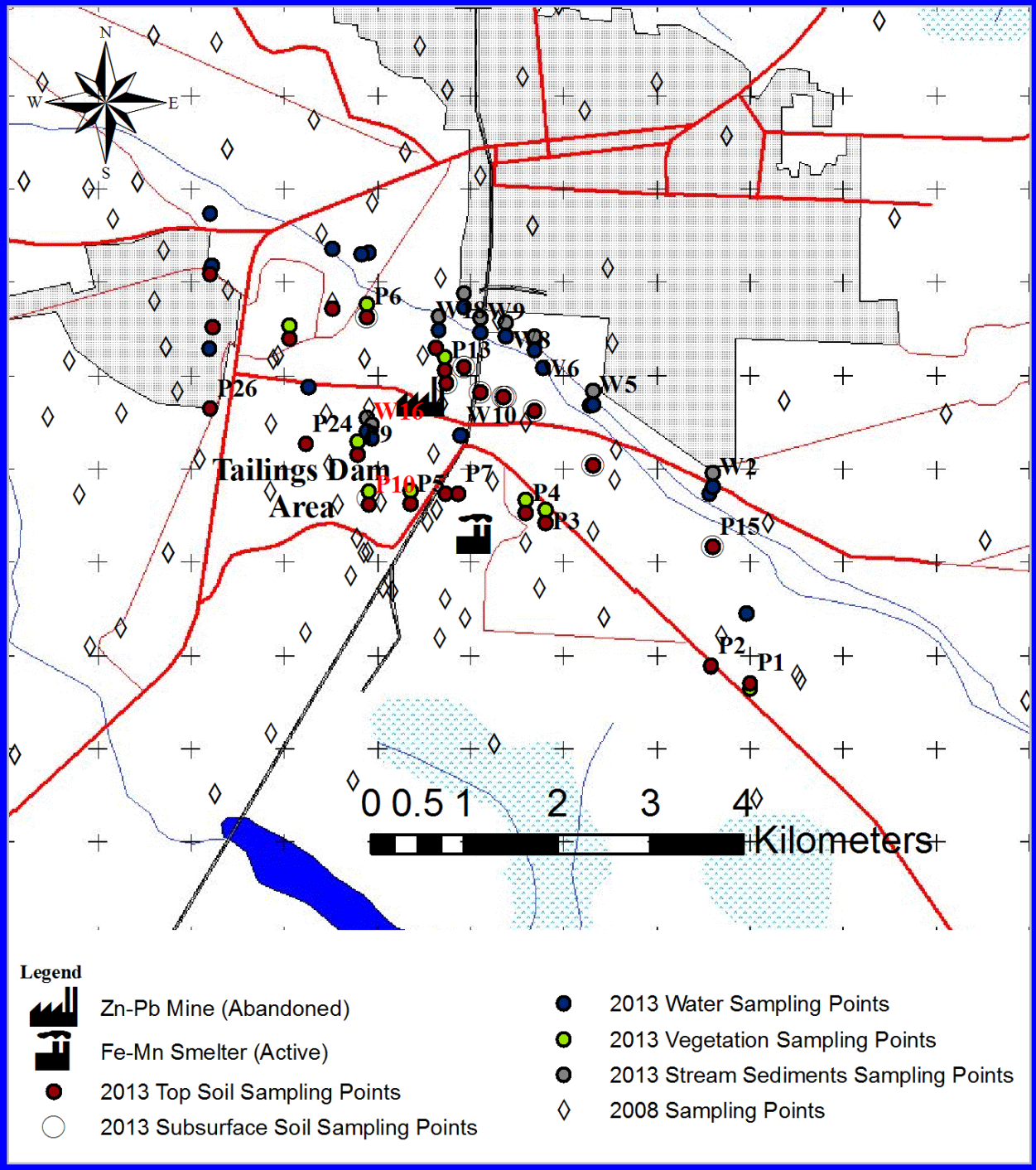
(i) Survey mapping following the work carried out by Czech – Zambia Geological surveys (2007 -2008), ZCCM- IH (2006-2009) and Hokkaido U. (2012) – to add to the existing data:

(ii) Collecting more samples – including Groundwater ; and

(iii)Outreach and educational activities to communities and mining companies.

2013 Study

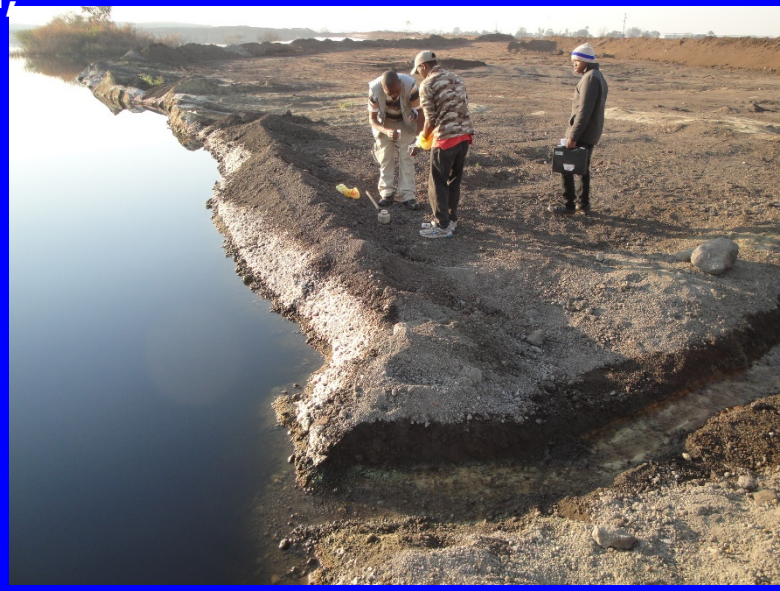
Fig. 1. Sampling Points for 2008 and 2013 studies



2 Methods

Soil (top & subsurface), stream sediment, vegetation, and SW & GW samples were collected (Figure 1)

Soil (Top & Sub.) = 29 samples



Surface / Groundwater = 23 S

Groundwater = 23 S

Stream Sediment = 11 S

Vegetation = 36 S

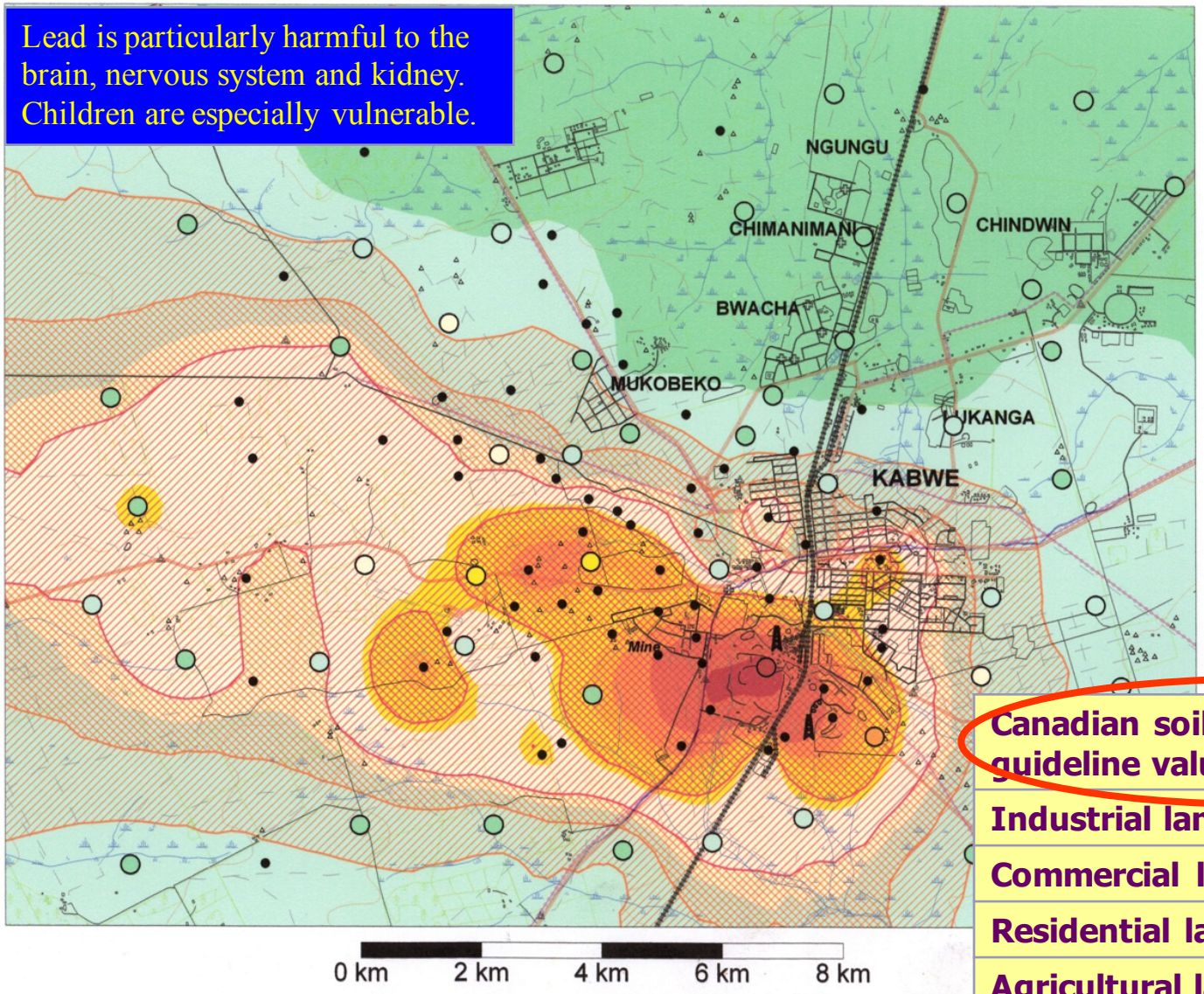
Rhizosphere at vegetation roots = 9 S

Precipitate = 1 S

Total = 109 Samples

Extent and magnitude of soil contamination in the Kabwe area

Lead is particularly harmful to the brain, nervous system and kidney. Children are especially vulnerable.



Soil contamination
Lead

Pb

ppm
20000
5000
2000
1200
500
200
35

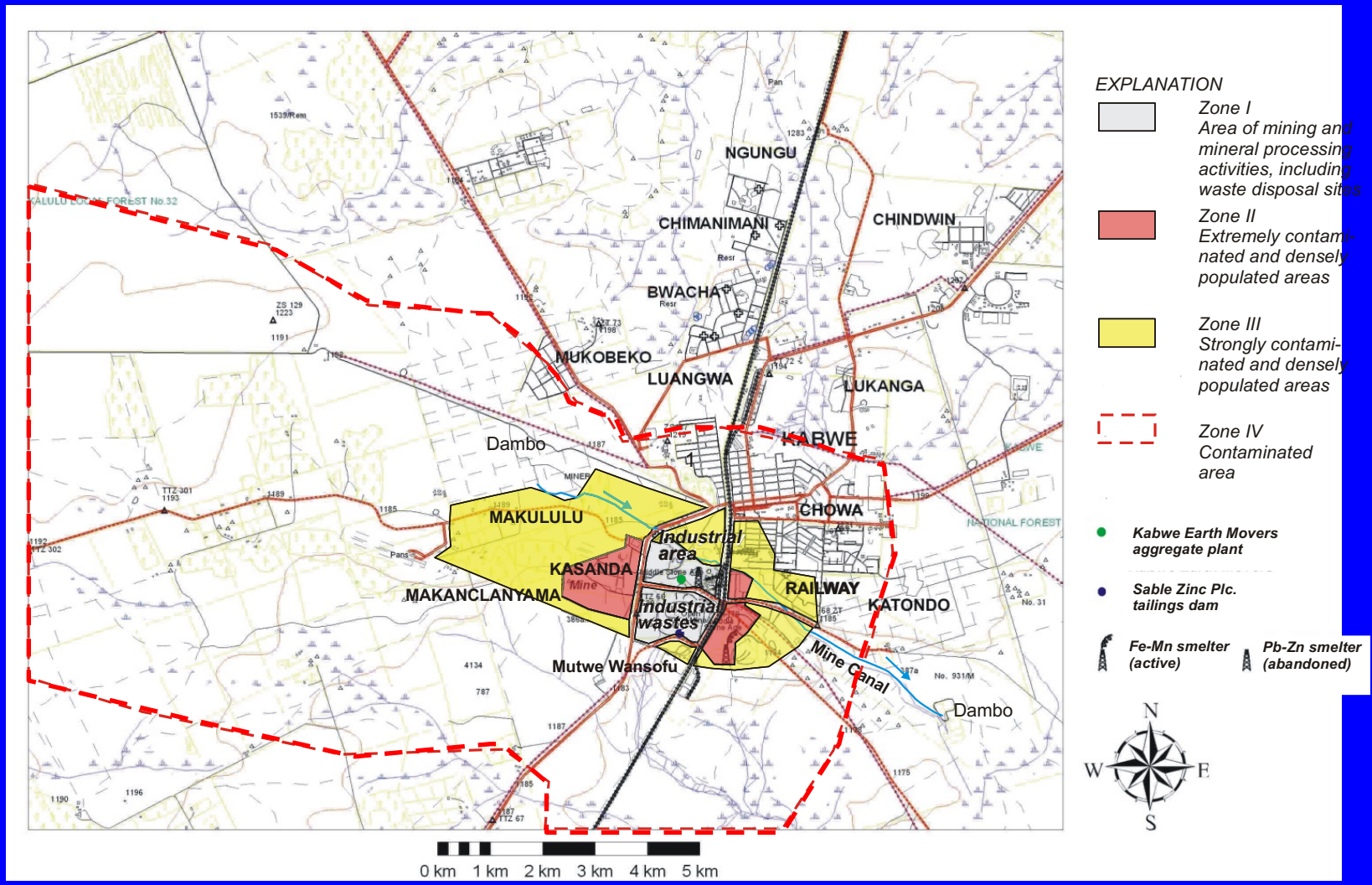
Exceeded limit for:
Industrial areas
Commercial areas
Residental areas
Agricultural areas

Fe-Mn smelter (active)
Pb-Zn smelter (abandoned)

Canadian soil quality guideline value	Lead (mg/kg)
Industrial land use	600
Commercial land use	260
Residential land use	140
Agricultural land use	70

Formulation of appropriate measures for the reduction of human health risk: long-term goals

Environmental subdivision of the Kabwe area



2013 Assessment of Soil Contamination

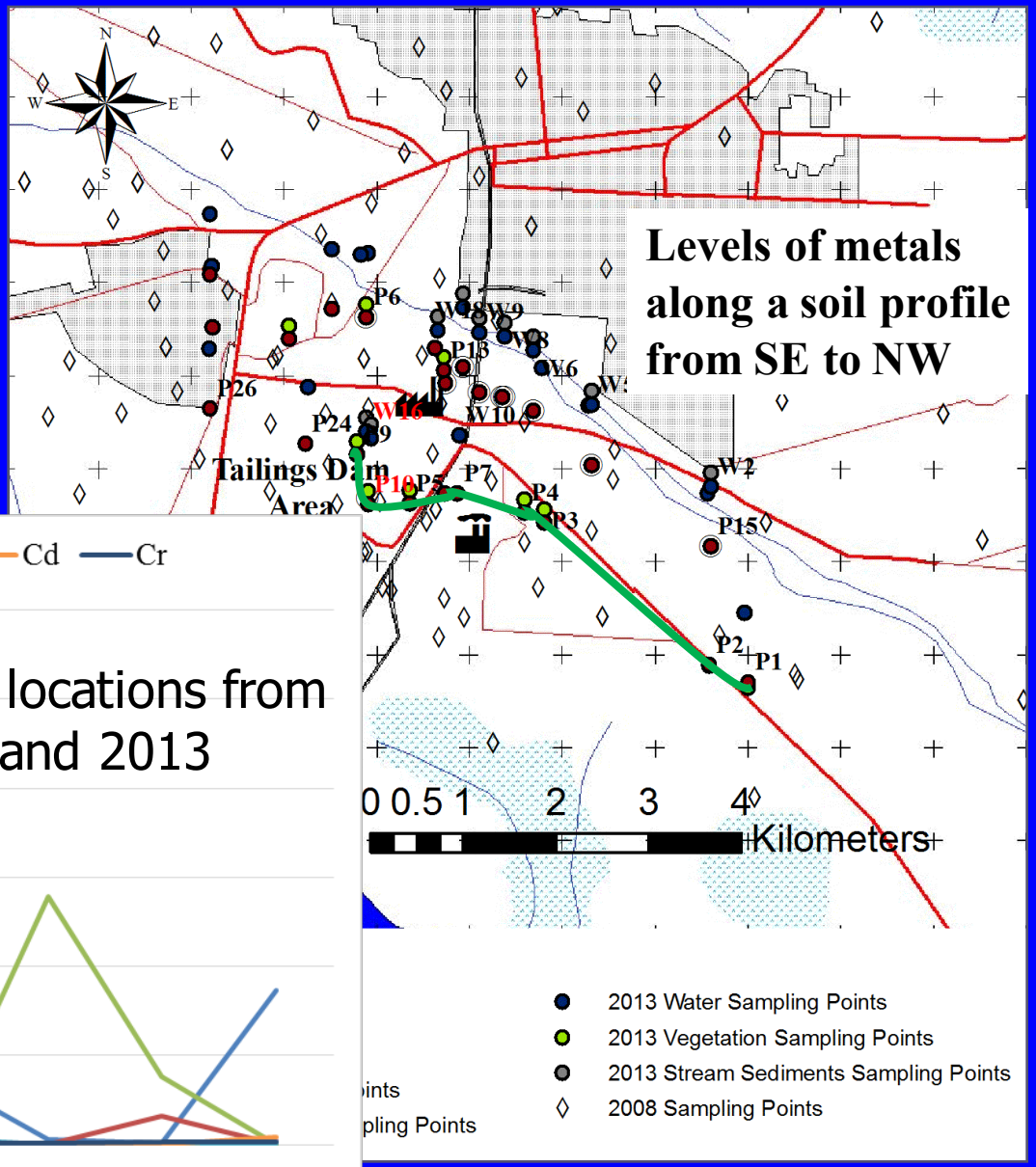
Pb = 23 - > 10 000ppm

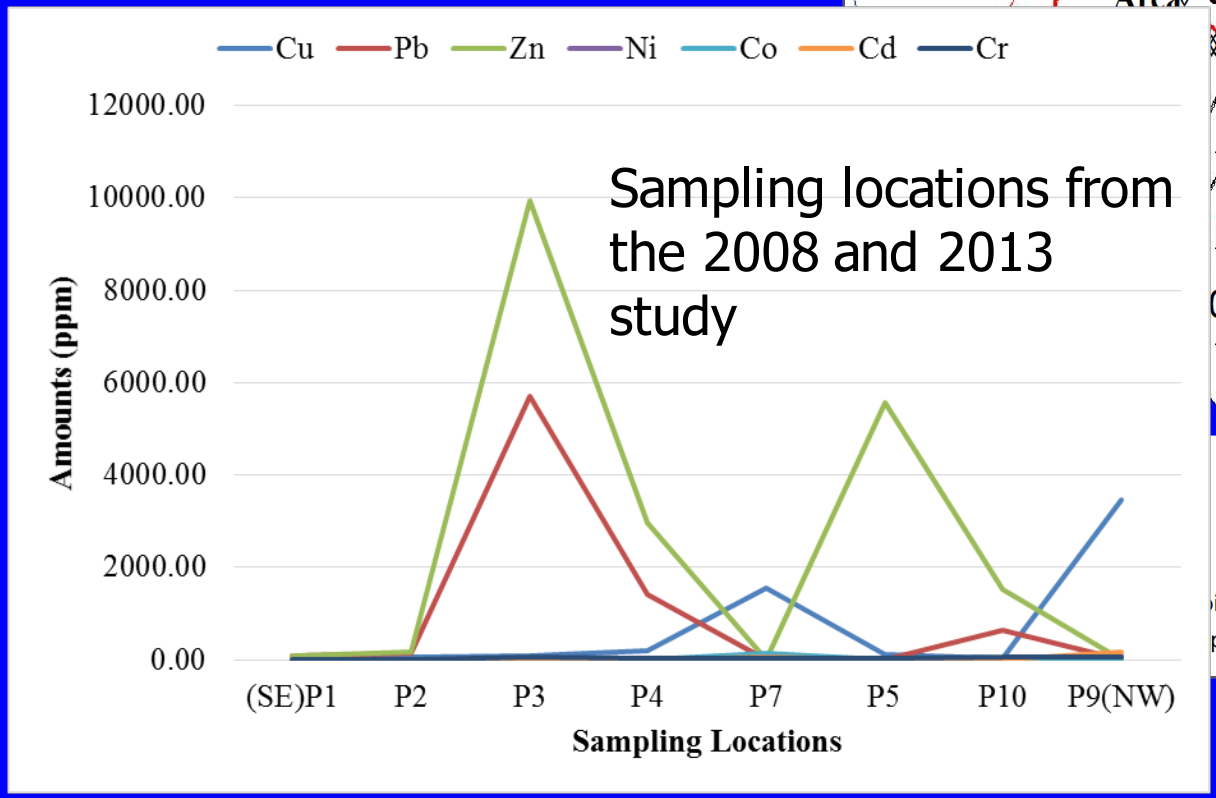
Zn = 53.6 (P1) - >10 000ppm

Cu = 9.72 - 3744.71ppm (P2)

and 500 – 3500ppm around Mine

Cd ~ 20 - 200ppm around the old mine





Stream Sediment Assessment

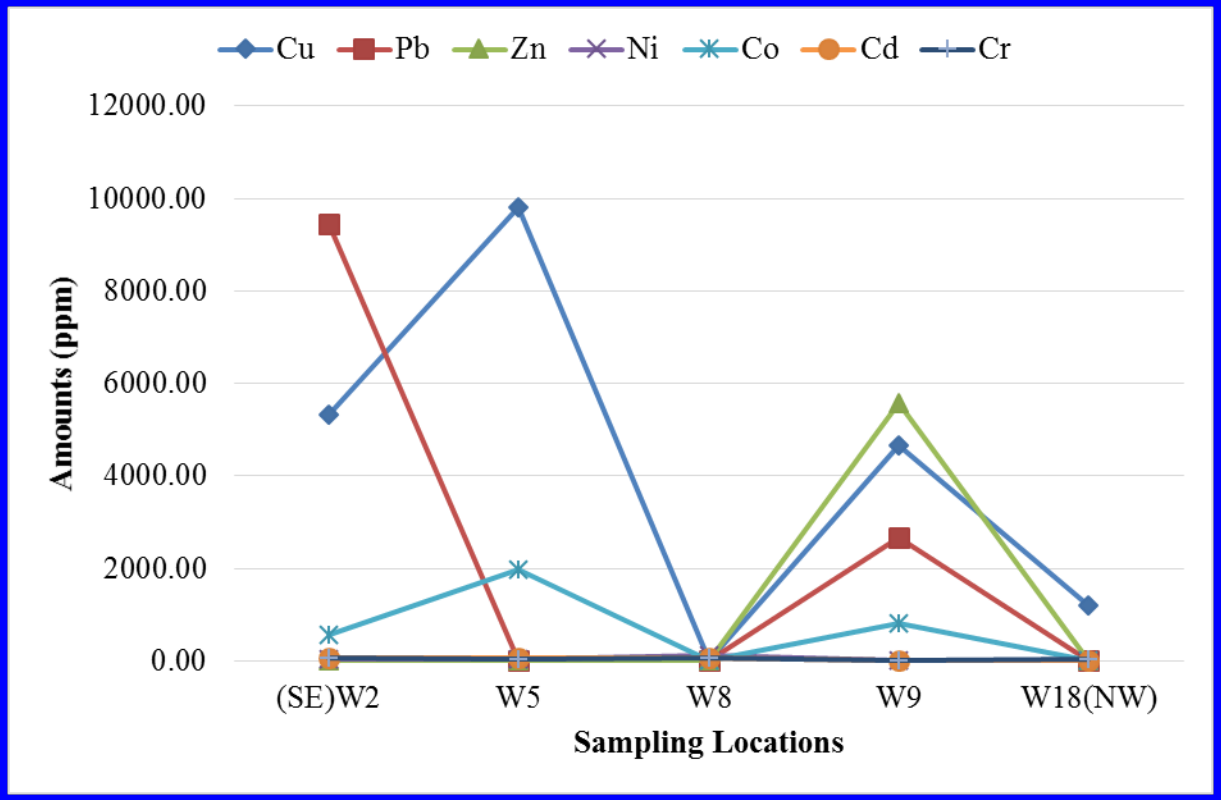
Lead = 553.87 > 10,000ppm

Zinc = 3343.5 > 10, 000 ppm

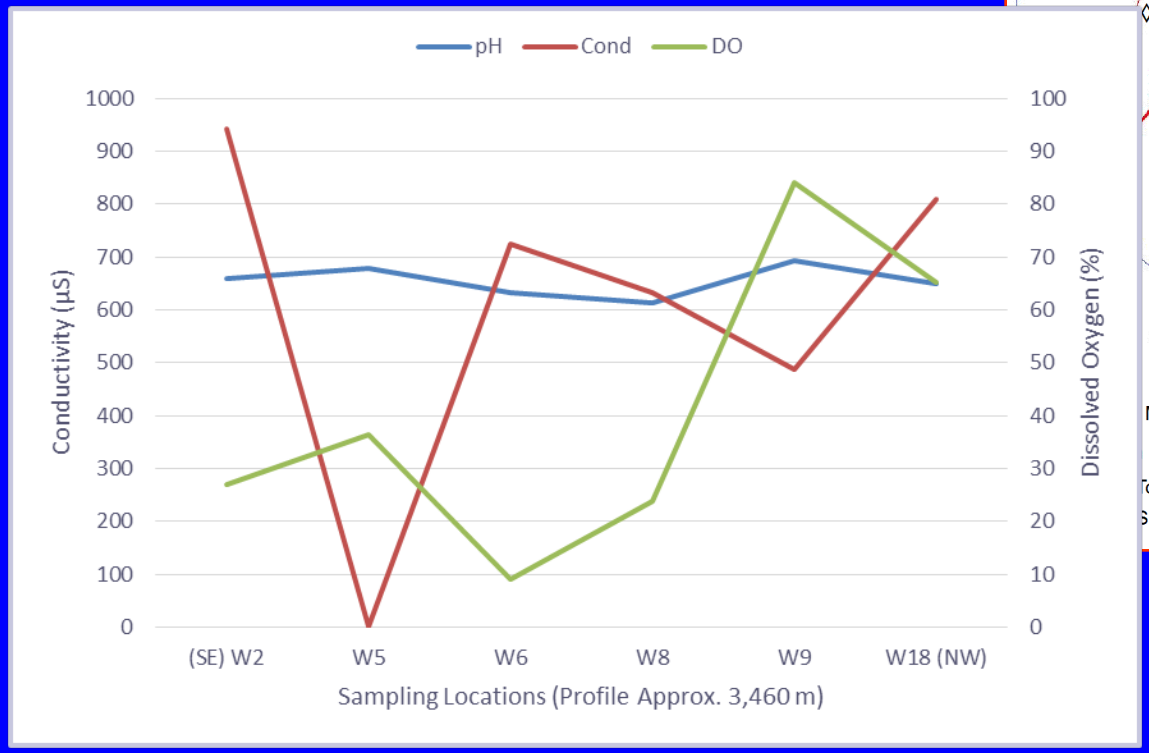
Copper = 21.36 - 10 000 ppm.

This demonstrates that sediments are the sinks of heavy metals and for the Kabwe area, the sediments have indicated the extent of the footprint of pollution in the lead – zinc mine.

For example, Heavy metal concentrations in stream sediments along the Canal SE to NW



Assessment of Surface water contamination



Though Cond. & DO varied, pH was between 5 and 7

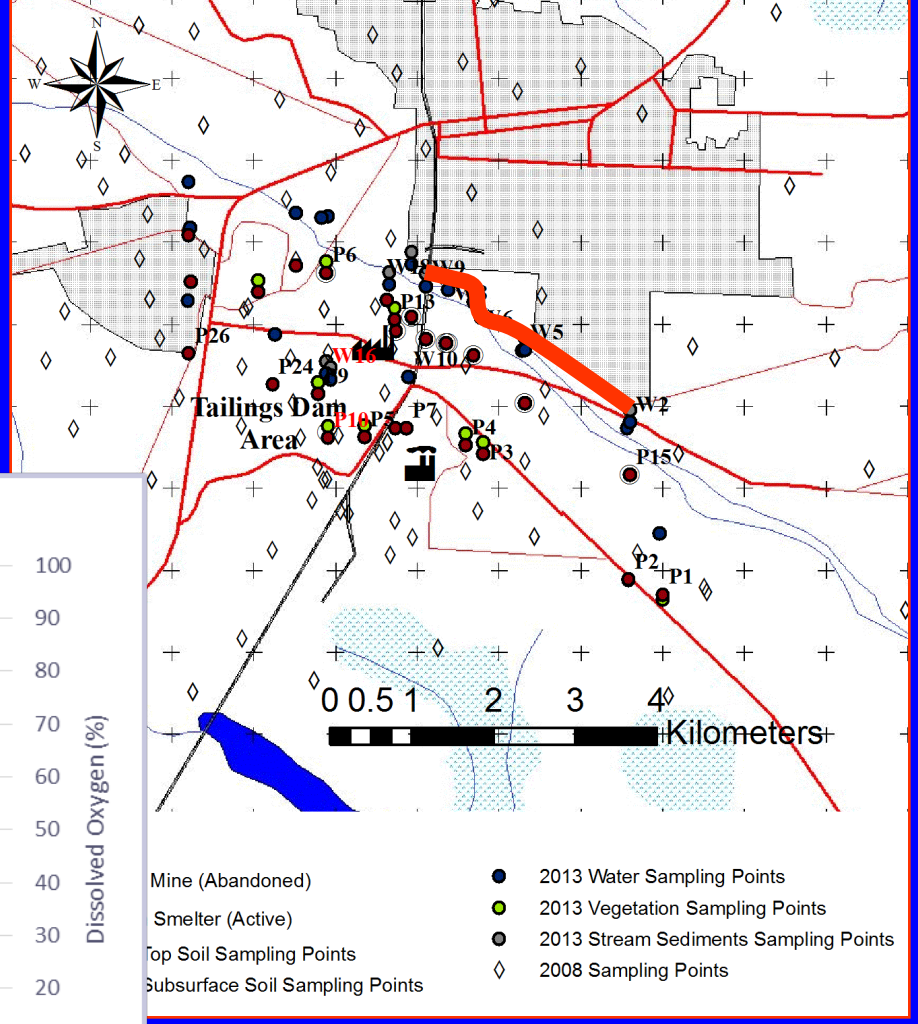
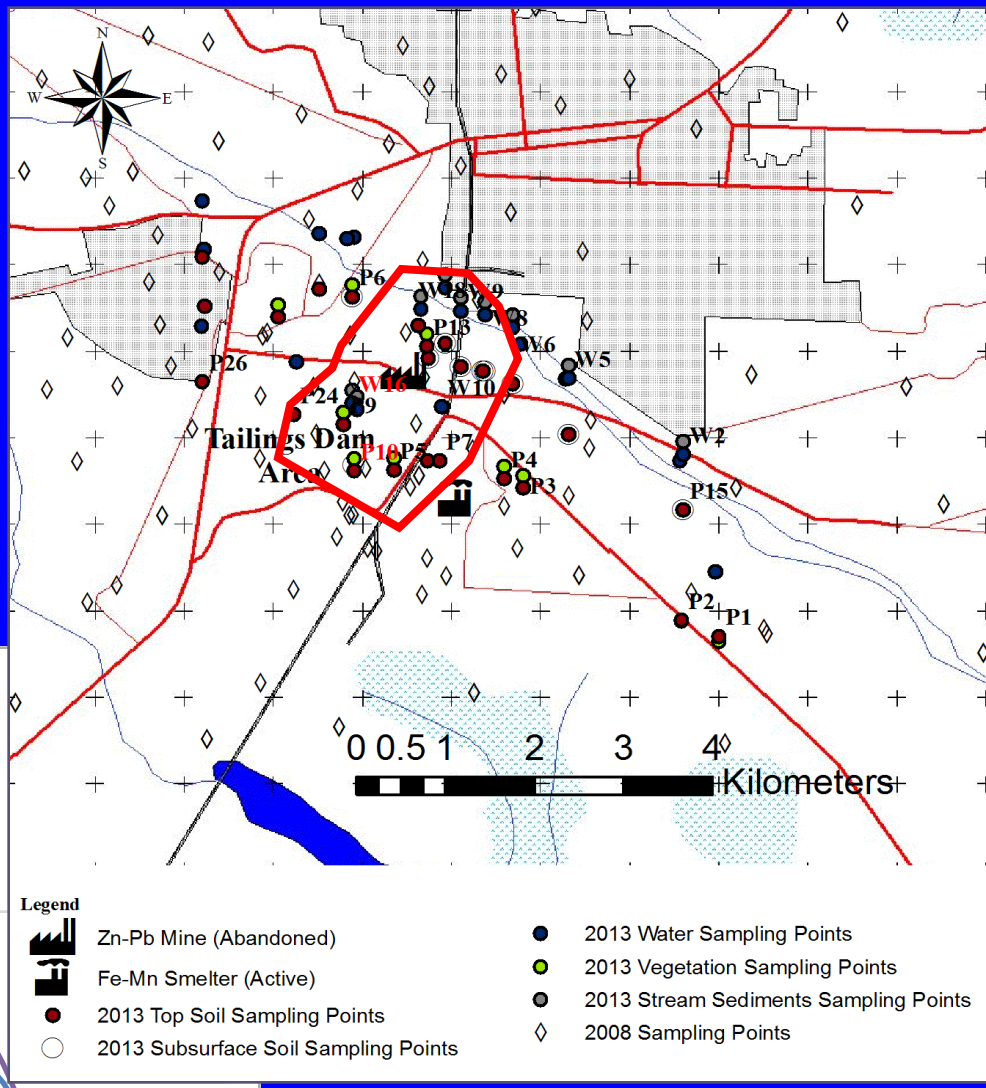


Figure 8: Surface water parameters along canal profile (RED)

For instance, zinc and lead concentrations were observed to increase to levels of between 500,000 ppb to around 2,000,000 ppb in this area (Fig., 9)



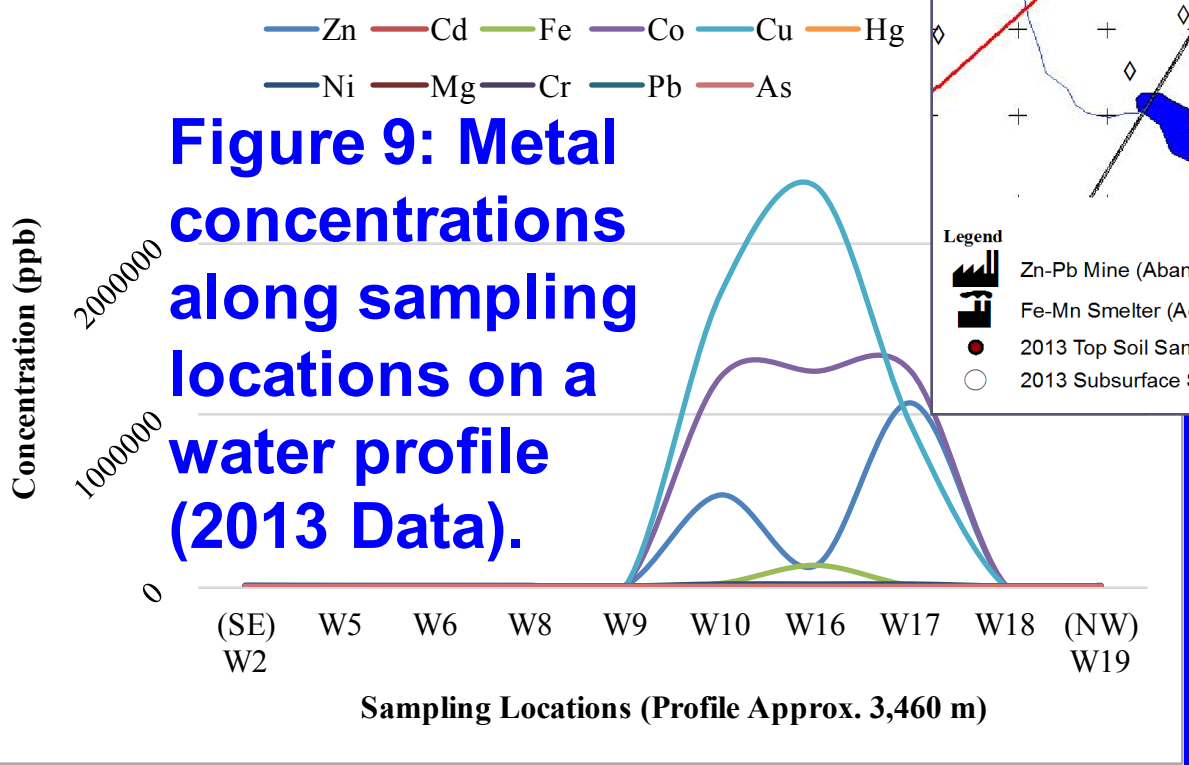


Figure 9: Metal concentrations along sampling locations on a water profile (2013 Data).

Assessment of Groundwater contamination

Lead ~ 189.6ppb

Zinc ~ 52 837ppb

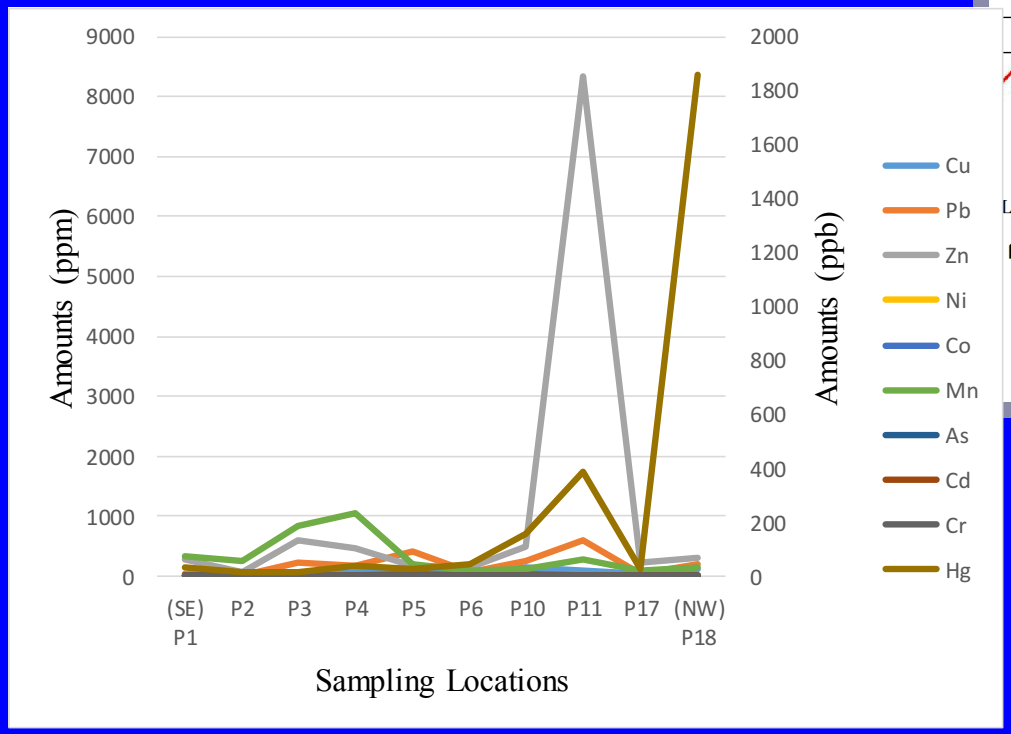
Other metals (Cu, Fe and Ca) showed significant increases within the vicinity of the old mine area

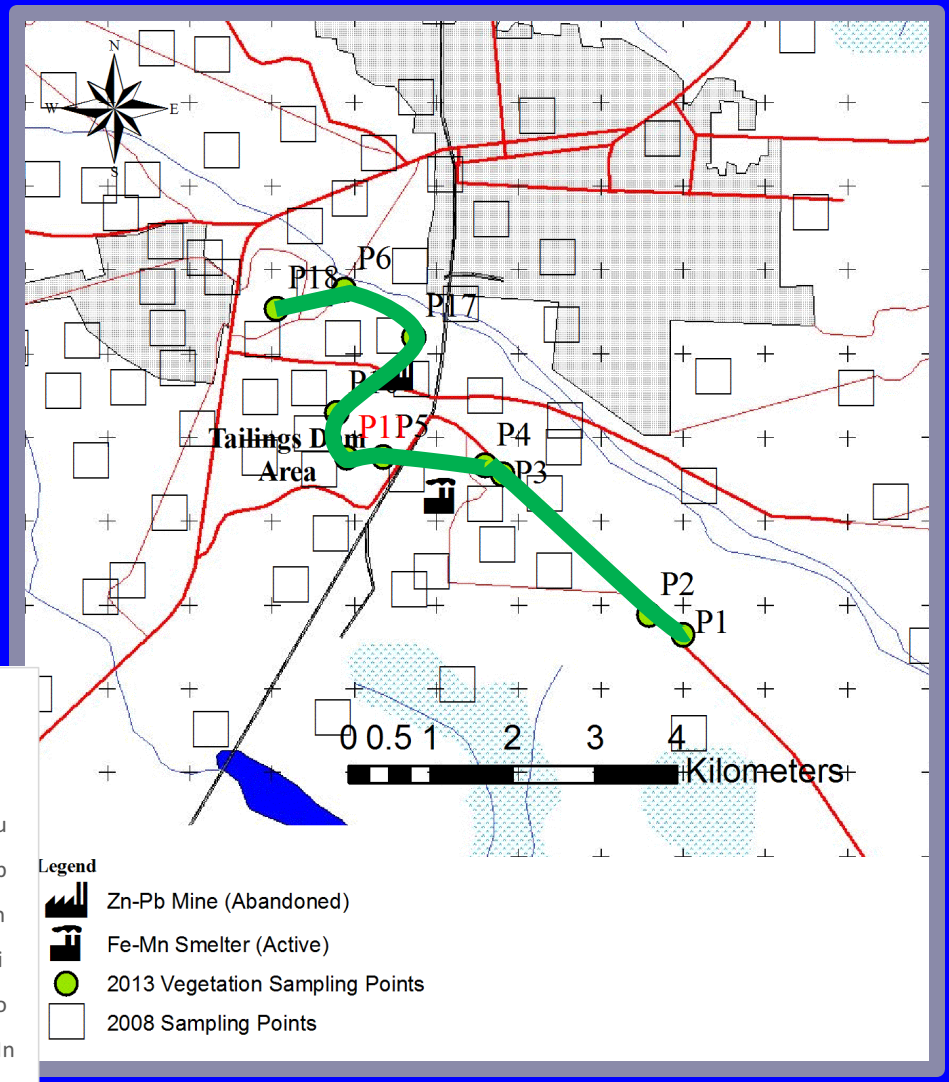
When compared to WHO and Zambia Bureau of Standards (ZABS), all the metal concentrations in groundwater samples were below these standards.

Assessment of Vegetation contamination green profile

Zinc ~ 8,000 ppm,

Lead & Mercury ~ 2,000 ppb





Vegetation Contamination

	Zinc ppm	Lead ppm	Copper ppm	Locality
Cassava Leaves	273.6	34.40	14.40	P1
Resp. Rhizosphere Soil	102.3	86.31	12.88	P1
Cassava Tubers	59.7	6.49	11.15	P1
Resp. Rhizosphere Soil	53.60	23.95	16.84	P1
Cassava Tuber Peels	41.00	10.87	7.28	P1
Sweet Potatoes	26.3	7.55	-	P1
Resp. Rhizosphere Soil	94.8	74.07	-	P1
Tomato Leaves	158.9			P6
Resp. Rhizosphere Soil	1516.9			P6

These crops take up heavy metals from polluted and disrupted agricultural land.

Vegetation Contamination

	Zinc ppm	Lead ppm	Copper ppm	Local.
Blurush	5550.20	2771.85	2084.78	P4
Resp. Rhizosphere Soil	10,000	10,000	560.70	P4
Lemon Grass	>10,000	1075.68	176.07	P4
Resp. Rhizosphere Soil	1783.10	1596.20	46.11	P4

Lemon grass has a higher photo-remediation potential to clean Kabwe of heavy metals.

Such plants could be used to clean both the canals and the disrupted agricultural land of Kabwe.

Metal concentrations in all edible vegetation samples taken was below WHO and ZABS standards in the sampled vegetation

Conclusion

- In the 2013 study, Pb concentrations were around 20,000 ppm near the old Zinc and Lead mine area, whereas the highest zinc concentrations were over 10,000 ppm in the same area as was sampled in 2008.

Most other locations sampled in 2013 had similar measurements as the 2008 study e.g. Zinc concentration at P3 east of the old mine area (this study), revealed similar results of 2960.5 ppm (2013) and around 2700 ppm in 2008.

- For copper, it was observed that there was some significant rise from around 320 ppm in 2008 to 3458.48 ppm within the sampling area, (P7 – Figure 1), located north-east of the active iron-manganese smelter.
- The same sampling location also had an increased concentration of iron from around 9.0% in 2008 to 16.0% in 2013.
- Manganese was found to be in excess of 7397 ppm in 2013 from the 2008 value of around 4000 ppm at sampling location near P3.

- It is noted that iron and manganese concentrations had increased significantly from the concentrations obtained by Kříbek et al., 2008.

This is attributed to the active iron-manganese smelter within the same area.

- Overall, despite the Government clean-up of the Kabwe area, concentration values for metals (lead, zinc, copper, iron and manganese) are either at the same levels or increasing due to continued processing of metal ores by the new operations who still use the same facilities for disposal .

- It is recommended to be addressed by all stakeholders through enforcement of existing legislation and re-introduction of rehabilitation programmes.

Outreach programmes to raise public awareness in local schools, municipalities and communities should be encouraged