Towards Understanding of Environmental Impacts on the Zambian Copperbelt and Kabwe

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SYMPOSIUM

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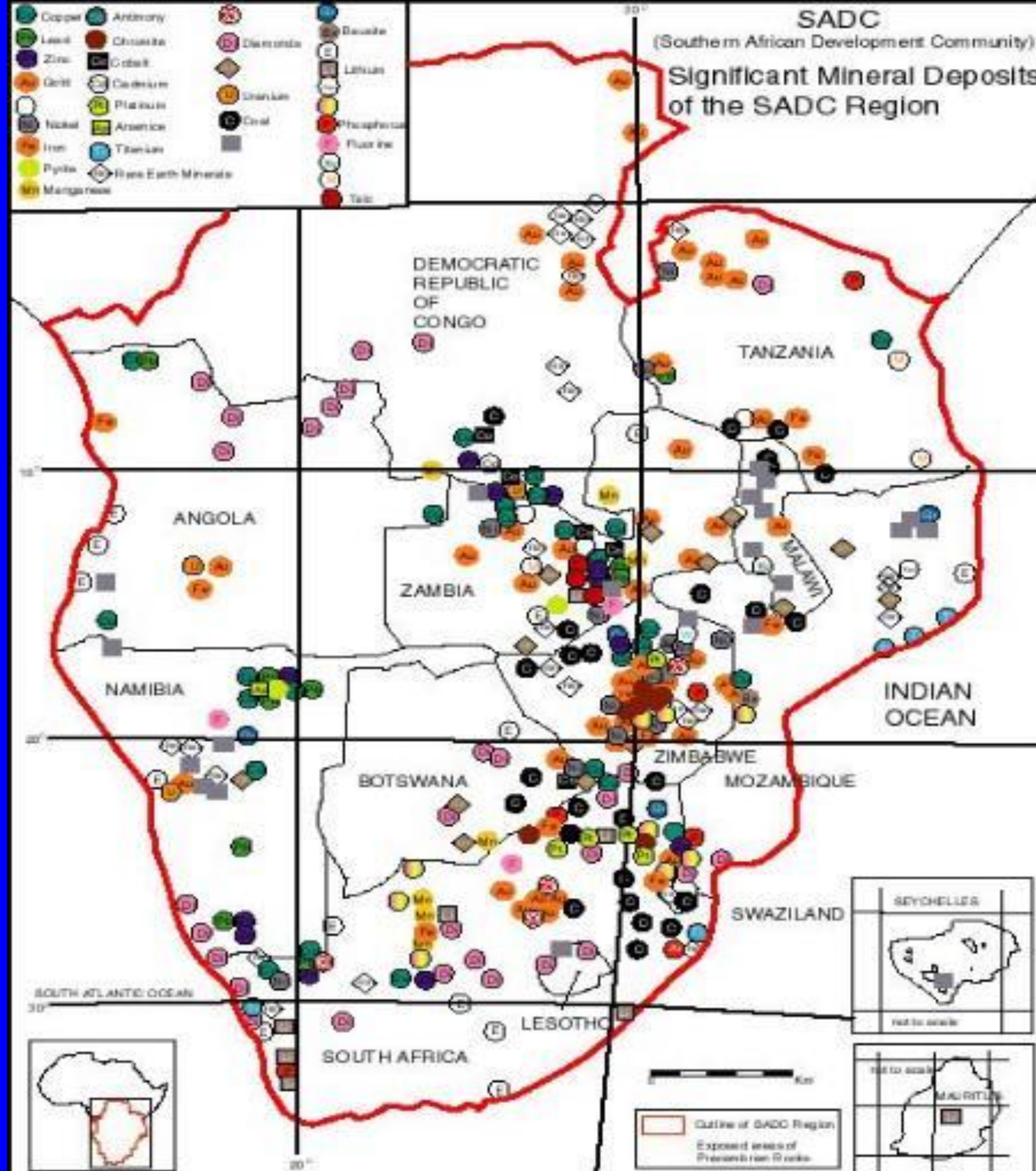
Acknowledgement: Prof. Bohdan Kribek – Czech Geol. Survey

1. INTRODUCTION

✓The Mining World

Over 7,000 mines in the world developed providing the raw materials for industries and the energy minerals on which our society is so dependent e.g. Even the strengthening agent for the paper we are currently using.

Significant minerals exploited in the SADC region



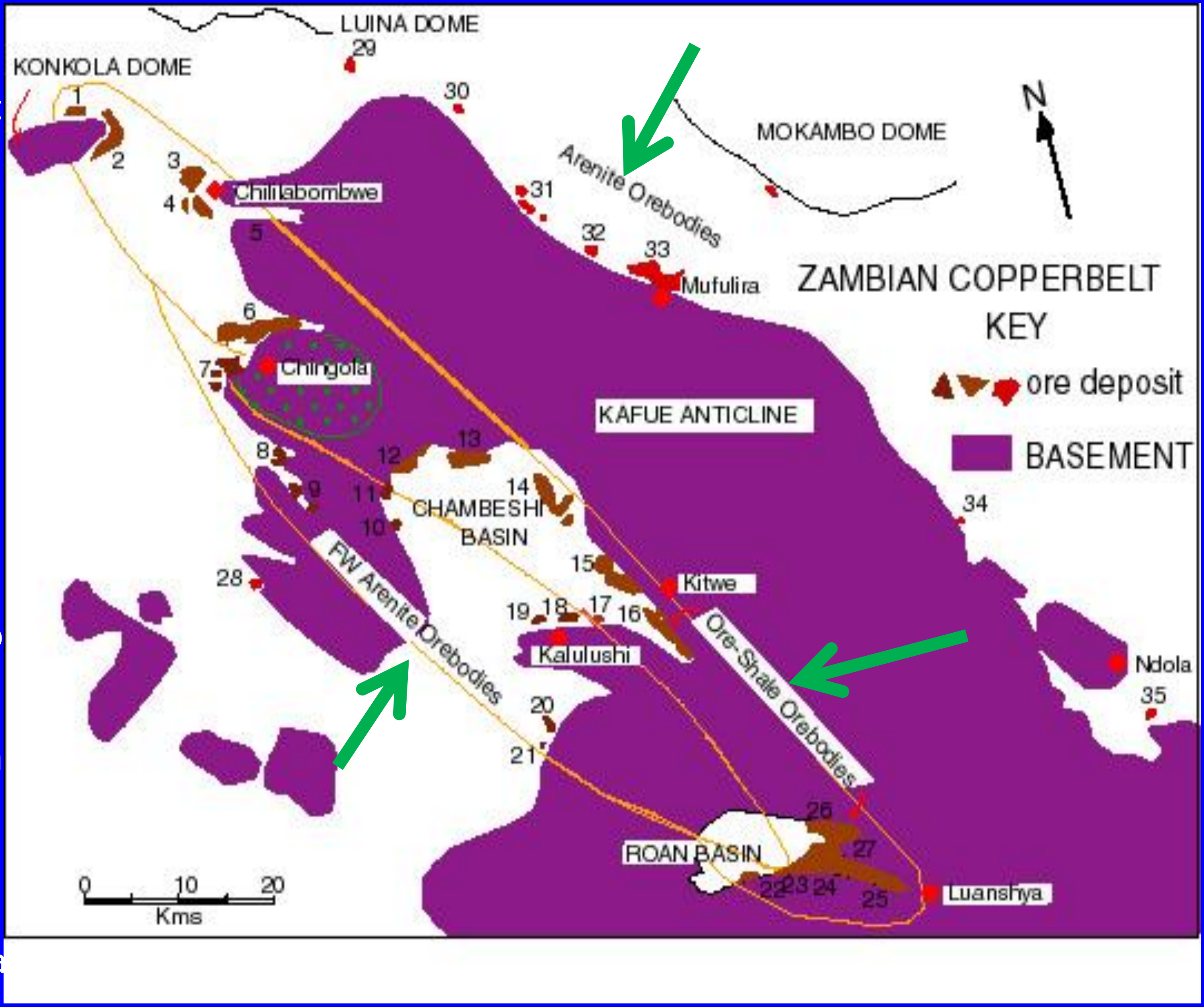
2. HISTORICAL BACKGROUND TO ENVIRONMENTAL IMPACTS

Past 90 years Zambia's economy and the health of its citizens dependent on copper and cobalt mining

Mining activities were focussed on profit making with no regard to the ecosystem health and biodiversity.

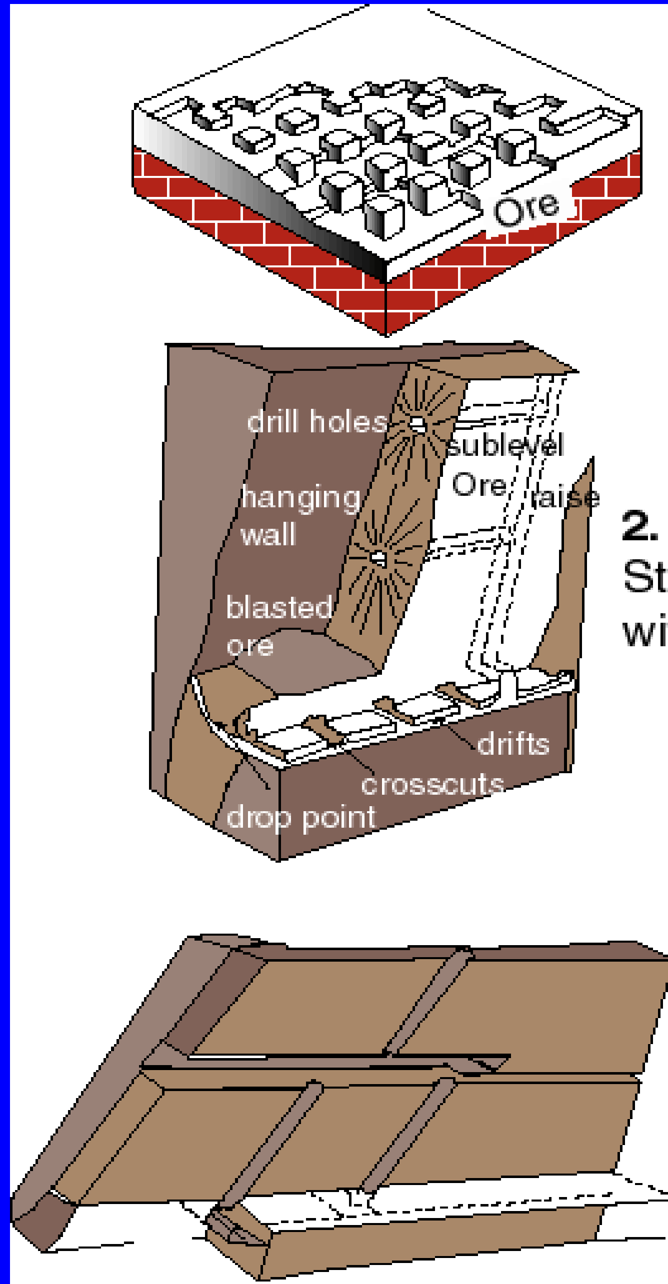
✓ In Zambia *Copperbelt Geology*

Figure 3: Distribution of copper-cobalt deposits in the Zambian Copperbelt Names on the map include
1 Konkola,
2 Chililabombwe,
3 Nchanga,
4 Chingola Orebodies,
5 Chambeshi,
6 Chambeshi South East,
7 Mindolo,
8 Nkana,
9 Nkana South Limb
10 Chibuluma,
11 Chibuluma West,
12 Chibuluma South
13 Muliashi,
14 Baluba,
15 Baluba East,
16 Mufulira,
17 Mbwana Mkubwa



Exploitation

Underground Mining Methods: Examples used on the Copperbelt



1: Room & Pillar
Shallow-dipping/ Flat Ore Bodies

2. Sub-Level Stoping
Steeply-dipping ore with strong wallrocks

3. Cut & Fill Stoping
Steeply-dipping or large orebodies

MEN DRILLING UNDERGROUND AT NCHANGA

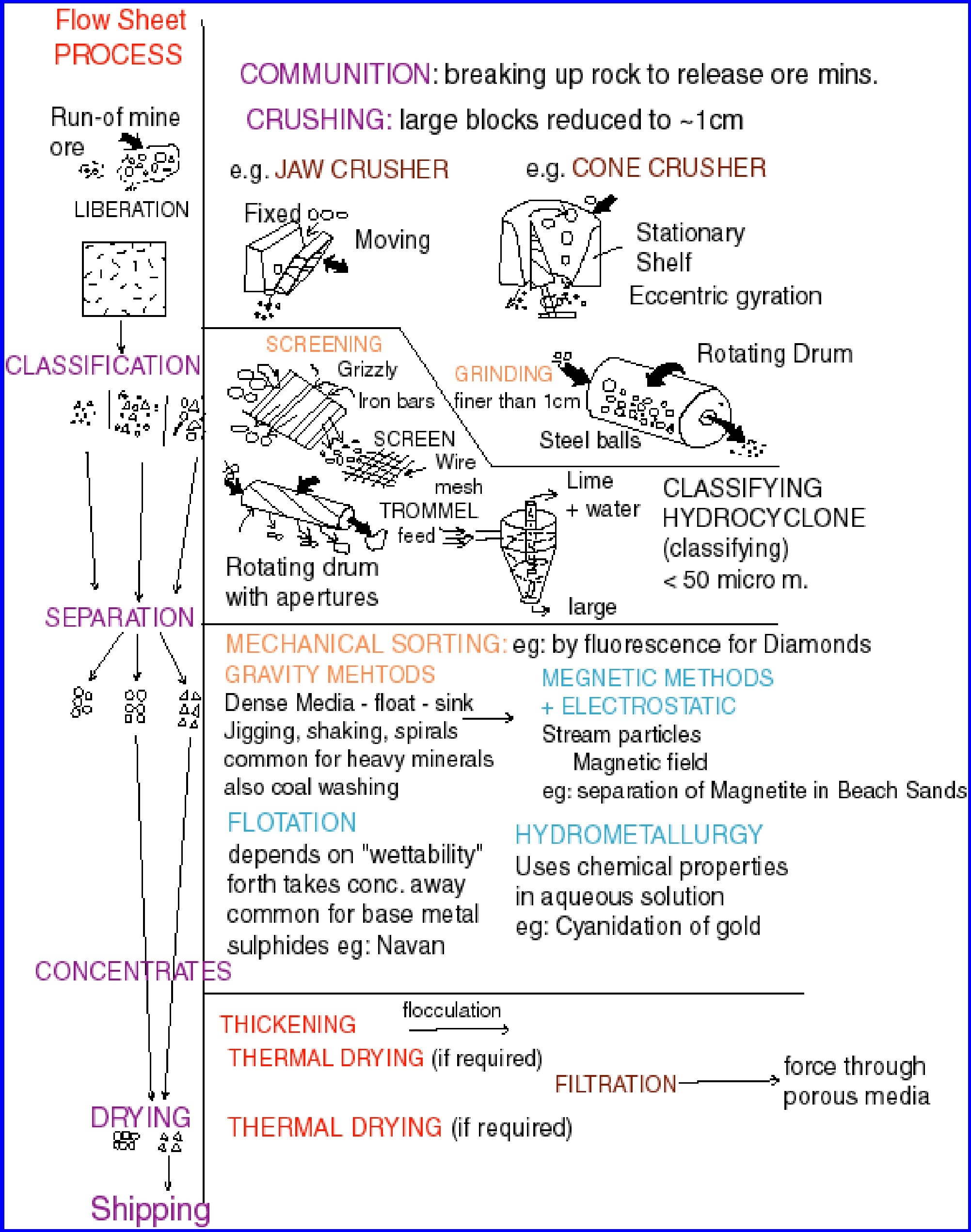
Nchanga Open pit, Copperbelt, Zambia

Reclaiming some of the Tailings Dumps material, Nchanga Mine, Chingola

Exploitation - Ore Processing

Mineral Dressing:

1. Ore Crushing
2. Concentrating - Concentrators
3. Smelting – smelters
4. Refining - Refineries

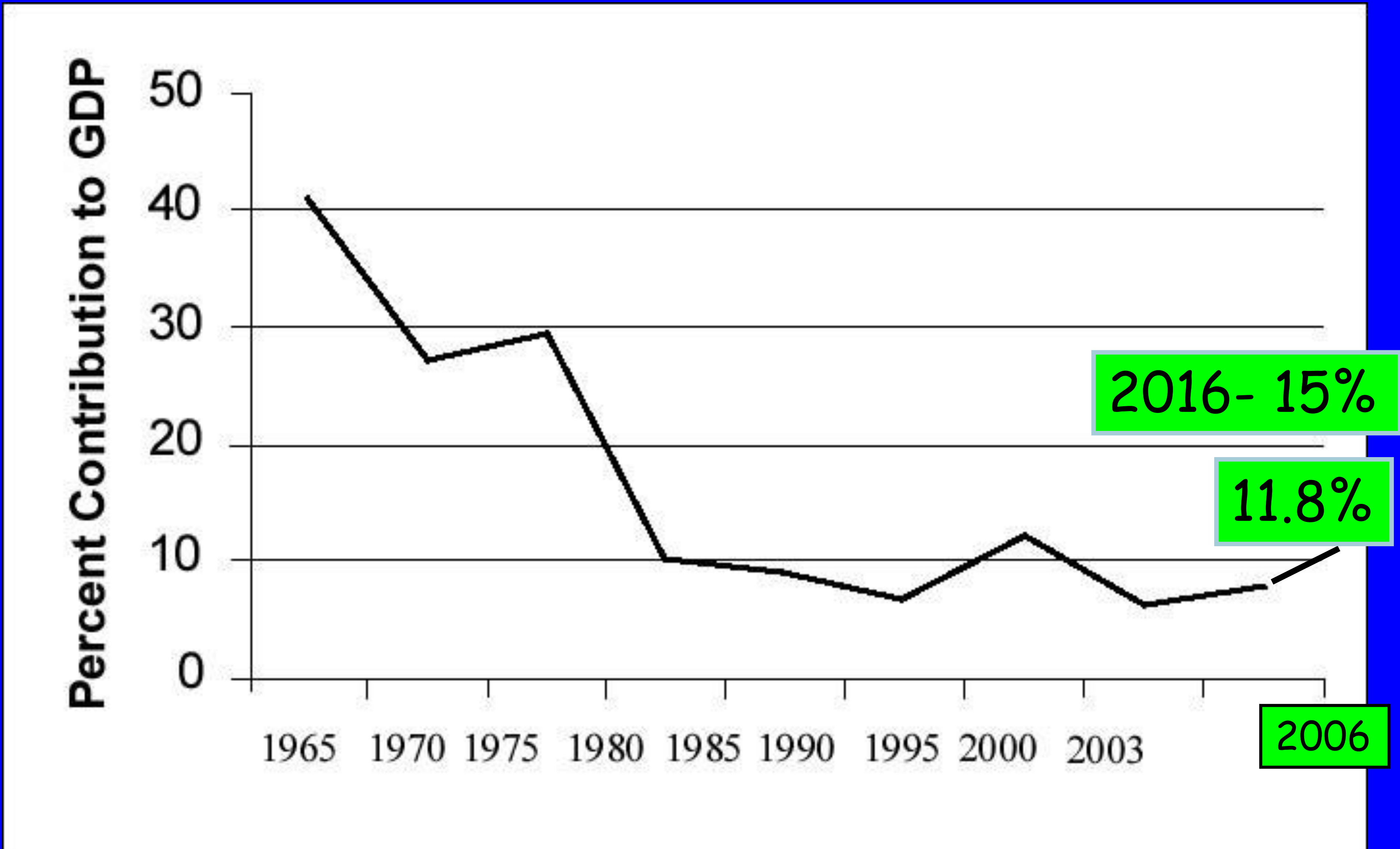


(i) Large-scale Mining

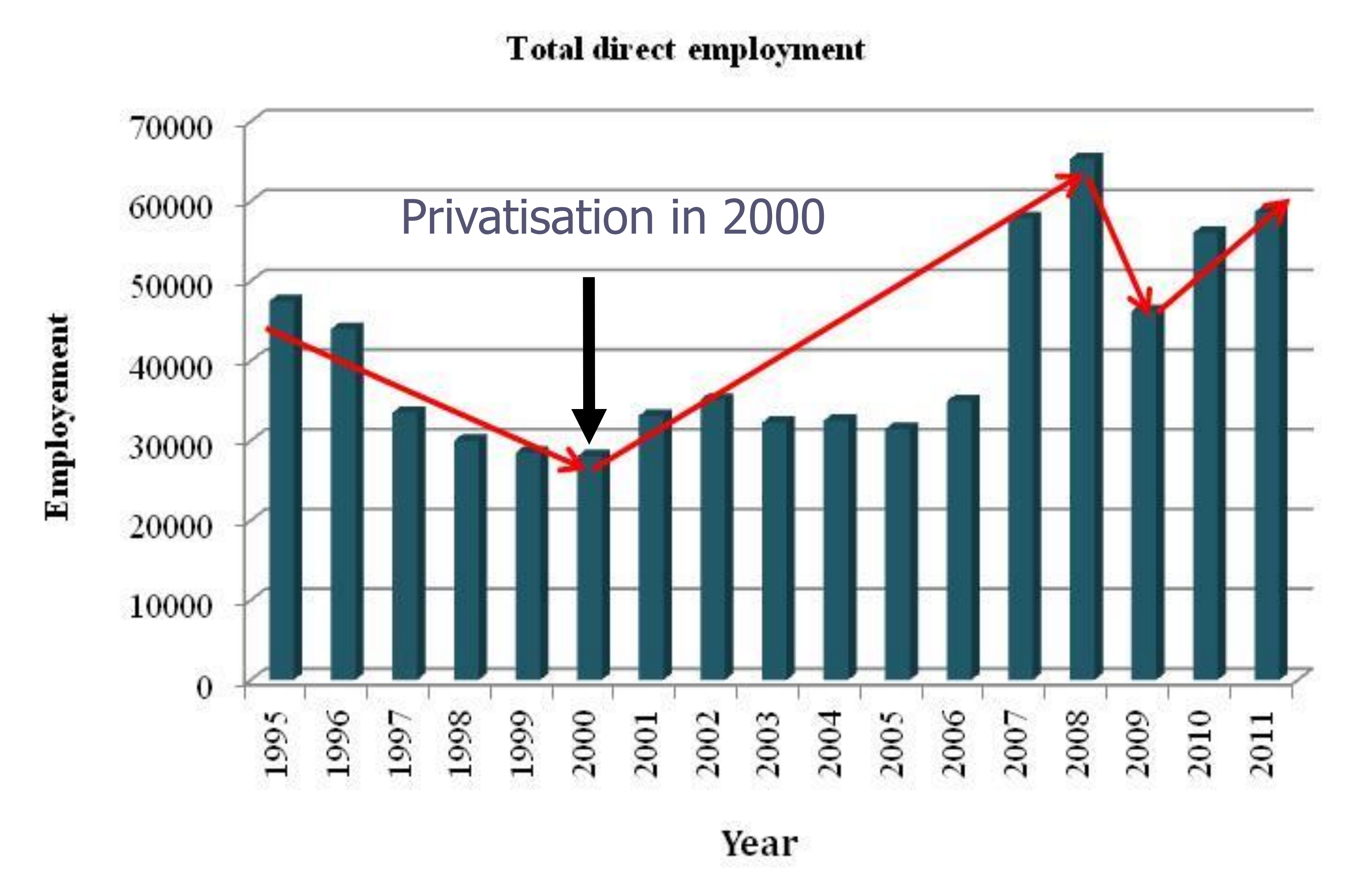
Ownership of Copper Mines in Zambia. Note that ownership is truly global

Zambian Company	Location	Controlling Company	Country
Mopani Copper Mines Plc (MCM), Nkana and Mufulira Mines	Kitwe and Mufulira	Glencore (Swiss 73%)/Xstrata/First Quantum (13%) / ZCCM (GRZ)	**Switzerland /Canada-Australia / Zambia**
Konkola Copper Mines Plc (KCM), Konkola, Konkola Deep and North, Nchanga Tailings, Nchanga	Chililabombwe and Chingola	Vedanta / ZCCM (GRZ)	**India / UK / Zambia**
Bwana Mkubwa Mining Ltd (BMML) Bwana Mkumbwa / Lonshi	Ndola	First Quantum Minerals Ltd (FQM)/ ZCCM (GRZ)	**Canada-Australia/ Zambia**
Chibuluma Mines Ltd. Chibuluma South and West	Kalulushi	Metorex / ZCCM (GRZ)	**South Africa / Zambia**
Non Ferrous Metals Africa Mining plc (NFC). Chambishi Mine	Chambishi	NFC / ZCCM (GRZ)	**China / Zambia**
China Luanshya/Baluba	Luanshya	Chinese / ZCCM (GRZ)	**China/Zambia**

Mining industry contribution of 8% - 11.8% to GDP (2000-2006) compared to an average of 35% (1965-1970) (Source: Central Statistics Office)

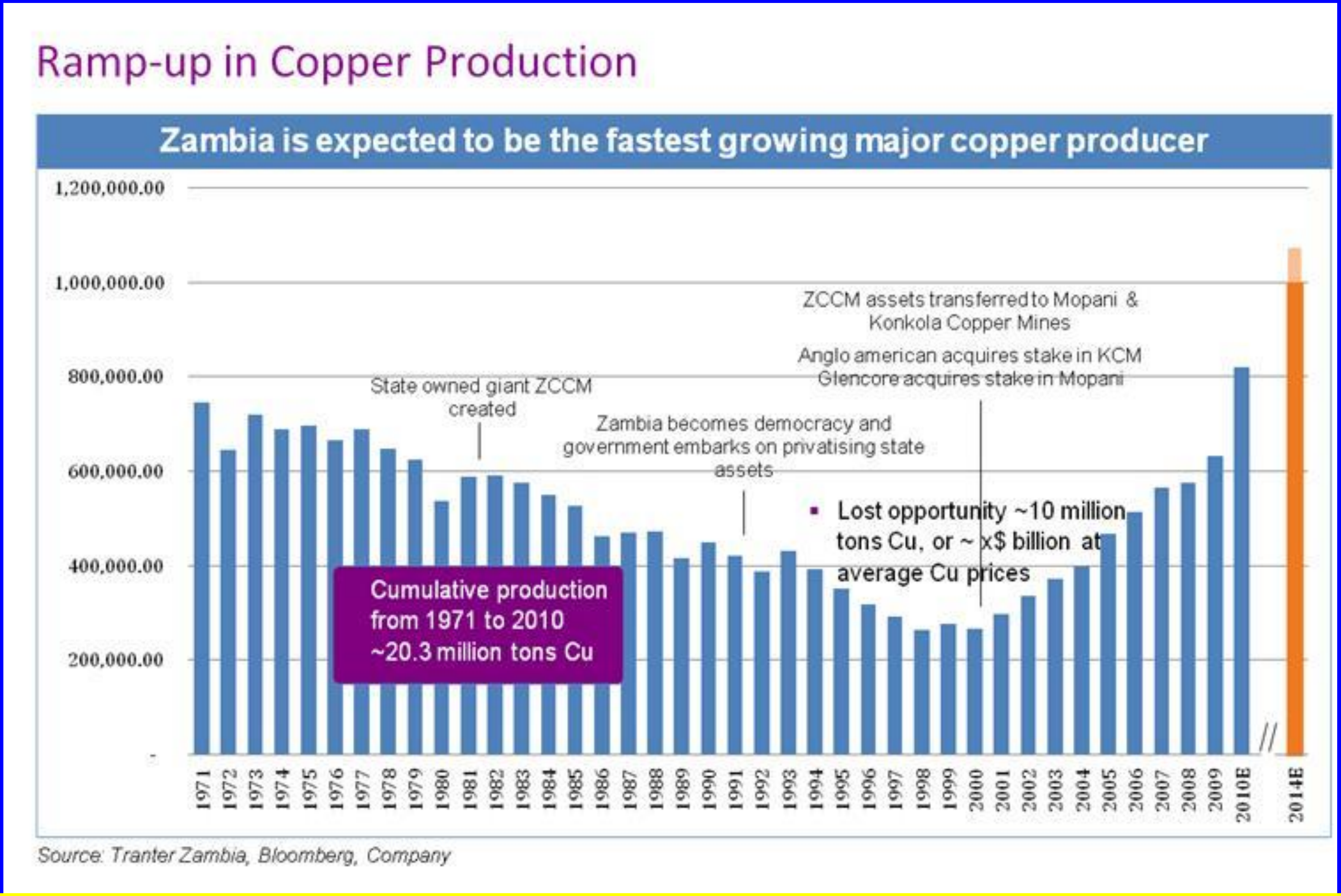


Mining Employment The trends in the total number employed in the mining industry from 1995 to 2011*(note: data excludes Small-scale mining sub-sector)*



✓Minerals Dependent Economy (Cont'd)

Figure 6b: Copper production 1971-2010 (adapted from Ngandu 2011)

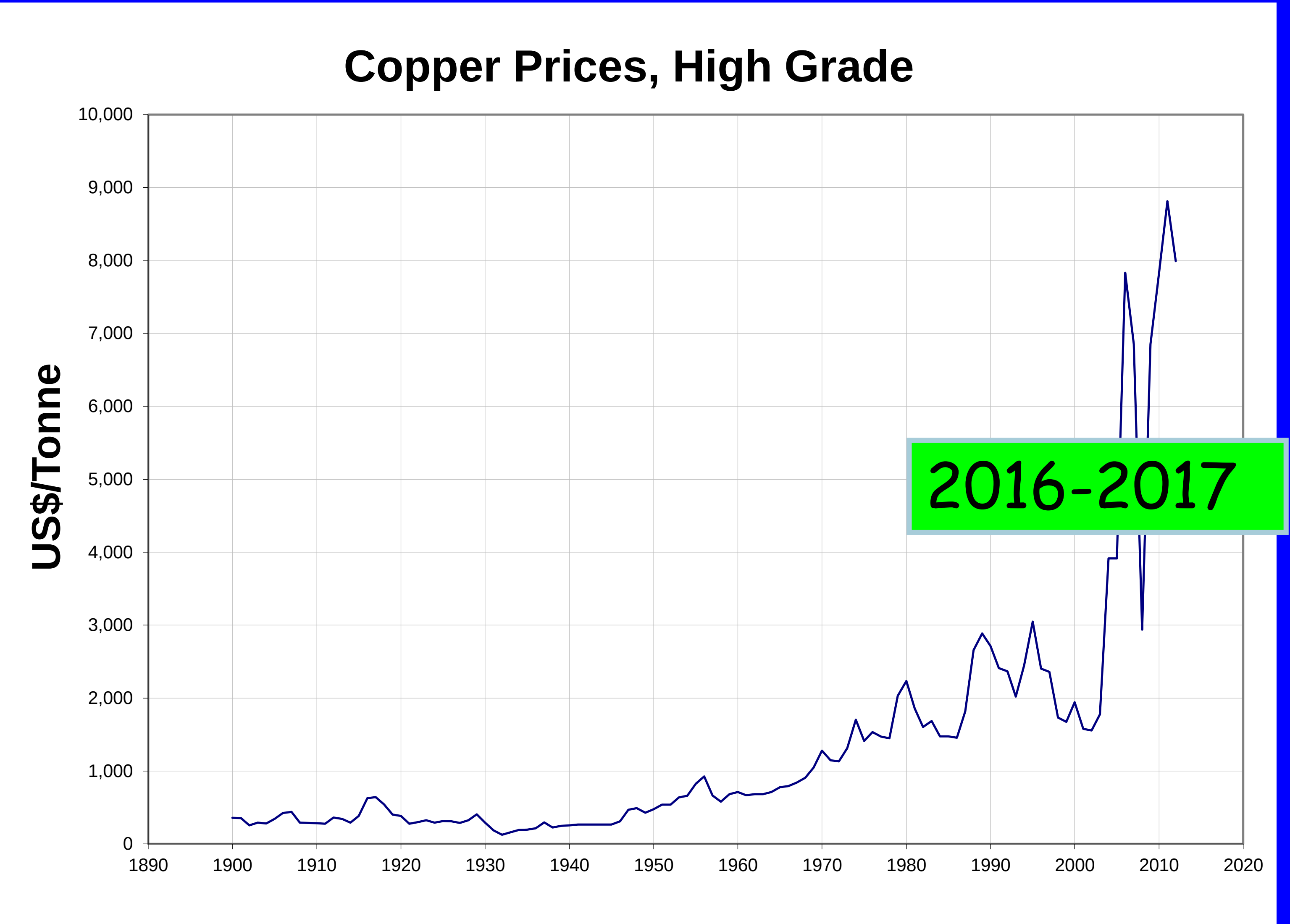


In 2011 – Zambia aimed to be the 4th World Largest copper producer by 2014 with over 1Mt of Copper Production

✓Minerals Dependent Economy (Cont'd)

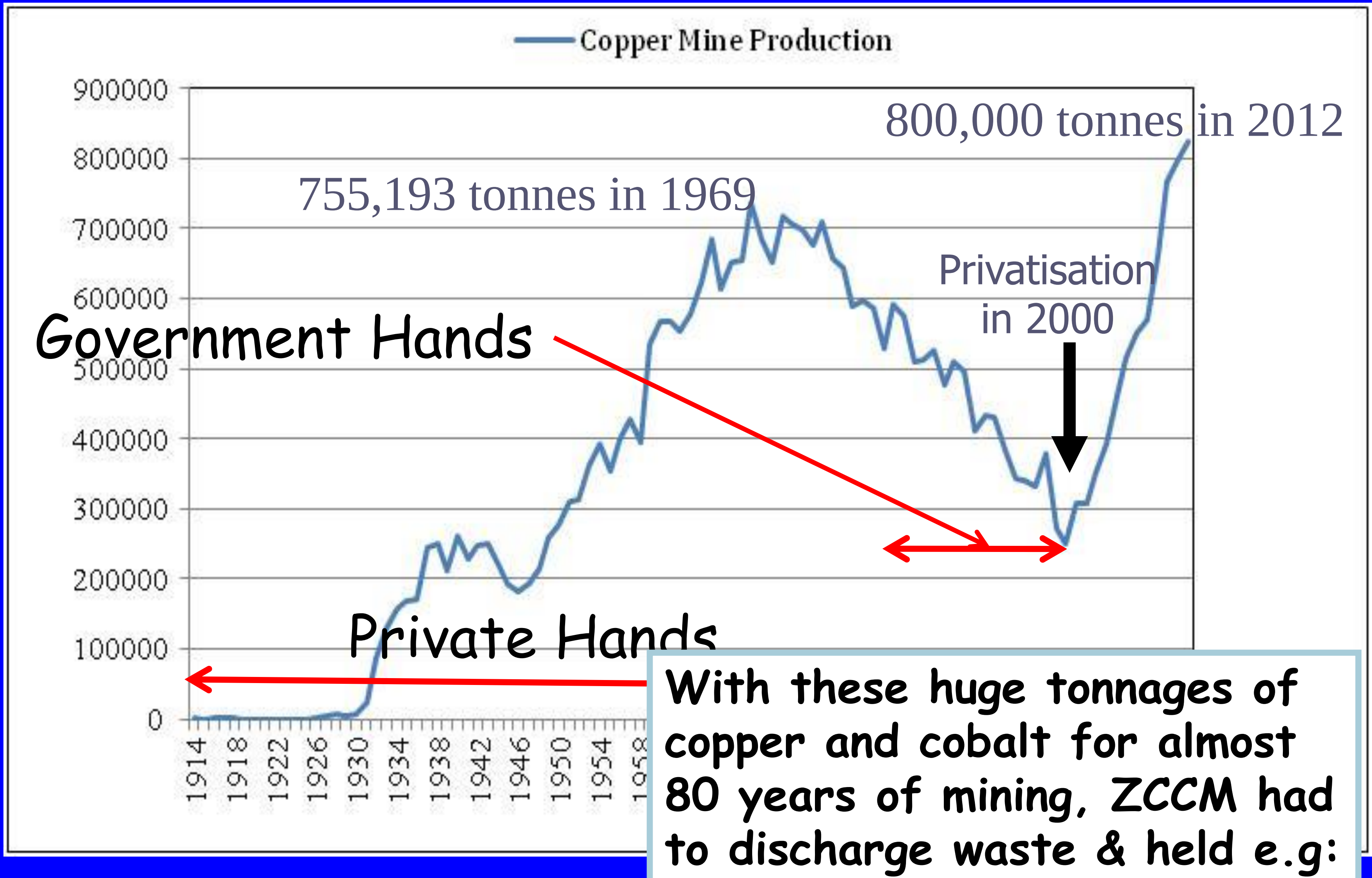
However, due to demand in the far east, particularly China, after 2002, copper prices picked to over $8,000/tonne by 2010 (Figure 9).

Graph showing the variations of copper prices per tonne since the 1900s to 2012



✓Minerals Dependent Economy (Cont'd)

Copper production 1914-2012 (data to 2002 supplied by Bonel)



7 licences to operate domestic waste disposal sites,
8 licences to transport tailings to tailings dams

9 licences, to discharge tailings effluent into public streams.

45 Tailings dams / dumps - 791million tonnes of tailings occupying 9125 hectares.

Part of the Slag dump, Nkana Mine, Kitwe

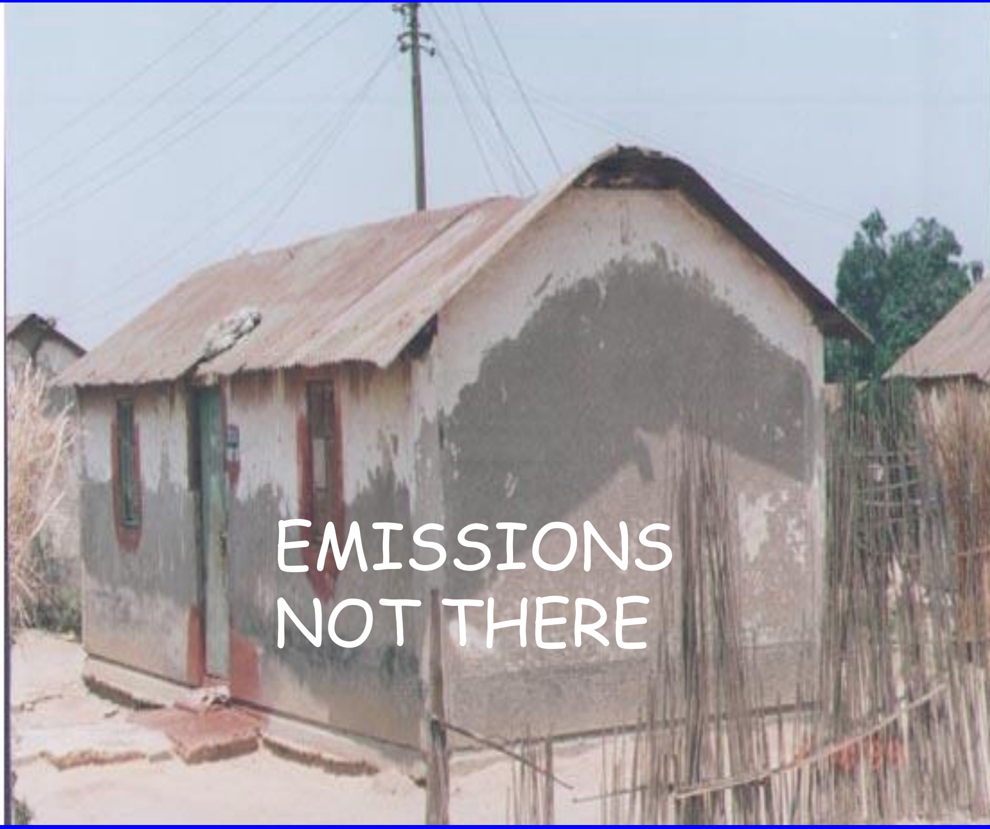
- **9 slag dumps -** 40 million tonnes of slag occupying 279 ha;

Copper sulphate stained sediment and rock - drainage trench below the Slag Dump, Nkana Mine, Kitwe

32 overburden dumps with 1,899 million tonnes covering an area of about 206,465ha;

21 waste rock dumps – 77 million tonnes of waste rock = 388ha; **Total 216,257 ha**

AIR POLLUTION



(a) Nkana Smelter showing air emissions;

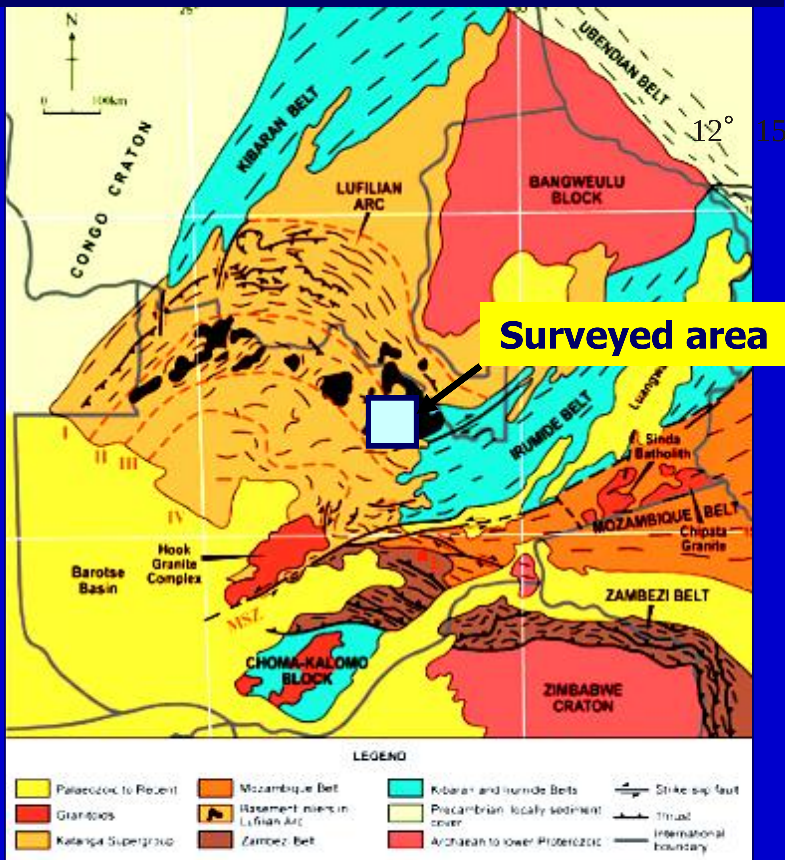
b) Effect of Sulphur Dioxide emissions on buildings in Kankoyo Township in Mufulira.

3. WHAT DID WE DO

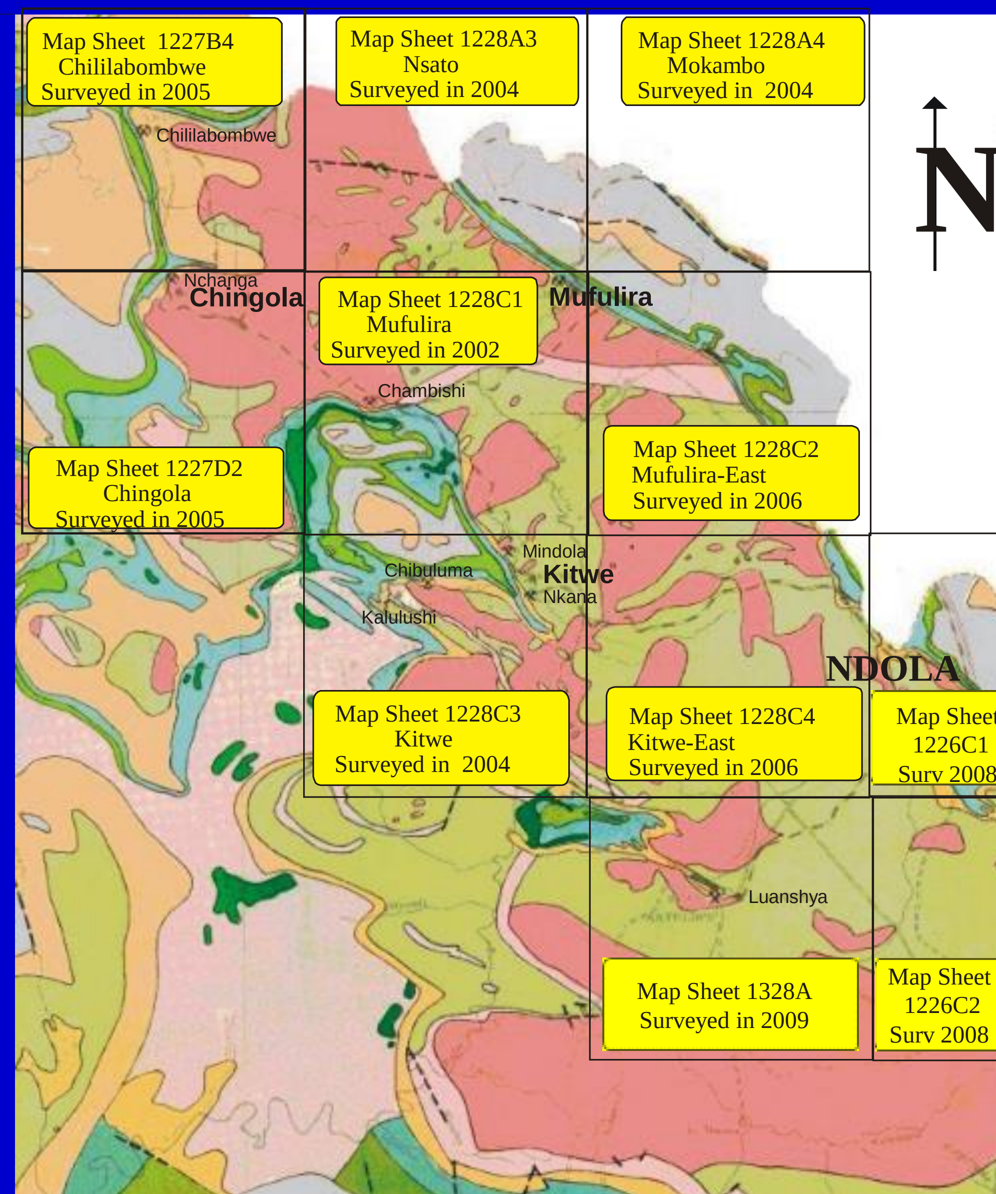
Development Cooperation Programme of the Czech Republic to the Republic of Zambia in years 2003-2006 and 2008 in Kabwe

Under UNESCO in 2013

GEOLOGICAL MAP OF ZAMBIA



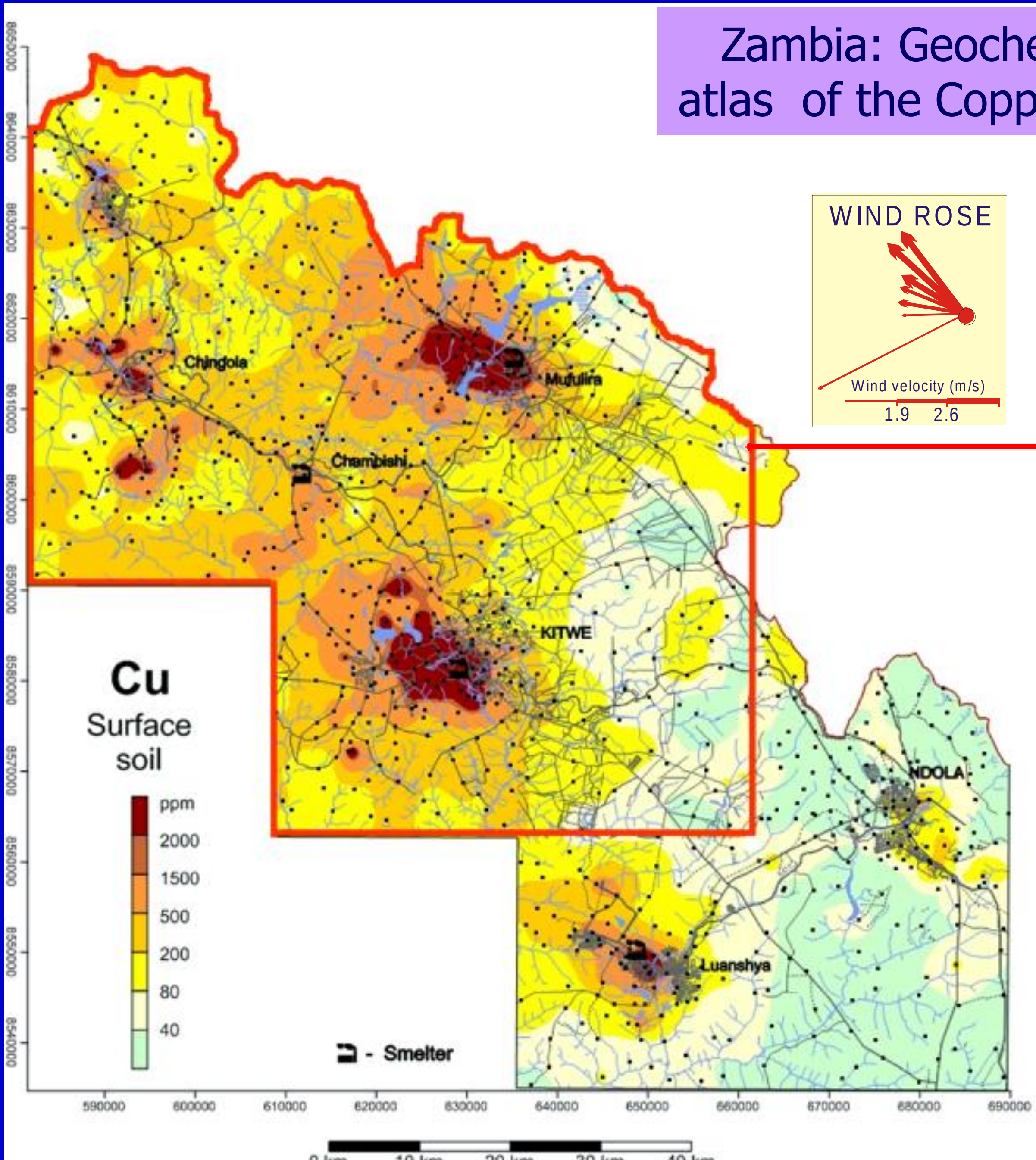
Geological sketch map of Zambian Copperbelt and the extent of the environmental-geochemical survey



Large-scale mining in the Zambian Copperbelt commenced in the late 1920s. Therefore, to assess the possible environmental impacts of mining and ore processing, the environmental-geochemical surveying was carried out in this region in 2001–2010.

GEOLOGICAL MAP OF THE AREA COVERED BY ENVIRONMENTAL-GEOCHEMICAL MAPPING

Zambia: Geochemical-environmental atlas of the Copperbelt Province, Zambia



Central-northern part of the Zambian Copperbelt (Kitwe, Mufulira, Chambishi, Chingola, Chililabombwe Mining Districts)

MAPPING
- 1223 composite samples of surface soil
- 266 samples of subsurface soils
- 337 samples of stream sediments
- 120 samples of surface waters
- 282 samples of vegetation

SPECIAL STUDIES
- Gaseous and dust emissions monitoring
- Dust gastric availability
- Dietary assessment
- Hazardous properties of mining wastes

METHODS OF THE ENVIRONMENTAL GEOCHEMICAL SAMPLING & ANALYSIS

Sampling followed Salminen, R. et. al (1998). FOREGS geochemical mapping field manual. Geological Survey of Finland, Guide 47. Espoo

Analysis: Except for those measurements required immediately in the field e.g. pH, drying & sieving – Rest were done at Czech Laboratories

Topsoil sampling, surface of abandoned tailings impoundment in Kitwe

Soil profile

SOIL SAMPLES:

Topsoil horizon

Lower soil horizon

(80-90 cm depth)

Lower soil horizon sampling

Groundwater = 23 S

In KABWE

Stream Sediment = 11 S

Vegetation = 36 S





In KABWE

Rhizosphere at vegetation roots = 9 S





Precipitate = 1 S

Total = 109 Samples

Zambian Copperbelt

SOURCES OF ANTHROPOGENIC CONTAMINATION

Soils and Plants:

- Gaseous and solid emissions from smelters
- Dust from dry parts of tailing impoundments
- Dust from mining operations, processing plants and slag deposits
- Transport of concentrate and products

Surface Waters and Stream Sediments

- Industrial water discharged into the watercourse
- Seepage and owerflow from tailing impoundments
- Erosion and washout of fine-grained particles from spoil banks and tailing impoundments (siltation)

SOURCES OF CONTAMINATION

Sulphur dioxide emissions from smelters – Nkana Smelter - 1998

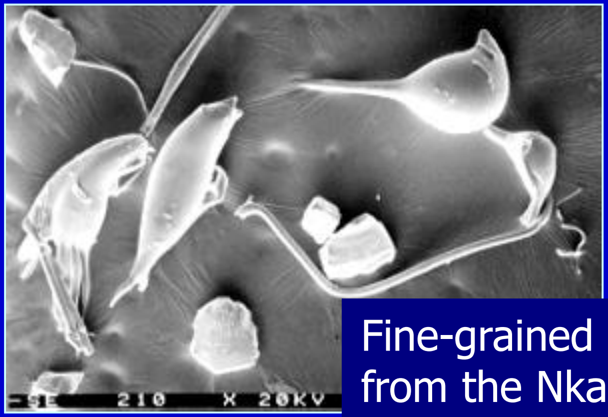
(a) Nkana Smelter showing air emissions;

b) Effect of sulphur sioxide emissions on buildings in Kankoyo Township in Mufulira.

SOURCES OF CONTAMINATION

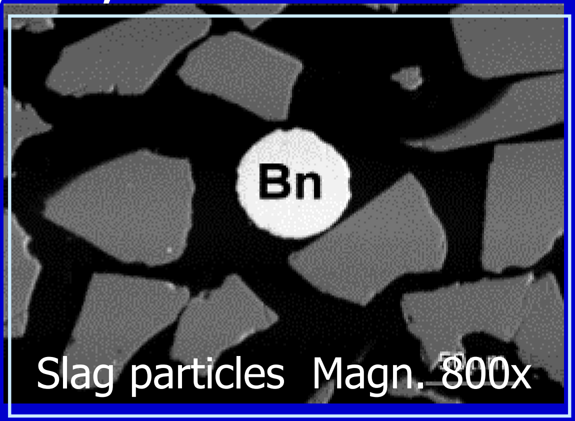
Airborne dust particles from slag deposits and from crushers

Dust particles contain: As, Be, Co, Cr, Cu, Hg, Mo, Se, Va Zn

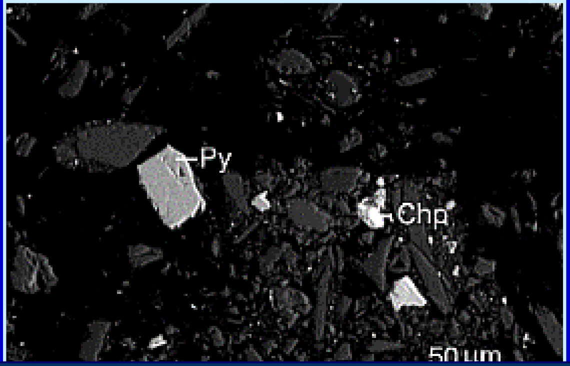


Fine-grained airborne particles from the Nkana Smelter slag
Magnification: 2000x

Slag deposits, the Nkana Smelter



Slag particles Magn. 800x

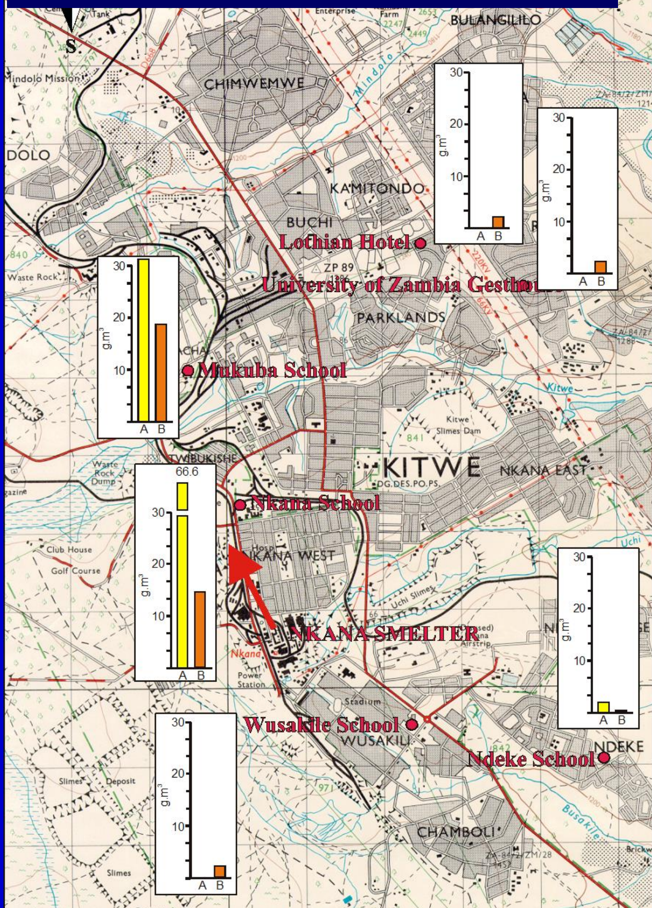


Dust particles, Nkana crushers
Magnification 600x

SOURCES OF CONTAMINATION

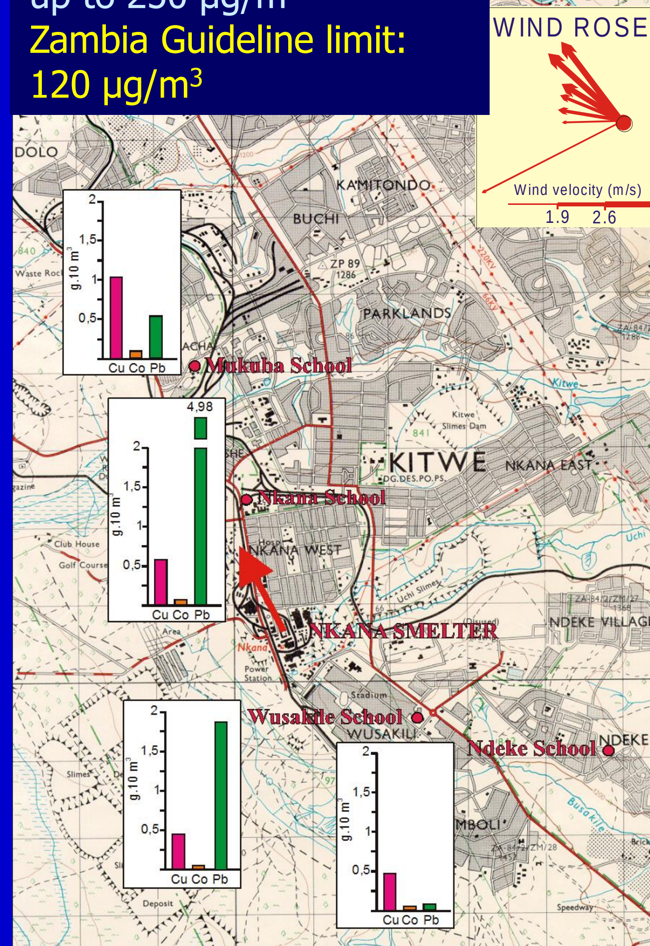
Gaseous emissions and airborne dust particles the Nkana Smelter -2006

Sulphur dioxide emissions:
up to 511 µg SO_2 /m^3
Zambia Guideline limit: 50 µg/m^3 SO_2 /m^3



Concentrations of sulphur dioxide in air around the Nkana Smelter

Total suspended particles:
up to 250 µg/m^3
Zambia Guideline limit:
120 µg/m^3



Concentrations of Cu, Co and Pb in dust fall-out from the Nkana Smelter

Voluntary collaborator in the dust falout monitoring, Mrs. Jean Chokwe, Mukuba Secondary School

Volunteers in dust fallout monitoring, Mrs. Malama Mable and Mrs. Lilian Namukoko, Wusakile Basic School

SOURCES OF ANTHROPOGENIC CONTAMINATION

Airborne particles from dry beaches of tailing impoundments – Mindolo 2009

Dust particles from the Mindolo Tailings Impoundment contain up to:
22 ppm As; 3 090 ppm Co;
9 350 ppm Cu; 0.02 ppm Hg;
88 ppm Mo; 124 ppm Ni;
95 ppm Pb; 21 ppm Se and
74 ppm Zn

Sandstorm over a dry beach of the Mindolo Impoundment

Sandstorm over the Mufulira Impoundment

SOURCES OF CONTAMINATION

Technological waters from mines, smelters and chemical leaching plants

Chibuluma- South II Open Pit

Chambeshi River, whitish precipitates of carbonates and gypsum, efluents
from the Chambishi Smelter

Technological water from the Nkana Smelter and Processing Plant

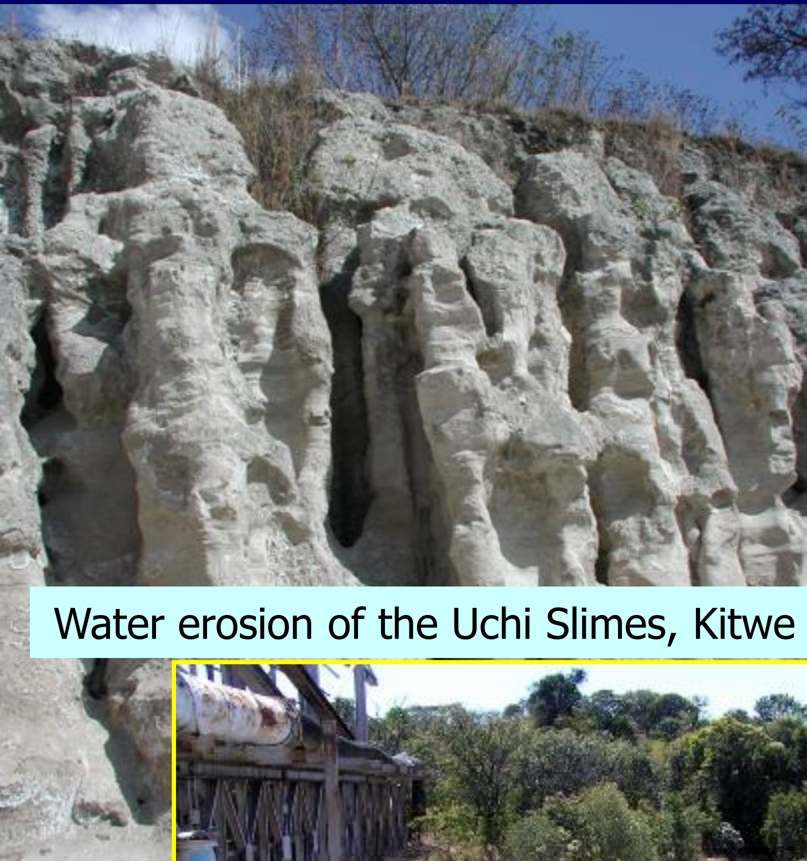
SOURCES OF ANTHROPOGENIC CONTAMINATION

Seepages through tailing impoundment dams

Iron hydrooxide precipitates contain up to: 0.035% As; 0.0001% Be; 0.19% Co; 0.004% Cr; 0.257% Cu; 0.006% Mo; 0.005% Ni; 0.003% Pb; 0.027% Se and 0.021% Zn.

Iron hydrooxide precipitates (ochres)

Erosion and washout of fine-grained particles from spoil banks and tailing impoundments (siltation)



Water erosion of the Uchi Slimes, Kitwe

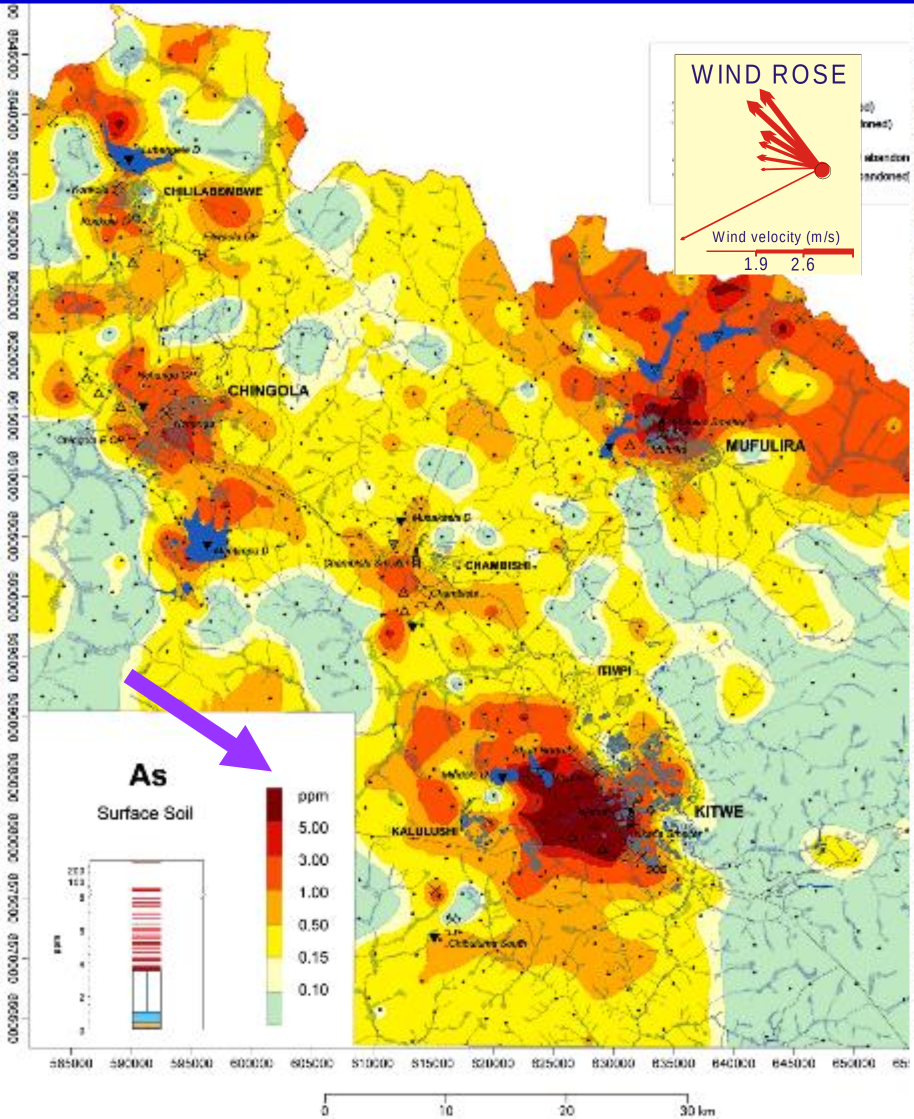
Washing of old flotation tailings, Chingola

Kafue River, Chingola Water Plant

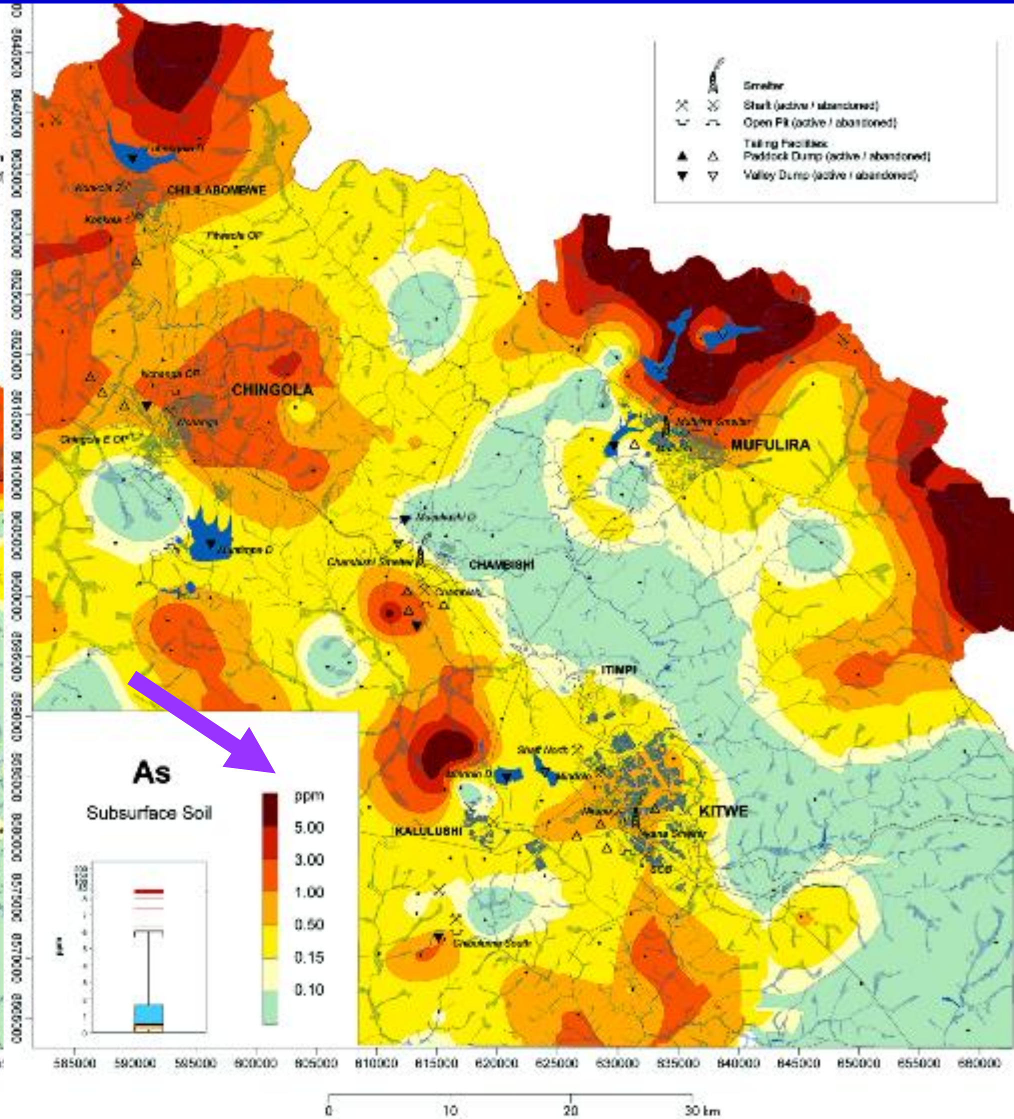
Siltation of the Mushishima River, Chingola

ARSENIC IN SOILS

ARSENIC IN SURFACE SOIL

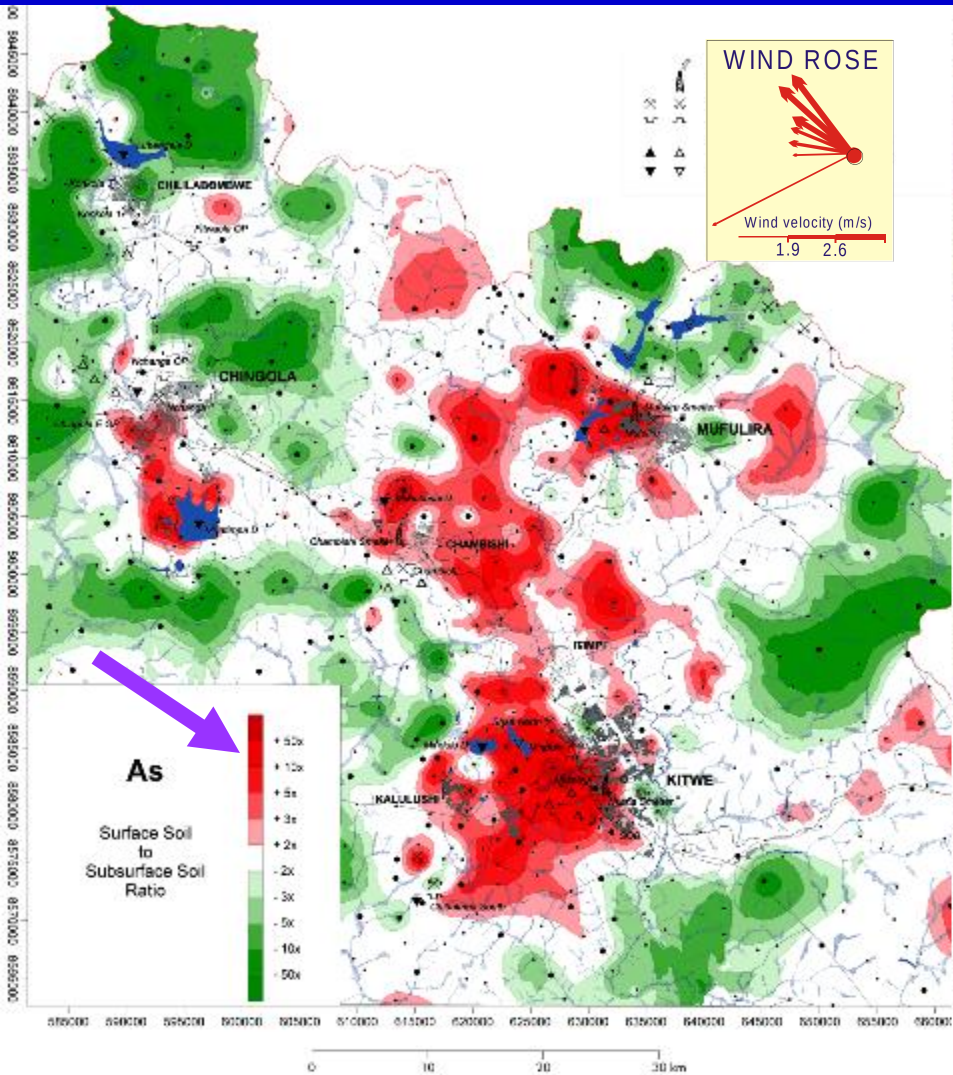


ARSENIC IN SUBSURFACE SOIL

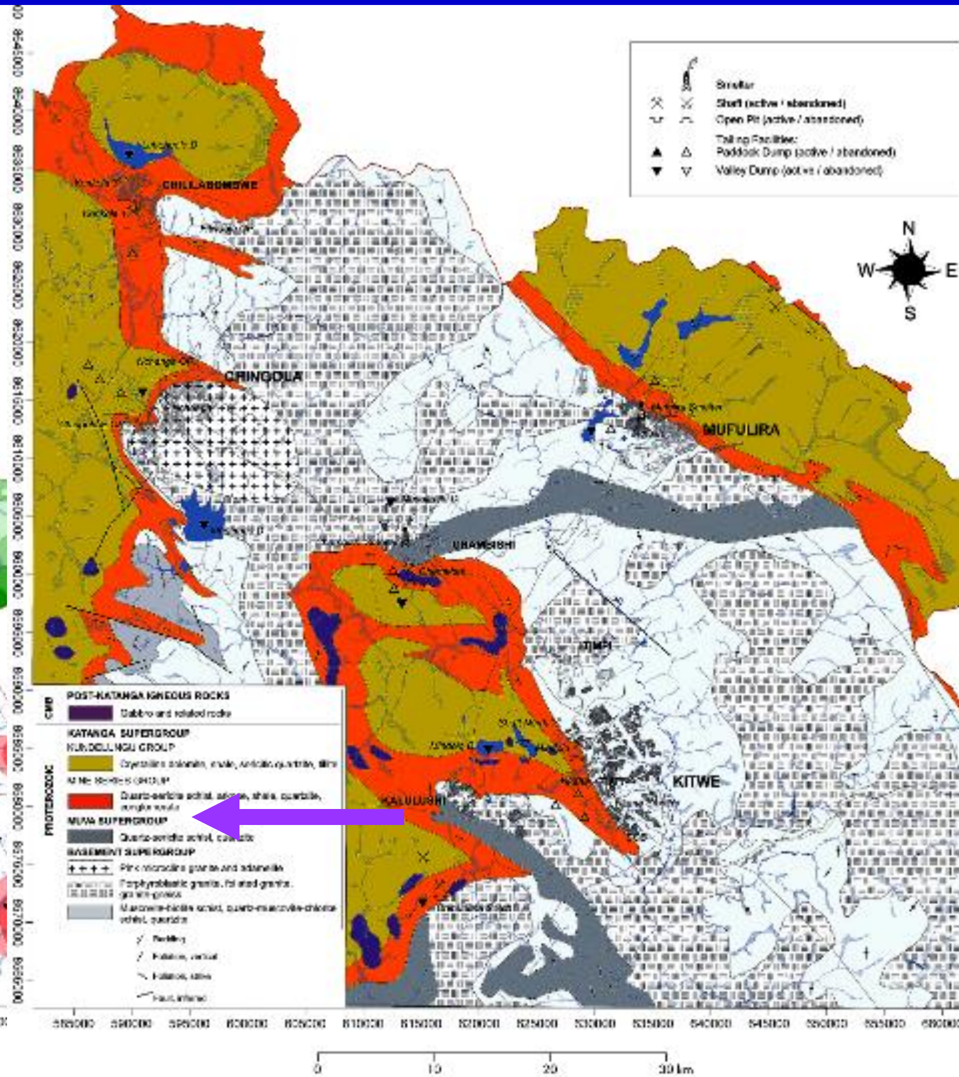


ARSENIC IN SOILS

DIFERENCE: SURFACE TO SUBSURFACE SOIL

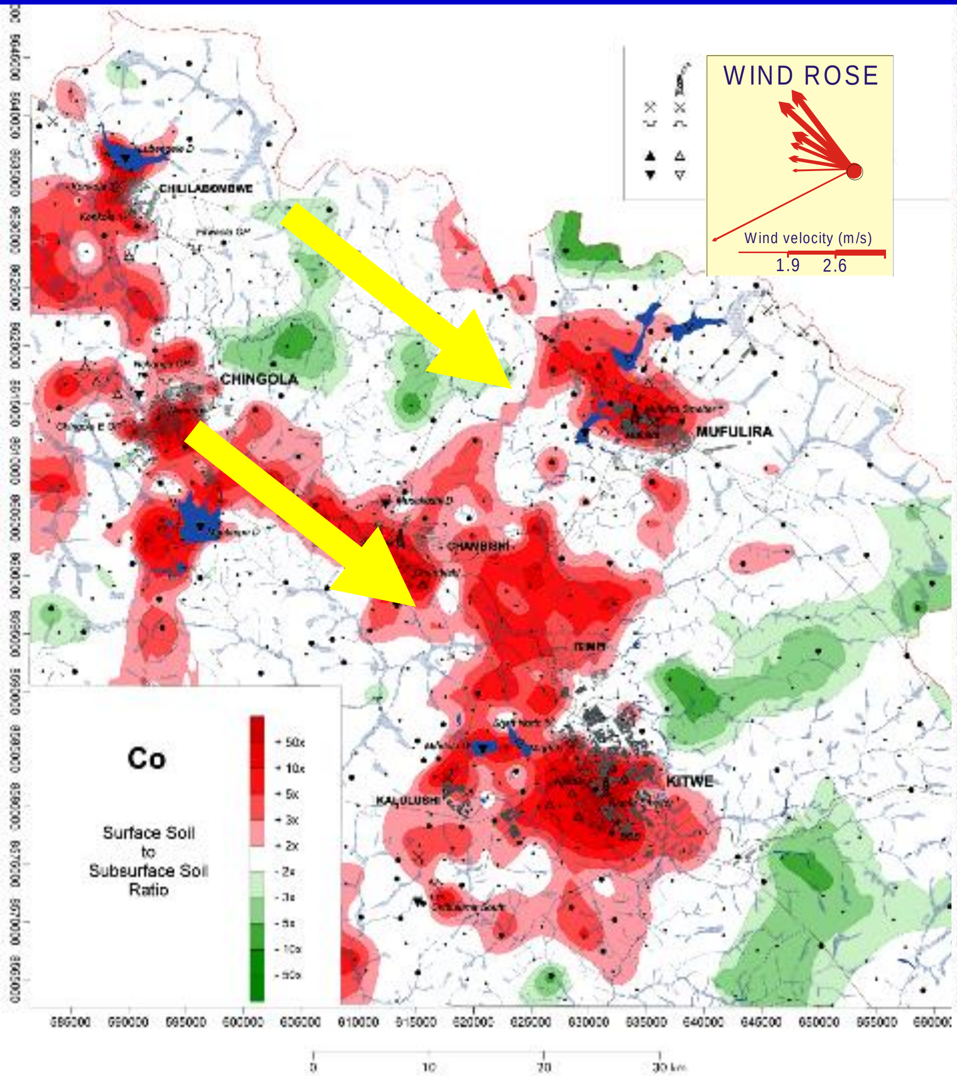


GEOLOGICAL MAP

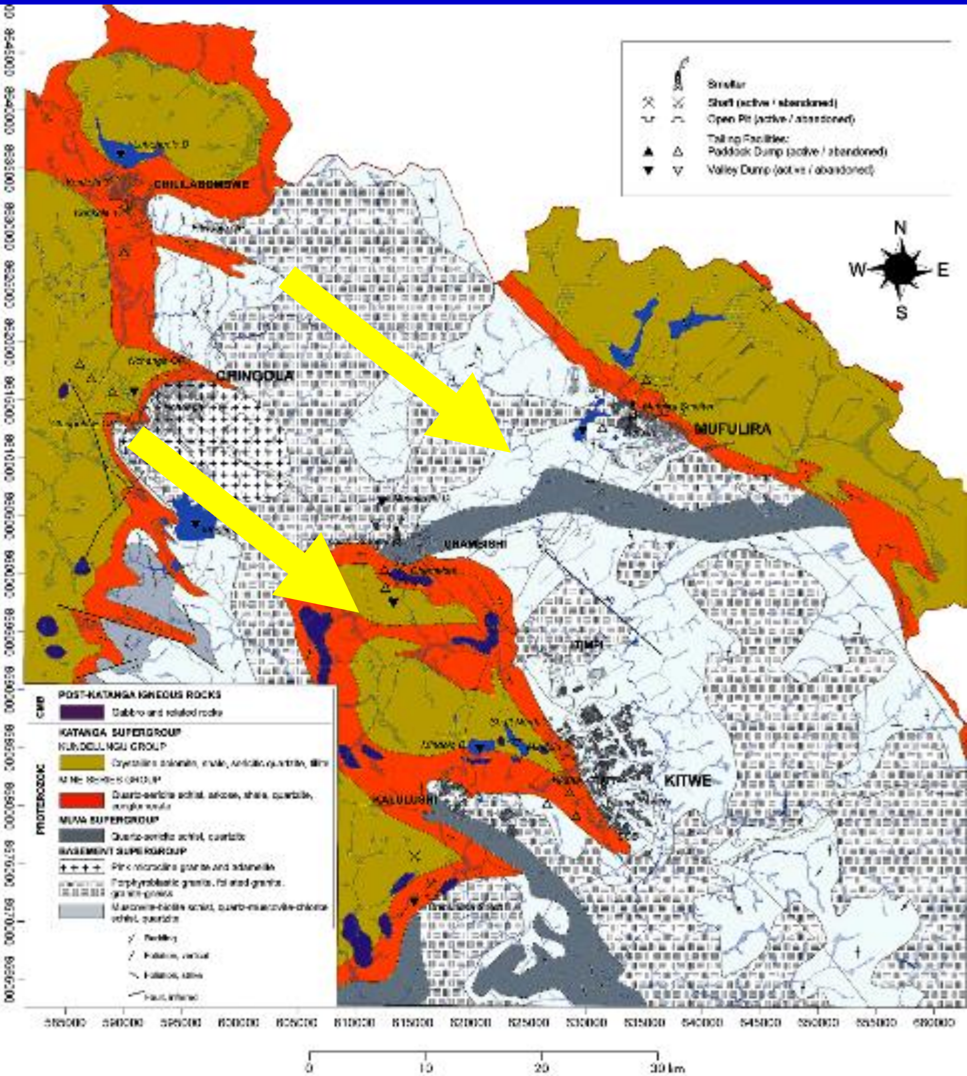


COBALT IN SOILS

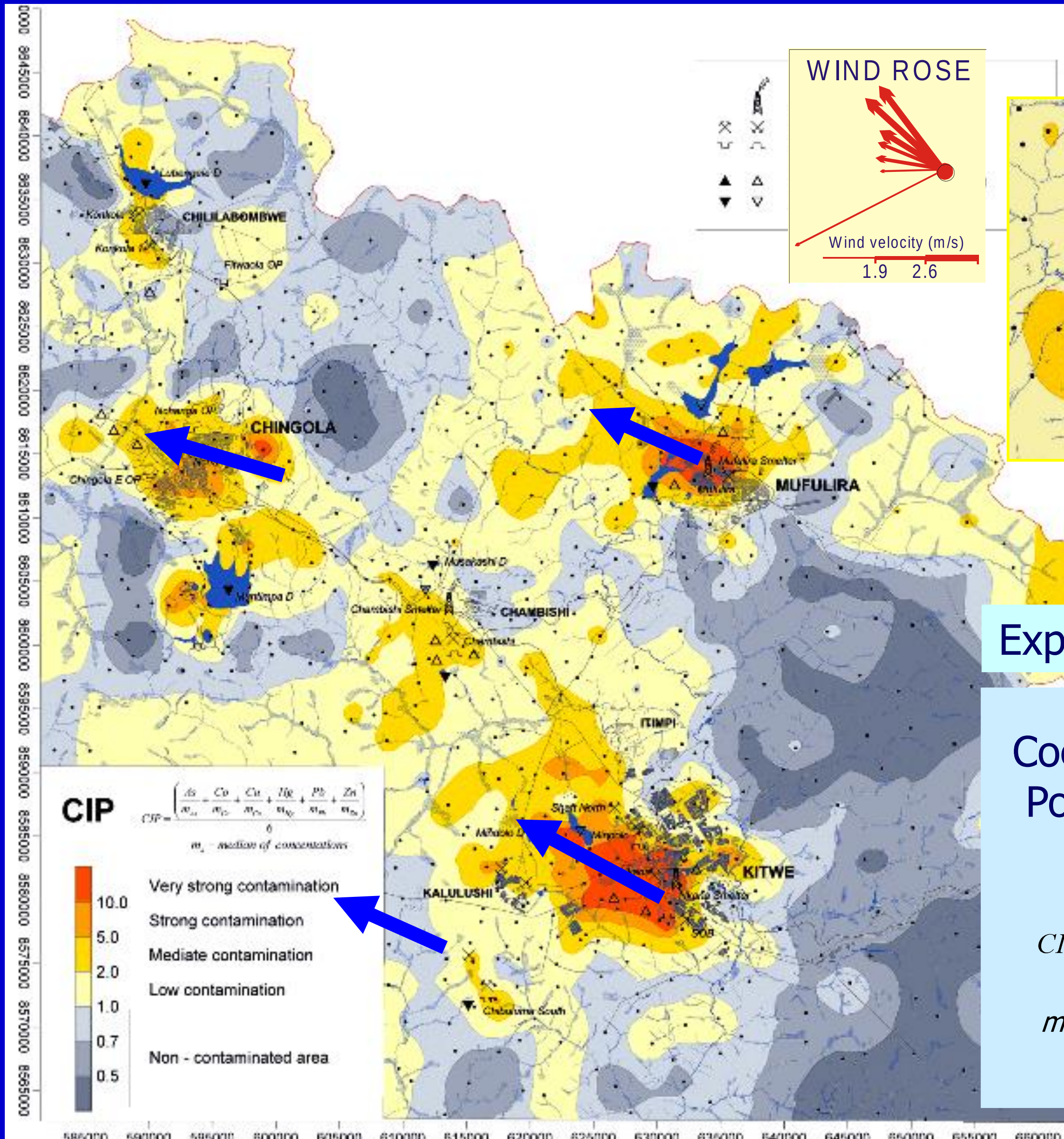
DIFERENCE: SURFACE TO SUBSURFACE SOIL

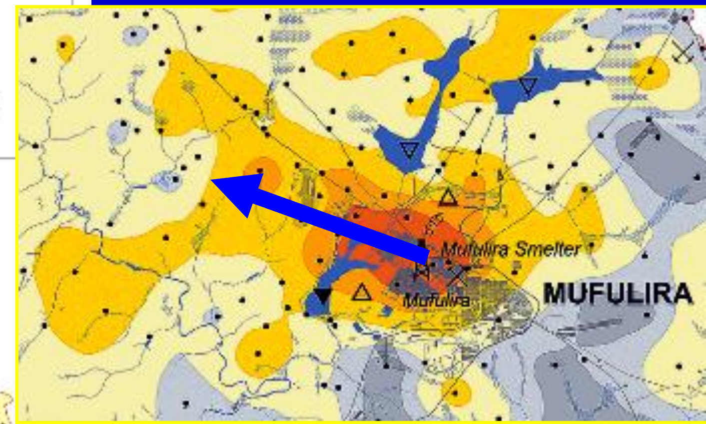


GEOLOGICAL MAP



COEFFICIENT OF INDUSTRIAL POLLUTION (SURFACE SOIL)





Close-up: Mufulira area

Explanation:

Coefficient of Industrial Pollution

$$CIP = \frac{\left(\frac{As}{m_{As}} + \frac{Co}{m_{Co}} + \frac{Cu}{m_{Cu}} + \frac{Hg}{m_{Hg}} + \frac{Pb}{m_{Pb}} + \frac{Zn}{m_{Zn}} \right)}{6}$$

m_X – value of the metal concentration

Metals in crop plants

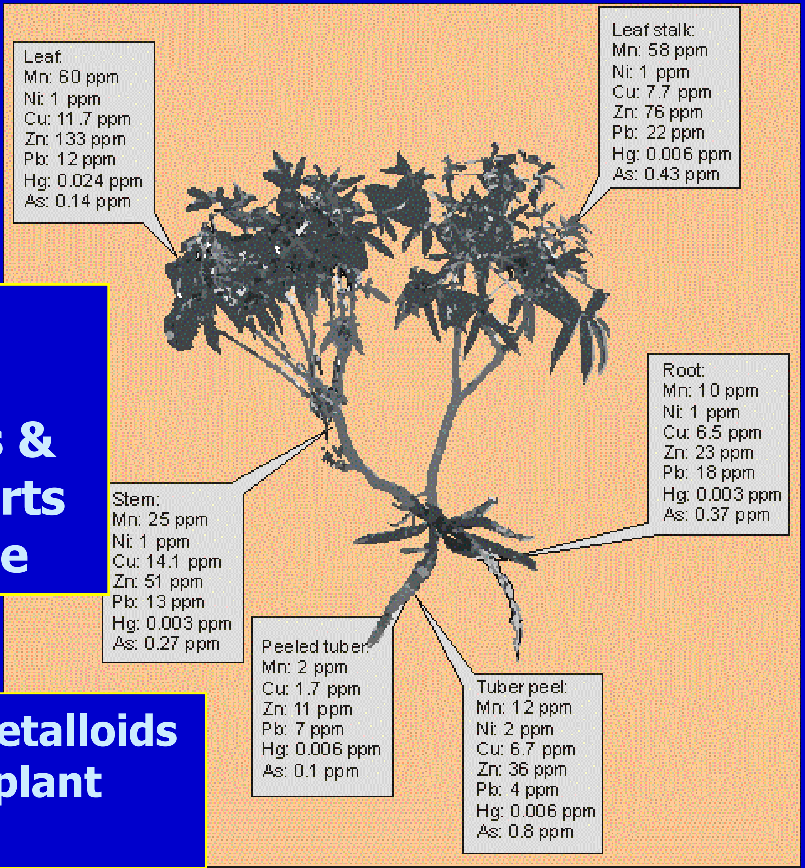
Sampled media:

Plant rhizosphere,
Cassava (*Manihot esculenta* sp.), leaves and tubers,
Sweet potato (*Ipomoela batatas* sp.), leaves and bulbs,
Maize (*Zea mays* ssp. *mays*), grains

Cu 11.7; 8.5ppm
As 0.43; 0.8ppm

Special studies:

Distribution of metals & metalloids in plant parts in relation to plant age



Distribution of metals and metalloids in diferent parts of cassava plant
Age of plant: 14 months

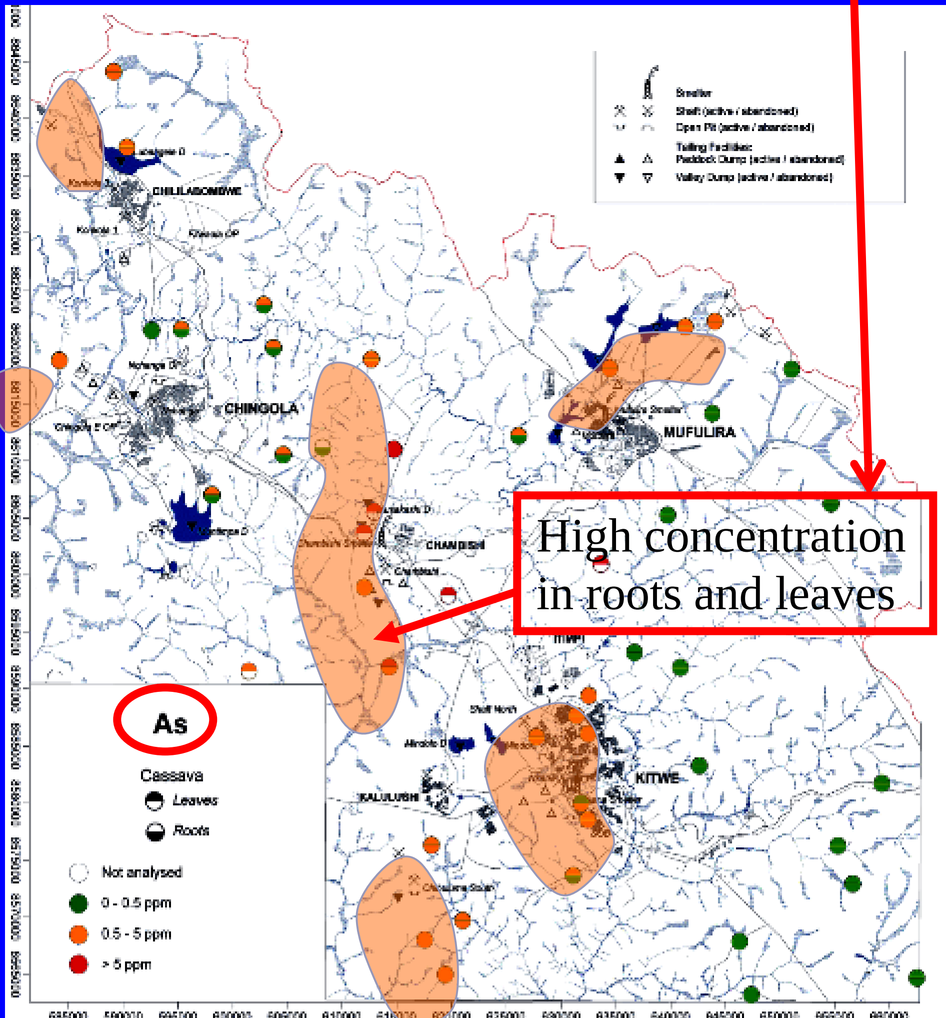
Close up:
Chlorisis of
cassava leaves

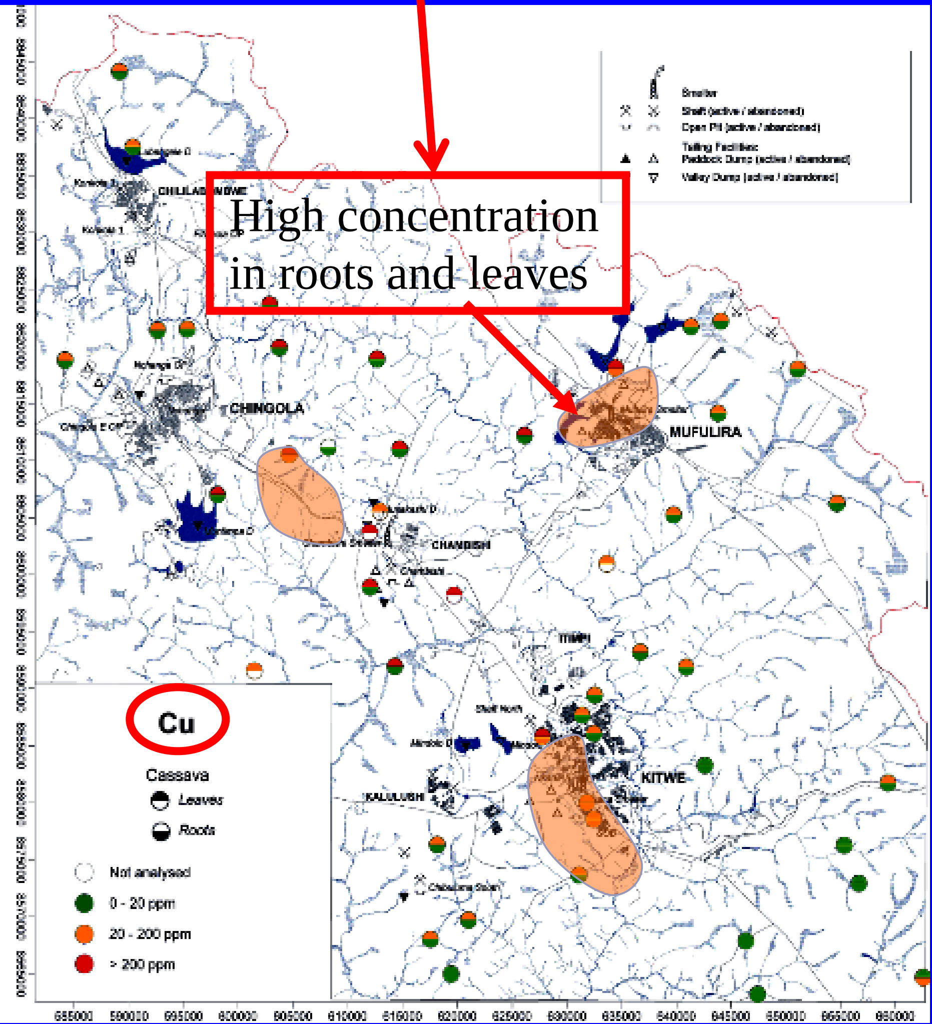
Cassava field near
Nkana Smelter.
Area strongly
affected by pollution.

METALS IN PLANTS

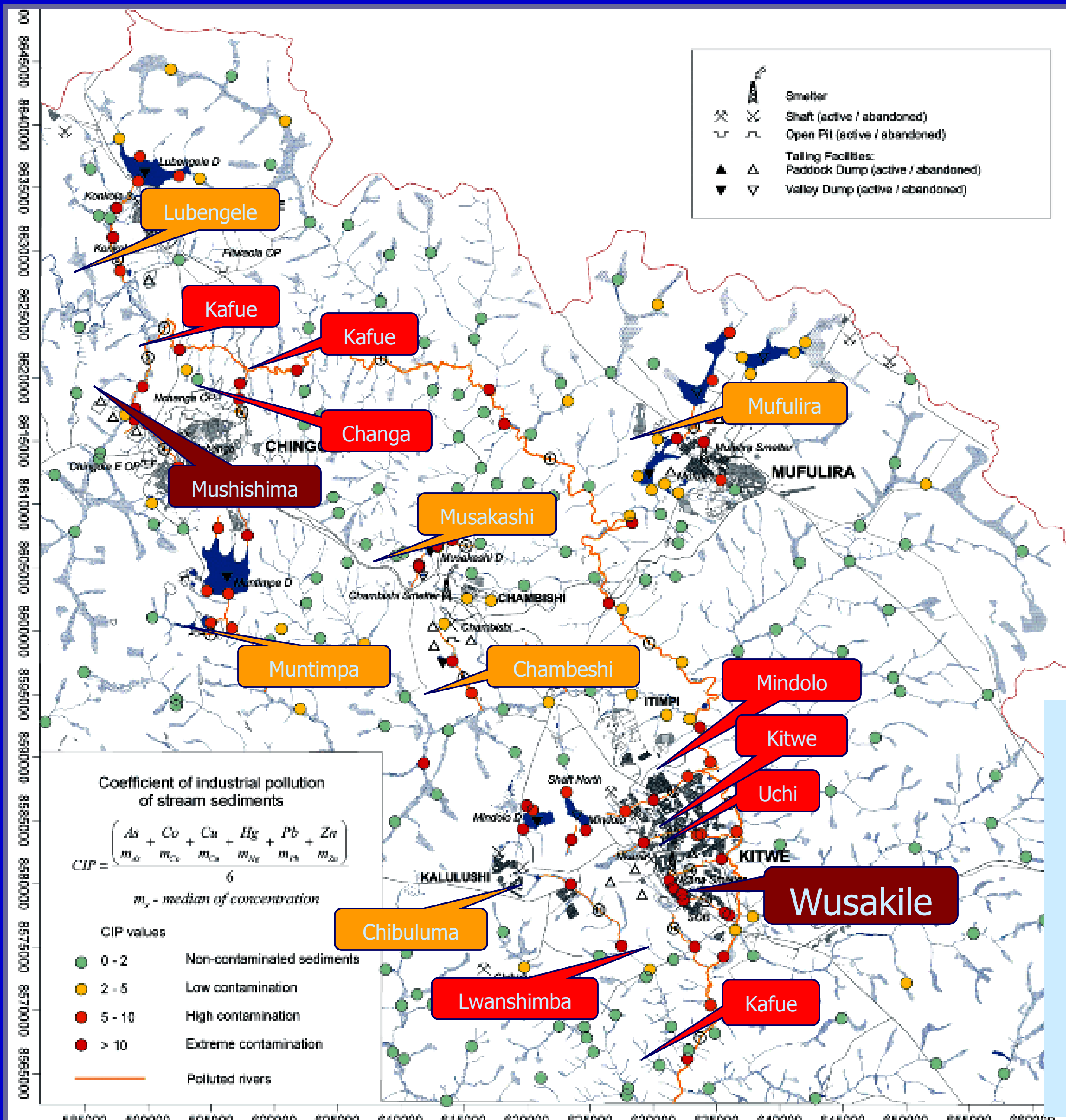
CONCENTRATION OF ARSENIC AND COPPER IN CASSAVA

Provide Informed Decisions to Authorities: Cassava in Contaminated areas





COEFFICIENT OF INDUSTRIAL POLLUTION - STREAM SEDIMENTS



Stream sediments, Wusakile River, Kitwe:

- As: 1296 ppm
- Co 3660 ppm
- Cu 65 465 ppm
- Hg 6.4 ppm
- Mo 48 ppm
- Ni 360 ppm
- Pb 1370 ppm
- Zn 3590 ppm
- S tot 2.1 %

Explanation:

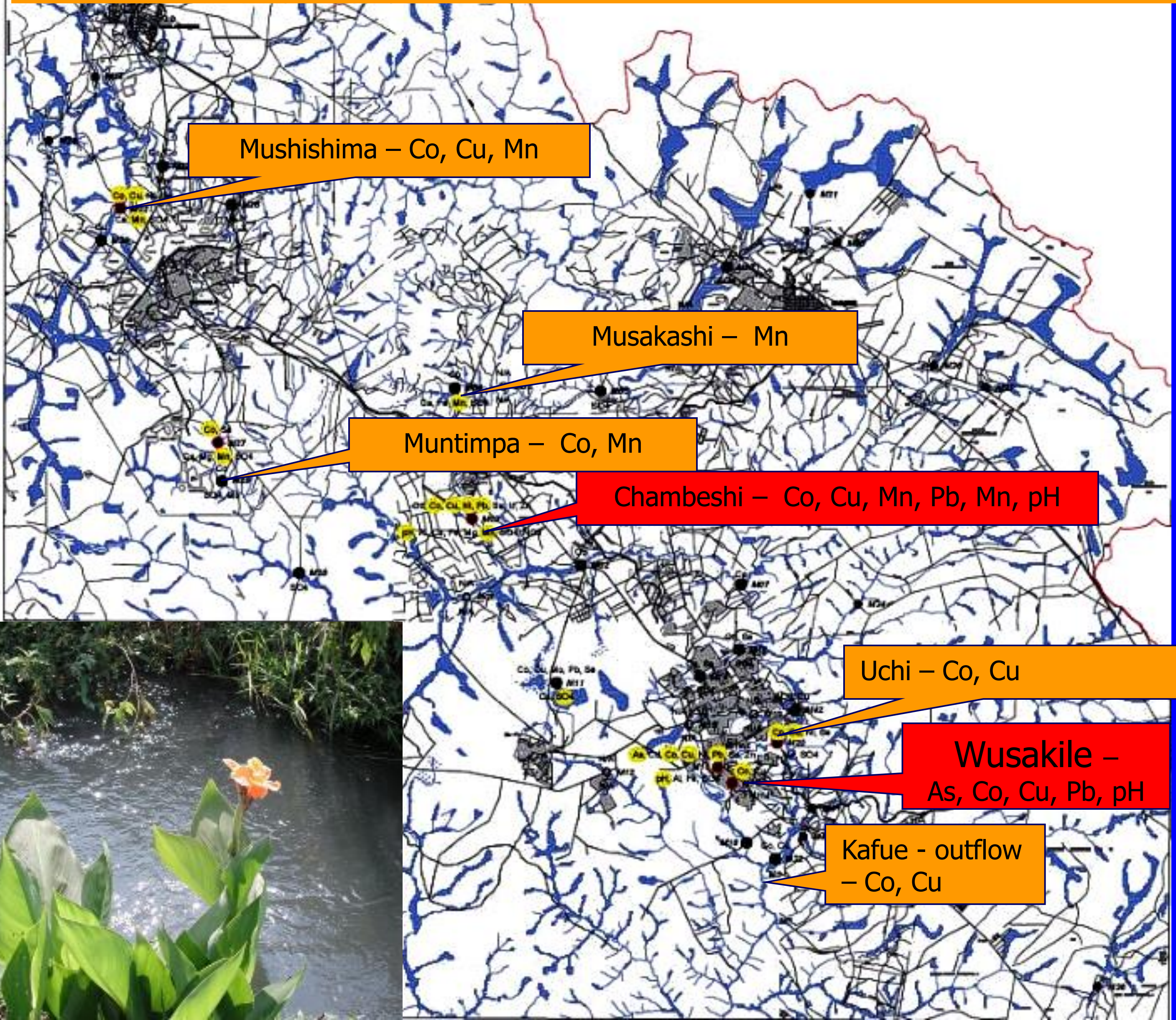
Coefficient of Industrial Contamination

$$CIP = \frac{\left(\frac{As}{m_{As}} + \frac{Co}{m_{Co}} + \frac{Cu}{m_{Cu}} + \frac{Hg}{m_{Hg}} + \frac{Pb}{m_{Pb}} + \frac{Zn}{m_{Zn}}\right)}{6}$$

m_X – *value of the metal concentration*

RESULTS OF THE ENVIRONMENTAL-GEOCHEMICAL MAPPING SURFACE WATER CHEMISTRY

River water exceeding Czech and European Union effluent limits shown in red colour



RESULTS OF THE ENVIRONMENTAL-GEOCHEMICAL MAPPING SURFACE WATER CHEMISTRY

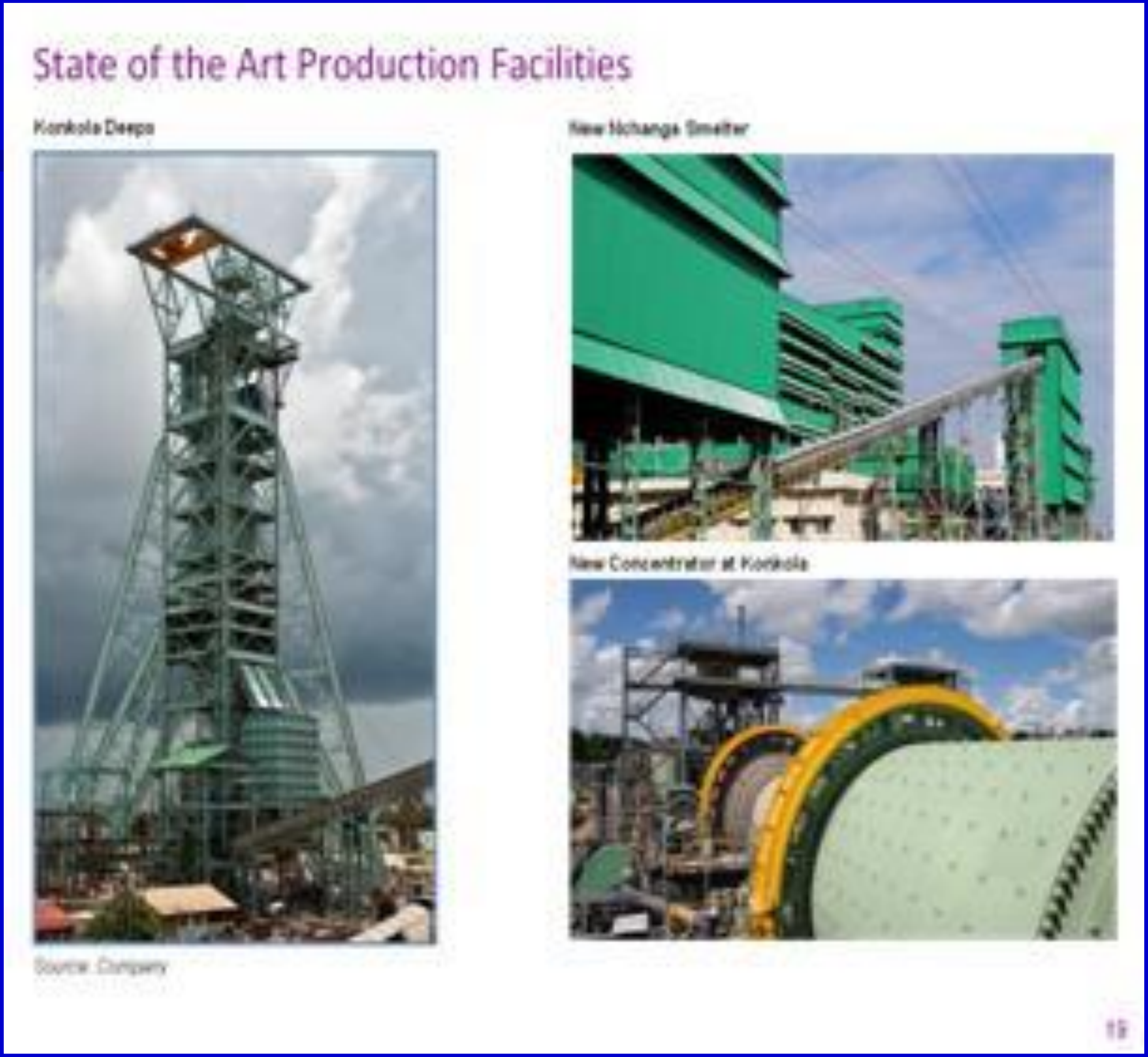
Kafue River chemistry: Inflow and outflow from the industrial part of the Zambian Copperbelt)

	pH	Al	Ca	Cd	Co	Cu	Mn	Ni	Pb	SO_4	Se	U	Zn
		µg/L	mg/l	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
EU limit E	6-8	1500	250	1	10	30	500	50	15	300	5	50	200
Kafue River - inflow	7.1	8	14	0.03	0.4	6	17	0.1	0.5	1	0.25	0.04	6.7
Kafue River outflow	7.2	20	34	0.03	19.0	66	152	1.1	0.4	76	0.25	1.4	4.6

Accidental acid spikes in the Kafue River tributaries (probably leakage of sulfuric acid from chemical plants)

	pH	Al	Ca	Cd	Co	Cu	Mn	Ni	Pb	SO_4	Se	U	Zn
		µg/L	mg/l	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
EU limit E	6-8	1500	250	1	10	30	500	50	15	300	5	50	200
Chambeshi 2006	3.6	6 929	709	500	1 000	16 442	8 673	1 776	317	2 617	38	99	1 741
Busakile 2006	2.1	2 115	197	7.02	909	7 405	466	51.5	161	1 396	13	5.2	346

Changes Seen: NEW SMELTERS)



Konkola Deep Shaft, New Nchanga Smelter, However

Tailing Dams

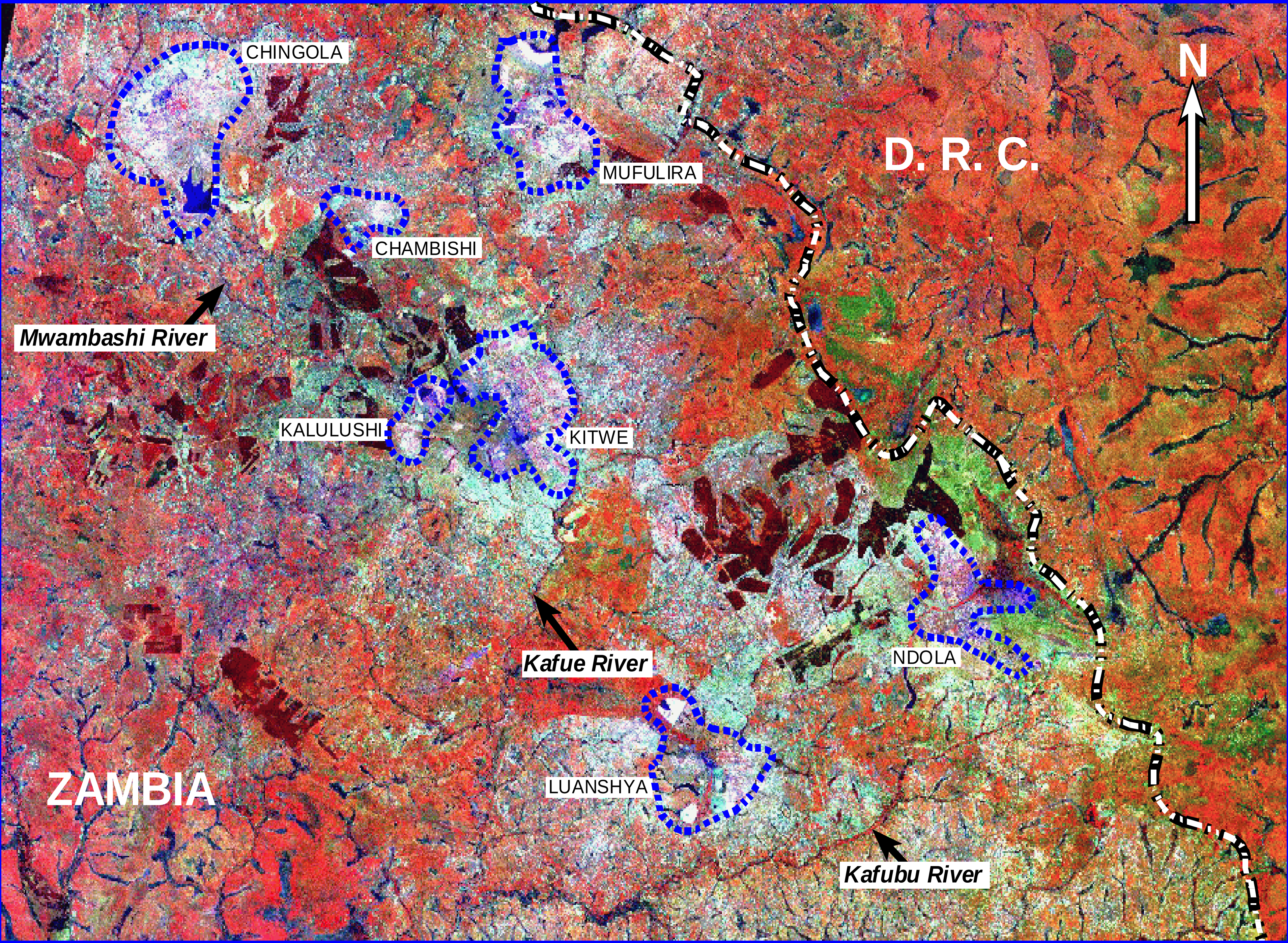
Still exist

PATHWAYS OF CONTAMINATION SPREADING - SILTATION

Collapse of the Luanshya tailings dam, Copperbelt, Zambia

Siltation of the Chingola river, Chingola, Zambia

REVISITED – JULY 2017:


CHINGOLA
MUFULIRA
CHAMBISHI
Mwambashi River
KALULUSHI
KITWE
D. R. C.
N
Kafue River
NDOLA
LUANSHYA
ZAMBIA
Kafubu River

Kabwe

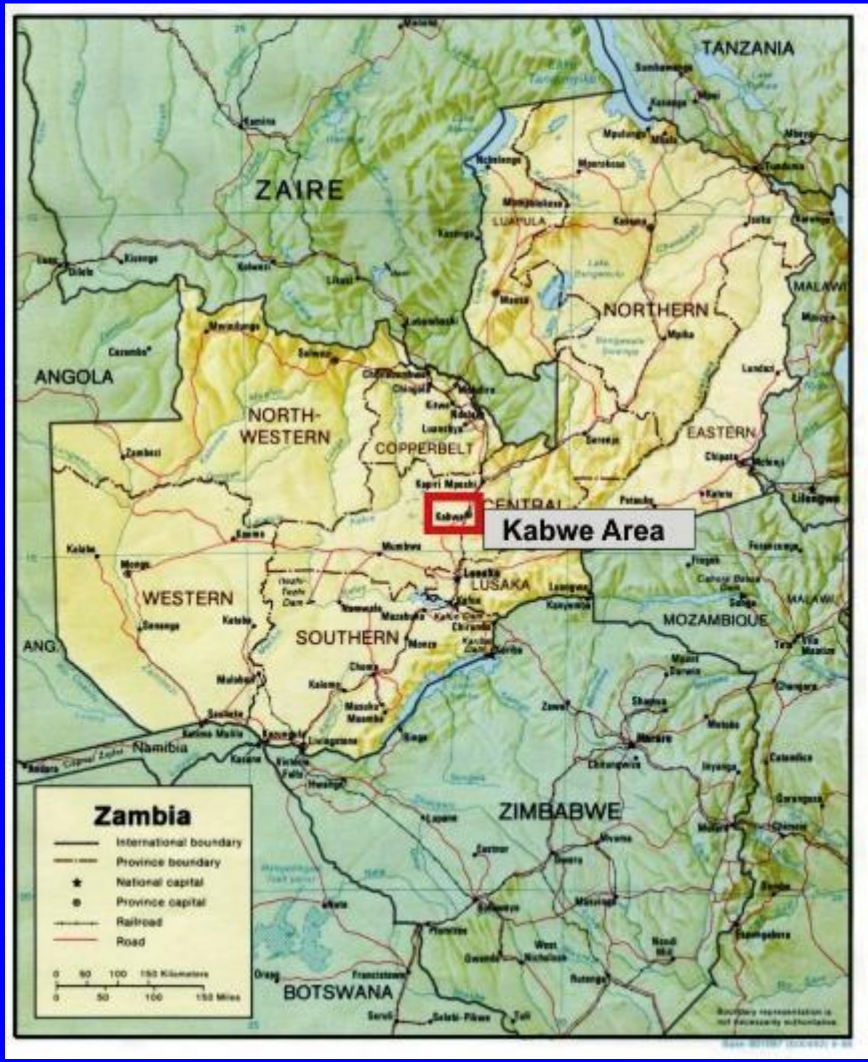
IGCP / Sida Projects 594 and 6006 CLOSING WORKSHOP, Praha, Czech Republic

26-28th May, 2014

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

Kabwe Old Mine Location

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

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

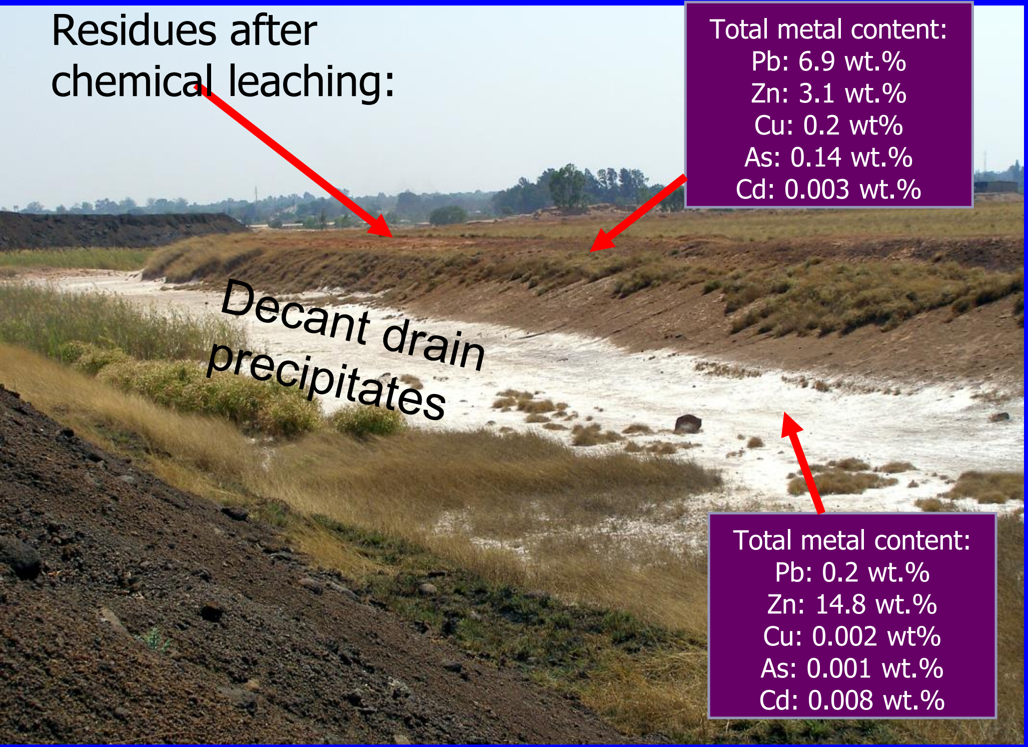
Worked on Kabwe Old Mine where previous mining activities still exist such as tailings, as well as new activities by undertaking:

(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:

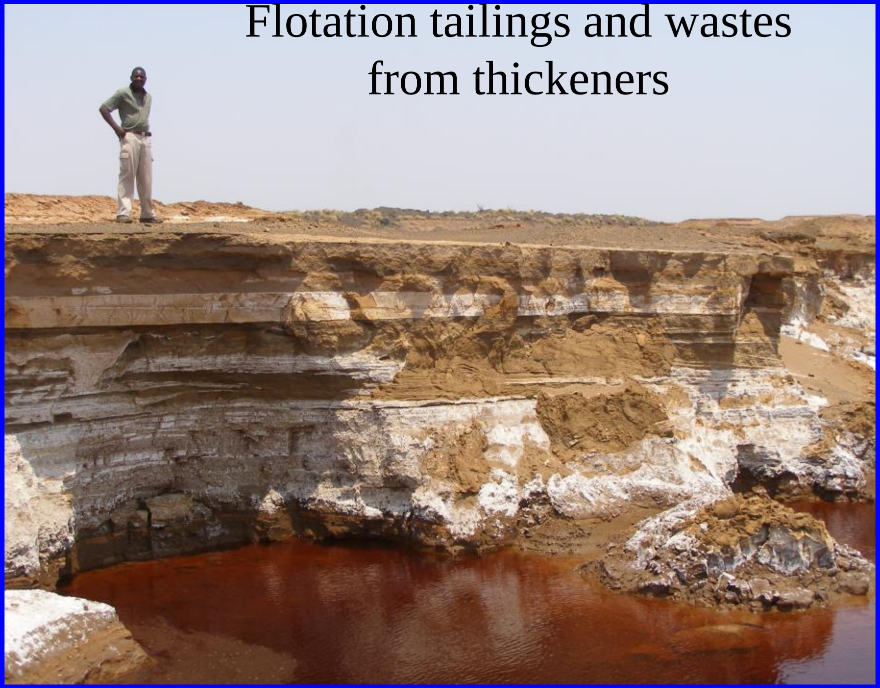
(ii) **Collecting more samples – including Groundwater** ; and

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

IMPACTS ON THE ENVIRONMENT – **EXAMPLE** – KABWE WASTES, ZAMBIA



Residuum from chemical leaching of lead and zinc ores and decant drain precipitates, Kabwe, Zambia



Flotation tailings after treatment of lead and zinc ores, Kabwe, Zambia

Pb: 6.9wt.%

Harmful properties:

Conductivity: 2490 (limit: 2000 mS/m)
Cadmium: 5.15 (limit 0.5 ppm)

Total metal content:
Pb: 3.1 wt.%
Zn: 13.1 wt.%
Cr: 0.3%
Cu: 0.1 wt%
As: 0.001 wt.%
Cd: 0.001 wt.%

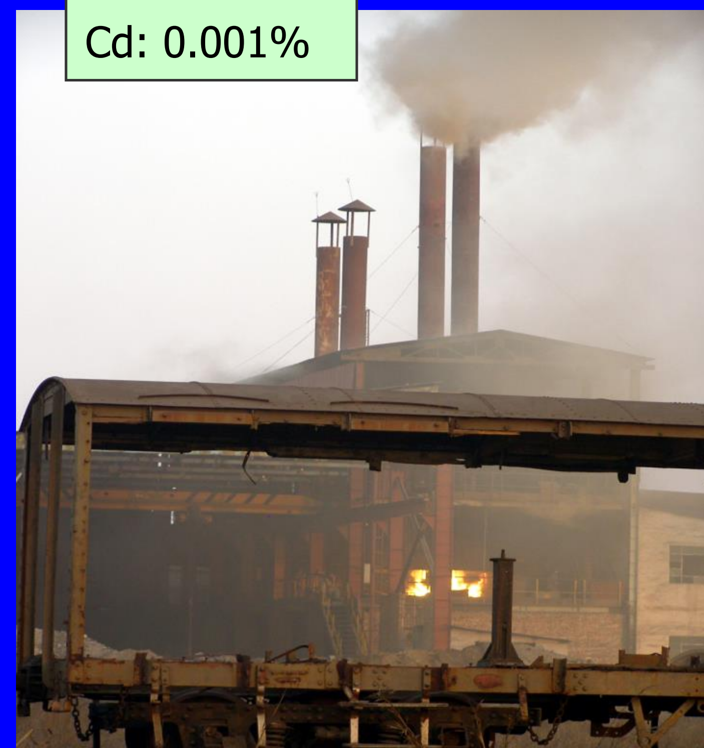
Dust fallout from the ferromanganese smelter in operation (Chiman Manufacturing Company Ltd.) and,
Dust fallout from stone crushers (Kabwe Earth Movers Plc.)

Chemical composition of dust

Zn : 6.5%
Pb: 1.7 %
Cu: 0.06%
Ba: 0.24%
As: 0.008%
Cd: 0.008%

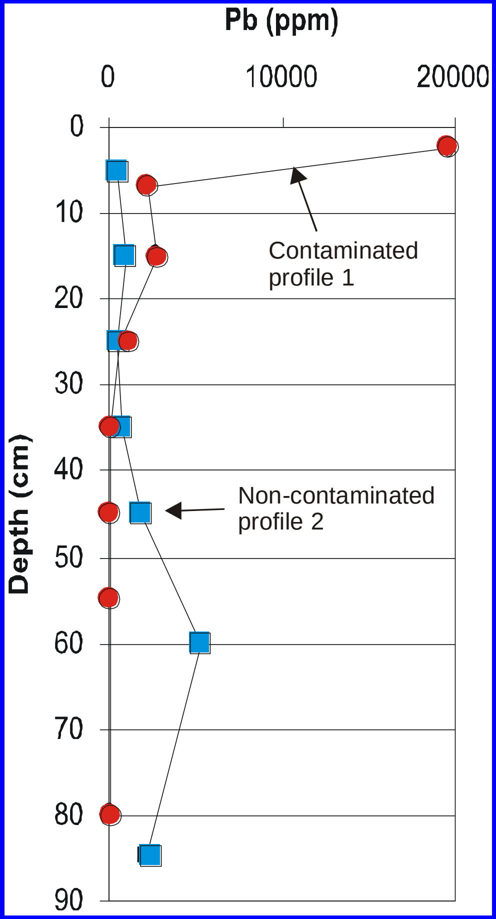
Fe: 19%
Mn: 14.5%
Zn: 0.6%
Pb: 0.4%
As: 0.02%
Cd: 0.001%

Not tested



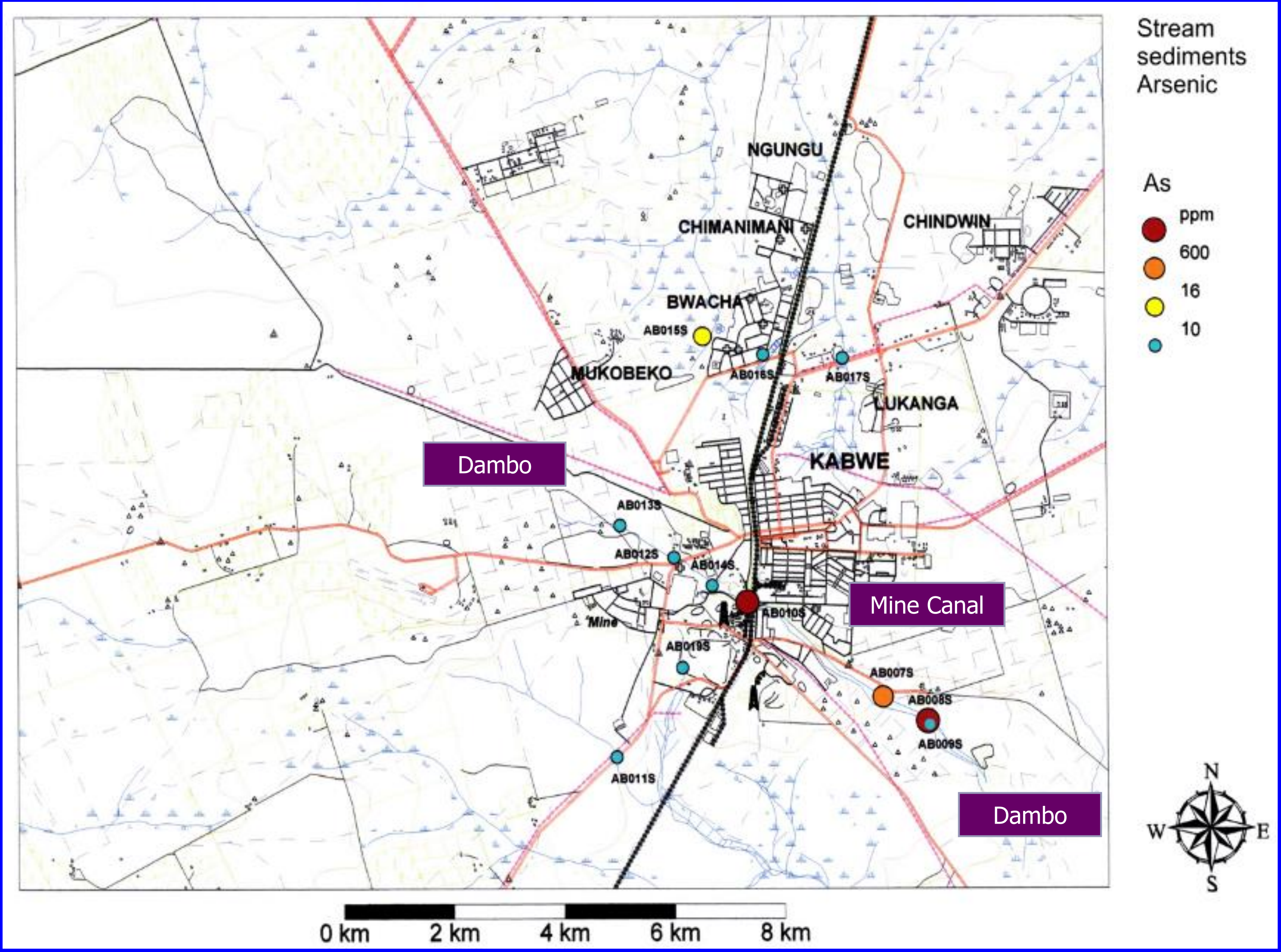
Degree of soil contamination with depth

Contaminated profile, Katondo



Non-contaminated profile,
Makululu

ASSESSMENT OF STREAM SEDIMENTS CONTAMINATION



HARMFUL PROPERTIES OF WASTES – KABWE AREA

OLD WASTES

- ❑ Dam of residues from chemical leaching of ores
- ❑ Wastes from roasting of ores (Waelz-Kiln residual)
- ❑ Granulated wastes after smelting of ores
- ❑ Flotation tailings and wastes from thickeners

CURRENT SOURCES

- ❑ Dust fallout from the ferromanganese smelter in operation (Chiman Manufacturing Company Ltd.)
- ❑ Dust fallout from stone crushers (Kabwe Earth Movers Plc.)
- ❑ Wastes from chemical leaching of copper and cobalt (Sable Zinc Plc.)

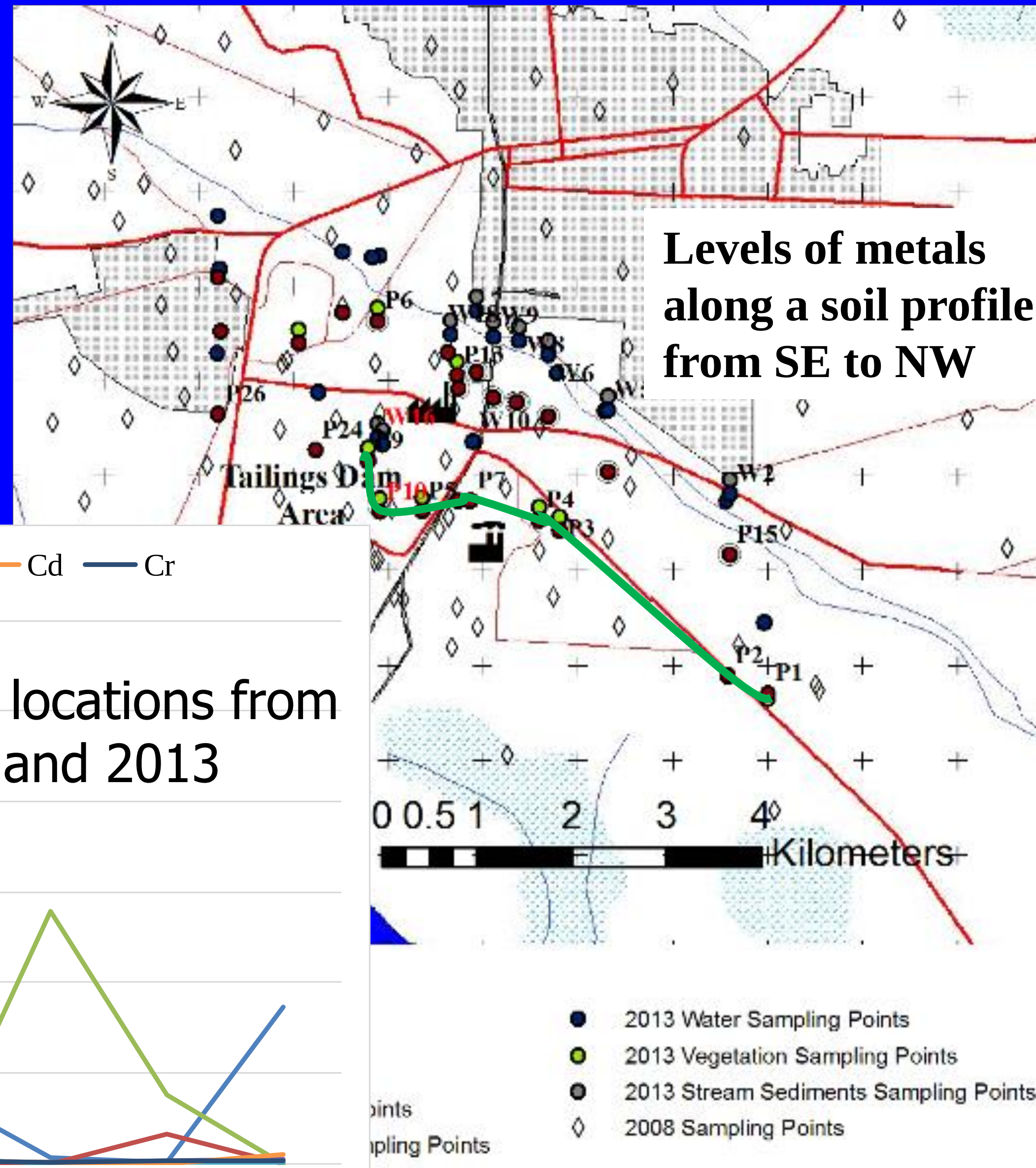
2013 Assessment of Soil Contamination

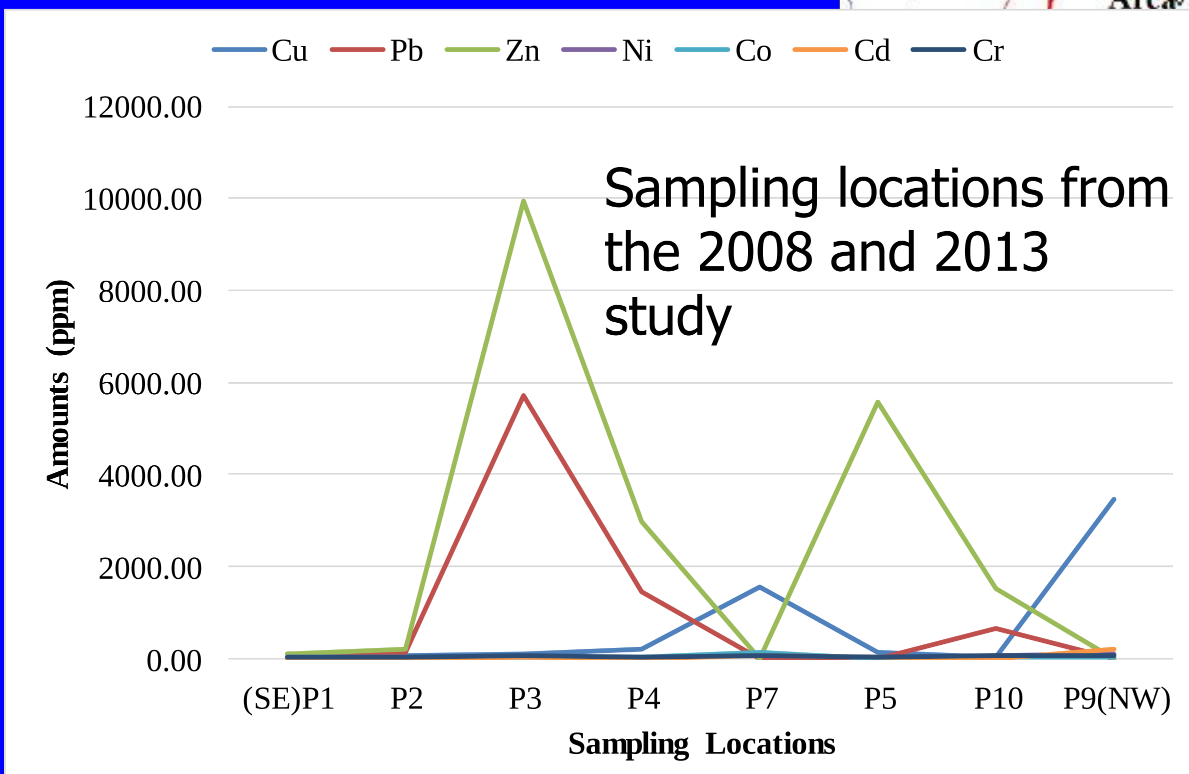
Pb = 23 - > 10 000ppm

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

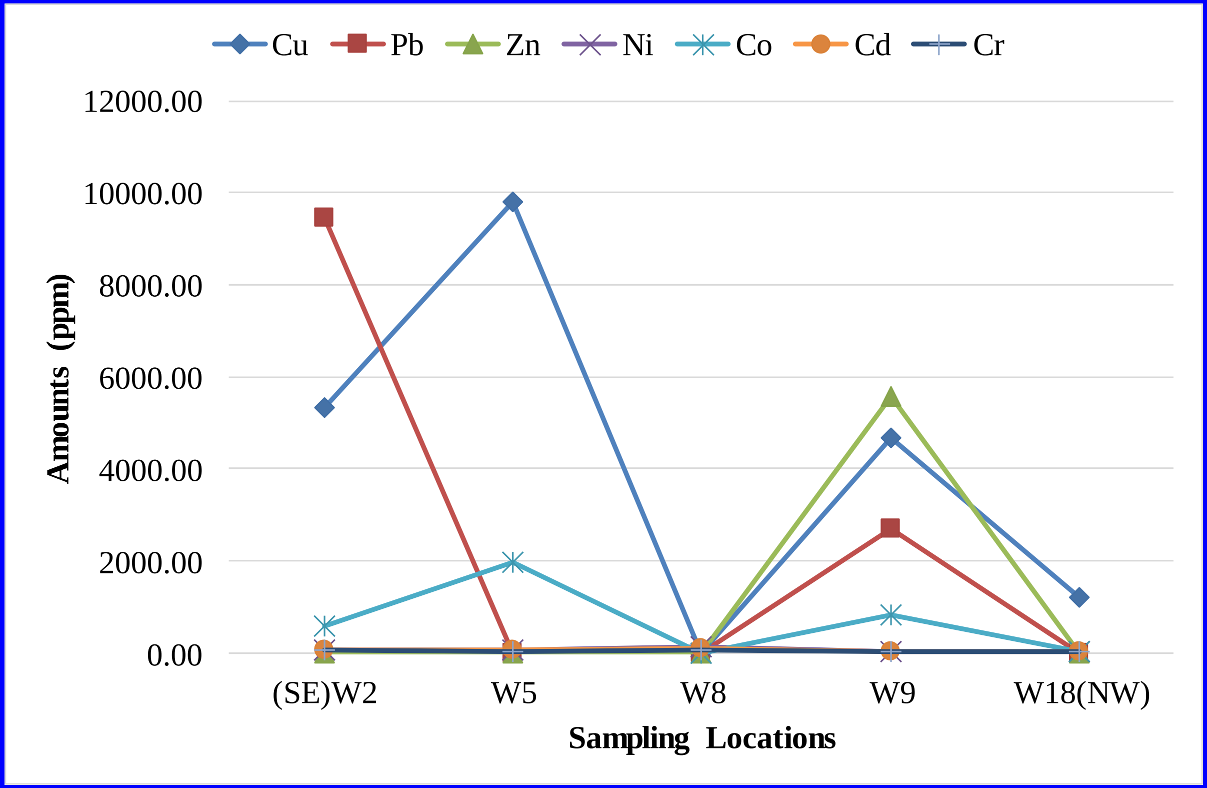
Lead = 553.87 > 10,000ppm

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



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 but below WHO and ZABS standards in the sampled vegetation.

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.

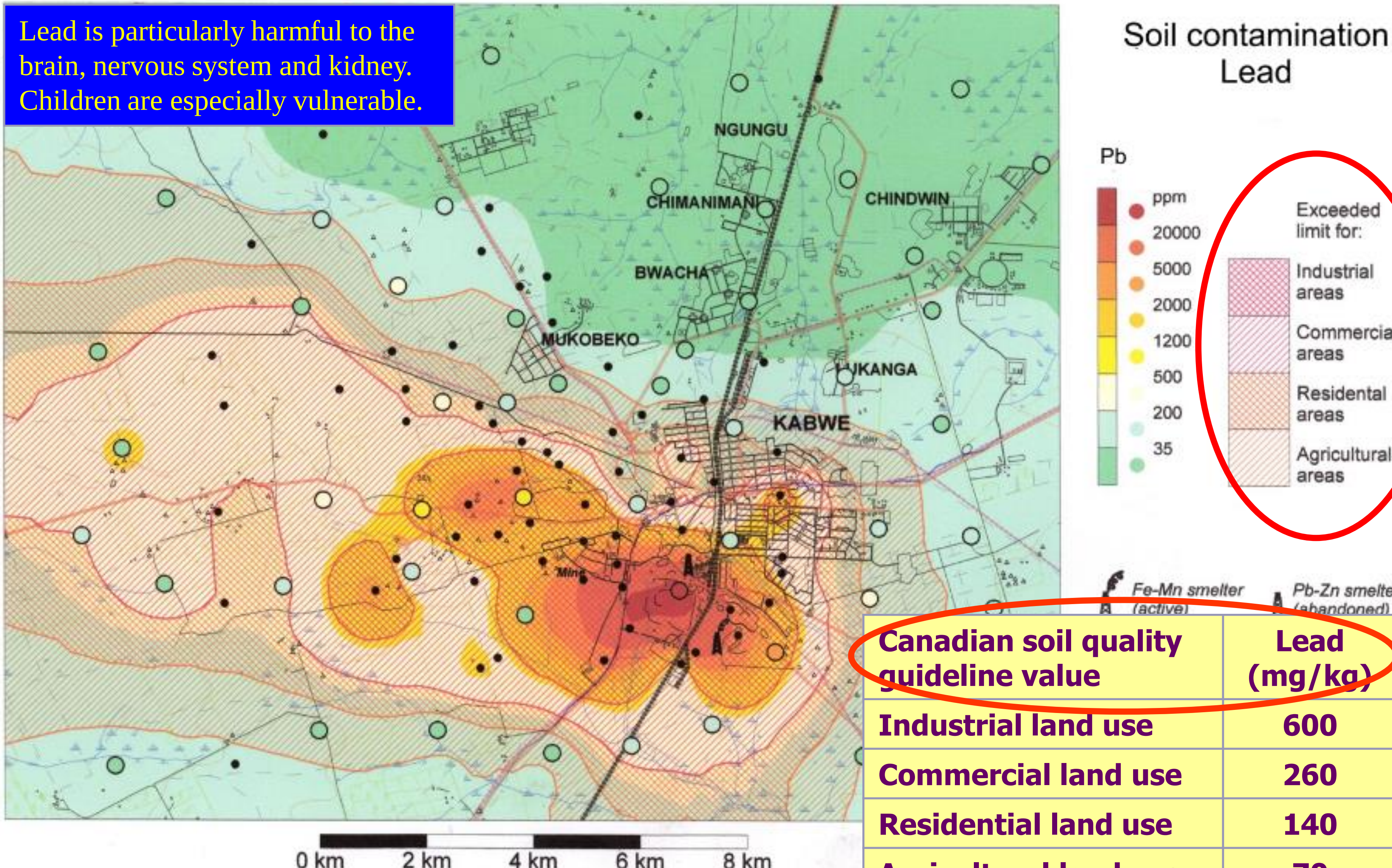
CONCLUSION

- 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 this issue is addressed by all stakeholders through enforcement of existing legislation and re-introduction of rehabilitation programmes.

Extent and magnitude of soil contamination in the Kabwe area

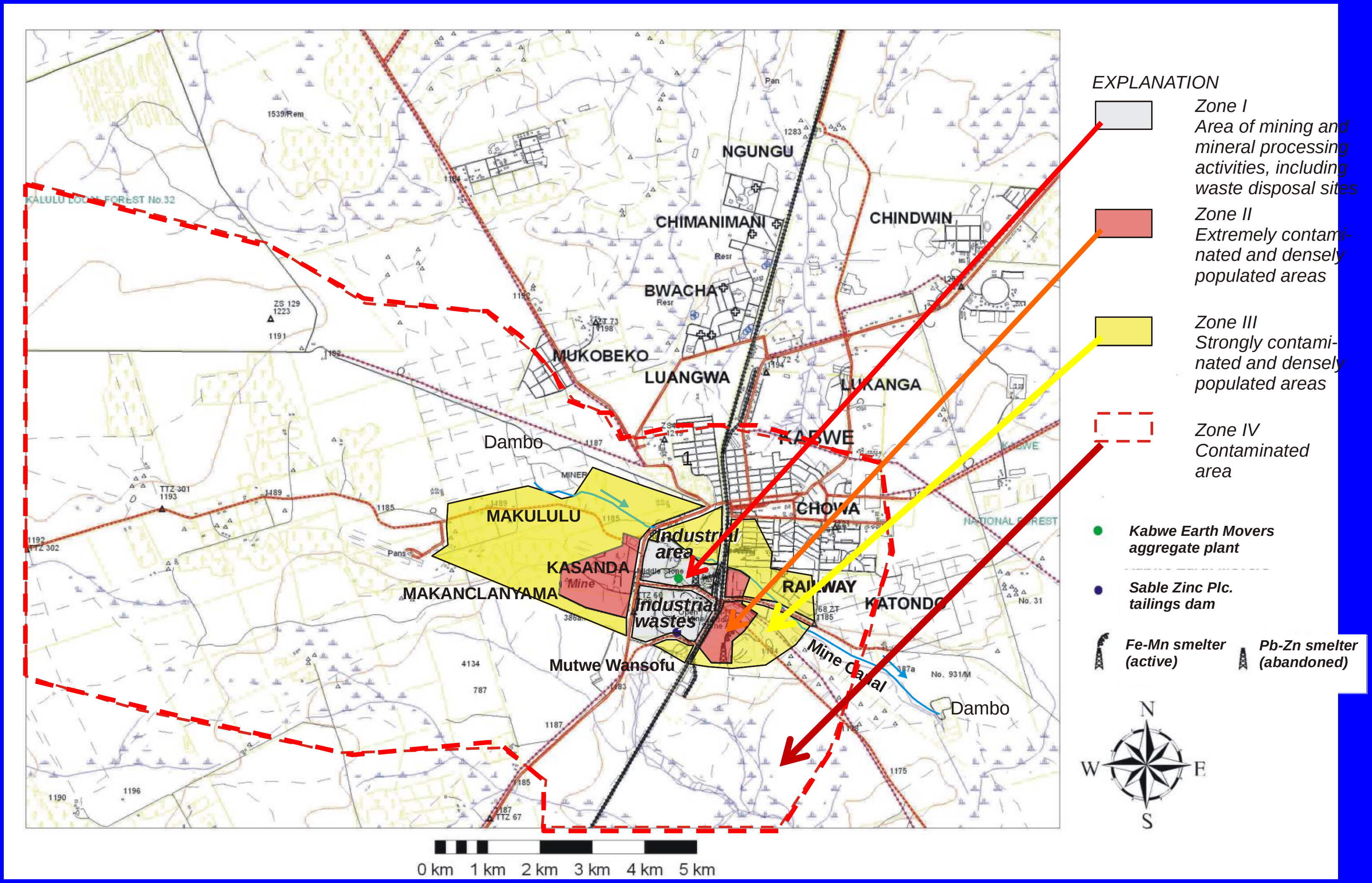
Lead is particularly harmful to the brain, nervous system and kidney. Children are especially vulnerable.



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



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

2. Encourage Research Uptake by Govt & Policy Markers

INVITATION TO THE 7th ZAMBIA WATER FORUM & EXHIBITION

11-13TH JUNE, 2018

EXHIBITION

ZAWAFE invites institutions and companies (e.g. drillers, manufacturers of water and sanitation equipment and contractors) to exhibit their merchandize at this Event in order to reach out to the Zambian populace on what they can offer in the sustainable management of water in Zambia.

REGISTRATION

A nominal registration fee will be charged to all participants and exhibitors. Participants interested in field trips should express their interest during registration. Registration forms can be downloaded from the NWASCO

water infrastructure for Job creation and Industrialisation

Sanitation Association of Zambia (**WASAZA**), Lusaka Water and Sewerage Company (LWSC), Devolution Trust Fund (**DTF**), Groundwater Research Support Project (**GReSP**), Ministry of Water, Sanitation and Environmental Protection, Ministry of Local Government, Ministry of Energy, Ministry of Water, Sanitation and Environmental Protection (MWSEP), Zambia Environmental Management Authority (ZEMA) and Water Resources Management Authority (**WARMA**).

Zambia Water Forum and Exhibition

Z A W A F E

Delegates, exhibitors and participants pose for a photo

2. Kabwe Mine Pollution Amelioration Initiative (Kampai) – JICA – Conference in 2018

Sessions

set up of some booths at zawafe 2015

Nwasco

ZAMBIA WATER FORUM AND EXHIBITION

CALL FOR PAPERS NOW OPEN


Despite these impacts, we still enjoy
Victoria Falls, Zambia