

THE UNIVERSITY OF ZAMBIA

**GEO-SPATIAL MAPPING OF SOIL LEAD DISTRIBUTION IN THE AREA SOUTH EAST OF
KABWE LEAD AND ZINC MINE**

BY

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A RESEARCH PROJECT REPORT

**SUBMITTED TO THE SCHOOL OF AGRICULTURAL SCIENCES IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF
AGRICULTURAL SCIENCES**

DEPARTMENT OF SOIL SCIENCE

LUSAKA, ZAMBIA AUGUST, 2014

ABSTRACT

Urban and industrial development have in many places, reduced the environmental quality. One major problem has been that of the emission of heavy metals into the terrestrial environment for example, soil contamination resulting from mining activities has occurred in Zambia's Kabwe district. This study was conducted in order to determine (i) the spatial extent of soil Pb as a function of distance from the Kabwe Pb and Zn mine (ii) the strength and direction of any relationship between lead concentration and soil texture and soil pH. A total of 37 top soil (0-20cm) samples were collected by stratified random sampling from strata created at 7.5km, 9.5Km and 12.5Km south east of the mine. The sampling points were geo referenced using a handheld GPS and described by the soil Pb concentrations and the soil attribute data within GIS 9.2. All spatial data were projected in the coordinate system WGS 1984 UTM zone 35 south. Soil lead was determined by using the Aqua Regia method, pH by the electrometric method and soil texture by the hydrometer method. The soil attributes were correlated with Pb concentration in SPSS. The measured Pb concentration was found not to conform to the normal distribution for undisturbed environments. The results also showed that Pb concentration decreased with an increase in distance in the south eastern direction. Correlations showed that strong to moderate relationships existed between soil Pb concentration and the soil attributes pH and clay respectively. The results further showed that a positive strong relationship existed between the soil Pb concentration and silt and clay respectively. The area was found not to have been polluted and was therefore safe for land development and human settlement. It was recommended that physical tags in form of beacons be installed by the local authorities at 7.5Km to delineate the area safe for land development.

ACKNOWLEDGEMENTS

I take this opportunity to express my gratitude to the following people that helped me to successfully complete this work; my supervisor, Mrs.Chabala. L. M for her unweaving support, time, tireless effort and most of all the skill that I have learnt from her. I am also grateful to Mr. Shitumbanuma, Dr. Mweetwa, Mr. Chalwe, Mr. Musukwa, Mrs Chishala and Mr. Kaluba .I also wish to thank Mrs. Emelia Mtonga the Chief Cartographer at the Ministry of Lands, Forestry, Natural Resources and Environmental protection and Mr. Soft Tembo from the School of Built Environment at the Copperbelt University for providing me with (GIS) software. I further want to thank my classmates, friends and Family. Above all i wish to thank the Almighty God for granting me the opportunity to be educated and successfully complete my studies at the University of Zambia.

DEDICATION

This work is dedicated to Miss Felistus Mubanga Kampamba, a geology student in the School of Mines at the University of Zambia and Mr. Victor Mubanga Kafwilo (Junior) my nephew, for their brilliance, love and support.

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LIST OF ACRONYMS

1. AAS: Atomic Adsorption Spectrophotometer
2. CEP : Copperbelt Environment Project
3. ESRI: Environmental Systems Research Institute
4. GIS : Geographical Information Systems
5. SPSS: Statistical Package for Social Sciences
6. UNZA: University of Zambia
7. USDA: United States Department of Agriculture
8. UTM: Unified Traverse Mercator
9. W.M.C: Water Management Consultants Limited of UK.
10. WGS : World Geodetic System
11. ZCCM-IH: Zambia Consolidated Copper Mines Investment Holdings
12. ZEMA: Zambia Environmental Management Agency

CHAPTER ONE: INTRODUCTION

It is widely acknowledged that the urban environment quality is of vital importance as the majority of people live in cities today. However, due to continuous urbanization and industrialization in many parts of the world, metals are continuously emitted into the terrestrial environment and pose a great threat on human health (Lee et al., 2005).

Mining of various minerals has been the main source of foreign exchange for many Sub Saharan countries including Zambia. In the recent years dealing with environmental problems like soil pollution has continued to pose a great challenge either in terms of inadequate resources to remediate contaminated sites or inadequate environmental regulation to ensure mining is conducted in an environmentally sensitive manner.

In Zambia Lead and Zinc pollution has occurred in Kabwe district. Although numerous studies have been conducted to generate lead concentration data, very few of these studies have made serious strides to spatially describe the data (Markus and McBratney, 2001). In order to identify contaminated land and to enable development of appropriate environmental guidelines, it is essential to have an understanding of the spatial nature of lead contamination in soil.

Environmental pollution is defined as the contamination of the natural environment by substances which can harm living things and cause diseases, intoxication and in extreme cases, death. Pollution emanates from mostly anthropogenic sources such as mines, urban effluent, waste, petroleum and paints (Tembo, 1993).

Lead and Zinc mining in Kabwe dates back as 1904 and lasted for several years. During this period of time statutory environmental controls within the mining sector were virtually none

Existent, therefore atmospheric discharge, water and soil pollution resulted from mining and processing operations at Kabwe mine without any control (W.M.C, 2004).

The soil lead prevalence concentrations in close proximity to the mine were reported to have exceeded all the internationally established intervention thresholds for residential and recreational land, in addition any edible plants grown on these soils led to human exposure by bio assimilation (W.M.C, 2004).

(Musonda and Tembo, 2004) established a geometrical and spatial anomaly of soil lead contamination to have been oriented in the northwestern side of the mine and further stated that this was consistent with the wind direction. The maximum elongation was found to have been in the western part (W.M.C, 2004).

The principle environmental constraint and hazard is still recognized to date because the areas south east of the mine where not compressively studied as those in the west. Therefore, characterization of the associated soil lead concentrations and spatial distribution in the area south east of the mine formed the focus of this project. In this project GIS functionality was incorporated to help explain the spatial variability of lead concentration in the soil.

1.1 Statement of Problem

Kabwe district is one of the most polluted towns in the world. During the past decade over 200,000 people were reported to have been affected by lead contamination (Mwansa, 2013). Exposure to even low levels of lead was noted to be harmful to most biological systems. In children exposure to lead resulted in the impairment of cognitive functions and led to abnormal infant behavior, in adults it was found to cause sterility in both men and women (Reagan and sibergeld, 1989).

The main mode of exposure to lead is through exposure to dry deposition or aerosolized particles carried by wind (CEP, 2001).

Most of the studies conducted concentrated on areas in close proximity to the mine and in the wind ward direction (northwestern direction). Localized soil lead pollution was possible in the area south east resulting from the periodic dredging and flooding of the main canal from the mine as it busted its banks at times and possibly caused redistribution of mine effluent containing lead.

A limited number of studies have tried to precisely describe the spatial extent of such contamination and its associated proximity to areas further away from the mine. The furthest studies on soil lead contamination went as far as Chowa and Kasanda for areas south east of the mine. It is therefore against this background that this study was instituted.

1.2 Rationale

Remediation and restoration efforts are worthless if it is not really known where to concentrate efforts and the extent to which the environment may be degraded. Thus studies are necessary as areas initially thought to be free from pollution may get polluted considering natural processes and the activities of man. Therefore, knowing how far the contamination is posing a threat from the perceived source of contamination will help in knowing whether contamination is spreading or not. Such knowledge would aid in the maintenance, monitoring and protection of soil resources and in general, environmental quality which is key to any form of land development.

1.3 Objectives

The main objective of the study was to determine the spatial extent of soil lead distribution in Kabwe district.

The specific objectives were:

- (i) To assess the spatial extent of lead contamination as a function of distance from the Kabwe mine.
- (ii) To investigate the strength and direction of any relationship between lead concentration and soil texture and soil pH.

CHAPTER TWO: LITERATURE REVIEW

2.1 History of Lead mining and Lead Pollution in Kabwe District

Mining and exploration of Lead and Zinc in Kabwe started around 1904 under the Broken Hill Company and operated until 1992. During this period virtually none existent environmental controls undoubtedly inhibited environmental due diligence to deal with environmental issues. In 1964 at the time the mine was closed, the most prominent hazard was that of soil contamination in the townships close to the mine. However, the possibility of more and more areas getting polluted was still certain (Komex International, 2001).

2.2 Pedological and Geological Controls for Kabwe District

Pedological and geological controls for a given area are usually a function of area's mineralogy. For Kabwe district dolomite deposits are predominantly massive with a lot of gneiss, in geological classification mineral deposits in Kabwe were classified to belong to the Roan group of minerals.

Pedological and geological controls are used to determine the background levels for any given mineral of interest. The background level for soil lead in Kabwe was found to vary between 0.7-50mg/kg, this does not mean that any site having soil Lead beyond this range is polluted. Each country has a soil pollution threshold and for Zambia the international intervention threshold for soil Lead is used which corresponds to 71 mg/kg soil (Musonda, 2004).

2.3 Health Hazards Associated With Lead Contamination in Soils

Human exposure to lead in the post mining periods was studied for areas in the vicinity of the mine and reviewed blood (Pb) levels of 35 and **45ng/6l** for people living in Kasanda and Chowa respectively (W.M.C, 2001).

Geophagia and Pica behavior further exacerbated the risk of human exposure to soil lead. Geophagia refers to the tendency of pregnant women and children to eat soil, contaminated soils would have been consumed in this way. Pica behavior refers to the tendency of children usually under the age of 7 picking and eating substances from the ground (Mwansa, 2013).

Lead was found to be toxic in most biological systems and not to have any systemic function, residents living in a lead polluted environment risked to having complications such as brain damage, nervous system failure, increased blood pressure, hearing and vision impairment, liver and kidney damage (Reagan and Sibergeld, 1989). These symptoms were found to be consistent with those observed in Kabwe during the period 1994-2001 (ZCCM-HI, 2004).

2.4 Soil Contamination, Bio Assimilation Hazard and Effects on Plant Growth

Soils in areas near the mine were found to contain very high amounts of lead exceeding all the internationally set thresholds for soil lead contamination. Soil used as a medium for plant growth in many areas where crops were grown both on large scale and local level in small gardens posed a health hazard as most would be bio assimilated into the systems of consumers. Pb concentrations in locally grown vegetables were found to be as high as 163mg/kg for giant rape

grown in Kasanda township, rape and cabbage were found to be the most effective bio accumulators of (Pb) (ZCCM-HI,2001).

Consumption of rape, cabbage, tomatoes, green paper mangoes and maize grown in the townships near the mine was therefore considered to be a health risk. Tembo (1993) substantiated that an excess of 30mg/kg lead in Chinese cabbage was possible and that this was significant for sites as far as 20km North West of Kabwe mine. Many inquiries have shown that many plants can accumulate lead in the shoots and the roots in a contaminated environment. The result is usually reduced vegetative growth and unbalanced biodiversity. Contaminated sites characteristically show sparse tree distribution in some cases barren patches of soil occur (Verma and Dube, 2005).



Figure 1: Tomato Harvest from Kasanda Township

2.5 Integrating GIS (Geographical Information Systems) As Tool for Problem Solving

Geographical information systems (GIS) are today used to manage spatial and time dependent attributes. Within a GIS, spatial and non-spatial descriptions basing on the functioning of environmental processes which may include various types of pollution can be used to capture, manage, analyze and create patterns, relationships and explain pollution phenomena (Matejiek, 2000).GIS originates from cartographic endeavor to automate and accelerate map development, update and production (Benesova, 2000).

Monitoring soil pollution is mostly focused on places exposed to industrial and agricultural activities. The fundamentals of evaluating soil contamination are based on the rules carried out by local and state authorities, the maximum permissible limits of hazardous elements (heavy metals, inorganic and organic substances, polycyclic aromatic hydrocarbons) are measured (Matejicek, 2000). The figure below is an



Figure 2: Application of GIS in Representing Soil Temperature Variation, Pollution Intensity and Surface Drainage

example of an application of GIS.

CHAPTER THREE: MATERIALS AND METHODS 3.1

Description of Study Area

The study was conducted in Kabwe district in the area south east of Kabwe lead and Zinc mine, which was the source of the perceived soil lead contamination. It is located between 14° 26'S and 28°27' with an altitude range of 900 m - 1,180 m above sea level. The area is approximately 130 Km from Lusaka, the detailed description of the study site is illustrated in figure 3 below.

The study site was selected upon considering the fact that many of the previous studies were conducted in the north western part of the of mine with respect to wind direction where wind was considered to be the main mode of transfer for contaminated soil particles.

In the area south east lays the main canal from the mine which at times burst its banks when flooded and carried mining effluent south east of the mine. The area is largely dominated by lixisols which are highly weathered soils in which clay has been washed out from an elluvial horizon in relatively dry areas.

Legend

- Main Canal Kabwe-kasancfa
- Rail line
- Roads
- Kabwe Lead and Zinc Mine
- Kabwe distria



Coordinate System W.G.S. 1984 UTM ZONE 35S

Figure 3: Map of Study Site

4 2 0 4 8 12 Kilometers

3.2 Data Sources and Its Background

The shapefiles data for Kabwe district were obtained from the University of Zambia, Geography Department. A topographic map which was acquired from the Ministry of Lands, Natural Resources and Environmental Protection served as a base map during field navigation and soil sampling.

3.3 Soil Sampling

The scope of the sampling area was restricted to the area south east of Kabwe Lead and Zinc mine. Stratified random sampling was used, with stratum created by varying distance from the mine. The first site was located 7.5km from the mine, the second site at 9.5Km and the third site at 12.5 km from the mine. Soils samples were collected in the top 0-20 cm of the surface. A total of 37 samples were collected from the field. Twelve (12) samples were collected from the 7.5Km and 9.5Km stratums while thirteen (13) samples were collected from the 12.5Km strata.

3.4 Laboratory Analysis

The soils were air dried, sieved and analyzed for texture (particle size distribution), soil reaction (pH), total lead and extractable lead as described below.

3.5 Particle Size Distribution (Soil Texture)

The Gee and Bauder (1986) hydrometer method was used to determine the particle size distribution. Fifty grams 50 g of air dried soil was placed in the dispersing cup to which 50ml of

sodium liexametaphosphate was added. The cup was filled with tap water up to the half way mark. The mixture was stirred continuously for five minutes. The suspension was then transferred into a sedimentation cylinder by using a stream of tap water. The cylinder was then filled to the mark of 1000ml afterwards; a plunger was used to mix the contents thoroughly. Readings for density and temperature were taken at 20seconds for sand and after 2 hours readings for clay were obtained, the equations below were used to calculate the percentage content of sand, silt and clay in each sample.

$$\% \text{ silt} + \% \text{ clay} = (p_i^{0 \text{ second reading}} - B_p \pm T_Q) * (^{\wedge}) \dots\dots\dots (1)$$

Where *p* is the density in (g/l). *B_p* is the blank density reading in (g/l) corresponding to *I_{g/l}* for water at room temperature and pressure (25°c and *I*atmosphere respectively) and *T_Q* is the temperature correction factor per degree rise. For clay determined after two hours the equation below was used. The USDA textural triangle was used to classify the classes determined.

$$\% \text{ clay} = (p_i^{2 \text{ hours reading}} - B_p \pm T_o) * (^{\wedge}) \dots\dots\dots (2)$$

$$[\% \text{ sand} = 100\% - (\% \text{ silt} + \% \text{ clay})] \dots\dots\dots (3)$$

$$[\% \text{ silt} = 100 - (\% \text{ sand} + \% \text{ clay})] \dots\dots\dots (4)$$

3.6 Soil Reaction (pH)

To determine the soil pH, the electrometric method as described by Pearson and Adams (1967) was used. Ten grams (10g) of air dried soil was placed into 50ml beaker to which 25ml of 0.01 M calcium chloride was added. Each mixture was placed on the mechanical shaker for 30minutes after which the pH was measured by using the pH meter.

3.7 Determination of Total Soil Lead

Total soil lead concentration was determined by using the Wixson and Davies (1993) Aqua Regia method. This involved weighing 1 .0g of air dried soil on an electronic balance and placing it in a 250ml volumetric flask to which 30ml of aqua regia solution was then added. The mixture was digested on a hot plate until enough solution had evaporated. The mixture was cooled then after cooling; 30ml of aqua regia solution was added to each flask. The mixture was placed in 50ml flasks and brought to the mark using distilled water. The amount of total lead was measured by using the AAS.

3.8 Determination of Extractable Lead

Extractable lead was determined using the nitric acid method. This involved weighing 20g of soil to which 40ml of 0.5M HNO₃ was added in order to extract only the Pb considered available for plant uptake. The mixture was allowed to shake for 2hours, afterwards it was filtered and the amount of extractable (Pb) was measured by using the AAS.

3. 9. Spatial Extent and Proximity Analysis 3.9.1

Description of Spatial Patterns

Description of spatial patterns to the data typically started with posting of the data values from windows excel to ArcGIS and the creation of shapefiles using the coordinates for each soil sampling location. The shapefiles created were projected to WGS (World Geodetic System) UTM 1984 Zone 35 South. All spatial data processing was done in ArcGIS 9.2.

3.9.2 Spatial Extent of Lead Contamination and Proximity Analysis

Kabwe district was selected from the *Zambian districts* layer obtained from University of Zambia and exported so as to obtain the overall boundary of the district. Buffer zones of 7.5 Km, 9.5 km and 12.5 Km were created around the shapefile representing the mine area. This was done using the buffer tool by setting the buffer distance at 7500 meters, 9500 meters and 12500meters for each buffer zone.

By definition, a buffer is a feature drawn at a specified distance in order to show an area of restriction or a restricted boundary. In geometry it can be viewed as the locus of all points with a distance shorter or equal to the radius that forms a cycle around the center (0, 0) or reference location, in this case, Kabwe Lead and Zinc mine was considered to be the reference location.

In order to select soil locations that were within the buffer 7.5 Km from those outside it, the select by location tool within the layers and tables views tool set (ESRI, 2012) was used. The input feature was the Kabwe Lead mine layer and the selecting feature was 7500 m buffer. The output of this operation resulted in the selection of all points that were completely within the mine buffer for which summary statistics were obtained. A switch selection was performed to separate soil sampling points that were outside the 7500 m mine buffer. A paired t test was done to compare the levels of contamination between the values within and outside the buffer zones. A similar approach was followed to separate the soil points that were within buffer zones of 9500 m and 12500 m respectively.

3.9.3 Test for Site Pollution Status

The back ground total lead levels for a non-polluted site in Kabwe district range between 0.7 -50mg/Kg (Musonda, 2004). For total lead as extracted using the Aqua Regia method however, the international intervention threshold is 71 mg/Kg soil (W.M.C, 2001).

The average total lead for the buffer zone that recorded the highest was used to test for site pollution status. This was done by performing a t- test against 71 mg/kg. using the equation (5) below for 11 degrees of freedom $n = (12-1)$.

$$t = i(Xo -M)/s/Vn) \dots\dots\dots (5)$$

Where (t) is the calculated critical value, () is the mean value of total lead calculated for samples within buffer radius 7.5Km, (s) is the standard deviation, (*n*) is the population mean herein considered to correspond to the international intervention threshold of 71 mg/kg , n is the total number of samples from which inferences were made.

3.9.4 Assessing the Relationship of Lead Concentration, Distance, Soil Reaction (pH) and Soil Texture.

To determine whether a relationship existed between lead concentration and the soil attributes of sand, silt, clay and soil pH, correlation analysis was implemented in SPSS. The correlation coefficients were used to interpret the strength and direction of the relationships between soil

lead concentration and soil pH, sand, silt and clay. The correlation coefficients were further used to determine if the relationship was statistically significant.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Summary Statistics for Total and Extractable Lead Distribution

In table I the summary statistics for total and extractable lead are shown. The mean total lead was 25.46 mg/kg and 2.60 mg/kg for extractable lead. Total lead showed very large variation (C.V 67.0) which could be attributed to variation in the concentration of soil lead with an increase in distance from the mine.

Digestion of the samples required a predefined temperature to which the hot plate was to be adjusted to. However, this provision was not available as the hot plate used could not be adjusted hence some of the samples could have had more Aqua Regia evaporated more than others. Heat distribution on the hot plate was not even because some parts of the plate were covered and other was not covered by the heating element.

It was further observed that the total lead (mg/Kg) in the area did not conform to the normal distribution (Figure 4) as would be expected for an undisturbed environment. The mean values for both for both total and extractable lead were found to be below the district maximum background level of 50mg/Kg and were classified to be low by using the USDA soil classification for Lead pollution as shown in table2 below.

Table 1: Summary Statistics for Total and Extractable Soil Lead (mg/Kg)

Parameter	(N)	Minimum Mg/Kg	Maximum mg/Kg	Mean mg/Kg	Co. Variance	Std. Deviation
Total Pb	37	6.34	56.20	25.46	67.0	17.03
Extractable Pb	36	1.93	4.99	2.60	26.15	0.68

10- total lead (mg/kg)

Figure 4: Distribution of Total Lead (mg/Kg)

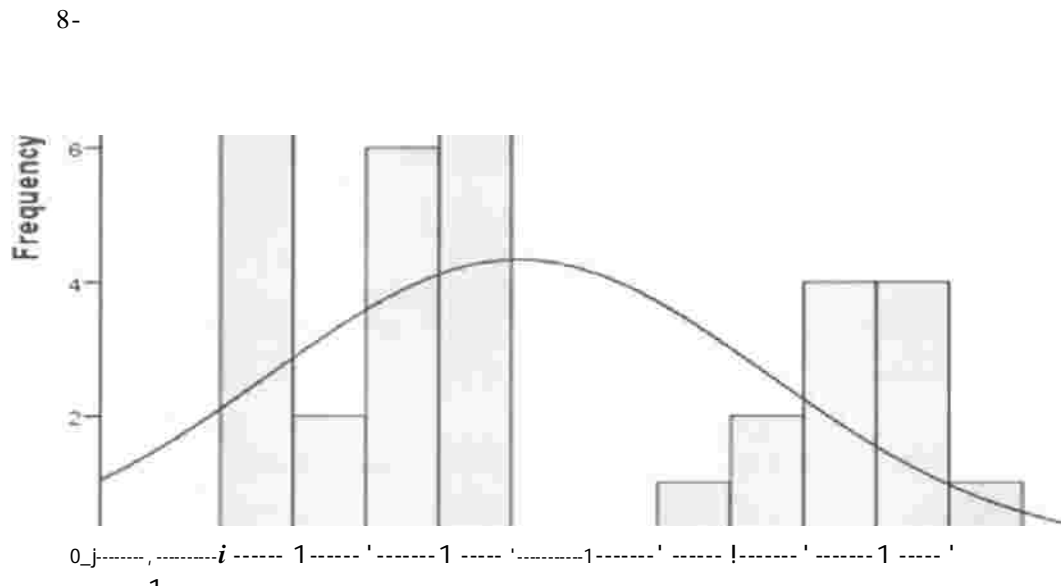


Table 2: USDA Soil Lead Classification (mg/Kg)

Lead level classification	Extracted level (mg/Kg)	Actual or total level (mg/Kg)
low	Less than 22	Greater than 299
medium	22-40	300 to 999
high	177-293	1000 to 2000
Very high	Greater than 293	Greater than 2000

4. 2. Spatial Extent and Proximity Analysis of Lead Concentration

Results indicated that both total and extractable lead decreased with an increase in distance from the mine in the south eastern direction. Table 3 and the figures 5, 6 and 7 below show the trend. This observation was attributed to the fact that the effects of mining activity on the soils were more profound in the buffer

Table 3: Summary Statistics for Site Specific Soil Lead (mg/ Kg)

Buffer Distance (Km)	Average total Lead (mg/Kg)	Standard deviations (s)	Coefficient of Variance	Average extractable Lead(mg/Kg)	Standard deviation(s)	Coefficient of Variance
7.5 km	48.30	5.01	10.60	3.35	0.70	20.01
9.5 km	20.51	2.51	13.10	2.30	0.21	11.41
12.5 km	8.43	1.64	18.52	2.20	0.15	7.00

Zones nearer to the mine than those further away.

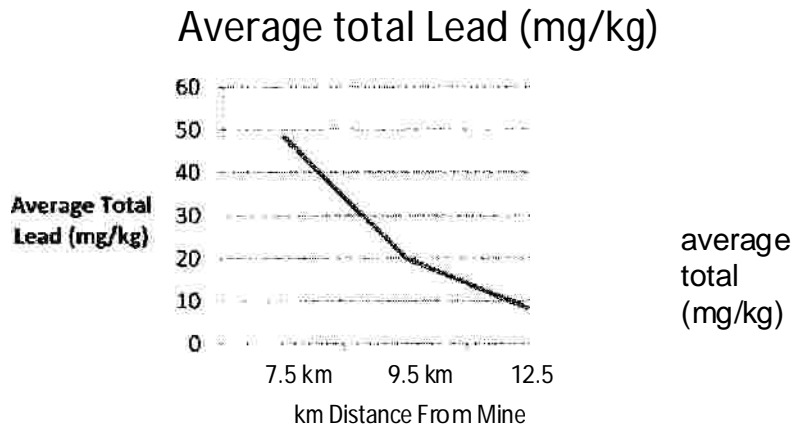


Figure 5: Average Total Lead (mg/Kg) against Distance (Km)

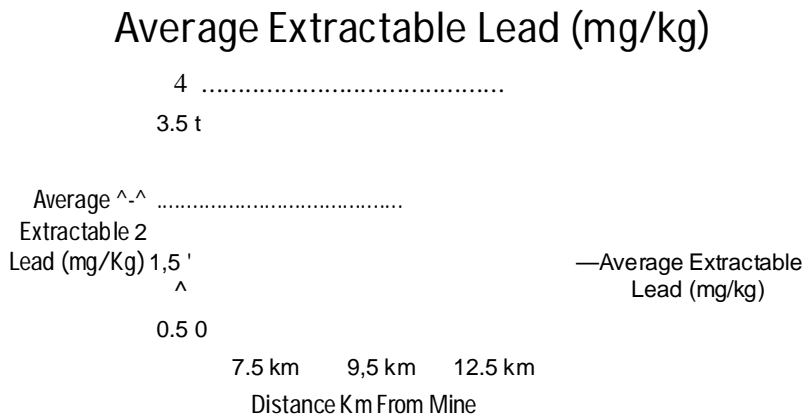


Figure 6: Extractable Lead (mg/Kg) against Distance (Km)

The 7.5 Km radius showed the highest lead concentration accounting for 63% for total lead measured from 37 samples, followed the 9.5 Km with 26%, then the 12.5Km with 11% as shown by the Pie chart below. 20 IP a g e

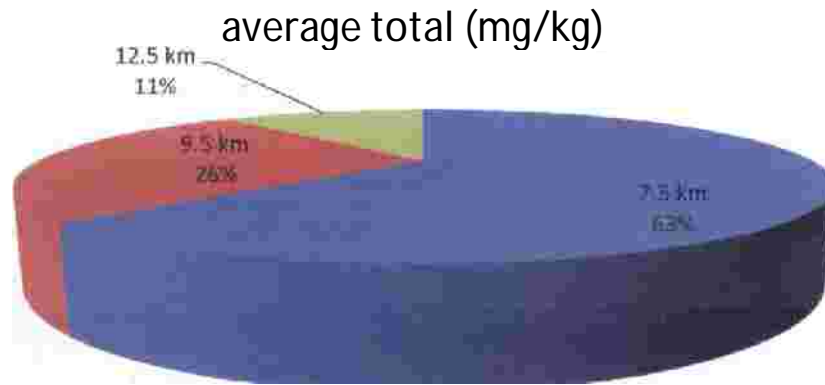




Figure 7: Pie Chart for Total Lead (mg/Kg)

4.3 Comparison of Lead Concentration Levels at Selected Distances

The results indicated that there were significant differences between total lead concentrations in the (i) 7.5Km and the 9.5Km, (ii) 9.5Km and 12.5Km, (iii) 7.5Km and the 12.5Km buffer radii. Extractable lead concentrations were found to be significantly different for all comparisons except for the concentration in the 9.5Km and 12.5Km which showed a non-significant difference. Table 4 below shows the mean values of soil lead as compared at $\alpha = 0.05$. The figures 8, 9 and 10 below show how the selection of points within radii

was done.

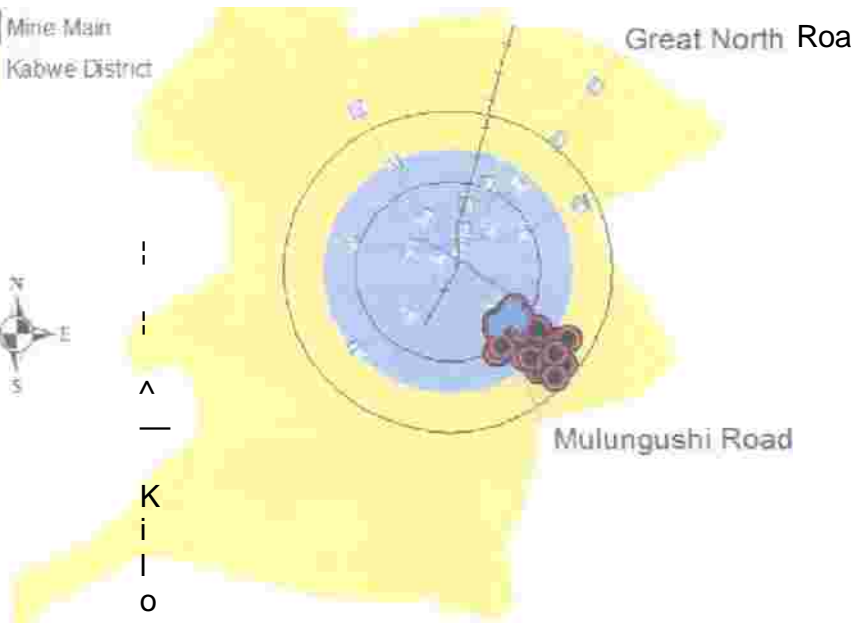
Legend

- ⊙ Soil Sampling Points
- Main Canal Kabwe-kasanda
- ^— Rail line H
- R 7.5 Km (t)
- o 12.5 Km Buffer (f)
- a 9.5 Km (o)
- d  Mine: Main
- s  Kabwe District

0 3 6
12 18
24



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COORDINATE SYSTEM: WGS 1984 UTM ZONE 35S

Figure 8: a Selection of all Points within 7.5Km Radius (in blue color)

Legend

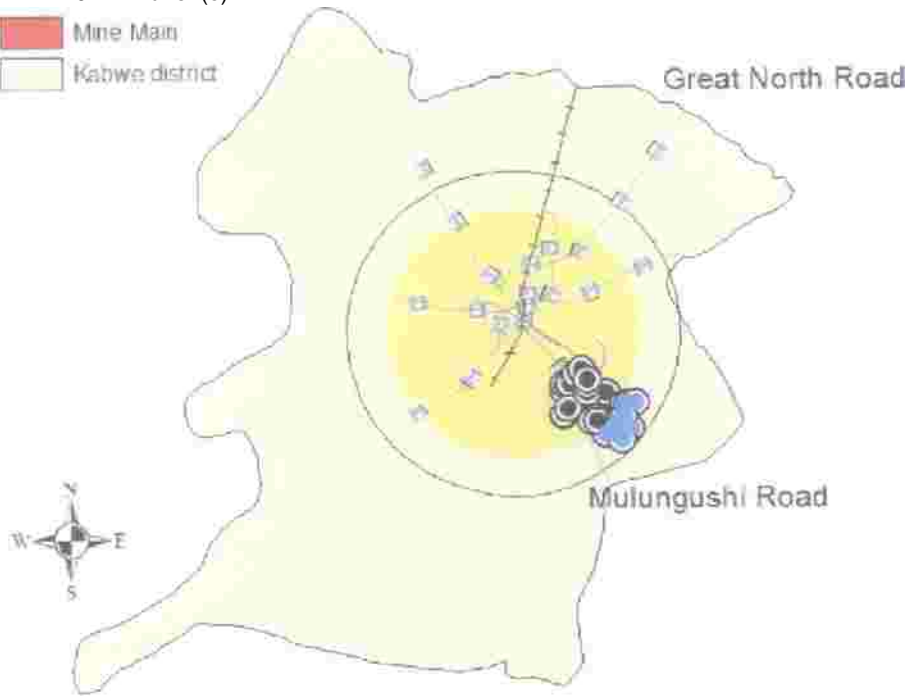
- ⊗ Sampling points
- Main Canal Kabwe-kasanda
- ^ Rail line a-

Roads

I 12.5 Km Buffer (f)

o 9 Km Buffer (o)

- Mine Main
- Kabwe district



0 2.5 5 10 15 20
Kilometers

Figure 9: a Selection of All Points within the 12.5Km Buffer Radius (in light blue color)

Legend

				#	Sampling Points 9.5 Km
				#	Sampling Points 12.5 Km
				0	Sampling points 9.5Km
					Main Canal Kabwe-kasanda
					Kabwe Lead and Zinc Mine
					12.5 Km Buffer Radius 9.5
					Km Buffer Radius 7.5 Km
					Buffer Radius Kabwe dlstnct
4 2 0	4	8	12		
ULI	Kilometers				

Coordinate System W.G.S. 1984 UTM ZONE 35S

Figure 10: a Selection of all Points within the 9.5Km

4.4 Tests for Pollution Results

The Results showed that the average total Lead did not exceed 71 mg/Kg and therefore confirmed at 95% confidence level that the area 7.5Km was not polluted and was safe for land development and human settlement.

4.5 Relationship of Lead Concentration, Distance, Soil Reaction (pH) And Particle Size (Sand, Silt and Clay)

Table 6 below shows the correlation coefficients for all the soil attributes that were measured. It was observed that a strong to moderate negative relationship existed between both total lead and extractable lead concentration and soil reaction (with correlation coefficients of -0.84 and -0.61 respectively). The results meant that as the pH values decreased the amount of soil lead in the soil increased due to enhanced dissolution of lead containing materials.

It was further observed that a strong negative (correlation coefficient -0.729) relationship existed between total lead concentration and clay %. This implied that the more clay particles occurred in the soil the lesser the amount lead that was detected. This was attributed to the fact clay represented a higher stage of weathering meaning that most of the lead containing material was weathered enough to reduce detection of lead. Extractable lead showed a weak negative relationship with correlation coefficient -0.49.

Strong to moderate positive relationships were observed to have existed between both total and extractable lead as correlated against sand with correlation coefficients 0.84 and 0.62 **25** IP a g e

respectively. This meant that as the amount of sand sized particles increased the amount of lead measured increased, this was attributed to the presence of lead containing materials. A similar trend was observed for the correlation against silt %. This was attributed to the fact that silt particles were much associated with movement of water that might have carried some of materials containing lead. The correlation coefficients were 0.89 and 0.66 for total lead and silt% and extractable lead against silt% respectively.

Table 5: Correlation Coefficients

parameter	Correlation	total lead (mg/kg)	extractable (mg/kg)	reaction (pH)	clay%	Sand%	Silt%
total lead (mg/kg)	Type a 0.05 Pearson on	1	.777"	-.838"	-.729"	.849"	.891"
	Sig. (1-tailed)		.000	.000	.000	.000	.000
	N	37	37	37	37	37	37
extractable (mg/kg)	Pearson Correlation	<i>nil</i> "	1	-.608"	-.498"	.620"	.666
	Sig. (1-tailed)	.000	.000	.000	.001	.000	.000

**significant at p 0.01 and 0.05

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

Soil lead distribution in the area south east of Kabwe mine was found not to conform to the normal distribution for an undisturbed environment. The area was found not to be polluted. The area showed a gradual decrease in both total and extractable lead with an increase in distance the highest lead concentration was measured in the buffer radius 7.5Km.

Assessment of the existence of a relationship between soil lead concentration and the soil attributes soil texture (sand, silt and clay) and soil pH. Sand and silt showed a positive relationship that was significant at 95 % confidence level while Soil pH and clay showed negative relationships.

The area 7.5 Km south east of Kabwe mine forms the bench mark for all areas in south eastern direction beyond which the influence of mining related soil contamination cannot be detected. It was therefore recommended that physical tags in form of beacons be installed by local authorities to mark areas beyond which the safety of the potential inhabitants would be guaranteed with confidence.

Finally, pedological and geological or background controls must be set for different metals in areas with high potential for industrial development prior to the authorization of investment. Information must be available within the GIS frameworks for easy retrieval, management and analysis or use by different individuals.

CHAPTER SIX: REFERENCES

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CHAPTER SEVEN: ANNEXIES

Legend

Kabwe
district
Zambia

s

Coordinate System: WGS 1984 UTM ZONE 35S

0 75150 300 450 600

| Kilometers

ANNEX 1: Map Zambia Showing Location of Kabwe District

ABSTRACT

Urban and industrial development have in many places, reduced the environmental quality. One major problem has been that of the emission of heavy metals into the terrestrial environment for example, soil contamination resulting from mining activities has occurred in Zambia's Kabwe district. This study was conducted in order to determine (i) the spatial extent of soil Pb as a function of distance from the Kabwe Pb and Zn mine (ii) the strength and direction of any relationship between lead concentration and soil texture and soil pH. A total of 37 top soil (0-20cm) samples were collected by stratified random sampling from strata created at 7.5km, 9.5Km and 12.5Km south east of the mine. The sampling points were geo referenced using a handheld GPS and described by the soil Pb concentrations and the soil attribute data within GIS 9.2. All spatial data were projected in the coordinate system WGS 1984 UTM zone 35 south. Soil lead was determined by using the Aqua Regia method, pH by the electrometric method and soil texture by the hydrometer method. The soil attributes were correlated with Pb concentration in SPSS. The measured Pb concentration was found not to conform to the normal distribution for undisturbed environments. The results also showed that Pb concentration decreased with an increase in distance in the south eastern direction. Correlations showed that strong to moderate relationships existed between soil Pb concentration and the soil attributes pH and clay respectively. The results further showed that a positive strong relationship existed between the soil Pb concentration and silt and clay respectively. The area was found not to have been polluted and was therefore safe for land development and human settlement. It was recommended that physical tags in form of beacons be installed by the local authorities at 7.5Km to delineate the area safe for land development.