CONCENTRATION OF SOME METALLIC POLLUTANTS IN THE ZAMBIAN ENVIRONMENT: DETERMINATION OF CADMIUM, COPPER, LEAD AND ZINC IN SOILS, ON AND IN VEGETATION AROUND KABWE

BY

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DEDICATION

Dedicated to my father Mr. Dickson Nyongani Tembo, and late mother Yeseniya Tonga Tembo; my beloved wife Lustica and my children Grace Tasila Tembo and Backsion Dickson Tembo Jr.

DECLARATION

I, BACKSION TEMBO, hereby declare that the results in this work are a result of my own work, and that no work has been done on the samples used for the purpose of a degree in this or any University.

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ABSTRACT

Environmental pollution has reached alarming proportions in Zambia. Mining and industrial activities have been responsible for water, soil, plant and air pollution. The principal objectives of this study were to determine the extent of pollution of soil and vegetation by cadmium, copper, lead and zinc and to determine the probable source of this pollution in Kabwe area.

The metal contents of the soil and plant samples in Kabwe area and some farms *near Lusaka were determined by atomic absorption spectrophotometry.*

The uptake of heavy metals by some food plants was also investigated. This was done by a comparison of the available heavy metal levels in the soils with the concentration of these metals in plants growing on these soils. The food crops investigated included maize, cabbage, rape, soyabean, tomato, banana, pawpaw, mango, groundnuts, wheat, cauliflower, carrots, onion and others. The results of analyses ranged between trace-28mg/kg Cd, 0.2-61mg/kg Cu, 0.1-758mg/kg Pb and 0.4-234mg/Kg Zn for soil samples and between 0.1-7.3mg/kg Cd, 2.0-44mg/kg Cu, 0.8-1060mg/kg Pb and 1.9-2390mg/kg Zn for plant samples.

This study showed that in Kabwe the probable source of environmental pollution is the mine. This was confirmed by the correlation coefficients(r) between soil metal content and plant metal content and distance, and between soil metal content and plant metal content. The concentration of pollutants decreased with increase in distance but was still high at a distance of 22km west of Kabwe in the direction of the prevailing wind. Plants growing near the smelter contained higher amounts of these metals than those far away. Elevated metal concentrations were partly the result of uptake via the root and partly a result of aerial deposition of metal enriched dust.

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LIST OF ABBREVIATIONS

ADI =Average daily intake.

AWI =Average weekly intake.

BW =Body weight.

DM =Dry mass.

mg/L =Milligramme per litre.

SD =Standard deviation.

SE =Standard error.

ICRA =International Centre for Research in Agroforestry.

SADCC =Southern African Development Coordination Conference.

WTI =Weekly tolerable intake.

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CHAPTER ONE

GENERAL INTRODUCTION

1.0. GENERAL INTRODUCTION

Environmental pollution may be defined as the contamination of our surroundings by substances which harm living things. These could cause disease or intoxication and in extreme cases, death.

Environmental pollution is thus an acute and pressing problem not only for the developed countries but also for the developing countries. It is an urgent and immediate problem which requires a concerted effort to solve since pollutants can move from country to country. The increase in pollution from a wide variety of sources presents a potential threat to living organisms.

Most textbooks and statements about world environmental pollution indicate that this problem emanates mostly from anthropogenic sources such as industry, mining, coal combustion, auto exhaust, effluent, petroleum and paint (1 - 25). The contribution from natural sources such as volcanic, forest foliage and erosion is minimal (26,27). The environment which comprises the atmosphere, hydrosphere and lithosphere can have changes in its chemical composition as a result, mainly, of human activities resulting in contamination. This contamination may be of either organic or inorganic compounds. Substances such as carbon dioxide, carbon monoxide, oxides of nitrogen, chlorofluorocarbons, oxides of sulphur, lead, cadmium, arsenic, selenium, mercury, thallium, copper and zinc are environmental pollutants which are significantly toxic and can constitute ecotoxicological risk to man, animals and plants (1,8,23,24,28,29,30,31,32,33). Some of these occur naturally but their concentrations were very low and were never a health hazard to both animal and plant life. However, the increase in population inevitably resulted into increased pollution. This could be attributed to several factors amongst which are lack of proper waste disposal, man's interaction with the environment in search of treasure such as minerals like silver and copper, industrialisation and continued use of leaded gasoline.

1.1 TYPES AND SOURCES OF ENVIRONMENTAL POLLUTION.

There are two main sources of environmental pollution. These are natural and anthropogenic sources. Natural sources include pollution which may emanate from wind blown and volcanic dust, sea sprays, forest foliage, erosion and weathering. The contribution of this type of pollution to the environment is minimal and has never been a major concern (26,27).

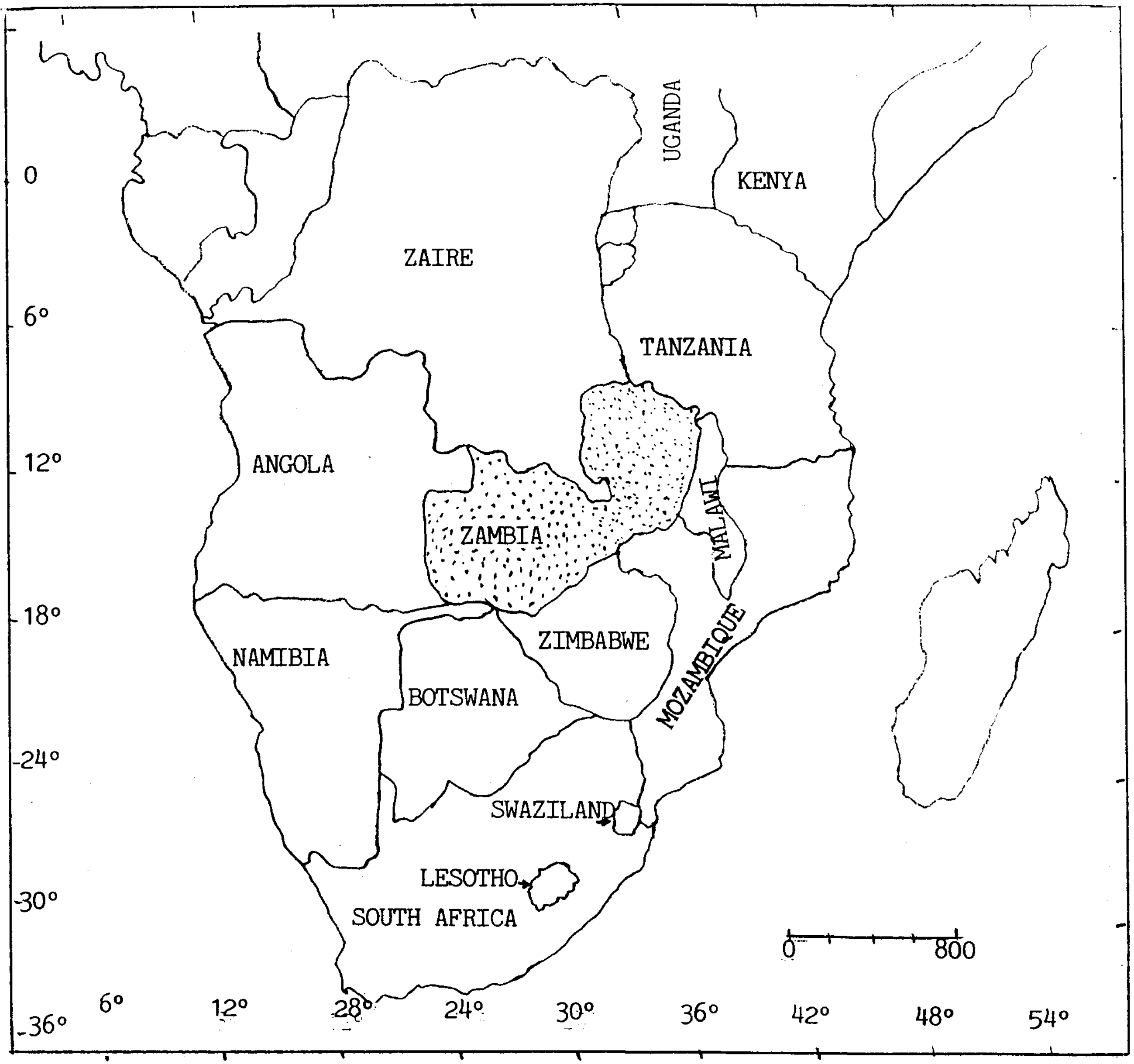
Anthropogenic sources are man made and these are the main causes of pollution in the environment. Primitive man lived without causing major changes in the environment as his main source of food were fruits, seeds and game meat. As soon as he started organising himself into communities, pollution started being a problem. He had to learn how to dispose of his waste and garbage. He started making fires to warm himself, drive off wild animals and for cooking purposes. He started farming which meant clearing trees and developing such systems as chitemene (where branches of trees are cut and burnt to make the soil productive) in the Northern province of Zambia. Later developments included the application of chemical fertilizers so as to improve his crop yield to feed the ever increasing human population. He started looking for ways of exploiting mineral resources, developing mines and their extra waste problems. Various industries were established such as iron and steel industries, chemical industries, power stations (using fossil fuels) where smoke and other by-products were produced. Trade was also established. He developed faster means of communication and travel leading to petrol driven vehicles. By trying to solve some of his problems and to develop a more comfortable life he created new and dangerous environmental pollution problems which now threaten his very survival.

1.2 ENVIRONMENTAL POLLUTION IN ZAMBIA.

1.2.1 ZAMBIA'S POSITION AND CLIMATE

Zambia is a land locked country in southern Africa, located between 8 and 18 degrees South and 22 and 34 degrees east and is bordered by Zaire, Tanzania, Malawi, Mozambique, Zimbabwe, Botswana, Namibia and Angola (Fig 1.1). She has a surface area of 752, 972 square kilometres. Zambia has a subtropical climate and there are three distinct seasons. The warm wet season stretches from November to April. Most of the precipitation occurs during this time. A cool dry season occurs from May to August with mean temperatures varying between 15°C and 27°C. A hot and dry season lasts from September and October with temperatures varying between 27°C and 32°C. During the dry season pollutants build up in the atmosphere and may precipitate as dust or particles on the ground surface. At the beginning of the rainy season, the bulk of the dry season residue may be channelled into rivers, streams or unprotected wells.

Fig.1.1 Map of Sub-Sahara Africa Showing Position of Zambia



1.2.2 MINERAL RESOURCES AND INDUSTRIES

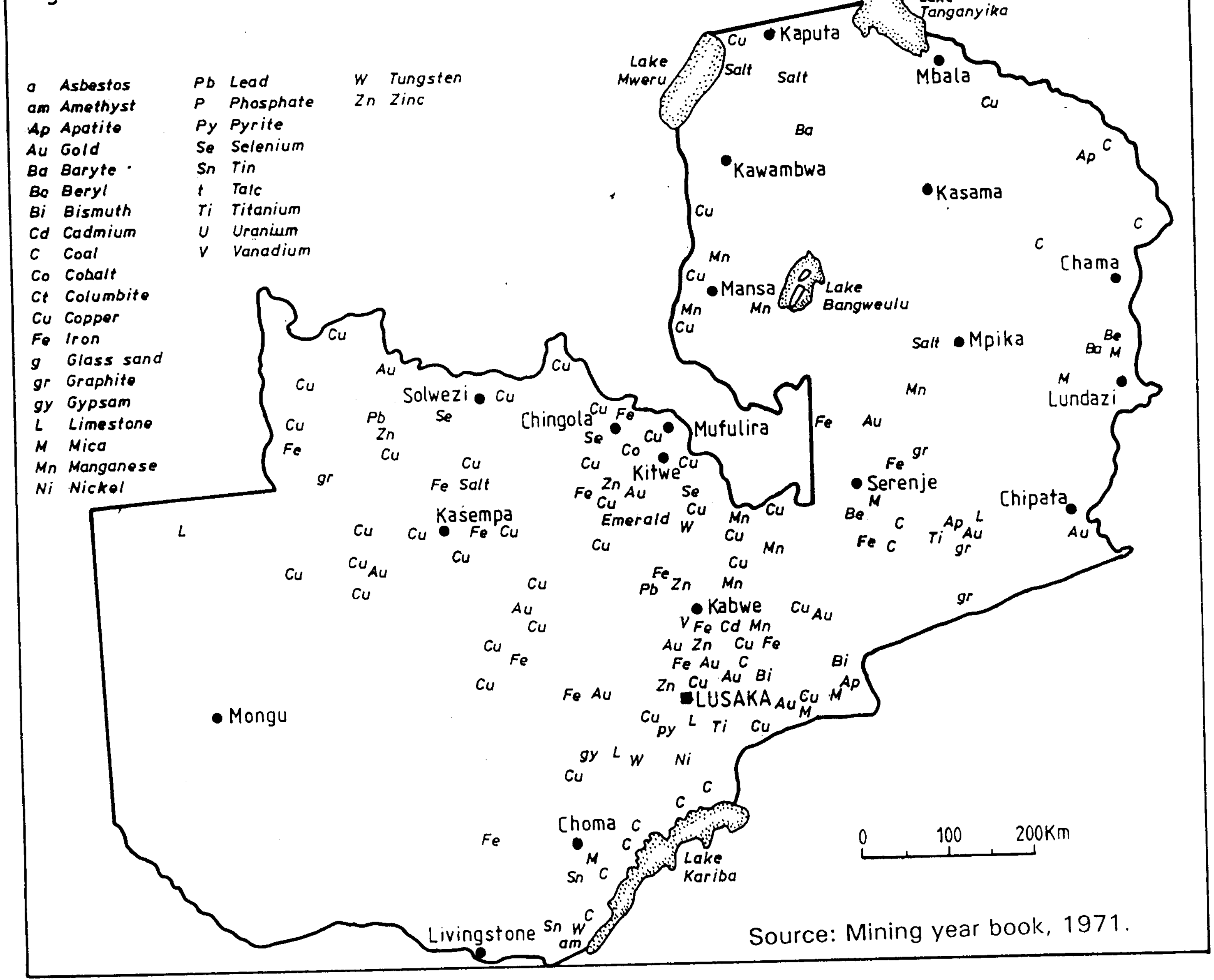
Zambia is one of the most industrialised countries in the sub-Saharan region (34). *She has rich mineral resources (Fig 1.2) and her major* deposits include copper and cobalt mined on the Copperbelt, lead and zinc mined at Kabwe in the Central Province, and coal at Maamba near Choma in the Southern Province. Gold and silver are produced as by-products of copper and lead/zinc mining. Zambia also produces small quantities of other metals including selenium, cadmium, manganese and tin; and plans to extract iron and uranium may soon be implemented (35). Other mineral resources include graphite, marble, sulphur, phosphate, gypsum and asbestos. Dolomite and limestone are quarried for local building industries.

The mining industry is thus the largest sector and has created serious environmental problems in localised areas(36). Other industries which also contribute significantly to environmental pollution problems include;

(a) Chemical industries such as:
    (i) Nitrogen chemicals of Zambia at Kafue which produces fertilizers, nitric acid and sulphuric acid.
    (ii) Shell Chemicals (Z) Limited at Lusaka which formulates pesticides, herbicides, fungicides and acaricides.
(b) Textile industries such as Kafue Textiles in Kafue and Mulungushi Textiles in Kabwe.
(c) Leather industries such as Bata tannery in Kafue and others.
(d) Oil Refinery at Indeni in Ndola, Copperbelt.
(e) Other manufacturing industries and agriculture.

Thus anthropogenic sources are likely to be the main causes of environmental pollution in Zambia. Most industries in Zambia are along the line of rail and pronounced industrialisation and urbanisation lie between Kafue Town and Chililabombwe (37). Consequently much pollution has occurred between these two towns.

Fig. 1.2: ZAMBIA'S MINERAL RESOURCES



Source: Mining year book, 1971.

1.2.3 MAN MADE POLLUTION IN ZAMBIA

In Zambia industrial pollution is a major source of worry. Mining and industrial activities have been responsible for water, soil and air pollution. Breakdown in the maintenance of sewage systems and industrial waste treatment facilities due to the country's poor economy has led to discharge of untreated sewage and effluent into streams and rivers.

Water pollution from industrial and mining discharges have been mainly on Kafue River (36) which starts on the Zambia-Zaire border near Kipushi Town. It passes through Zambia's main mining and industrial area of the Copperbelt, and continues south through the heavy industrial areas of Kafue and Nakambala sugar estate in Mazabuka. Some of the effluents discharged into the river include organic pollutants (from municipal and other industries), heavy metals (such as copper and zinc), suspended solids, chlorides, sulphates, nitrates and phosphates. High organic matter, nitrates and phosphates lead to eutrophication and oxygen depletion which may result in death of aquatic life such as fish. Sometimes both rural and urban residents may obtain their water supplies from such contaminated rivers or streams near where they stay. This would have a negative effect on health and may lead to outbreaks of serious water borne diseases such as cholera, dysentery and typhoid. Other ailments may also be contracted.

Air pollution is a serious problem in areas where industrial and mining activities take place. The most prone areas to air pollution in Zambia are:

(a) The Copperbelt - from mining and smelting operations, oil refining operations, sulphuric acid and cement production and others.

(b) Kabwe - from lead, zinc and cadmium mining and smelting operations and sulphuric acid production. It seems the air in and around Kabwe is the most polluted in the whole of Central Africa (38).

(c) Kafue - from fertilizer, nitric and sulphuric acid production.

(d) Lusaka - from cement and lime production, auto exhaust and incinerations and others.

(e) Maamba - from coal mining.

Most ores mined on the Copperbelt and Kabwe contain sulphur (39,40) and when roasted, sulphur dioxide and other acidic gases do form. Huge amounts of sulphur oxides especially sulphur dioxide are released from the mines and other industries annually and daily discharge of sulphur dioxide sometimes exceeds recommended values (36). These have adverse effects on living organisms and *buildings. Both plants and animals are affected. Plants are more susceptible to* sulphur dioxide toxicity (40). The gas damages plants causing the leaves to turn yellow and later, dry. As an acidic oxide, sulphur dioxide can also dissolve marble, erode iron and steel and irritate upper respiratory tracts causing bronchitis and other respiratory diseases (39,41). Furthermore sulphur dioxide combines with water (especially during the rainy season) to form acid rain which lowers soil pH by raising the soil acidity. Acid rain has adverse effects on the infrastructure, land and the ecosystem.

At Kafue, the situation may be worsened by nitrogen oxides produced in addition to sulphur dioxide. Nitrogen dioxide also contributes to formation of acid rain and has a bleaching effect on various materials (41). Prolonged exposure to low nitrogen oxides may be harmful to the lungs and may also cause leaf injury to plants (41).

In Kabwe the situation is made worse by the production of toxic metals. The dense fumes which come from chimneys of mines are also rich in metallic pollutants such as cadmium, copper, lead and zinc in addition to sulphur oxides. Copper and zinc can form volatile carbonyls which may be present in these fumes. However, both metals may also be present in the fumes in other forms. Lead and cadmium are also likely to be present in the fumes. These metallic pollutants in the air eventually precipitate on to the ground surface increasing concentration of such elements in the adjacent areas as far as 45 - 65 km away (42) depending on weather conditions. As these metals are non biodegradable, their pollution is long lasting.

Leather, textile and chemical industries are also significant polluters of the environment. Kafue in the Central Province has all these industries and the effluent from these are discharged into Kafue River on the upstream. Municipal effluent are also channelled in the same way. Water for use in Lusaka is taken from down stream. Thus toxins from these industries such as chromium from the leather industry, nitrates and sulphates from fertilizer and acid plants, sulphates and dyes from textile industry may affect not only people in Kafue but also those in Lusaka who may use contaminated water.

A significant amount of pollution also come from automobiles especially in large cities like Lusaka. According to fuel consumption data in Zambia (36), the total emission into the atmosphere in 1987 was about 60900 tonnes as follows:

	Tonnes/year
Carbon dioxide	43240
Nitrogen oxides	6530
Sulphur dioxide	990
Hydrocarbons	6350
Aldehydes	970
Particulates	2410
Lead	420

Lead emissions from traffic are still remarkable as Zambia has not yet controlled the levels of lead in petrol(36). The increase in vehicles has resulted in even greater traffic emissions. Most vehicles are not properly maintained and do emit a lot of fumes into the environment. Lack of spare parts or their high prices simply increases these emissions. The fumes may contain toxic substances such as carbon monoxide, lead, sulphur dioxide, benzopyrene, aldehydes, hydrocarbons, organic acids, dust and smoke (43). The problem of exhaust fumes from vehicles has been a major public concern (44). These vehicles emit a lot of fumes in the surroundings and are a health hazard to human beings and other living organisms, hence the outcry. Although the fumes from such vehicles do not go very far, they do affect living organisms within at least 500m from the road (9). Many houses in Zambian towns are built within this distance.

Burning and incineration of waste may also have an effect on pollution. The type of pollutants greatly depends on what is burnt or incinerated, however, carbon dioxide and other gases may be major pollutants. Metallic pollutants such as lead and cadmium may also be present especially when paper, tyres and metallic scraps are being incinerated.

Agricultural chemicals such as insecticides, herbicides, growth regulators (homones) and fertilizers also contribute to polluting the environment. Insecticides, herbicides and hormone sprays may stick to or get absorbed by farm products. When these are eaten by man or other animals they enter the bodies of consumers. Food contamination could be a serious problem for toxic chemicals which degrade slowly and can be concentrated in the normal food chain such as 1,1,1- trichloro-2, 2-di-(4-chlorophenyl)-ethane (DDT). Dieldrin:(1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo-1,4-exo-7,8-dimethanonaphthalene) and aldrin:(1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-endo-1,4-exo-5,8-dimethanonaphthalene) which have been found in milk and consequently in human tissue due to careless use in crop protection (36). DDT has also been found in fish eagles in Lake Kariba in Zambia and endosulphan killed fish during spraying (36).

Soils may also suffer adversely from the effects of insecticides, herbicides and fertilizers (45).

Although DDT and dieldrin are banned in other countries, they may be still be in use in Zambia (46) and Shell Chemicals which formulates, stocks and sells insecticides, herbicides, fungicides and acaricides only stopped the sale of dieldrin in June 1991 (46). It seems Zambia has no defined policy on pesticides registration. This makes Zambia an easy dumping ground for unwanted pesticides.

1.3 POLLUTION ANALYSIS AND GOVERNMENT POLICY IN ZAMBIA

Environmental pollution has reached alarming proportions in Zambia (37,39,40). The increase in industrialisation has brought about diverse pollutants into the environment. Most of these pollutants are significantly toxic and their dispersion into the environment should be monitored, controlled and possibly removed from the environment altogether to enhance living conditions of plant and animal life.

There has been however, little pollution analysis done in Zambia. Most of the studies have concentrated on water quality (36,47,48). Those done on food have concentrated mainly on the nutritional status of food (49). A few have dwelt on contamination of food by organic substances (50,51). Not much has been done on metallic pollutants in food and plants which can be eaten by both man and animals. Thus the fitness of this food for human consumption has not been ascertained. Furthermore, most of these analyses have mainly looked at organic and some other inorganic pollutants.

The first description of serious environmental pollution by metals in Zambia was given by A. Reilly and C. Reilly (52). They described three areas: a rural area, urban area and the contaminated (52) mining area of Kabwe. However, their research concentrated on an area within 1km from the zinc and lead smelters and looked only at maize as food sample.

The lack of such adequate pollution analysis may be attributed to the lack of a clear government policy on pollution prevention, monitoring and abatement measures. Lack of such a policy for a very long time has led to serious levels of pollutants which may now be very difficult and expensive to control or bring to acceptable levels. Even if the levels of pollutants can be controlled, persistent ones like metallic pollutants will continue to exert their influence on man and other living organisms for many years to come. Lack of pollution abatement measures caused a corresponding lack of adequate pollution analysis as there might have been no 'need'.

The new government has created the Ministry of Environment and Natural Resources which may work to reverse the trend of the previous government.

1.4 BIOCHEMICAL EXAMPLES OF POLLUTION

Pollutants are toxic substances which interfere directly or indirectly with living organisms. Most of these pollutants alter certain processes occurring in living organisms thereby inhibiting good health and welfare of these organisms. This usually leads to disease and in extreme cases, death of an organism. It is evident that these pollutants threaten the very existence of not only plants and animals but even man himself. This renders man to be a bad steward of the things he has been entrusted with by God the Creator.

It could be that man may have not been aware of the results of his activities (53). However, once bad effects manifest themselves it is incumbent upon him to identify these and try by all means to correct the causes. Failure to do so is tantamount to his incapability to manage well what has been entrusted to him for his good. This seems to be the case and unless controlled, pollution will continue to increase. Already environmental pollution is a very serious and pressing issue today. Good health for all living organisms is of primary importance but good health can only be experienced in a good environment.

It is thus imperative for any government to see to it that its citizens and indeed the entire environment is clean and safe enough for other living organisms to live. It is important for the government to enact laws to protect the lives of its citizens by protecting the environment by making sure that undue pollution which emanate from industries, mining, automobile and others are kept to a minimum thereby protecting the unreplaced and unequalled human life. Companies or industries involved in polluting the environment must be made to comply with pollution abatement measures and install devices which may help reduce dispersion of these pollutants into the environment and thus reduce risks to human life and that of other organisms.

1.5 ECONOMIC IMPORTANCE OF POLLUTION

Pollution may mark and discolour foliage reducing the visual attractiveness and value and marketability of fruits, vegetables and ornamental plants. Environmental pollution has a very bad effect on the ecosystem. Pollutants can cause damage to infrastructure such as sulphur dioxide which can erode steel infrastructure and buildings and which can form acid rain which has damaging effects on the ecosystem. Metallic pollutants can cause debilitating diseases in humans thereby reducing the well being and capabilities of individuals. This may reduce productive undertakings, development slows down and the economic viability of the country may be affected.

Removal of pollutants from the environment is more expensive than preventive measures. A lot of money and other resources meant for development ventures are thus rechannelled to remove pollutants, treat diseases caused by these pollutants, repair damaged infrastructures and treat other effects.

The pollutants do contaminate food eaten not only by animals but also by humans. When levels of these pollutants are higher than recommended values, knowledgeable individuals would shun consumption and buying of such foods. Export of farm produce may thus be harmed as no country would like to import food toxic to its citizens.

Furthermore, environmental degradation will drive away tourists and deprive the country of the much needed foreign currency. No tourist would like to visit highly polluted areas as this would endanger his/her life.

It is thus important to protect our environment by controlling pollution and environmental degradation before it worsens.

1.6 EFFECTS OF CADMIUM, COPPER, LEAD AND ZINC ON PLANT AND ANIMAL LIFE.

Some metallic pollutants are significantly toxic even in very small amounts because of their non biodegradability and cumulative nature including their reactions with proteins in the body which renders essential reactions impotent (1,8,23,24,28,29,30,31,32,33). Some metals can cause debilitating diseases in human and animals as they cause irreversible changes in the body especially in the central nervous system leading to psychotic disorders and other ailments (1,3,13,33,54,55).

Contamination of the soil by metals is a serious issue as toxic metals pose a great danger to both plant and animal life.

Human beings exposed to environmental pollution may accumulate abnormal amounts of metals in various body organs. Excess accumulation of metals that are not usually associated with biological function may lead to toxic symptoms or even death(12, 16, 42). The cummulative properties of cadmium and lead (23) provide a special problem as they are highly toxic(12, 16, 42) and may induce a wide range of toxic manifestations(16). Although copper and zinc are essential trace elements(2, 42), they can also cause toxic effects when in excess(56).

1.6.1 CADMIUM

Cadmium is widely distributed in the earth's crust at an average concentration of about 0.1mg/kg and is commonly found in association with zinc and phosphates. All zinc ores contain small amounts of cadmium and the predominant ore of cadmium is greenockite(CdS) which is often associated with deposits of zinc sulfide(ZnS).

The metal enters the environment mainly through lead -zinc-copper mining and smelting operations or industries using cadmium alkaline accumulators, alloys, paints and plastics or even those burning oil or coal.(1,12, 13, 23).

It is a non-essential toxic (19,23) and non-biodegradable trace element(24) which accumulates in the bodies of consumers especially in the kidneys, liver, spleen and lungs(8,13,16,56). Cadmium has great affinity for the thiol groups (-SH) present in enzymes and other proteins, rendering them impotent. Cadmium may cause renal tubular dysfunction, emphysema, anaemia, yellow coloration of the teeth, bone marrow disorders, bone lesions, hypertension, liver dysfunction and malignant tumours(1,3,8,19,23,25,57,58,59,60,61,63,64,65). It is also thought to be mutagenic and teratogenic (4,13,25,61).

High cadmium intake in man causes painful decalcification of bones causing them to break easily even on turning in bed. X-ray examination of bones reveal decalcification, multiple fractures and bone deformity (1,4,66). The toxic nature of cadmium is well known and it caused a very painful disease in Japan called itai-itai amongst women (1,23). Limited studies indicate that occupational exposure to cadmium in some form increases the risk of cancer in man (13,19,61,67,68,69). In a battery plant in in Sweden there was a significant increase in incidents of cancer of the prostate (70).

1.6.2 COPPER

Copper is widely distributed in the earth's crust and is present in all living organisms. It is commonly found in association with silver, arsenic, antimony, iron, tin, bismuth and lead. Some of its ores are: malachite($CuCO_3.Cu(OH)_2$), azurite($CuCO_3.2Cu(OH)_2$), chalcopyrite($CuFeS_2$) and chalcosine(Cu_2S).

It enters the environment mainly through copper mining and smelting operations, industries that use copper and in agriculture through use of copper containing fertilizers and fungicides.

Copper is an essential trace element for both animals and plants (2,5,58). In man it is required for normal metabolism of all tissues and is a co-factor for many body enzymes, although its functions are by no means limited to this role. There are about twenty six enzymes which require copper at their active site. These perform different functions including transport of oxygen and electrons, catalyst in redox reactions and protection against deadly oxygen radicals and harmful ultra-violet rays of the sun (13). It is essential for the formation of haemoglobin, blood vessels, bones, tendons and myelin sheath in man and in plants it is essential for plant growth(2).

Thus too much or too little copper results in malfunctioning of the cell. Adequate intake of copper is needed to prevent the onset of many disorders including anaemia, connective tissue disorders and neurological disorders. There are about twenty two diseases associated with elevated levels of copper(13). A few of these are common in Zambia like malaria, sickle cell anaemia, allergic reactions, central nervous system disorders, diabetes mellitus, schizophrenia and tuberculosis (13,56).

Copper deficiency causes leucopenia, demineralisation of bones, anaemia, fragility of large arteries and demyelination of neural tissue (13,56). Excess copper causes Wilson's disease which is associated with abnormal accumulation of copper in the liver and the brain (13,56) which may lead to mental illness and death. Copper is about twice more toxic than zinc(8).

1.5.3 LEAD

Lead is widely distributed in the earth's crust at an average concentration of about 15mg/kg and is commonly associated with zinc and cadmium. Lead ores include galenite(PbS), anglesite($PbSO_4$) and cerussite($PbCO_3$).

Lead enters the environment through the smelting and refining of lead, the burning of petroleum fuels containing lead additives, smelting of other metals, the burning of coal and oil and from paint (3,8,12,13,25).

Lead, like cadmium, has great affinity for thiol(-SH) groups and it is for this reason that enzyme inhibition occurs. Lead fulfils no known essential or useful biochemical function in man. Present day levels of lead in food, water and air and consequently in man are clearly elevated in comparison to natural levels calculated prior to the beginning of lead technology some 5000 years ago and found in ancient skeletons. Present day body burden in man appears to be 100 to 1000 times greater than natural levels against which man evolved and is assumed to have adapted(13). The unnatural nature of body lead burdens, now being regarded as normal, constitute one major reason for special concern over environmental lead.

Another focus of concern lies in the neurotoxicity of lead. Lead causes mental disturbance at exposure levels well below those liable to produce overt symptoms of clinical poisoning. Lead poisoning results in brain damage, mental *deficiency, serious behaviour problems, kidney damage, anaemia, peripheral neuritis, tremor and premature loss of teeth (3). Thus lead has an obvious* potential to disturb learning ability, adaptative responses, and other aspects of behaviour and personality (such as decreased intelligence quotient, IQ).

Lead is very dangerous for new born children because it can damage their brains(56). Children are affected more than adults because they absorb about 50% of ingested lead compared to 10% in adults(72,96). Lead passes into the brain more easily than cadmium(16), and in this and other organs, lead can replace calcium in metabolism allowing lead to attach to essential enzymes thus disrupting vital organ functions. As the body grows, it develops barriers against lead's destructive traits but since lead is non-biodegradable and is poorly excreted it accumulates in the body, thereby disrupting other organs when high concentrations are reached.

Twenty years ago medical doctors believed that children were safe with up to 40ug/100ml of lead in blood. The 'safe' level has slowly fallen so that by October 1991 the U.S. Centres for Disease Control(CDC) issued new warnings alerting doctors that anything higher than 10ug/100ml can be harmful to children. The CDC recommended that children should be tested for plasma lead as part of their regular check up. Furthermore, families were urged to check their homes for lead piping, paints etc and remove it before children show obvious signs of poisoning. Although lead poisoning is controllable, it is still the most common associatory devastating disease of young children.The damage can occur not only after birth but even before conception.Thus low levels of environmental exposure to males can produce seminal damage(73). Animal studies have shown that lead and cadmium can act synergistically on the formation of sperm at blood lead and cadmium levels down to 20µg/100ml, and these metals also act synergistically in pregnant female animals(74).

More dangerous are organo-lead petrol additives (R_4Pb where $R = CH_3^-$ or $CH_3CH_2^{-)}$ from which the very highly toxic trialkyl lead (R_3Pb^+) species can be formed in the mammalian liver (13). These are toxicologically distinct from Pb^{2+}, are even more powerfully neurotoxic.They eventually degrade to Pb^{2+} in the body and the environment.

1.6.4 ZINC

Zinc is an abundant element and constitutes approximately 0.04g/kg of the earth's crust. The most common zinc mineral is sphalerite(ZnS), which is often associated with the sulphides of other metallic elements such as lead, copper, cadmium and iron.

Excess environmental zinc is mainly due to zinc mining and smelting operations and other industries involving its use, such as roofing materials.

Zinc, like copper, is an essential element in living matter and is required in a variety of essential processes in both plants and animals (2,13,56). It is an essential part of many enzymes such as carbonic anhydrase, alcohol dehydrogenase, alkaline phosphatase and carbonyl peptidase A and B. It plays a key role in protein synthesis, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) metabolism, carbohydrate and lipid metabolism as well as energy metabolism (13,56,75,76) . It is also required for the synthesis of tryptophan, a precursor of the plant hormone indole acetic acid,an auxin. Zinc deficiency, on the other hand, results in poor wound healing and in children it also results in poor growth and impairment of sexual development (5).

Zinc can also exert toxic reactions when in excess. Zinc toxicity in animals starts if zinc content of the diet exceeds 1000mg/kg. Excess zinc is thought to be a cause of cancer of the prostate gland in males (5).

1.7 IMPORTANCE OF POLLUTION ANALYSIS

Environmental pollutants can be debilitating to living organisms. For living organisms to live well and enjoy good health, these pollutants have to be removed or their dispersion into the environment reduced to a minimum - to levels that may be 'safe' for the organisms. Usually it is difficult to know whether the air we breathe in, the water we drink and the food we eat are safe enough from these environmental toxicants. Although an increase in industrialisation may be a sure sign of increase in pollution, this does not necessarily indicate that pollution has occurred especially if pollution abatement measures have been employed in such industrialisation from the beginning.

The presence of these toxic substances in air, water, food and the general environment can often not be detected using any of the human senses. The only sure and certain way to know whether material is unadulterated is to carry out chemical analysis.

The four elements studied are even more dangerous as they are bioaccumulative and many people may be exposed to these through air, water and particularly food. These metals should not be allowed to reach toxic levels in food and pasture as even small amounts can cause irreversible changes in the bodies of man and other animals. It is necessary that they are analyzed in the environment to check whether or not they are within the internationally accepted limits especially in the air, water and food.

1.8 METHODOLOGY

1.8.1 SELECTION OF POLLUTANTS FOR ANALYSIS

The present work looked at cadmium, copper, lead and zinc in soils and plants (including food samples) in and around Kabwe.These four heavy metals were especially chosen because:

(a) they are present in ores mined at Kabwe.

(b) two of these cadmium and lead, are highly toxic to living organisms.

The mining industry is usually a major dispersive agent of these metals into the environment. Their indiscriminate discharge into the environment poses a serious danger to plant and animal life.

1.8.2. SELECTION OF PLANTS FOR ANALYSIS

Plants differ in the uptake of nutrients and other substances from the soil even in the same type of soil (2). This would suggest that concentration of substances in plants may vary from one tissue to another and depends on the physiological stage of the plant. Where a distance of over 15km is to be sampled, there is a problem of not finding the same type of plant species throughout the sampling area. The texture and composition of the soil may also change with change in distance. However, the plants will only take up what is available in the soil.

In this work the same type of plant species were collected. Plants that are eaten by animals were especially selected so as to determine the mineral status of the four metals studied. Grass and pasture grass samples were collected from farms in and around Kabwe and some near Lusaka.

1.8.3. ANALYTICAL METHODS

Sensitive and selective analytical methods are required to determine trace amounts of heavy metals in soil and plant samples. There are many analytical methods that can be employed in the analysis of metals (78,79,80,81,82). One metal may be analyzed by more than one method. The method chosen depends on several factors. These are the amount of analyte present in the sample, the accuracy required, the time required to complete the analysis and of course the availability of the reagents and equipment.

Many available methods possess varying degrees of selectivity, sensitivity, accuracy and precision. Rapidity or speed is a factor that is also considered when selecting the analytical method. It is thus important that the method used should have good selectivity and sensitivity for the analyte in question. Instrumental methods of analysis are now preferred to classical methods.Most commonly used methods are:

(a) POTENTIOMETRIC METHODS

Potentiometric titration are accurate but are not trace methods. Direct potentiometry using ion selective electrode is important but lacks sensitivity and reproducibility due to interferences.

(b) POLAROGRAPHY AND OTHER VOLTAMMETRIC METHODS

Direct current (DC) polarography can not be used for concentrations below 10^{-5} M due to the fact that charging current dominates at lower concentrations and the noise becomes too high. Pulse and differential pulse polarography are trace techniques in ppb levels but are meant for fewer samples.

Stripping voltammetry on the other hand is very good but requires experience and cannot be used with a lot of samples as it is slow.

(c) **RADIOCHEMICAL METHODS**

Neutron activation analysis is a trace method but requires a nuclear reactor which may be difficult to handle safely. It is also very expensive and some elements (such as lead) cannot be measured at lower concentrations.

(d) **SPECTROSCOPIC METHODS**

There are a number of spectroscopic methods but the following are of significance and their instrumentation may be available.

(i) Ultraviolet and visible spectroscopy is good but may require preconcentration and extraction. This would require relatively large amounts of chemicals.

(ii) Atomic absorption spectroscopy has a high sensitivity and selectivity for most elements. It is the most used method for trace metal analysis in soil, food, alloy, ore and other samples.

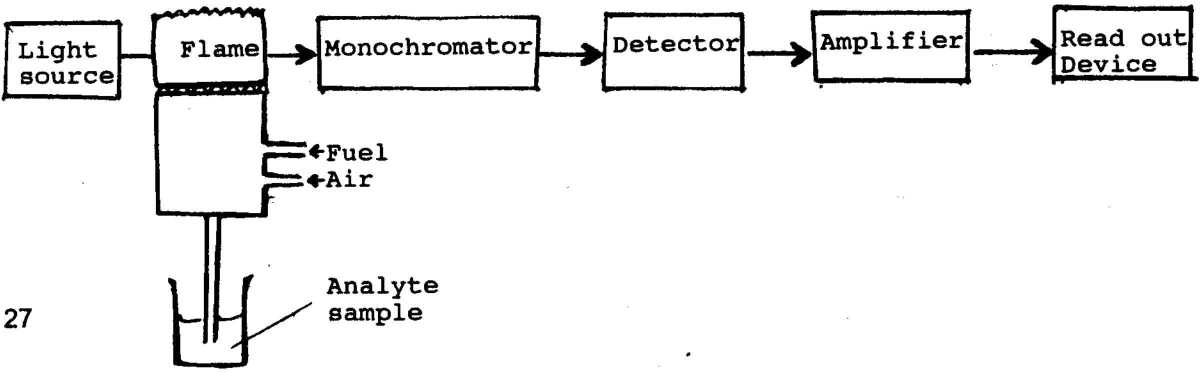
In this work atomic absorption spectroscopy was used because it is very selective, it is sensitive, it is fast and easy to handle and it is available. In this method the sample must be in solution. The sample is aspirated into a flame and the absorbance is recorded.

THE PRINCIPLE OF ATOMIC ABSORPTION SPECTROSCOPY

Atomic absorption spectroscopy (AAS) involves the absorption of radiant energy by atoms in accordance with Kirchhoff's law which states that all matter absorbs light at the wavelength at which it emits. During absorption, valence electrons are excited from a low energy state to a higher energy state.

The principle on which AAS works is that the sample, which must be in solution form, is aspirated into a flame where the sample element is converted to atomic vapour. This enables the flame to contain atoms of the element. Although some atoms are excited, most of them remain in the ground state and can absorb radiation given off by a radiation source made from that element. The absorption follows Beer's law in which the absorbance is directly proportional to the atomic vapour in the flame and consequently to the concentration of the analyte in the solution being aspirated. The sample solution once injected into the flame is then scanned with a lamp emitting the spectrum of the same element and the absorption is measured as a ratio of the intensity of the scanning beam to that of unabsorbed beam at constant wavelength. .

Light from a source is directed through the sample and monochromator slit system to a detector. The latter measures how much light is absorbed by measuring the intensity of radiation before and after it passes through the sample in the flame.



METAL EXTRACTION.

Trace metals are present in plants and soils in varying amounts so that sensitive methods are required for their determination. There are two methods used for plant sample dissolution. One involves wet digestion in which various acids in various combinations are used to effect organic removal from the samples. The acids usually used for this are nitric acid, sulphuric acid and perchloric acid. This method is suitable when smaller samples of less than or equal to 2g are used (20). It requires more chemicals and there is a risk of contamination from reagents.

Dry ashing on the other hand can effect organic removal from samples using only oxygen as reagent. Contamination may not occur in this case especially if proper equipment is used. This method was used in this study. The metals were extracted from the ashes using one molar(1M) analytical grade nitric acid. One molar nitric acid is usually used in pollution analysis (83) to extract pollutants from plant samples.

Although several extraction procedures exist for soil samples, 0.5M of analytical grade, nitric acid was used in this study to extract the available pollutant as it is recommended in pollution studies (83). Once in solution, cadmium, copper, lead and zinc can be determined by atomic absorption spectroscopy. There are no interferences for all these four metals in the air-acetylene flame (20).

1.9 OBJECTIVES

The present work, which was carried out over a period of twelve months, was carried out to provide data in an area of mining pollution. The main objectives of this research were:

- (a) to determine the extent of pollution of soil and vegetation (including food samples) by cadmium, copper, lead and zinc in and around Kabwe and to relate the findings to their ecological effects and economy.
- (b) to determine whether the extent of pollution is due to the mine by determining relationships between:
    - (i) distance with content in soils
    - (ii) distance with content in plants and
    - (iii) content in soil with content in plant.

CHAPTER TWO

MATERIALS AND METHODS

2.0 MATERIALS AND METHODS

2.1 AREA OF STUDY

Kabwe is a lead and zinc mining town in the Central Province of Zambia. Cadmium and silver are also produced as by-products. Kabwe is also the provincial capital and is situated at about 28° 26'E and 14° 27'S. Fig 2.1 shows a sketch map of Zambia showing the study area and fig 2.2 shows a sketch map of Kabwe showing sampling areas in relation to the mining area and the ore body.

2.2. SAMPLING

2.2.1 SOIL SAMPLES

The soil samples collected were analyzed for the four metallic elements. These are cadmium, copper, lead and zinc. Samples were collected from and around Kabwe. Some samples were also collected from areas near Lusaka for comparative purposes. This study was carried out over a period of twelve months, from April 1991 to May 1992.

Soil samples were sampled randomly from various areas in Kabwe in the preliminary study. Samples were also collected from the four areas around Kabwe, namely east, west, north and south with a distance of at least 20km in each direction. In a survey of farms, samples were collected from Tobwe Estate, Bonanza Farm, Moyo Farm and Makombe Farm near Kabwe and Golden Valley Farm, 60 km north of Lusaka, Kyindu Farm and Chalimbana ICRAF/SADCC station in Lusaka region. These were for comparative purposes. At least three composite soil samples were collected from each area or sampling distance.

Soil samples were collected into transparent plastic bags using a steel Auger from the depth of 10-15cm.

2.2.2. PLANT SAMPLES

Plant samples were collected randomly from the same areas as soil samples. Great care was exercised to obtain representative samples. Where possible, the same type of species at almost the same physiological level of growth were collected. This is because there are differences in nutrient uptake by different plants even in the same type of soil. Samples were collected in transparent plastic bags and packed into cardboard boxes for easy transportation. The third and fourth leaves of maize and some vegetables from the top were sampled throughout the farms. Top leaves of other plants were sampled.

2.2.3. FOOD SAMPLES

Food samples were also randomly collected from the same areas as soil samples. Food samples, mainly vegetables, maize and other grains were especially collected because they are widely used by human beings as food. The samples were packed in transparent plastic bags.

Fig 2.1 Map of Zambia Showing The Study Area in KABWE

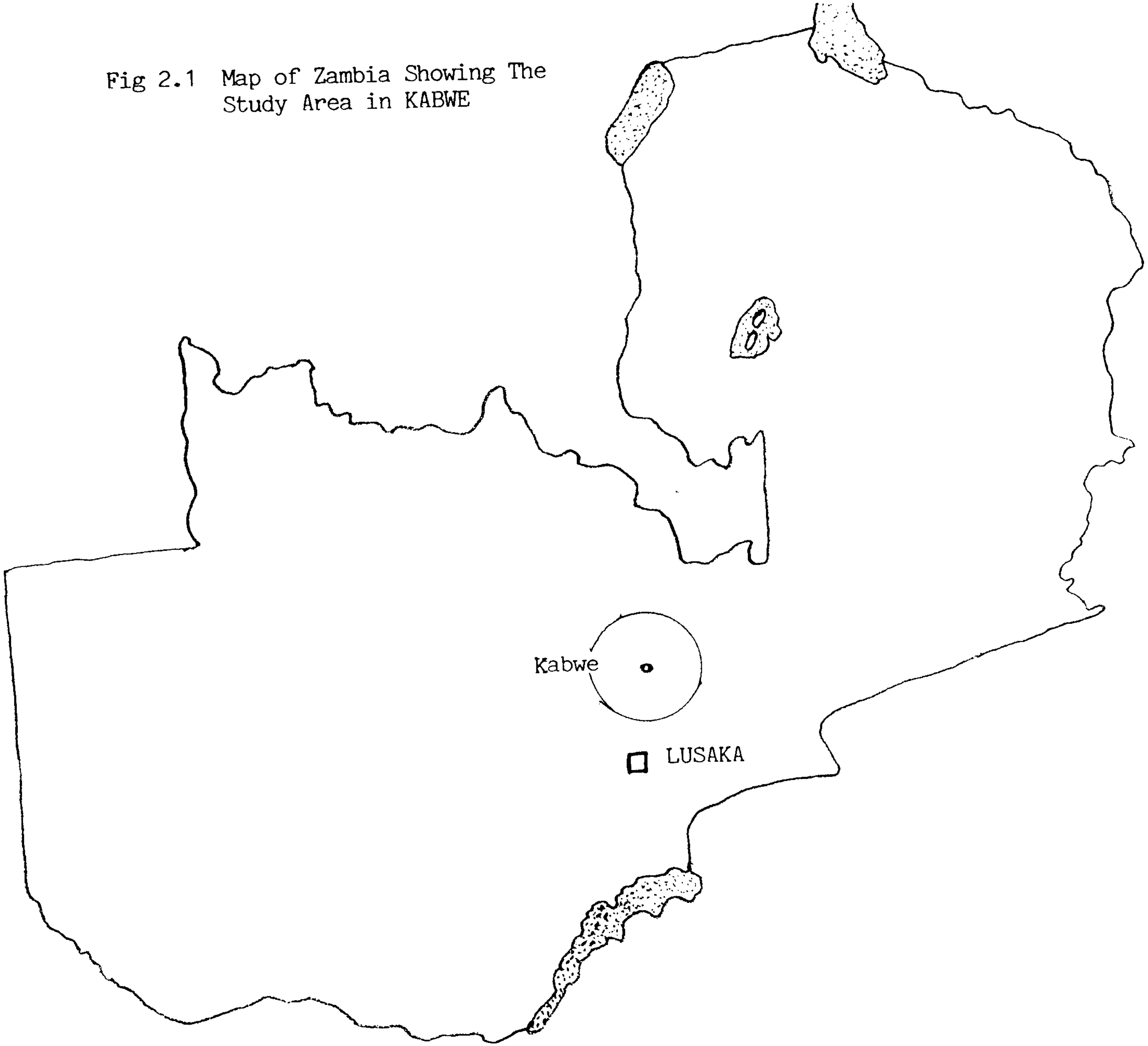
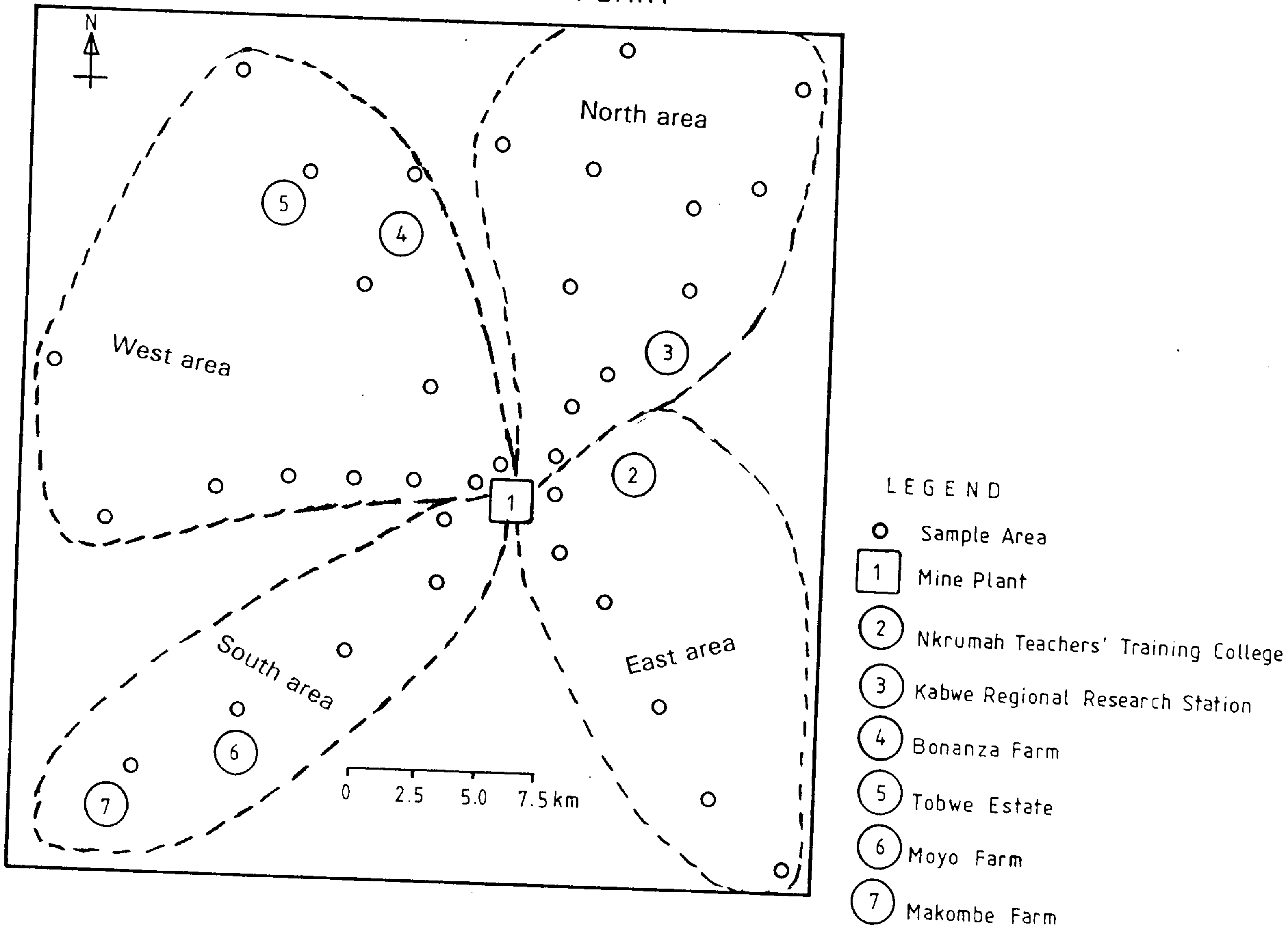


Fig. 2.2. SKETCH MAP OF KABWE SHOWING SAMPLE AREAS IN RELATION TO THE MINE PLANT



2.3 PREPARATION OF SAMPLES

2.3.1. SOIL SAMPLES

The soil samples were air-dried in the laboratory by being spread out on transparent plastic on a bench for several days. They were then passed through a 2mm sieve and repacked in transparent plastic bags.

Twenty (20.00g) grammes of sieved air-dried soil samples were placed in well cleaned 250cm^3 conical flasks and 100cm^3 of 0.5M nitric acid added. The flasks were mechanically shaken for at least thirty minutes using an MVK shaker. The samples were then filtered into 100cm^3 plastic bottles through ashless Whatman filter paper 40.

Some samples were spiked with known amounts of cadmium, copper, lead and zinc and passed through the whole process so as to determine the recovery rate of the method. General purpose reagent cadmium nitrate of minimum purity of 99% was used in the preparation of solution used to spike the samples. Analytical grade nitrate salt of lead was used and analytical grade granules of copper and zinc were used in the preparation of solutions used in the spiking of samples.

A reagent blank for each metal was also prepared and passed through the whole process so as to be used in the determination of the samples for the chosen metals.

2.3.2 PLANT SAMPLES

The samples were subjected to different preparative steps before the actual chemical analysis was carried out. The following preparative steps were carried out:

2.3.2.1 *CUTTING*

The samples were cut into small pieces using stainless steel scissors and placed into well cleaned stainless steel trays for drying. The trays were weighed when empty and when fresh samples were placed into them and after drying the samples.

2.3.2.2. *DRYING*

The trays containing weighed cut samples were then placed into a steel electric oven, Hirasawa works FFS6No. N-1402. The hot air oven was operated and maintained at 110°C for at least three hours. This was done to remove moisture, stop enzymatic reactions and prepare the sample for grinding (82,83,84).

2.3.2.3 *GRINDING*

The dried samples were ground to enable the samples to be handled easily and to ensure greater uniformity in their composition (20,83,84). The grinding was achieved by using a steel grinding mill with 20 and 40 mesh screens. The ground samples were packed in transparent plastic bags and placed in desiccators before ashing.

2.3.2.4. *DRY ASHING*

Three grammes (3.000g) of the ground dried plant samples were weighed into well cleaned and dried silica crucibles using analytical balance. The crucibles were then covered with silica lids and placed in a controllable muffle furnace. At first the temperature was adjusted slowly until samples charred without catching fire, then the furnace was maintained between 450-500°C for at least four hours as the ashing period and allowed to cool in a desiccator (82,83,84).

2.3.2.5 *SOLUBILISATION OF MINERALS*

The ash obtained from the ashing procedure was quantitatively poured into pyrex beakers (83). Twenty cubic centimetres (20cm^3) of 1M analytical grade nitric acid was added and acid digested for at least 30 minutes on a controllable heating mantle. The samples were filtered through ashless whatman papers into 100cm^3 volumetric flasks. The residue on the filter paper was washed several times with distilled-deionised water. The resulting filtrate was diluted to the mark using the same water. A reagent blank was also prepared and passed through the whole procedure.

2.3.3. FOOD SAMPLES

The food samples were subjected to the same preparative steps as the plant samples. Grains such as maize, sorghum, soyabeans and cow peas were treated similarly from drying.

2.4 PREPARATION OF STANDARDS

Standard stock solutions from which the intermediate and working standards were prepared were made as outlined below for each element.

2.4.1 CADMIUM.

The standard stock solution was prepared from cadmium nitrate as the metal (83) or its sulphate salt were not available. There was also no analytical grade cadmium nitrate. General purpose reagent (GPR) cadmium nitrate of minimum purity (according to the manufacturers - Hopkin and Williams Limited, England) of 99% was dried in an electric oven at 110°C for two hours and cooled in a desiccator. 2.103 grammes of dried cadmium nitrate (containing 1g of cadmium) was dissolved in a mixture of nitric acid (analytical grade) and distilled-deionised water (1:4v/v) and diluted to 1000cm^3. This stock solution contained 1000mg/L cadmium. A 100mg/L cadmium intermediate standard was prepared by diluting 10.00cm^3 with distilled-deionised water. The working standards were prepared as required from the intermediate standard solution. The typical working standards of 0, 0.2, 0.4, 0.8, 1.0, 1.2 and 1.4 mg/L were prepared by diluting the intermediate standard solution appropriately and using appropriate pipettes.

2.4.2 COPPER

Copper standard stock solution was prepared by dissolving 1.0006grams of copper granules in 20% analytical grade nitric acid solution and then diluted to a litre(1000cm^3) with distilled-deionised water (82,83,84). This stock solution contained 1000mg/L copper. A 100mg/L copper intermediate standard solution was prepared by diluting 10.00cm^3 of the stock standard solution to 100cm^3 with distilled-deionised water. The working standards were prepared fresh from the intermediate standard solution as required. The typical working standards of 0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, and 5.0mg/L were prepared by diluting the intermediate standard solution appropriately and using suitable pipettes.

2.4.3 LEAD

Analytical grade lead nitrate was dried in an electric oven at 110°C for two hours and cooled in a desiccator. Then 1.5986grams of the dried lead nitrate (20,81,82) (containing 1g of lead) was dissolved in a mixture of analytical grade nitric acid and distilled-deionised water (1.4v/v) and diluted to one litre with distilled-deionised water. This stock solution contained 1000mg/L lead. A 100mg/L lead intermediate standard was prepared by diluting 10.00cm^3 with distilled-deionised water. The working standards were prepared as required by diluting the intermediate standard solution. The typical working standards of 0,1,2,3,4,5 and 6mg/L were prepared by diluting the intermediate standard solution appropriately and using suitable pipettes.

2.4.4. ZINC

Zinc standard stock solution was prepared by dissolving 1.0006grams of analytical grade zinc granules in a 20% analytical grade nitric acid solution and then diluted to one litre with distilled-deionised water (81,82,83). This stock solution contained 1000mg/L zinc. A 100mg/L zinc intermediate standard solution was prepared by diluting 10.00cm^3 of the stock solution to 100cm^3 with distilled-deionised water. The working standards were prepared fresh from the intermediate standard solution as required. The typical working standards of 0,0.5,1.0,1.5,2.0,2.5,3.0,3.5,4.0 and 4.5mg/L were prepared using appropriate dilutions of the intermediate solutions and suitable pipettes.

2.5 ESTIMATION BY ATOMIC ABSORPTION SPECTROPHOTOMETRY

The four elements, cadmium, copper, lead and zinc were determined using a Varian Techtron AA6 atomic absorption spectrophotometer and corresponding metallic hollow cathode lamps were used (83). Acetylene gas was used as the fuel and air as the support. Oxidising flame was used in all cases.

The following table shows the different parameters at which the instrument was set for each metal.

Table 2.1 showing different parameters set on Varian Techtron AA6 atomic absorption spectrophotometer.

ELEMENT	BAND WIDTH (nm)	WAVELENGTH (nm)	LAMP CURRENT (mA)	COMMENT
cadmium	0.5	228.8	3	
copper	0.2	324.8	12	multi element lamp was used.
lead	1.0	217.0	6	
zinc	0.2	213.9	5	

The standards were prepared as described above. A reagent blank was also prepared for each set of standards. Each set of samples had its own reagent blank treated in the same way as the samples. Corresponding calibration curves were made and typical calibration curves for the four metals are shown (fig 3.1 - 3.4). The reagent blank was used to zero the instrument. The standards were aspirated next followed by soil and plant samples.

2.6 ANALYSIS OF RESULTS

The results of an analysis are of prime importance . They are a back bone to correct interpretation of the findings. The results obtained in this study were analysed using the computer with relevant analytical soft wares. The packages used in the analysis of results were quattro and surfer modules.

Some of the most common statistical formulae used are those of standard deviation(SD), standard error(SE) and correlation coefficient(r)

Standard deviation measures the variation in a data set by determining how far the data values are from the mean, on the average. It is given by:

$$SD = \sqrt{\frac{\Sigma (x - \bar{x})^2}{n - 1}}$$

Where x = any given value

$\bar{x}$ = mean value

n = number of values

Standard error is the standard deviation of the mean and is given by :

$$SE = \frac{SD}{\sqrt{n}}$$

where SD = standard deviation

n = number of values.

The correlation coefficient is used as a measure of the linear relationship between two variables , x and y as in y = A+Bx and is given by

$$r = \frac{n \Sigma xy - \Sigma x \Sigma y}{\{ n\Sigma x^2 - (\Sigma x)^2 \} \{ n\Sigma y^2 - (\Sigma y)^2 \}}$$

It has values from -1 to +1. A positive value of r indicates positive relationship between the two variables (hgh values of x corresponds to high values of y) whereas a negative value indicates a negative relationship. When r=0, there is no correlation between x and y.

CHAPTER THREE

RESULTS

3.0 RESULTS

For the purpose of comparison and discussion, the experimental results of samples collected from the Kabwe area and those collected near Lusaka are presented in Tables 3.1 - 3.20 below. The results are expressed in mg/kg for soil samples and in mg/kg DM for plant and food samples. The typical calibration curves for the standards are also presented (fig. 3.1 - 3.4).

Tables 3.1 and 3.2 show average amounts of metallic elements in samples collected in the preliminary survey of Kabwe. The average amounts of metallic elements in samples collected from the four areas surveyed around Kabwe are shown in Tables 3.4 - 3.14 and Tables 3.15 - 3.20 show average metal content in samples collected from the farms surveyed in Kabwe and those near Lusaka.

Results of recovery rates for soil and plant samples for each sample spiked with known amount of each metal are shown in Tables 3.21 - 3.28.

Figures 3.5 - 3.16 show analysis of metal content in soil and plant samples and Tables 3.29 - 3.31 show relationships for each metal with distance from Kabwe. Table 3.32 shows error analysis results.

3.1 Results of the preliminary survey

TABLE 3:1 Average amounts in mg/kg of Metallic elements in soil samples collected in Kabwe.

SAMPLE	NUMBER OF SAMPLES	AREA COLLECTED	Cd	Cu	Pb	Zn
Soil	10	Makululu *(About 2km West of Mine)*	27.5	61.1	547.6	89.2
Soil	4	uncultivated area *(2.5km South of mine)*	0.3	2.5	53.8	31.7
Soil	8	cultivated area *(3 km south of mine)*	0.5	2.8	91.8	0.7
Soil	3	Kabwe Regional Research Station *(About 10km North-East of mine)*	0.1	2.1	3.1	7.0
Soil	5	Nkrumah T.T.C *(About 4km North-East of mine)*	0.1	2.9	32.2	17.9
Soil	4	Waya area *(About 1.5km East of mine)*	0.9	14.6	267.5	73.3

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TABLE 3.2 Average amounts in mg/kgDM of metallic elements in plant samples collected from Kabwe.

SAMPLE	NUMBER OF SAMPLES	AREA COLLECTED	Cd	Cu	Pb	Zn
Cynodon dactylon	8	Makululu (West of mine)	3.2	15.7	331.1	2390.2
Grass	4	Makululu (West of mine)	5.7	12.6	446.5	474.3
Maize leaves	2	Mine compound (M section)	2.2	21.5	597.9	1273.0
PPS	2	About 2.5 km south of mine (uncultivated area)	3.8	14.9	121.6	536.2
Cynodon dactylon	6	About 3 km south of mine (uncultivated area)	1.5	10.4	42.8	264.4
Cynodon dactylon	2	Njanji market	2.3	29.5	TR	112.3
Maize leaves	2	Waya area (East of mine)	2.2	35.4	55.0	160.9
PPS	2	Waya area (East of mine)	2.2	35.0	TR	168.5
Cynodon dactylon	2	Waya area (East of mine)	2.2	44.7	15.0	516.7

PPS = pennisetum purpureum schum.
TR = Trace

TABLE 3.3 Average amounts in mg/kg DM of metallic elements in food samples bought and/or collected from Kabwe.

Sample	Number of samples	Place obtained	Cd	Cu	Pb	Zn
Rape	2	Central Market	0.3	44.1	35.2	72.5
Cabbage (Chinese)	2	Central Market	1.5	36.5	38.9	115.6
Cabbage (Chinese)	2	Buyantashi Market	2.2	15.3	27.9	63.5
Rape	2	Buyantashi Market	2.2	21.2	27.9	73.7
Cowpea leaves	2	Buyantashi Market	2.2	30.9	27.9	78.1
Groundnuts	2	Buyantashi Market	0.9	9.0	13.0	38.9
Rape	4	Njanji Market	2.2	25.0	27.9	95.6
Tomato leaves	2	Nkrumah T.T.C	2.2	36.1	27.9	182.5
Cabbage	4	Nkrumah T.T.C	2.2	26.9	27.9	95.5
Bidens schimperise	2	Nkrumah T.T.C	2.2	43.3	27.9	79.2
Amaranthus	2	Nkrumah T.T.C	2.2	34.0	27.9	115.8
Sweet potato leaves	2	Waya area	2.2	39.2	27.9	97.6
Sweet potato stem	2	Waya area	2.2	39.2	113.8	256.9
Mealie meal	2	Kabwe Milling Co.	TR	5.3	6.0	12.5
Maize bran	2	Central Market	0.2	3.7	19.2	1.9
Sweet potato tuber	2	Central Market	0.2	9.4	28.2	7.5
Sorghum	2	Central Market	0.9	1.9	25.6	36.0
Cow pea	2	Central Market	1.3	8.8	25.9	28.9
Magoye Soyabean	2	Kabwe R.R.S	2.1	5.8	27.0	33.6
Santa rosa Soyabean	2	Kabwe R.R.S	2.1	8.0	27.0	34.9
Hernon Soyabean	2	Kabwe R.R.S	2.3	9.4	31.2	49.5
Kaleya Soyabean	2	Kabwe R.R.S	2.1	7.3	31.2	46.7

TR = Trace

Kabwe R.R.S = Kabwe Regional Research Station

T.T.C = Teachers' Training College

3.2 Results of the four areas surveyed in Kabwe

TABLE 3:4 Average amounts in mg/kg of metallic elements in Soil samples from east of Kabwe.

Distance in Km	Number of samples	Cd Mean	SD	Cu Mean	SD	Pb Mean	SD	Zn Mean	SD
0	4	0.33	0.02	8.5	0.9	130.5	8.5	234.0	24.8
5	3	0.29	0.01	7.6	0.8	110.1	9.9	170.7	18.1
10	4	0.06	0.01	2.0	0.5	23.0	1.5	11.9	1.4
15	4	0.03	0.00	1.6	0.6	11.1	1.3	2.2	0.8
20	4	0.01	0.00	6.6	1.6	9.7	2.8	1.2	0.1

TABLE 3.5 Average amounts in mg/kg DM of metallic elements in some plant samples from east of Kabwe.

Distance	Name of	Number of	Cd		Cu		Pb		Zn	
in Km	Plant	Samples	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	PPS	3	3.7	0.5	10.7	1.1	112.3	12.3	294.0	20.6
5	PPS	2	3.2	0.4	7.8	0.8	76.4	6.8	205.5	12.4
10	PPS	5	3.5	0.3	10.3	1.0	78.8	7.1	123.0	6.2
15	PPS	4	3.2	0.3	8.8	0.9	35.8	4.7	88.8	10.6
20	PPS	4	1.6	0.2	6.4	0.7	13.5	1.2	31.7	4.1

PPS = Pennisetum purpureum schum.

TABLE 3.6: Average amounts in mg/kg DM of metallic elements in plant and food samples from east of Kabwe.

Distance in Km	Name of Sample	Number of Samples	Cd	Cu	Pb	Zn
0	PPS	3	3.7	10.7	112.3	294.0
5	Pawpaw	1	3.4	7.8	54.9	42.8
	Banana	1	2.6	12.6	45.1	28.7
	BSS	1	3.5	31.9	113.6	83.3
	PPS	2	3.2	7.8	76.4	205.5
	Grass	2	3.3	8.8	103.8	316.1
	Maize leaves	1	3.4	11.6	70.5	164.9
	Maize	1	2.8	9.7	80.3	40.1
10	Maize	1	2.6	7.8	84.2	28.6
	PPS	5	3.4	10.3	78.8	123.0
15	Cowpea	1	4.1	19.4	72.5	53.9
	Maize	1	3.7	7.8	76.4	23.0
	PPS	4	3.2	8.8	35.8	88.8
20	PPS	4	1.6	6.4	13.4	31.7
	Maize	1	0.8	3.9	4.0	19.8

PPS = Pennisetum purpureum pchum

BSS = Bidens schimperi sch. bip ex walp

TABLE 3:7 Average amounts in mg/kg of metallic elements in soil samples from west of Kabwe.

Distance in Km	Number of samples	Cd Mean	Cd SD	Cu Mean	Cu SD	Pb Mean	Pb SD	Zn Mean	Zn SD
0	3	22.3	6.7	58.2	8.7	758.6	3.4	106.3	0.5
3	3	4.0	0.08	14.0	2.1	604.3	87.9	101.5	1.1
6	3	1.6	0.60	6.4	1.1	517.4	79.6	97.4	2.2
9	3	1.4	0.5	7.3	0.1	255.5	60.6	96.6	3.4
12	3	0.9	0.1	3.2	0.5	209.2	61.4	92.8	8.3
17	3	0.4	0.05	2.6	0.4	72.8	8.7	69.6	9.1
22	3	0.5	0.06	4.5	0.7	70.9	8.5	52.6	6.9

TABLE 3.8 Average amounts in mg/kg DM of metallic elements in some plant samples from west of Kabwe.

Distance in Km	Name of Plant	Number of Samples	Cd Mean	Cd SD	Cu Mean	Cu SD	Pb Mean	Pb SD	Zn Mean	Zn SD
0	Grass	3	2.9	0.1	22.9	2.9	805.9	137.0	454.5	0.2
3	Grass	3	4.7	0.6	11.9	1.5	672.3	100.8	453.6	0.9
6	Grass	2	4.3	0.5	17.1	2.0	708.0	92.0	453.0	0.0
9	Grass	3	2.0	0.3	7.5	0.8	119.7	16.8	443.3	1.1
12	Grass	1	2.3	0.0	4.7	0.0	95.1	0.0	332.2	0.0
17	Grass	3	1.3	0.2	4.4	0.3	49.4	6.4	121.5	9.7
22	Grass	2	1.7	0.2	1.6	0.05	68.9	9.7	187.9	9.4

TABLE 3:9 Average amounts in mg/kg DM of metallic elements in plant and food samples from west of Kabwe.

Distance in km	Name of sample	Number of samples	Cd	Cu	Pb	Zn
	Cynodon dactylon	1	3.0	34.5	1207.3	454.7
0	Grass	2	2.9	17.1	605.1	454.4
	Grass	1	7.3	13.9	714.5	453.7
	Mango	2	1.0	7.2	187.4	322.6
3	Maize leaves	1	4.6	28.8	1059.7	454.7
	Cynodon dactylon	1	2.3	14.6	242.7	452.4
	Pawpaw	1	1.2	7.5	266.5	119.5
	Maize	1	0.3	6.1	16.0	121.7
6	Maize leaves	1	3.4	19.6	793.7	453.0
	Grass	1	5.3	14.6	622.3	453.0
9	PPS	2	1.6	6.8	96.4	442.7
	Grass	1	3.0	9.0	166.2	444.4
	PPS	1	2.3	4.7	95.1	332.2
12	Maize	1	1.8	3.6	23.9	38.2
	Mango	1	1.2	16.1	18.6	26.8
17	PPS	2	1.8	3.6	64.8	137.6
	Grass	1	0.3	6.1	18.6	89.2
	PPS	2	1.7	3.2	68.9	187.9
	Mango	1	2.5	4.0	58.2	17.6
22	Groundnuts	1	0.5	2.4	6.1	34.8
	Cow pea	1	0.6	3.8	20.5	39.2
	Maize	1	1.9	2.5	39.7	54.0

PPS = Pennisetum purpureum pchum

TABLE 3.10 Average amounts in mg/kg of metallic elements in soil samples from North of Kabwe.

Distance in Km	Number of samples	Cd Mean	Cd SD	Cu Mean	Cu SD	Pb Mean	Pb SD	Zn Mean	Zn SD
0	4	0.03	0.0	4.3	0.3	38.0	4.6	31.6	3.8
5	4	0.03	0.0	3.4	0.5	30.3	3.3	23.9	3.3
10	3	trace	0.0	0.2	0.0	37.8	1.2	4.4	0.7
15	4	0.02	0.0	4.1	0.5	13.2	1.2	22.0	2.9
20	4	0.07	0.0	3.6	0.3	9.0	0.6	6.5	0.9

TABLE 3.11 Average amounts in mg/kg DM of metallic elements in some plant samples from north of Kabwe.

Distance in Km	Name of Plant	Number of Samples	Cd Mean	Cd SD	Cu Mean	Cu SD	Pb Mean	Pb SD	Zn Mean	Zn SD
0	PPS	3	3.0	0.0	17.1	1.5	17.2	1.3	97.0	16.5
5	PPS	3	2.2	0.6	15.4	1.2	17.2	1.2	80.8	18.6
10	PPS	3	2.2	0.4	14.0	0.9	4.0	0.3	51.8	8.8
15	PPS	4	1.3	0.2	2.5	0.2	23.0	1.4	32.2	5.4
20	PPS	2	1.2	0.1	2.0	0.2	9.4	0.6	35.1	4.6

PPS = Pennisetum purpureum schum.

TABLE 3.12: Average amounts in mg/kg DM of metallic elements in plants and food samples from north of Kabwe.

Distance in km	Name of Sample	Number of samples	Cd	Cu	Pb	Zn
0	PPS	3	3.0	17.0	17.2	97.0
5	PPS	3	2.2	15.4	17.2	80.8
10	Maize leaves	1	3.1	14.0	11.2	30.0
	Maize grain	1	2.6	TR	14.8	35.2
	PPS	3	2.2	14.0	4.0	51.8
15	PPS	4	1.3	2.4	23.0	32.1
20	PPS	2	1.2	2.0	9.4	35.1
	Maize	1	0.9	TR	11.2	30.3

TR = Trace
PPS = Pennisetum purpureum schum.

TABLE 3.13 Average amounts in mg/kg of metallic elements in soil samples from south of Kabwe.

Distance in Km	Number of samples	Cd Mean	Cd SD	Cu Mean	Cu SD	Pb Mean	Pb SD	Zn Mean	Zn SD
0	3	0.44	0.05	7.9	0.4	160.2	23.8	72.2	0.9
5	3	0.37	0.06	5.4	0.2	116.8	17.3	71.0	4.8
10	3	0.05	0.01	5.4	0.2	33.1	4.9	22.5	0.5
15	3	0.08	0.01	22.6	6.1	37.8	5.7	37.3	0.4
20	3	0.10	0.01	11.3	1.0	17.5	1.6	20.8	0.2

TABLE 3.14 Average amounts in mg/kg DM of metallic elements in some plant samples from south of Kabwe.

Distance in Km	Name of Plant	Number of Samples	Cd Mean	Cd SD	Cu Mean	Cu SD	Pb Mean	Pb SD	Zn Mean	Zn SD
0	Grass	3	2.0	0.02	6.8	0.3	42.7	5.8	91.8	16.5
5	Grass	4	1.5	0.02	6.3	0.2	34.9	5.2	78.9	4.3
10	Grass	3	1.9	0.4	6.9	0.7	35.6	6.4	68.4	3.7
15	Grass	3	0.6	0.01	6.8	0.5	38.6	7.6	47.5	4.7
20	Grass	3	0.1	0.01	6.8	0.7	19.2	3.2	27.2	3.5

3.3 Results of the survey of Farms in Kabwe and those near Lusaka.

TABLE 3.15 Average amounts in mg/kg of metallic elements in soil samples from farms around Kabwe.

Farm	Number of Samples	Cd		Cu		Pb		Zn	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Bonanza	10	0.2	0.03	1.4	0.2	6.1	0.8	4.9	0.8
Makombe	4	0.2	0.02	2.3	0.3	9.1	2.0	6.7	1.3
Moyo	4	0.2	0.02	6.6	1.2	23.2	3.1	8.1	1.2
Tobwe	4	0.1	0.01	1.5	0.2	14.9	0.6	3.4	0.4

TABLE 3.16 Average amounts in mg/kg Dm of metallic elements in plant and food samples collected from farms around Kabwe.

FARM	Name of plant	Number of samples	Cd	Cu	Pb	Zn
Bonanza	Guava leaves	2	TR	5.1	24.5	48.5
	Pawpaw leaves	2	TR	9.3	38.2	42.3
	Star Grass	6	0.1	5.5	20.2	35.3
Makombe	Cabbage (Chinese)	2	0.6	9.1	8.0	51.9
	Cabbage	2	0.6	7.4	TR	65.2
	Rape	2	0.6	8.9	TR	56.6
	Orange leaves	2	0.6	7.8	TR	17.5
	Star grass	4	0.6	9.7	TR	34.9
Moyo	Cabbage	2	0.6	8.6	TR	25.8
	Amaranthus	4	0.6	7.3	TR	45.2
	Sorghum	4	1.0	14.8	TR	56.8
Tobwe	Star grass	8	0.5	9.7	53.7	64.6

TR = Trace

TABLE 3.17: Average amounts in mg/kg of metallic elements in soil samples from farms near Lusaka.

Farm	Number of Samples	Cd	Cu	Pb	Zn
Chalimbana ICRAF/SADCC Station	10	TR	1.1	0.1	0.4
Kyindu Farm	10	TR	5.4	1.7	2.0
Golden Valley Farm	8	0.2	13.9	8.8	3.0

TR = Trace

TABLE 3.18: Average amounts in mg/kg DM of metallic elements in plant and food samples from Chalimbana and Kyindu.

Farm	Name of sample	Number of Samples	Cd	Cu	Pb	Zn
Chalimbana	Maize leaves	10	TR	17.7	TR	40.3
Kyindu	Cauliflower	3	1.7	0.8	13.1	10.0
	Irish potato	3	0.4	TR	TR	10.0
	Carrot	1	1.5	12.2	8.1	32.7
	Maize leaves	3	0.2	16.1	0.8	21.8
	Lettuce	1	0.3	17.6	TR	65.1
	Cabbage	2	1.0	8.0	2.2	24.5
	Spinach	1	2.2	20.0	15.6	61.8
	Onion shoot	1	1.5	12.8	15.6	31.8
	Onion bulb	1	0.6	14.0	19.4	35.0
	Orange	1	TR	6.8	TR	3.4
	Cynodon dactylon	2	0.9	18.8	3.1	33.4
	Tomato	1	0.6	11.6	19.4	25.4
	Maize grain	1	TR	5.6	11.9	59.3
	Rhodes grass	2	TR	8.6	TR	14.1
	Irish Potato Leaves	3	2.0	4.0	19.4	25.6

TR = Trace

TABLE 3.19: Average amounts in mg/kgDM of metallic elements in food samples from Golden Valley Research Farm.

Name of Sample	Number of Samples	Cd	Cu	Pb	Zn
Karate rape	2	1.8	14.9	0.9	41.2
Lettuce	1	1.4	21.4	13.8	64.1
Amaranthus hybridus	1	2.4	21.4	4.2	57.9
Maize MM 501	1	0.6	25.8	TR	35.1
Maize MM 502	1	0.2	25.8	TR	28.3
Maize MM 601	1	0.6	21.4	TR	23.0
Maize MM 603	1	0.6	25.8	TR	23.0
Maize MM 604	1	0.9	25.8	TR	18.7
Maize MM 612	1	0.4	21.4	TR	24.8
Maize MM 752	1	0.6	30.1	TR	21.6
Herald tomato	1	1.8	41.2	TR	23.1
Heinz 1370 tomato	1	1.7	39.6	3.3	16.0
Roma tomato	1	1.4	34.5	23.4	18.0
Money maker tomato	1	3.2	30.1	16.1	25.7
Cabbage-copenhagen	1	5.6	30.1	11.4	17.2
Cabbage purple variety	1	5.1	30.1	40.0	22.8
Wheat	3	0.4	24.3	2.0	39.4
Wheat Chaff	3	0.7	21.4	40.8	24.8
Dill	2	2.9	19.3	24.5	66.2

TR = Trace

TABLE 3:20: Average amounts in mg/kg DM of metallic elements in pasture samples from Golden Valley Research.

Name of sample	Number of Samples	Cd	Cu	Pb	Zn
Desmodium discolar	2	0.9	30.1	2.1	37.4
Desmodium distorm	3	4.6	33.0	32.1	32.5
Silver leaf desmodium	3	4.0	31.6	24.1	24.3
Siratro	4	1.7	48.6	21.5	23.8
Stylo graham	3	2.3	60.5	16.1	25.6
Glycine sel 104	3	1.7	51.9	23.3	40.9
Rhynchosia sublobata	3	1.3	54.7	28.1	24.5
Andropogon	5	0.9	49.2	10.9	12.1
Buffel grass	4	0.2	57.7	12.6	25.1
Rhodes grass	4	0.3	19.3	19.1	29.2
Bana grass	3	TR	27.2	5.9	15.6

TR = Trace

3.4 Results of the recovery rate

TABLE 3:21 *Showing cadmium recovery in soil samples.*

Sample	Amount of *Cadmium* Added (mg/kg)	Total Cd *present* prior to spike (mg/kg)	Total Cd *found* after spike (mg/kg)	Amount *of spike* found (mg/kg)	*Recovery* %
Soil 1	0.05	0.09	0.14	0.05	100
Soil 2	0.05	0.09	0.14	0.05	100
Soil 3	0.10	0.06	0.14	0.08	80
Soil 4	0.10	0.06	0.14	0.08	80
Soil 5	0.30	0.02	0.29	0.27	90
Soil 6	0.30	0.02	0.29	0.27	90
Soil 7	0.50	0.02	0.29	0.27	98
Soil 8	0.50	0.04	0.53	0.49	98
Soil 9	0.60	0.01	0.56	0.55	92
Soil 10	0.60	0.01	0.56	0.55	92

TABLE 3:22 Showing cadmium recovery in plant samples

Sample	Amount of Cadmium added (mg/kg)	Total Cd Present prior to spike (mg/kg)	Total Cd found after spike (mg/kg)	Amount of spike found (mg/kg)	Recovery %
Plant 1	0.20	0.10	0.29	0.19	95
Plant 2	0.20	0.10	0.29	0.19	95
Plant 3	0.50	0.13	0.55	0.42	84
Plant 4	0.50	0.13	0.55	0.42	84
Plant 5	0.50	0.09	0.58	0.49	98
Plant 6	0.50	0.09	0.58	0.49	98
Plant 7	0.50	0.12	0.59	0.47	94
Plant 8	0.50	0.14	0.58	0.44	88
Plant 9	1.00	0.17	0.88	0.71	71
Plant 10	1.00	0.17	0.88	0.71	71

TABLE 3.23 Showing copper recovery in soil samples

SAMPLE	Amount of Copper added (mg/kg)	Total Cu present prior to spike (mg/kg)	Total Cu found after spike (mg/kg)	Amount of spike found (mg/kg)	Recovery %
Soil 1	2.00	0.36	2.35	1.99	99.5
Soil 2	2.00	0.36	2.35	1.99	99.5
Soil 3	4.00	0.85	4.84	3.99	99.8
Soil 4	4.00	0.85	4.84	3.99	99.8
Soil 5	6.00	0.77	6.10	5.33	88.8
Soil 6	6.00	0.77	6.10	5.33	88.8

TABLE 3.24 Showing copper recovery in plant samples

SAMPLE	Amount of copper added (mg/kg)	Total Cu present prior to spike (mg/kg)	Total Cu found after spike (mg/kg)	Amount of spike found mg/kg)	Recovery %
Plant 1	2.00	0.77	2.17	1.40	70
Plant 2	2.00	0.77	2.17	1.40	70
Plant 3	2.00	0.77	2.17	1.40	70
Plant 4	2.00	0.77	2.17	1.40	70
Plant 5	4.00	0.90	3.83	2.93	73
Plant 6	4.00	0.90	3.83	2.93	73
Plant 7	4.00	0.31	3.88	3.57	89
Plant 8	4.00	0.31	3.88	3.57	89
Plant 9	6.00	0.60	6.13	5.53	92
Plant 10	6.00	0.60	6.13	5.53	92
Plant 11	6.00	0.16	4.18	4.02	67
Plant 12	6.00	0.16	4.18	4.02	67
Plant 13	8.00	0.20	7.60	7.40	92
Plant 14	8.00	0.20	7.60	7.40	92

TABLE 3.25 Showing lead recovery in soil samples

SAMPLES	Amount of Lead added (mg/kg)	Total Pb present prior to spike (mg/kg)	Total Pb found after spike (mg/kg)	Amount of spike found (mg/kg)	Recovery %
Soil 1	1.00	0.17	1.08	0.91	91
Soil 2	1.00	0.17	1.08	0.91	91
Soil 3	2.00	2.58	4.17	1.59	80
Soil 4	2.00	2.58	4.17	1.59	80
Soil 5	3.00	0.00	2.45	2.45	82
Soil 6	3.00	0.00	2.45	2.45	82
Soil 7	5.00	3.12	7.30	4.18	84
Soil 8	5.00	3.12	7.30	4.18	84

TABLE 3.26 Showing lead recovery in plant samples.

SAMPLE	Amount of lead added (mg/kg)	Total Pb present prior to spike (mg/kg)	Total Pb found after spike (mg/kg)	Amount of spike found (mg/kg)	Recovery %
Plant 1	3.00	0	2.76	2.76	92
Plant 2	3.00	0	2.76	2.76	92
Plant 3	3.00	0	2.34	2.34	78
Plant 4	3.00	0	2.34	2.43	78
Plant 5	6.00	0	4.60	4.60	77
Plant 6	6.00	0	4.60	4.60	77
Plant 7	6.00	0	4.74	4.74	79
Plant 8	6.00	0	4.74	4.74	79
Plant 9	8.00	0	7.76	7.76	97
Plant 10	8.00	0	7.76	7.76	97
Plant 11	8.00	0.16	6.47	6.31	79
Plant 12	8.00	0.16	6.47	6.31	79

TABLE 3.27 Showing Zinc recovery in soil samples

SAMPLE	Amount of Zn added (mg/kg)	Total Zn present prior to spike (mg/kg)	Total Zn found after spike (mg/kg)	Amount of spike found (mg/kg)	Recovery %
Soil 1	0.50	1.07	1.55	0.48	96
Soil 2	0.50	1.07	1.55	0.48	96
Soil 3	1.00	1.00	1.95	0.85	85
Soil 4	1.00	1.10	1.95	0.85	85
Soil 5	2.00	0.69	2.59	1.90	95
Soil 6	2.00	0.69	2.59	1.90	95
Soil 7	4.00	0.27	3.71	3.44	86
Soil 8	4.00	0.27	3.71	3.44	86
Soil 9	6.00	1.81	7.45	5.64	94
Soil 10	6.00	1.81	7.45	5.64	94

TABLE 3.28 Showing zinc recovery in plant samples

SAMPLE	Amount of Zn added (mg/kg)	Total Zn present prior to spikes (mg/kg)	Total Zn found after pike (mg/kg)	Amount of spike found (mg/kg)	Recovery %
Plant 1	0.50	0.69	1.17	0.48	96
Plant 2	0.50	0.69	1.17	0.48	96
Plant 3	0.50	0.56	1.03	0.47	94
Plant 4	0.50	0.56	1.03	0.47	94
Plant 5	1.00	0.83	1.62	0.79	79
Plant 6	1.00	0.83	1.62	0.79	79
Plant 7	2.00	0.83	2.48	1.65	82
Plant 8	2.00	0.83	2.48	1.65	82
Plant 9	2.00	4.32	8.30	3.98	80
Plant 10	5.00	4.32	8.30	3.98	80

TABLE 3.29 Correlation coefficients (r) between soil metal content and distance in the four directions around Kabwe.

METAL	EAST	WEST	NORTH	SOUTH
Cadmium	- 0.93	- 0.66	0.44	- 0.84
Copper	- 0.48	- 0.67	- 0.05	0.53
Lead	- 0.92	- 0.95	- 0.87	- 0.87
Zinc	- 0.95	- 0.95	- 0.70	- 0.85

TABLE 3.30 Correlation coefficients (r) between plant metal content and distance in the four directions around Kabwe.

METAL	EAST	WEST	NORTH	SOUTH
Cadmium	- 0.78	- 0.73	- 0.95	- 0.83
Copper	- 0.67	- 0.88	- 0.93	0.36
Lead	- 0.97	- 0.86	- 0.21	- 0.76
Zinc	- 0.99	- 0.89	- 0.95	- 0.99

TABLE 3.31: Correlation coefficients (r) between soil metal content and plant metal content in the four directions surveyed around Kabwe.

METAL	EAST	WEST	NORTH	SOUTH
Cadmium	0.52	0.18-	0.38	0.56
Copper	- 0.18	0.80	- 0.28	0.57
Lead	0.81	0.96	0.50	0.62
Zinc	0.95	0.90	0.68	0.79

3.5 ERROR ANALYSIS

TABLE 3.32 Showing average values (AV), standard deviations (SD) and standard error (SE)

Nature of Sample	Number of Samples	Cd	Cu	Pb	Zn
SOIL	8	AV 0.37	AV 14.80	Av 5.68	AV 0.76
		SD 0.05	SD 2.96	SD 0.96	SD 0.20
		SE 0.02	SE 1.05	SE 0.34	SE 0.07
PLANT	11	AV 2.52	AV 4.00	AV 602.32	AV 4 50.81
		SD 0.35	SD 1.12	SD 67.10	SD 6.58
		SE 0.10	SE 0.32	SE 21.22	SE 2.08

Fig 3.1 Typical calibration curve for Cadmium

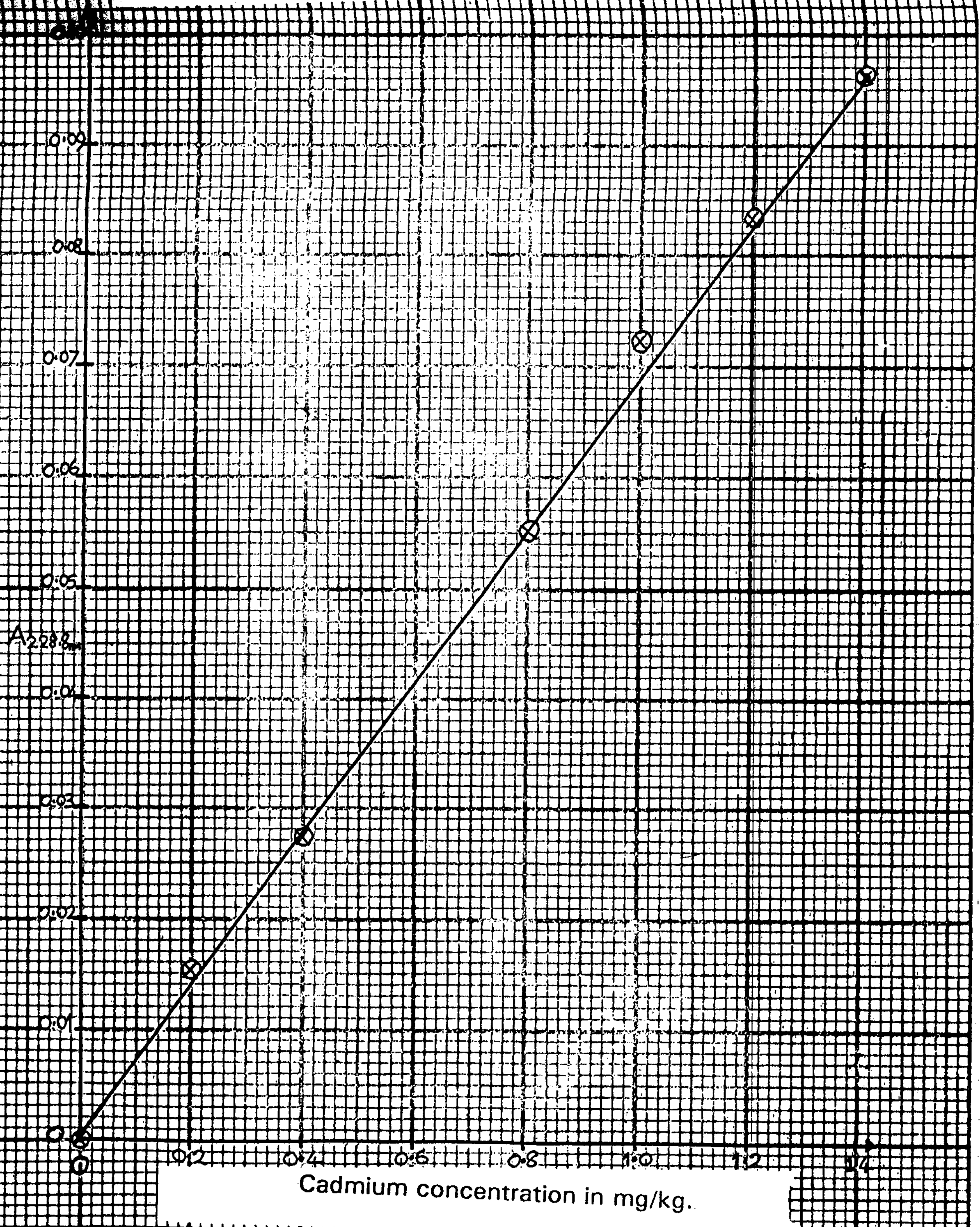


Fig 3.2 Typical calibration curve for Copper

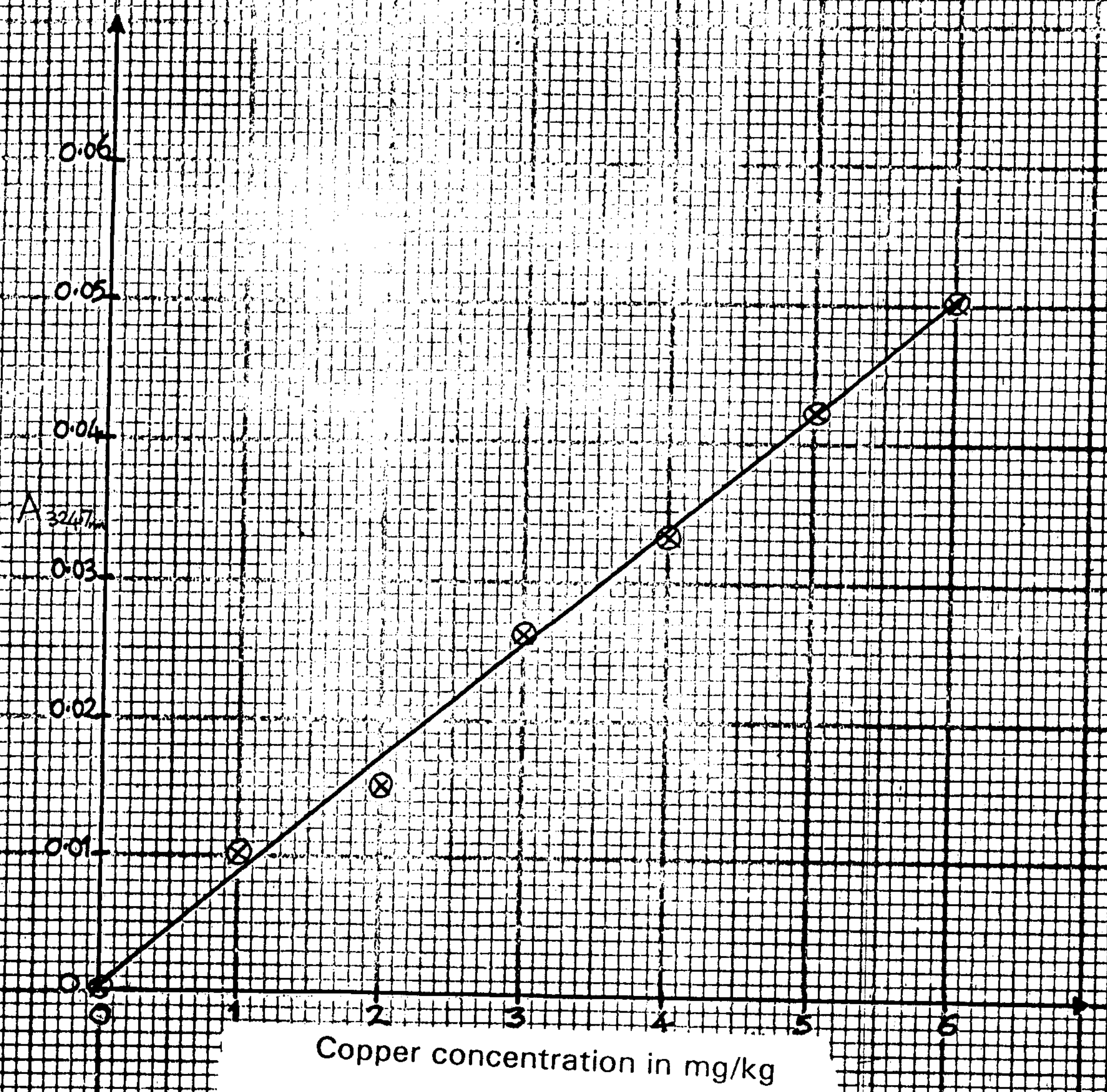


Fig 3.3 Typical calibration curve for Lead.

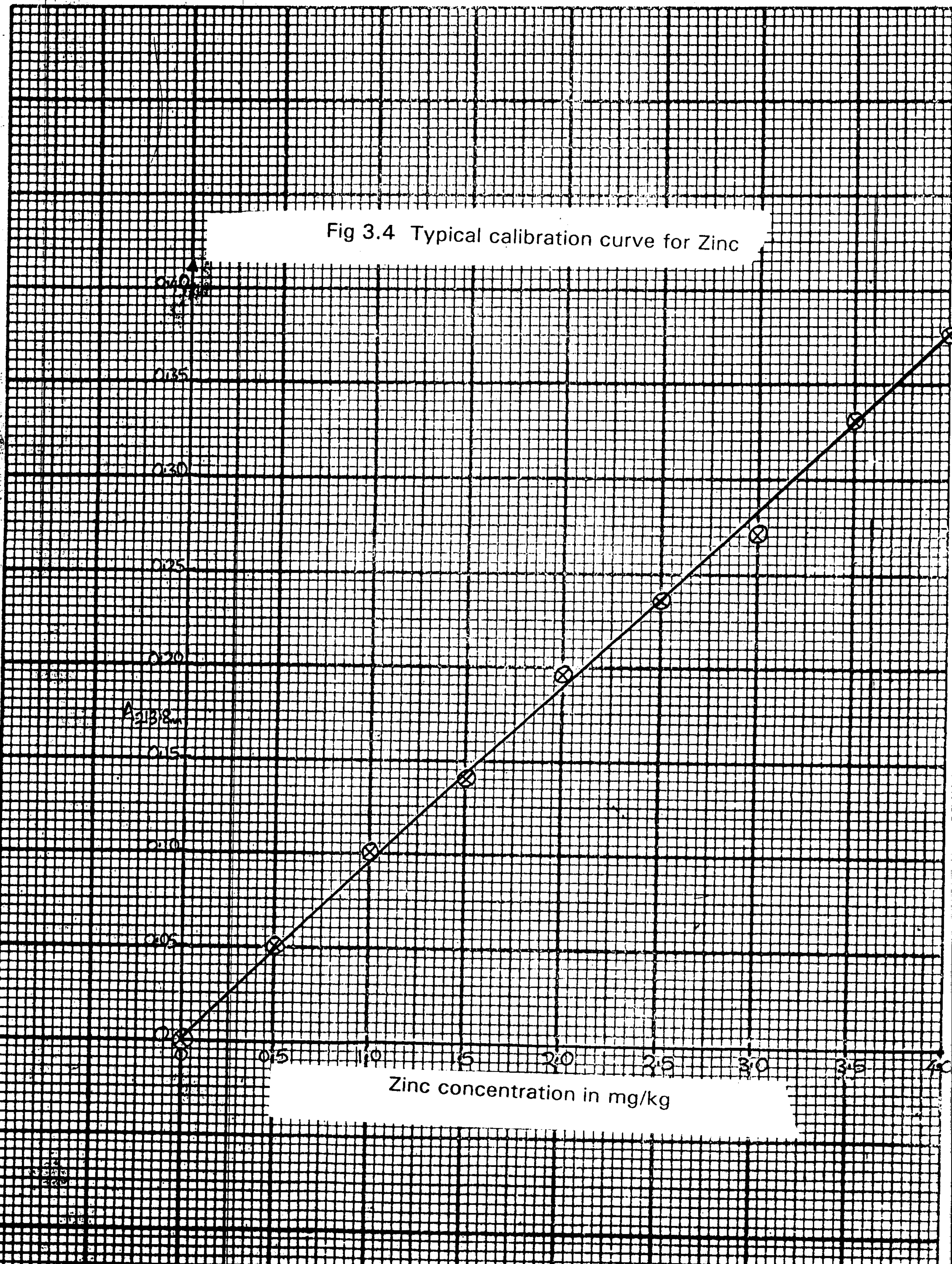


Fig 3.4 Typical calibration curve for Zinc

Fig.3.5 Cadmium concentration in soil samples around Kabwe

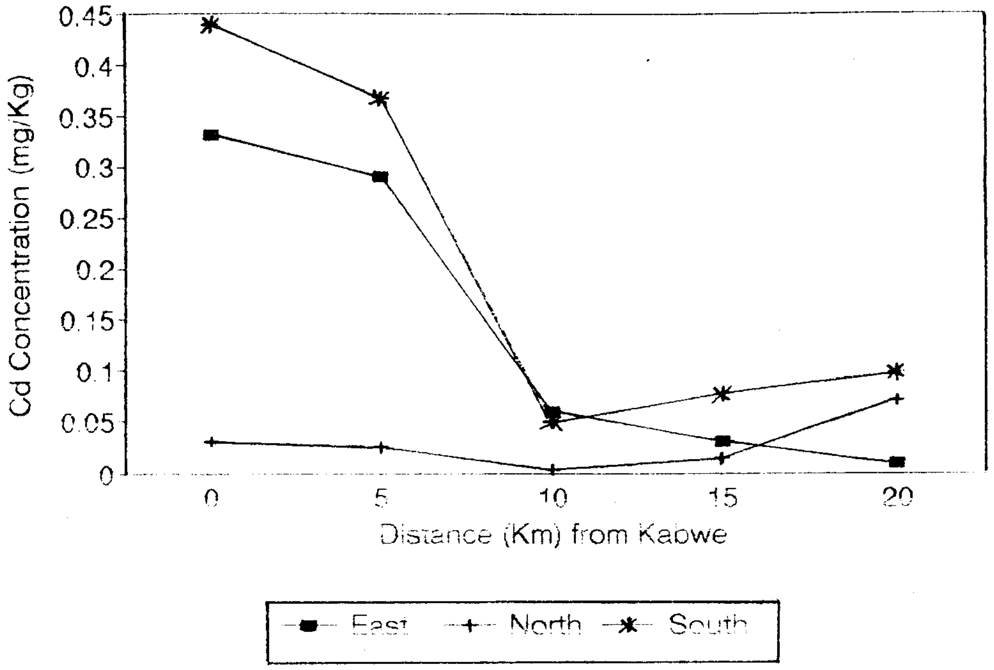


Fig.3.6 Cadmium concentration in Grass samples around Kabwe

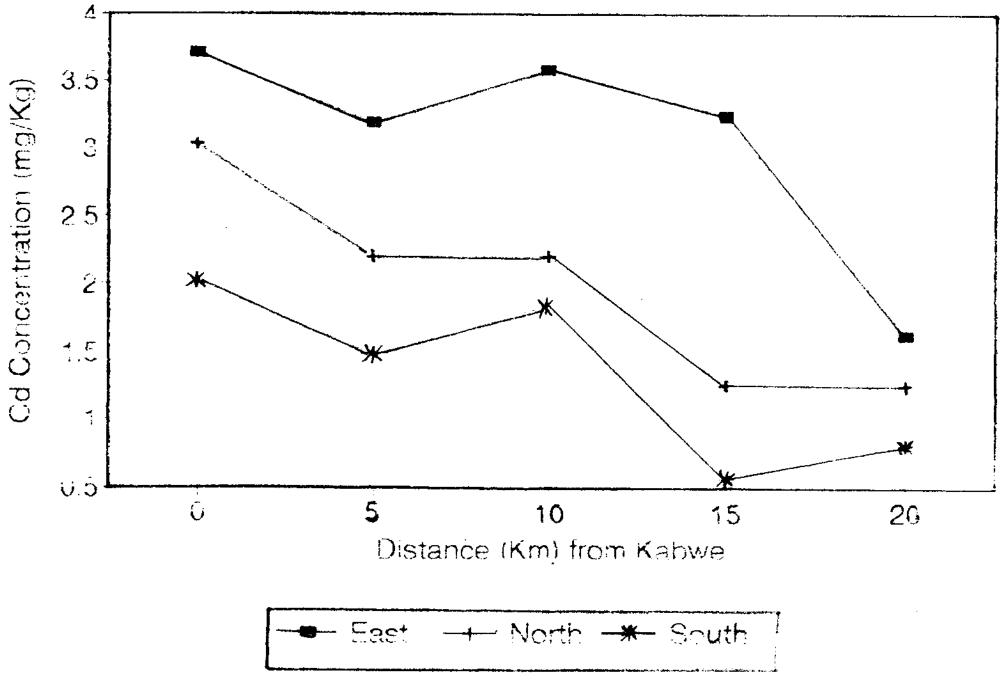


Fig.3.7 Cd and Cu concentration in soil
samples west of Kabwe

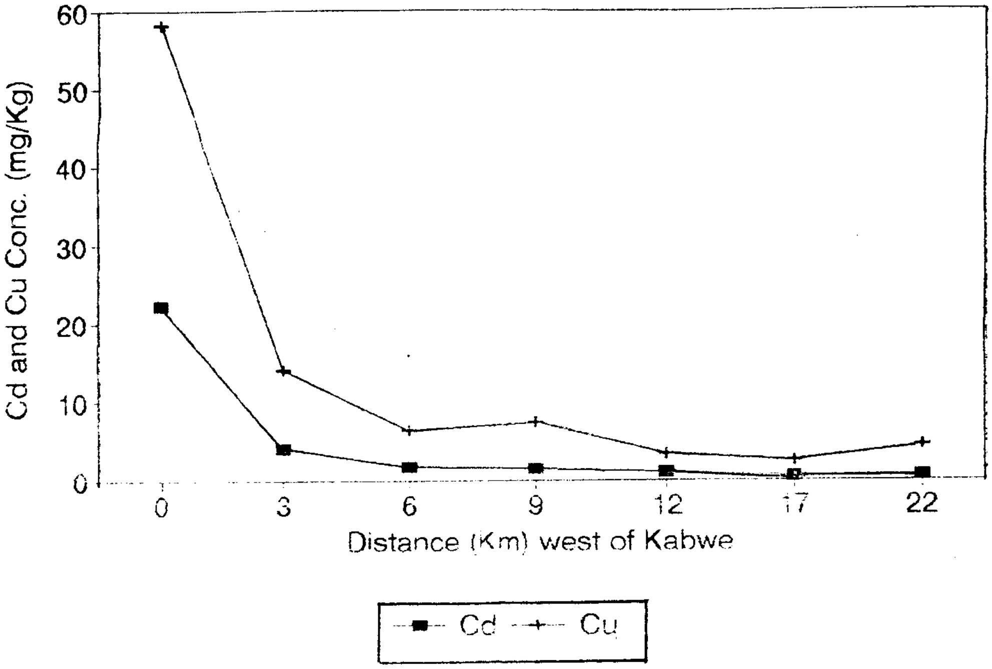


Fig.3.8 Cd and Cu concentration
in Grass samples west of Kabwe

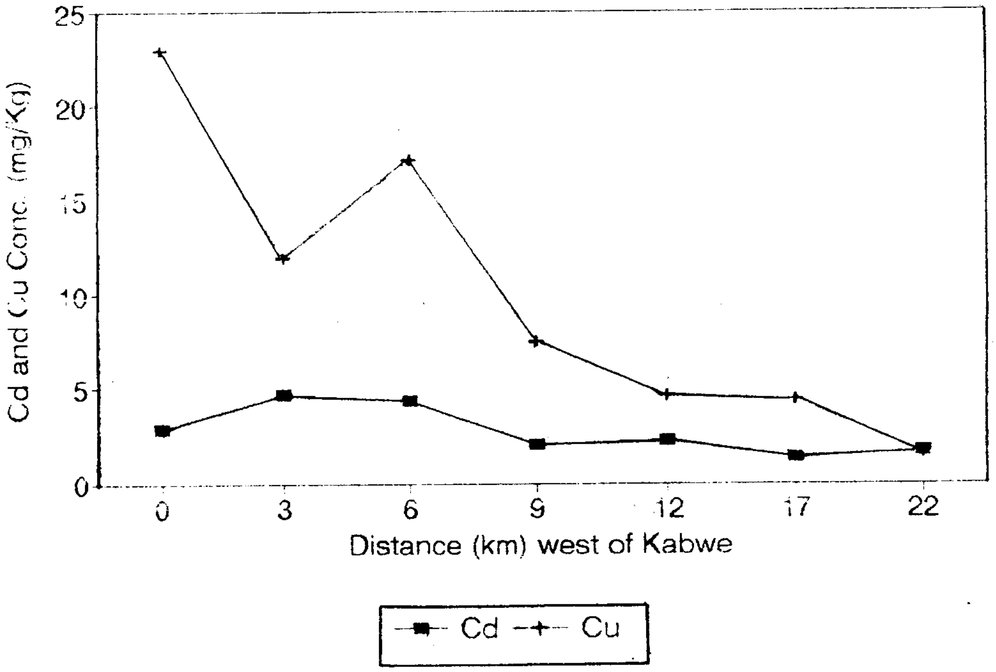


Fig.3.9 Copper concentration in soil samples around Kabwe

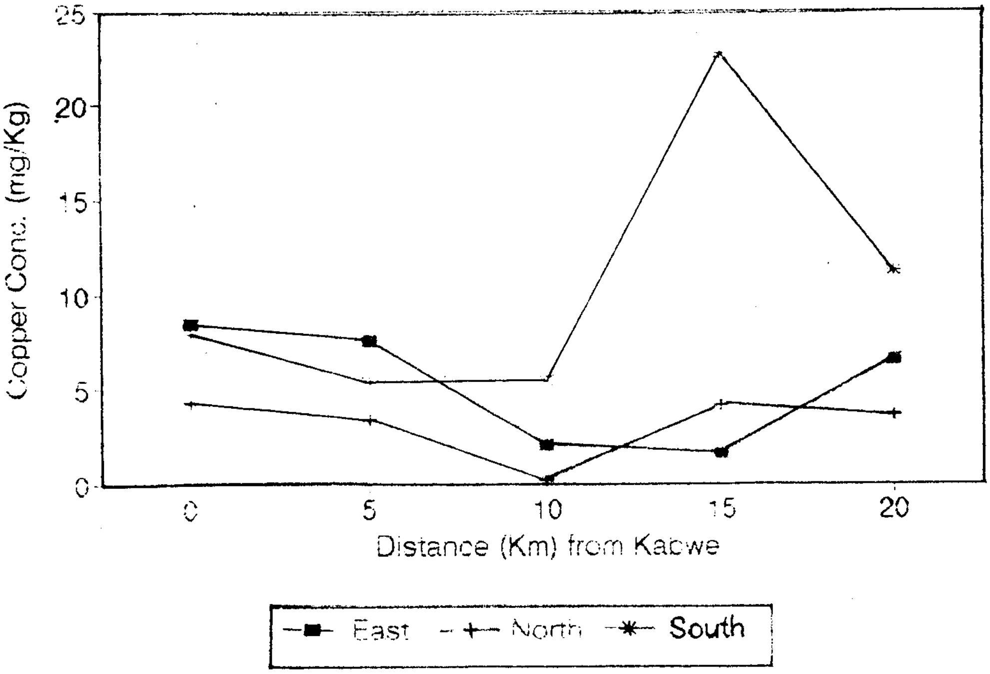


Fig.3.10 Copper concentration in grass samples around Kabwe

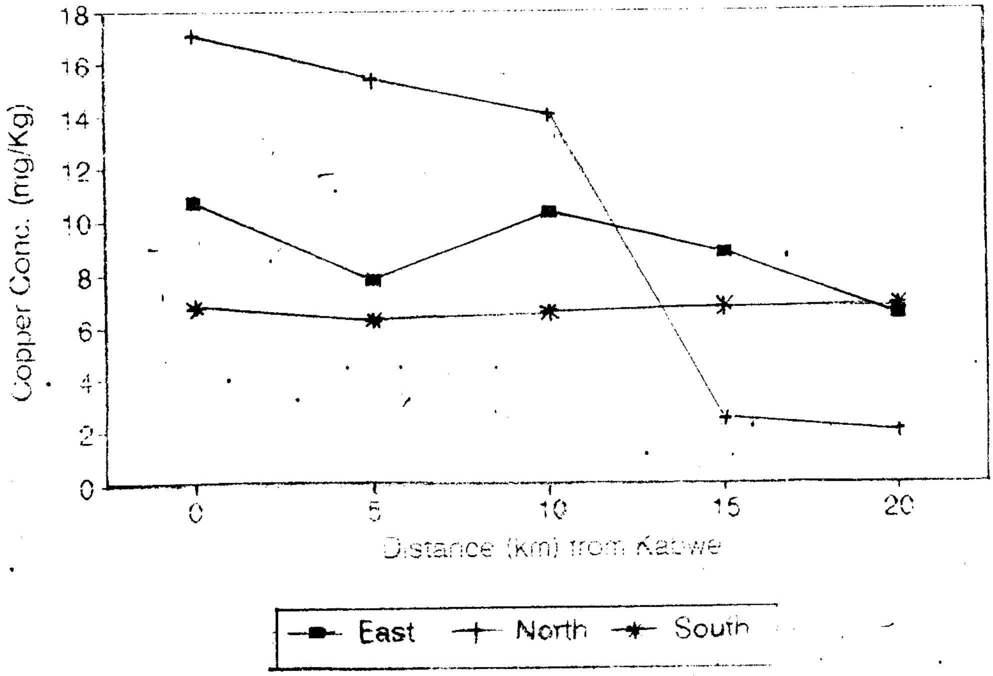


Fig.3.11 Lead concentration in soil samples around Kabwe

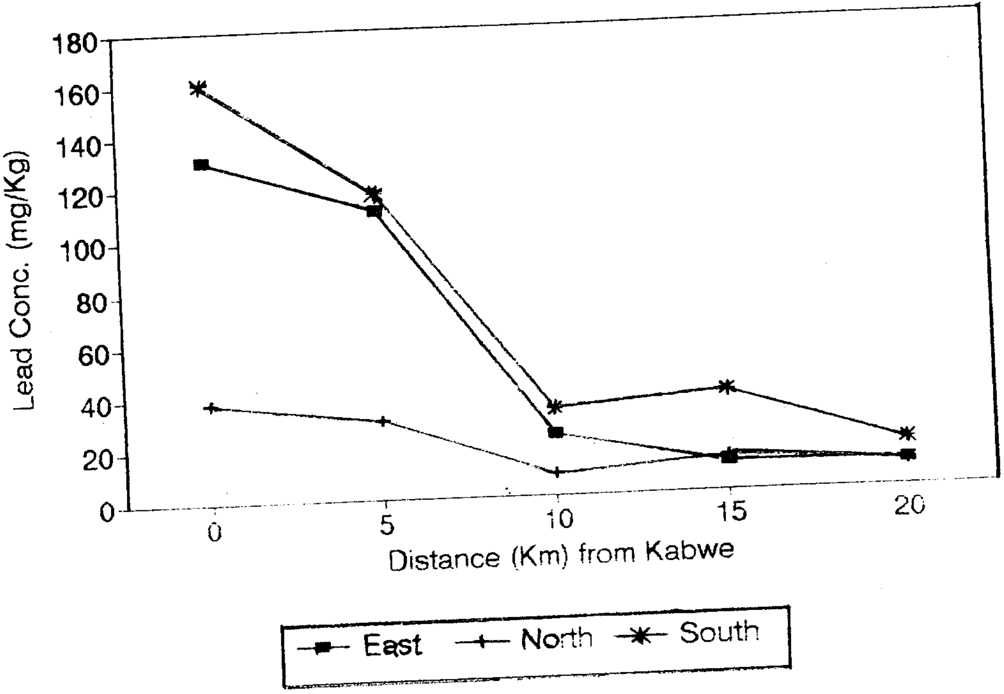


Fig.3.12 Lead concentration in Grass samples around Kabwe

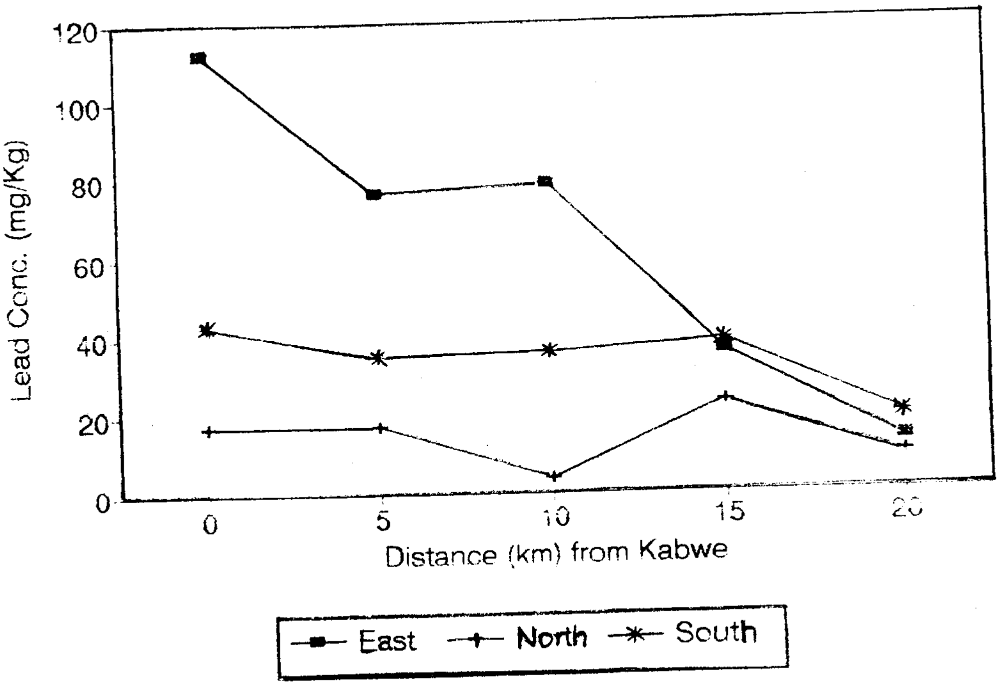


Fig.3.13 Pb and Zn Concentration in soil samples west of Kabwe

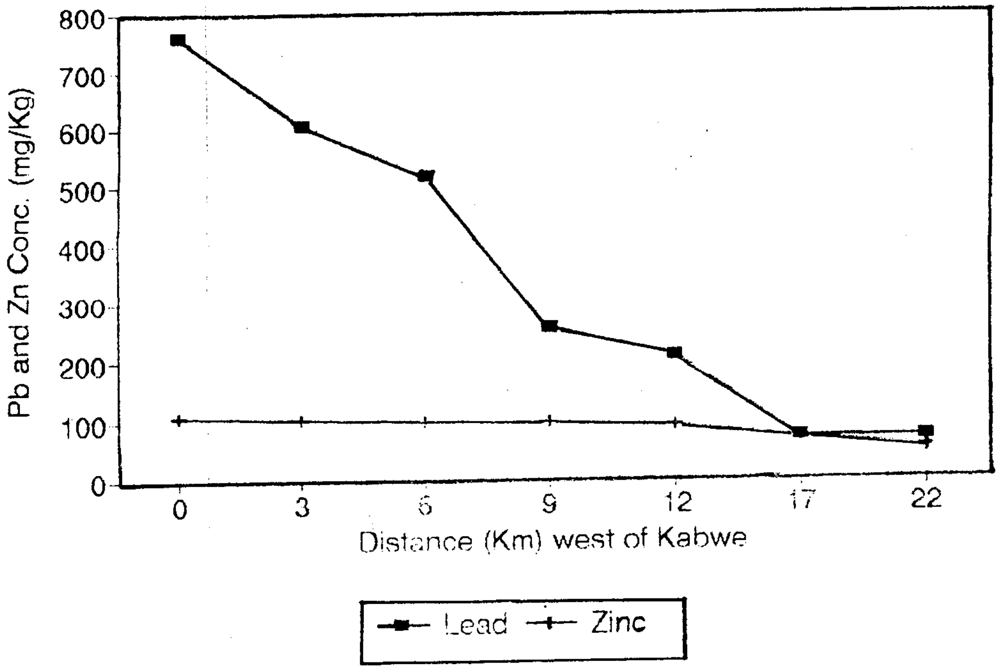


Fig.3.14 Pb and Zn Concentration in grass samples west of Kabwe

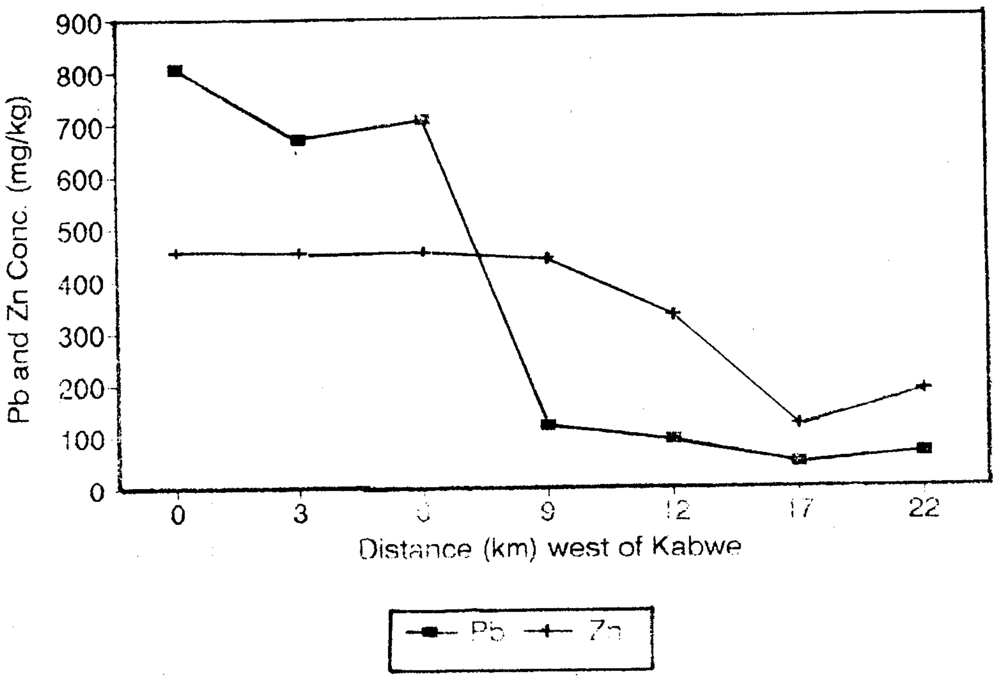


Fig.3.15 Zinc concentration in soil samples around Kabwe

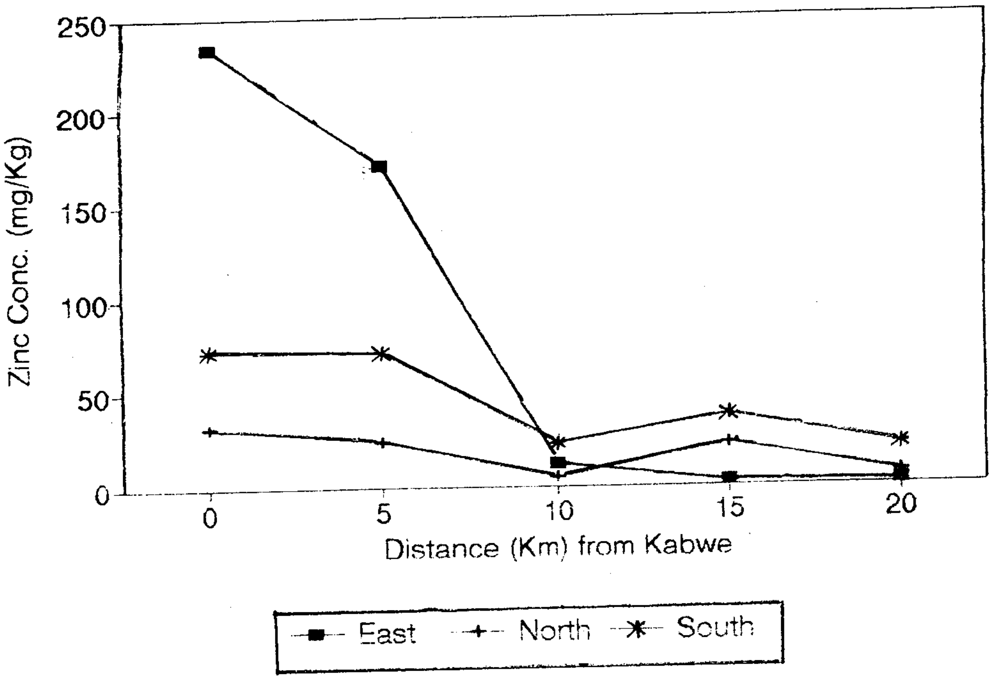
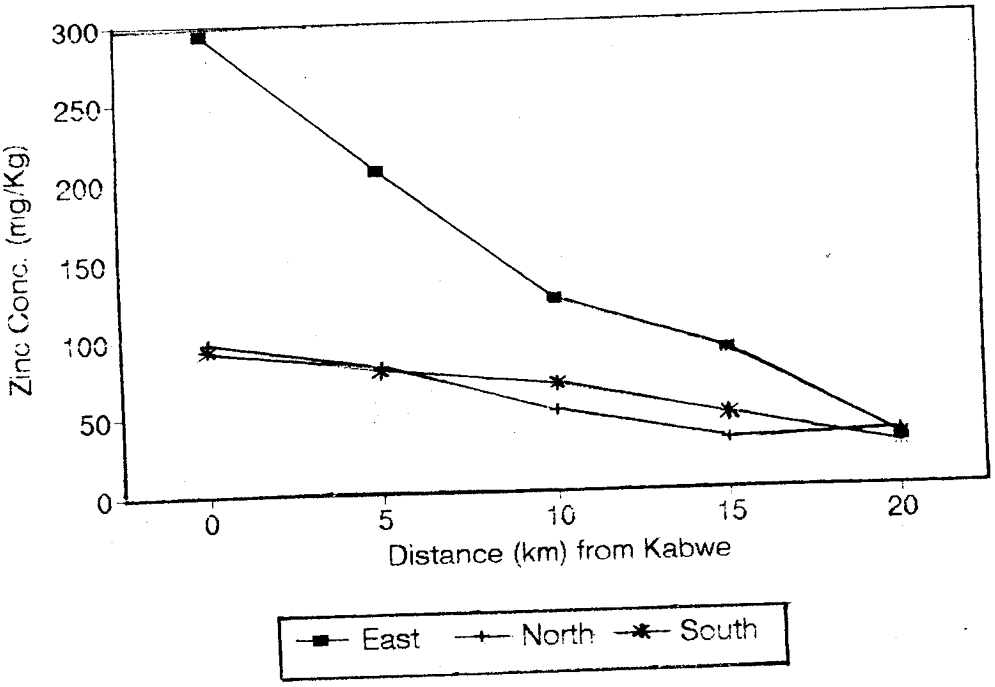


Fig.3.16 Zinc concentration in Grass samples around Kabwe



CHAPTER FOUR

DISCUSSION

4.0 DISCUSSION

4.1 GENERAL SURVEY OF KABWE

A large variety of industrial exhaust fumes may be responsible for air pollution with heavy metals and consequently soil pollution when these precipitate onto the soil surface. The prevailing winds in Kabwe are mainly the easterly, south-easterly, and north-easterly(see Appendix). It was thus expected that precipitation of metallic pollutants in the atmosphere occurs mainly on the western, north-western and south-western part of Kabwe. This was confirmed by the results obtained in this study. The western part of Kabwe had the highest content of the four metals in both soil and plant samples.

The results of the preliminary survey in Kabwe showed significantly high levels of cadmium, copper, lead and zinc in both soil and plant samples (Tables 3.1 - 3.3). The concentration of these metals was higher on the western part of the mining area than the other directions. This necessitated a further survey of the four directions in Kabwe.

The results of analysis of food shown in table 3.3 were higher than those recommended by FAO/WHO, i.e. Cd 0.4 - 0.5 mg/kg WTI, Cu 3.5-35mg/kg ADI, Pb 3mg/kg AWI and Zn 21-70 mg/kg ADI. This is a serious situation as consumption of such foods may be hazardous. The high metallic content of soils (Table 3.1) poses a great danger as plants can take these up into their tissues. Plants grown in these soils had high levels of these metals (Table 3.2,3.3) thereby endangering health to human beings and other living organisms.

It was also noted that plant samples contained higher metallic levels than their corresponding soil samples. This showed plants to concentrate these metals greatly in their tissues. This agrees well with what Mengel et al(2) have found. However aerial deposition may have also contributed a considerable amount. Vegetables grown in backyard gardens in Kabwe townships may not be safe for human consumption as they accumulate these metals into edible parts to higher levels than those recommended by FAO/WHO,i.e Cd 0.4 - 0.5 mg/kg WTI, Cu 3.5-35mg/kg ADI, Pb 3mg/kg AWI and Zn 21-70 mg/kg ADI (80).

4.2 SURVEY OF THE FOUR DIRECTIONS IN KABWE

There was a general decrease of metallic concentration for both soil and plant samples from Kabwe in the four directions surveyed (Tables 3.4 - 3.14). Metallic concentrations were highest near the mining area and decreased outward. This suggested that pollution was due to the mining and smelting operations. The negative correlation coefficients (r) between soil metal content and distance in the four directions around Kabwe (Table 3.29) also confirmed this and showed that concentration of the metals decreased as one went outward from Kabwe. However, positive correlation coefficients (r) for cadmium in the north and copper in the south showed that the level of these metals in the soil increased as one moved further away from Kabwe. This was also shown in fig 3.5 and 3.9 but was slight as the correlation coefficients were low. These findings suggested that the increase in metal content of these metals in soil was due to geological composition rather than due to pollution. The negligible negative correlation coefficient between soil copper content and distance in the northern direction of Kabwe also suggested that the copper in the soil was naturally there.

The negative correlation coefficients (r) between plant metal content and distance in the four directions around Kabwe(Table 3.30) also showed that metallic concentration decreased as one went away from Kabwe. This further confirmed that pollution emanated from the mine. The high negative correlation coefficient(r) between plant cadmium content and distance in the north of Kabwe showed that the metal content decreased as one went away from Kabwe. However, the corresponding positive correlation coefficient between soil cadmium content and distance in the same direction showed that the metal content was increasing away from Kabwe. It was thus expected that plants grown on soils with high cadmium content were likely to absorb more of this metal. Naturally it was more likely to have a positive correlation coefficient in plant also. Thus the negative correlation coefficient does not make sense and the reasons are presently not clear. However, the lower average cadmium soil content in this direction(especially for samples collected within a distance of 10km from Kabwe) may have increased instrumental and human errors leading to the anomaly.

The positive correlation coefficients(r) between soil metal content and plant metal content(Table 3.31) showed that normally plants absorbed what was available in the soil. Zinc had the highest correlation coefficients in the east, north and south; had second highest correlation coefficients in all directions except west where it and cadmium was the least correlated. There was no significant correlation coefficients for cadmium in the west and north, and for copper in the east and north of Kabwe.

Fig 3.6 shows that cadmium concentration was highest in the east and lowest in the south. The concentration on the Western side was highest especially near the mine. Metallic concentration was higher in plant or food samples than in corresponding soil samples. This showed that plants concentrated metals in their tissues. Here too, aerial metallic deposition could have played a part in polluting plant surfaces.

High metallic contents in grasses and foods pose a health risk not only to animals but also to man himself as they result in elevated concentrations for consumers. The western part of Kabwe seemed to be the most polluted part out of the four directions surveyed. Even at 22km from Kabwe there were still very high levels of lead in soil samples. This high available lead concentration could easily be taken up by plants. Although lead translocation in plants may be limited as it is bound on to cell walls(2), depletion or overloading of chelating agents may cause some of the metals to reach other parts of the plants. In addition, aerial deposition may also play a major role in lead absorption by plant tissues.

The higher metallic content in plant samples than in corresponding soil samples further confirmed that plants concentrate metals in their tissues. Cadmium and zinc concentrations were also high on the west in both soil and plant samples. The soil samples from the north seemed to contain the lowest amounts of the four metals studied. Thus pollution due to the mine may be highly influenced by the prevailing winds. Contamination in the north was not as much as the western part or the other two directions. For plant samples cadmium, lead and zinc seemed to be second highest in the east, and cadmium and zinc third highest in the north, and lead was third highest in the south. Although metallic content in samples may be influenced by wind direction, other factors such as temperature, transpiration and soil pH may also play a significant role.

4.3. A SURVEY OF FARMS IN KABWE AND THOSE NEAR LUSAKA

The soil and plant samples from farms around Kabwe had higher metallic content than samples from farms near Lusaka (Tables 3.15 - 3.20). Generally metallic concentrations in plant samples were higher than those in corresponding soil samples. This confirmed further that plants concentrate higher amounts in their tissues than what may be available in the soil.

Samples from Bonanza Farm and Tobwe Estate, north-west of Kabwe, had higher metal content than Moyo and Makombe Farms on the south of Kabwe. The differences may however, be due to the prevailing winds which blow in this direction. The soil samples from farms near Kabwe were not contaminated by the four metals studied, levels observed were Cd 0.35mg/kg, Cu 30mg/kg, Pb < 35mg/kg and Zn 90mg/kg,below normal levels according to Bowen(5), although these were higher in plants. Plant samples from Bonanza Farm (about 11 km north-west of Kabwe) had toxic levels of lead. The same trend was seen for samples obtained from Tobwe Estate which is about 14km from Kabwe in the same north-west direction. Cadmium content was found to be within the normal range but may be of concern since the metal is very poisonous and is biocumulative.

Soil samples from farms near Lusaka had normal values for cadmium, copper, lead and zinc. No traceable cadmium was found in both plant and soil samples from Chalimbana ICRAF/SADCC Station. The soil had some lead but plant samples had none. This may suggest that lead is not readily translocated or taken up by plants. Although metallic content in plant samples were higher than in soil samples, they were found to be within 'normal' range.

Plant and soil samples from Mount Makulu Research Station's Golden Valley Farm, about 60 km from Lusaka towards Kabwe, had copper and zinc content of 30mg/kg Cu in soil, 5-15mg/kg Cu in plants and 90mg/kg Zn in soil and 20-400mg/kg Zn in plants which is normal according to Bowen(5). However, some vegetables and pasture had accumulated cadmium and lead to higher levels, causing concern. The same trend was observed at Kyindu Farm, east of Lusaka. Here too, some vegetables accumulated higher concentrations of cadmium in their tissues, for instance cauliflower (1.7mg/kg DM), carrot (1.5mg/kg DM), cabbage (outer leaves 1.0 mg/kg DM) and onion shoot (1.5 mg/kg DM). This may cause great concern as these vegetables are eaten by man and the metal is toxic. Continual consumption of such vegetables may result in ill-effects on consumers especially if consumption continues for many years. Furthermore, such vegetables may find their way to Lusaka's markets exposing many people to the metal through food.

4.4 DISTRIBUTION OF HEAVY METALS USING GEOCHEMICAL CONTOUR MAPS

Due to the spatial nature of geochemical data it is best presented in the form of element distribution maps. The most common distribution maps include the element value and contour maps.

CONTOUR MAPS

Geochemical contour maps can be plotted from either irregular or regularly spaced data. Regularly and closely spaced data which is normally collected on a pre-established grid pattern is ideal for plotting contour maps. Irregularly and sparsely spaced data require gridding prior to plotting. The data presented in this dissertation was collected on an irregular pattern and an appropriate gridding procedure was utilized prior to plotting of contour maps. The purpose of gridding was to transform the irregularly and sparsely spaced data into regularly and closely spaced data.

The transformation was conducted on an IBM PS/2 Computer using the geographical information system (surfer) that uses gridding and plotting modules to generate distribution maps. The data was entered into the Computer file in the format presented below:

Sample Number	Coordinates		Element Concentration (ppm)			
	X	Y	Cd	Cu	Pb	Zn
1	655660	8446770	3	10	100	60
2	646660	8433087	4	15	170	70

This data was transformed into regularly spaced data by the grid module in surfer.

The following specifications were used during gridding:

(a) Grid spacing of 1000 m in both X and Y directions

(b) Search radius of 10000m using a maximum number of six (6) nearest data points in the computation of the values at grid points.

(c) Inverse squared distance method of calculating grid values.

GRIDDING

The first stage in the gridding process was the establishment of a grid pattern over the area of interest. This involved specification of the grid limits in the X and Y directions and the grid lines at a spacing of 1000m were established in the X and Y directions respectively. The second stage in the gridding process involved calculation of values at grid points using the most appropriate method, the normal method. This method requires the user to specify the search radius and the number of nearest data points whose values should be considered in the calculation of grid values. Only data points within the search radius were considered at each grid point. For calculation of values at grid points the following formula (Inverse squared distance method) was used:

$$V_{x,y} = \sum_{i=1}^{n} \frac{V_i}{d_i^2} \Big/ \sum_{i=1}^{n} \frac{1}{d_i^2}$$

Where

$V_{x,y}$ is the value at a grid point defined by X and Y coordinates.

n is the number of data points considered in the gridding process.

V_i is the value at the ith data point.

d_i^2 is the squared distance of an i^{th} data point from the grid point.

CONTOURING

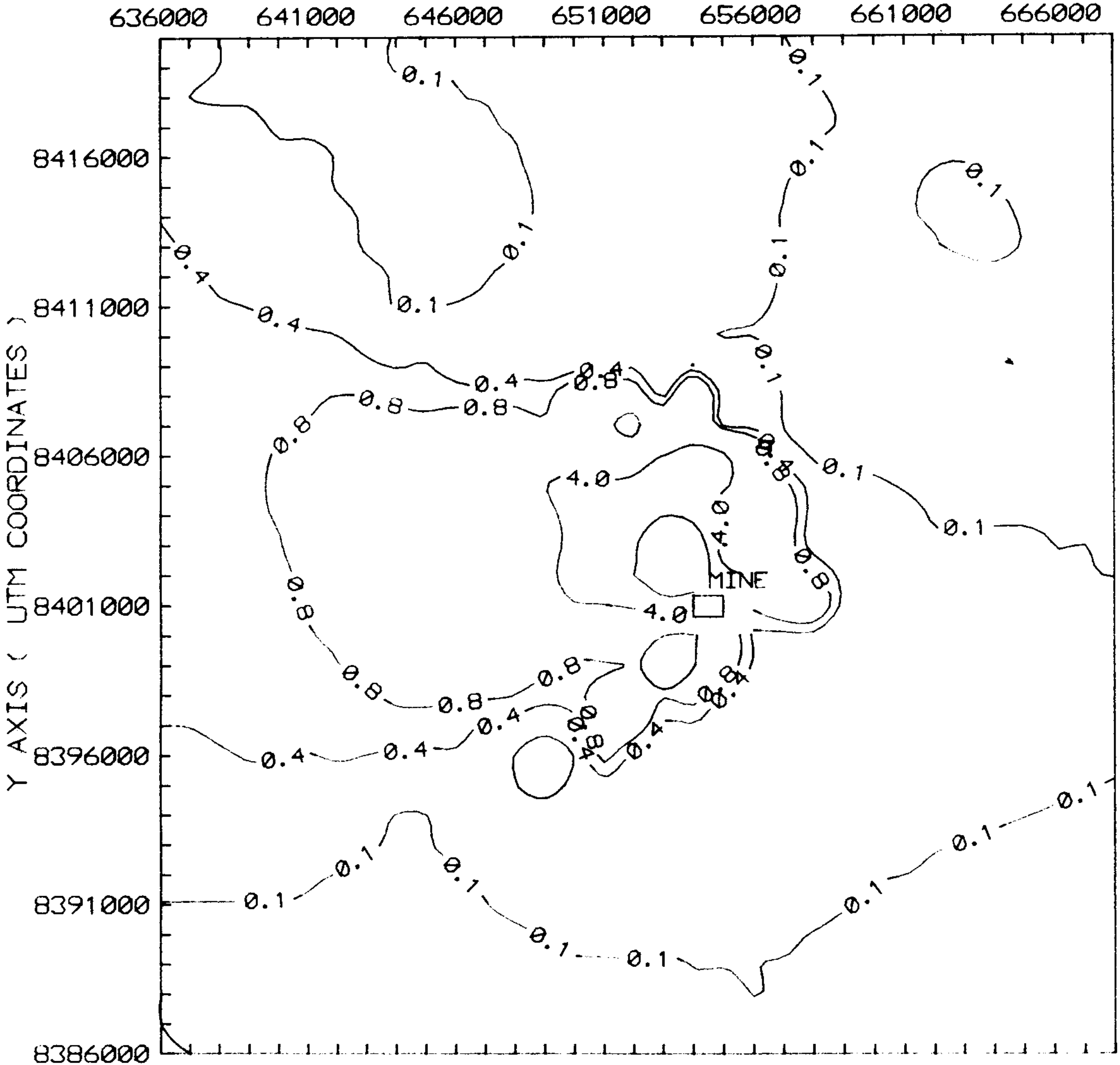
Contour maps were plotted from gridded data. The gridded data was contoured using appropriate contour levels. The contour levels which were used in this study were chosen in order to summarize the data in the best possible way. The geochemical contour maps were plotted using the topo and plot modules in surfer. The geochemical contour maps for the four elements in vegetation and soil samples are shown below(figs 4.1-4.4).

TRENDS AND COMMENTS

It is evident from the contour maps that the sample content for each metal was highest near the mine plant but decreased as one moved away from the plant.

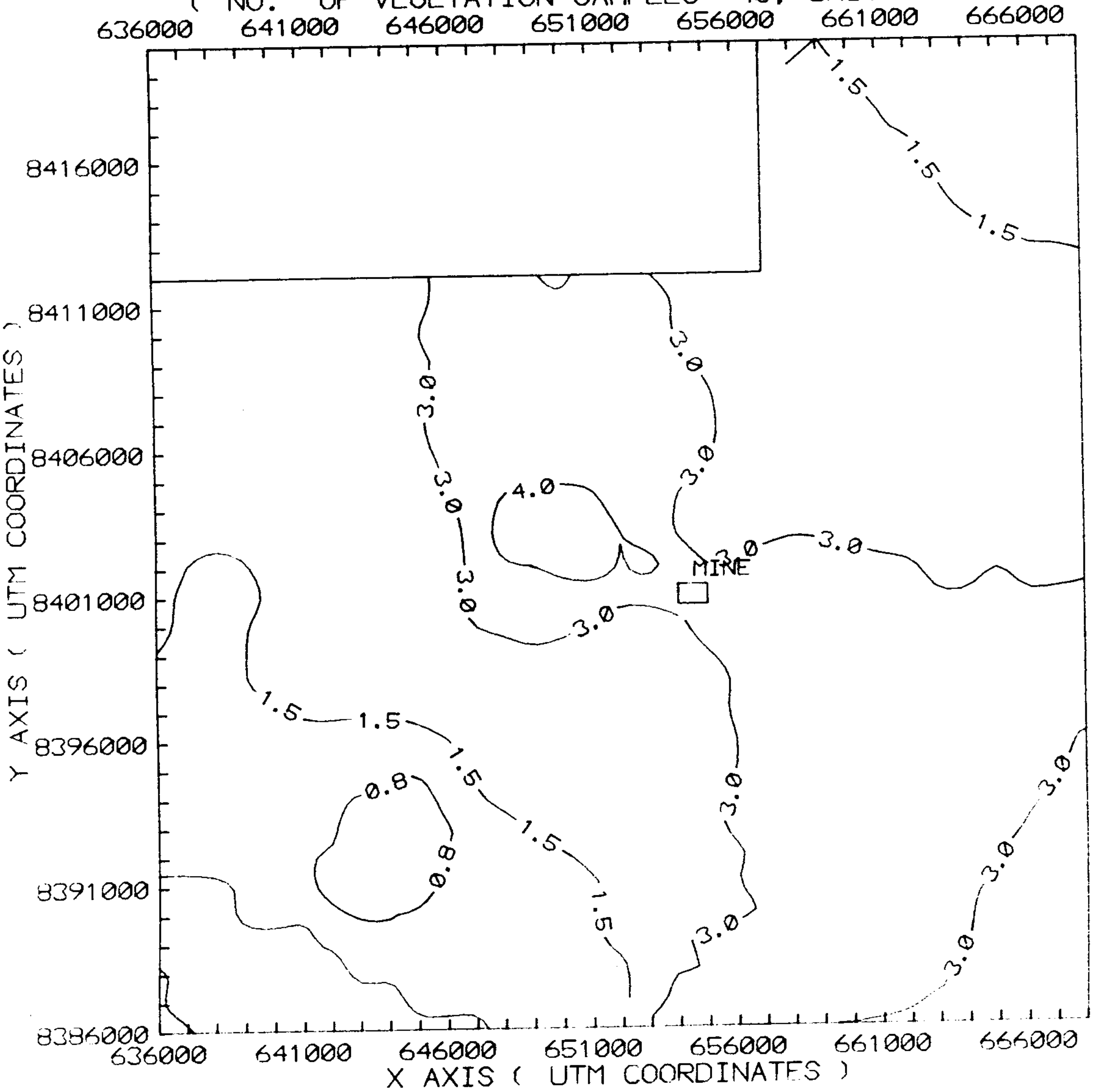
Fig. 4.1a DISTRIBUTION OF Cd IN KABWE MINE AREA

(NO. OF SOIL SAMPLES = 60, UNIT = PPM)



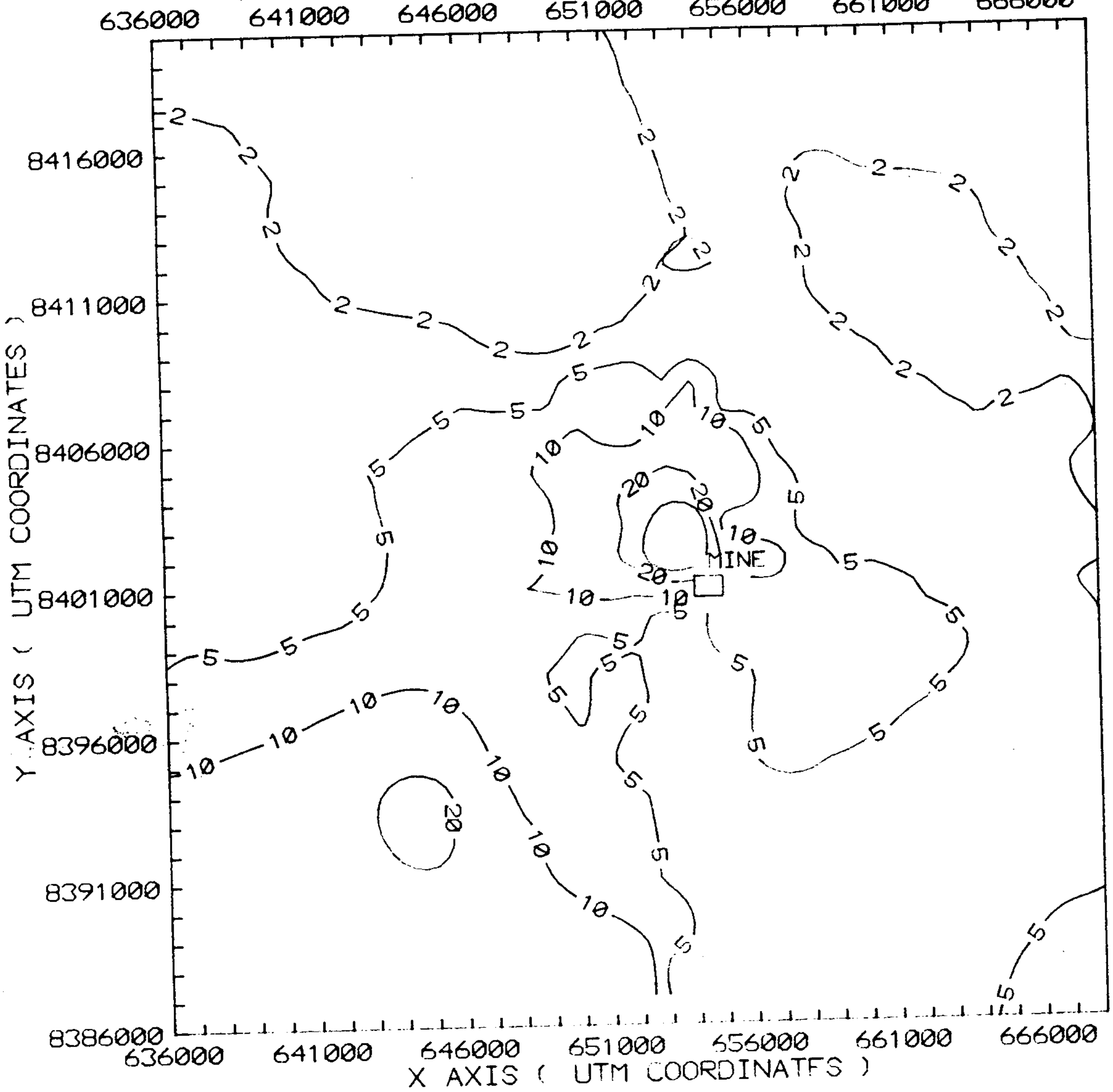
SCALE 1 cm. = 2500 metres

Fig. 4.1b DISTRIBUTION OF Cd IN KABWE MINE AREA
(NO. OF VEGETATION SAMPLES= 40, UNIT = PPM)



SCALE 1 cm. = 2500 metres

Fig. 4.2a DISTRIBUTION OF Cu IN KABWE MINE AREA
(NO. OF SOIL SAMPLES = 60, UNIT = PPM)



SCALE 1 cm. = 2500 metres

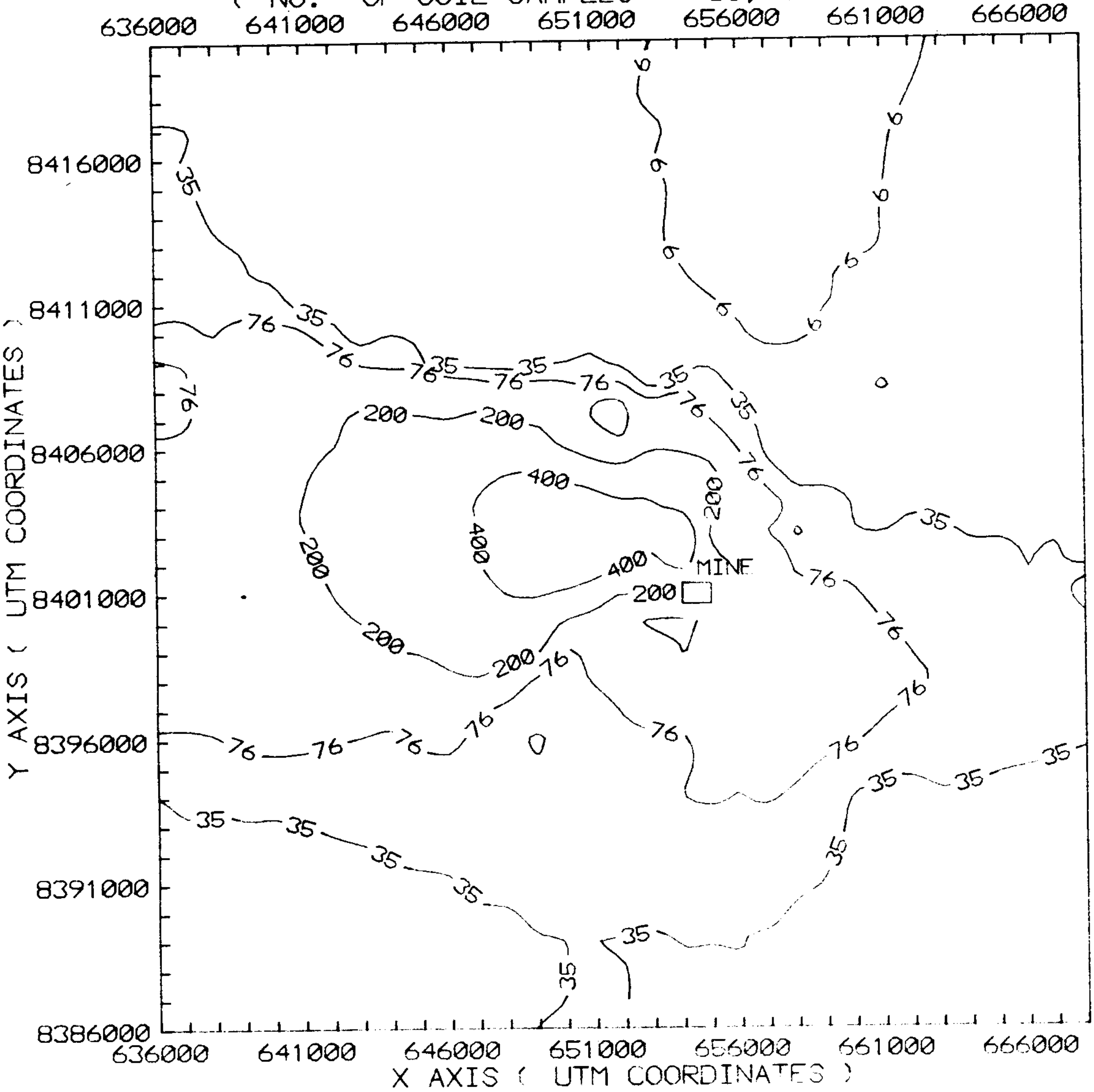


Fig. 4.3a DISTRIBUTION OF Pb IN KABWE MINE AREA

(NO. OF SOIL SAMPLES = 60, UNIT = PPM)

SCALE 1 cm. = 2500 metres

Fig. 4.3b DISTRIBUTION OF Pb IN KABWE MINE AREA

(NO. OF VEGETATION SAMPLES= 40, UNIT = PPM)

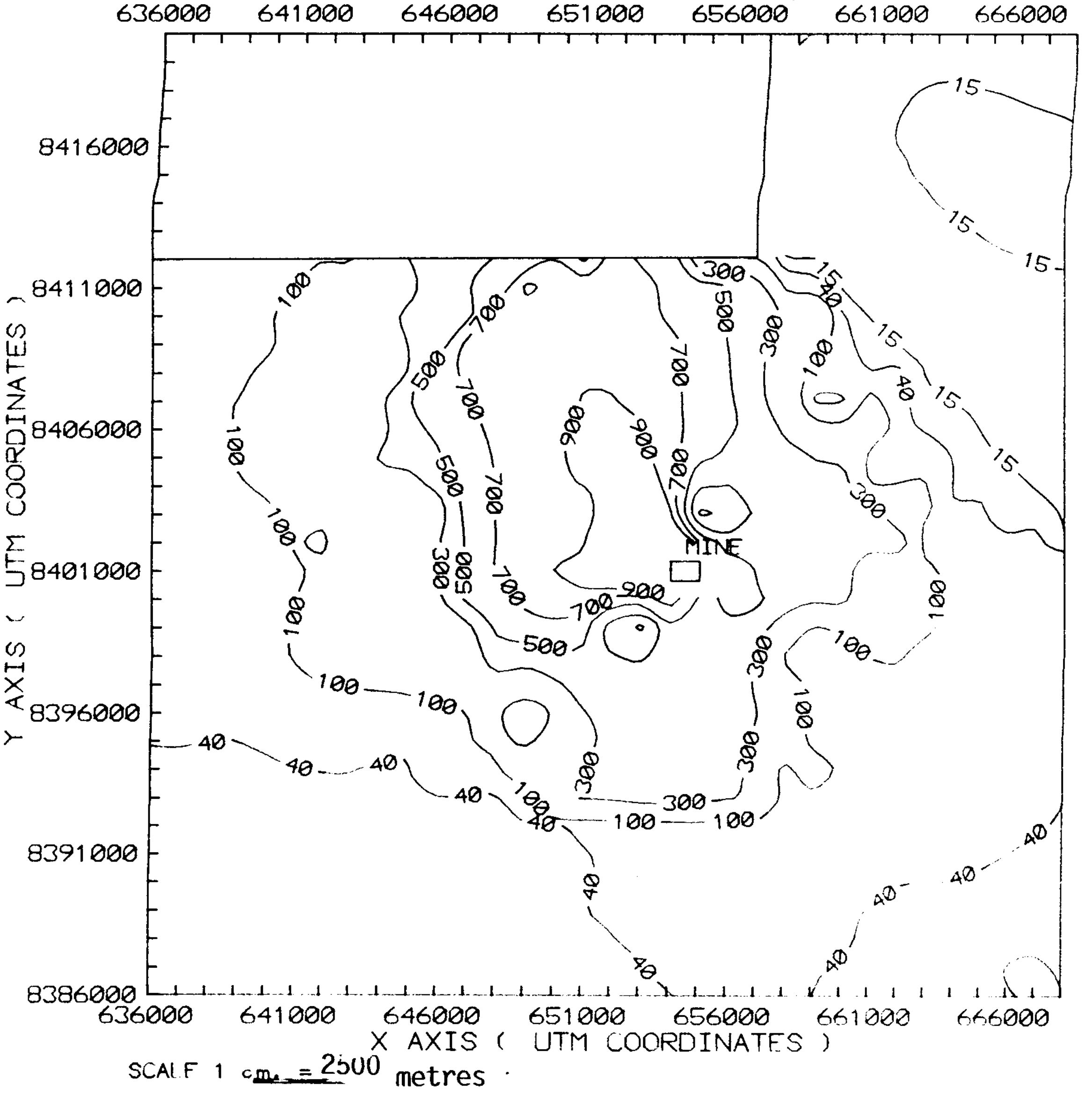
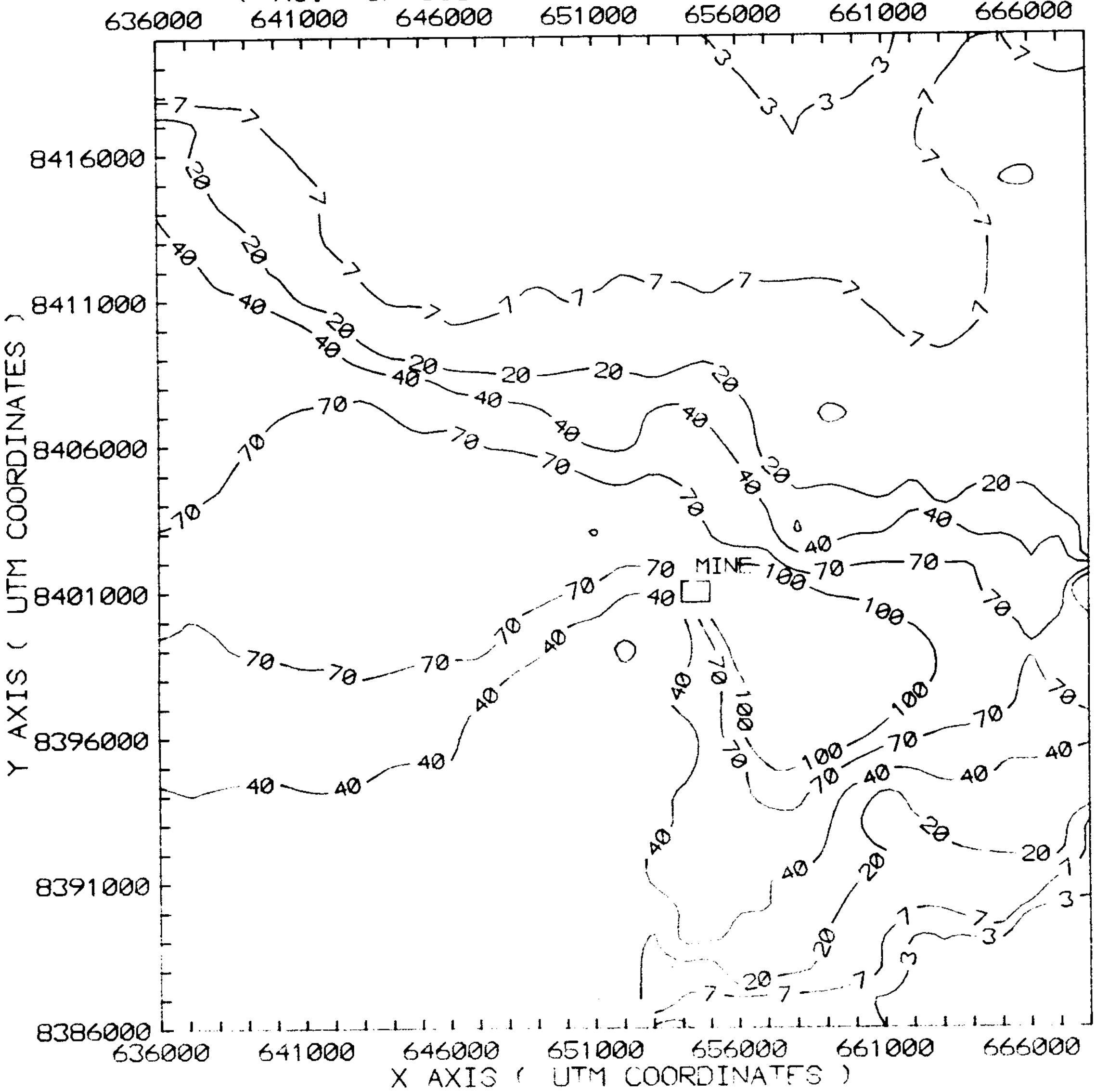


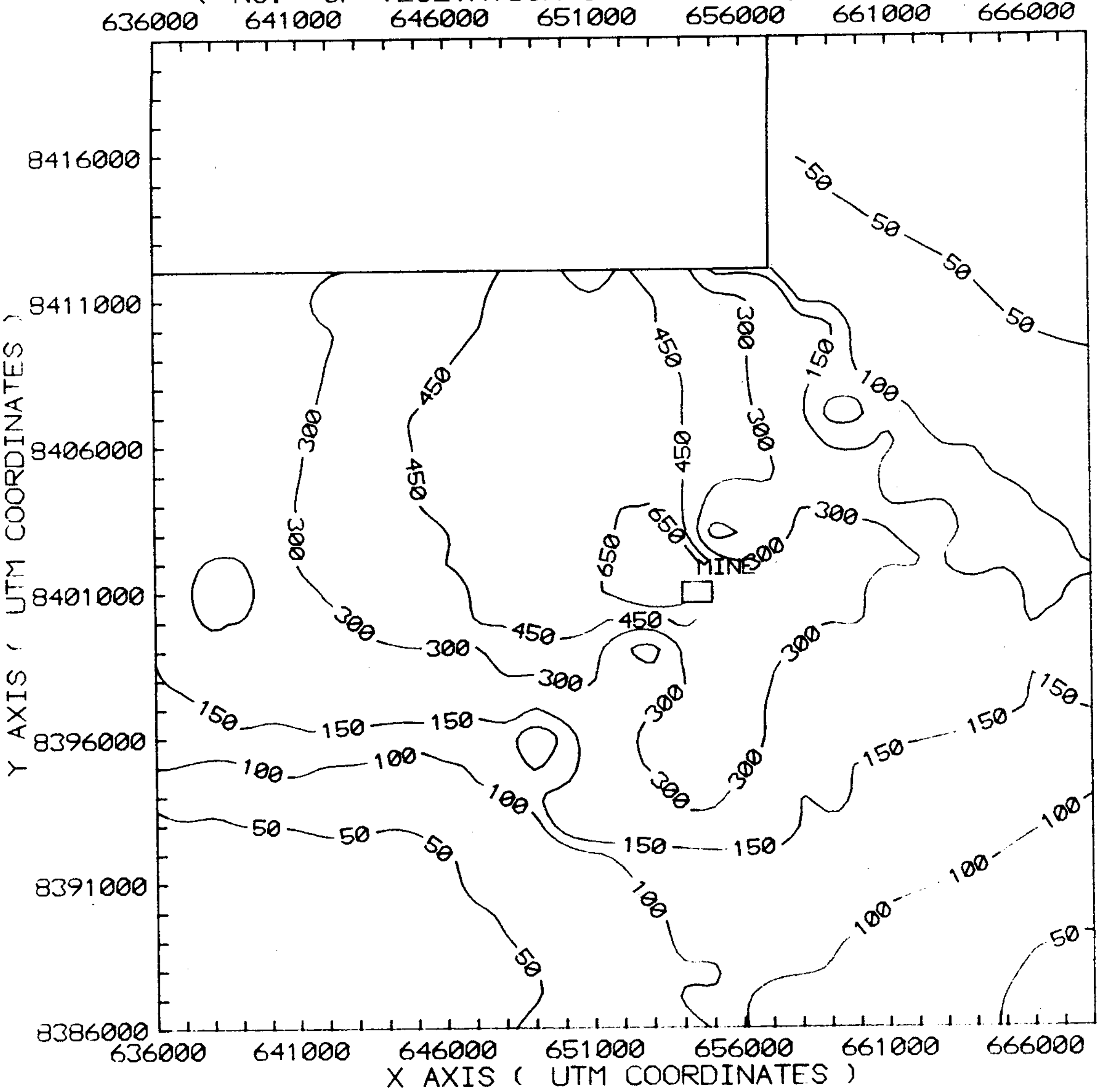
Fig. 4.4a DISTRIBUTION OF Zn IN KABWE MINE AREA
(NO. OF SOIL SAMPLES = 60, UNIT = PPM)



SCALE 1 cm. = 2500 metres

Fig. 4.4b DISTRIBUTION OF Zn IN KABWE MINE AREA

(NO. OF VEGETATION SAMPLES= 40, UNIT = PPM)



SCALE 1 cm. = 2500 metres

4.5 COMPARISON WITH OTHER COUNTRIES.

Environmental pollution is a serious problem facing every country in the world as pollutants can move from one country to another. It would require a concerted effort to solve this problem of environmental pollution. Environmental pollution studies conducted in other countries such as Australia, Germany, Libya, Nigeria, Japan, U.S.A and Zimbabwe further show that environmental degradation is a world wide problem and many nations are now realising and taking necessary steps to correcting the problem. Table 4.1 shows the results of some of the work done in these countries. The results from Libya and Nigeria are low. The cadmium level in rice samples from Japan is very high and this could be the cause of the itai-itai disease(1). Some samples from USA have higher levels of lead than others. The soil samples from Zimbabwe have very high lead content due to auto exhaust pollution.

The survey in Australia was most complete as it covered both soil and plant samples and covered all the metals studied in the present work. It is evident from the table that the values from Australia and Zimbabwe are particularly higher than those of other countries.

In relation to these, the results obtained in this research were even higher than those from Australia and Zimbabwe.

Table 4.1 Comparison with other Countries.

Country	Sample	Cd	Cu	Pb	Zn
Australia(85)	Lettuce	4.5±1.2	64±10	23±4.9	316±64
	Leaf vegetables	1.16±0.4	55±17	10.3±5.2	227±52
	Chillies	0.63	16.5	1.0	60
	Soil	1.99±0.3	847±114	13.3±3.1	229±52
Germany(86)	Corn			2.7	
	Beans			3.4	
	Cabbage			1.9	
	Tomato			2.7	
	Lettuce			17.4	
	Potatoes			6.6-7.5	
Libya(87)	Carrots, Onions Millet	TR	2.46-14.56	TR	5.52-47.79
Nigeria(88)	Water leaf	0.15-0.47	1.53-4.51	0.21-0.71	5.59-43.38
Japan(1)	Rice	1-69			
USA(25)	Soil			25-65	
	Lettuce			4.8-6.5	
	Carrots			1.5-1.6	
	Tomato			1.2-1.6	
	Sweet Corn			0.21-0.82	
	Soyabean			0.1-0.28	
Zimbabwe(89)	Soil			404-1480	
	Vegetation			8.0-23.3	
Zambia	Soil	0.01-28.0	1.6-61.0	0.9-759	0.9-106
	Vegetables	0.3-2.2	9-44	8-39	16-182
	Maize grain	2.8	9.7	80.4	40.1
	Cabbage	1.0-2.2	8.0-30.1	2.2-40.0	24.2-95.5

TR = Trace

NOTE: All figures in mg/kg or parts per million (ppm).

There are several sources of this contamination. In Zambia's Kabwe area, the most probable source of environmental pollution appears to be the mine plant.

4.6 THE FOUR METALLIC POLLUTANTS AND THEIR ECOLOGICAL EFFECTS.

The increase in industrialisation in Zambia has promoted a dramatic increase in mining and processing of metallic elements and further uses. The production of cadmium, cobalt, copper, lead, silver and zinc has been going on for many years now. Man has been aware of potential toxicity as well as usefulness of metals for a considerable time. Lead poisoning was being suspected by the Romans for instance. Recent decades though have resulted in both a significant increase in the incidence and better detection of identifiable toxicity in humans exposed to metals. This has occurred mainly due to occupational exposure and there have been several incidents of major concern involving environmental contamination particularly of cadmium and lead(13). Most environmental lead is in the inorganic(Pb^{2+}) form.

Fig 4.5 shows possible routes of these metallic pollutants to man and other animals. As the accumulation of these metals increase in food chains, the concentration of the same in man who may ingest meat of contaminated animals may be serious. The effects of such continual accumulation are not difficult to envisage. It should also be pointed out that sensitivity to toxic substances differs from person to person and depends on the amount of toxicant and the period of exposure. More sensitive persons may be affected faster than less sensitive persons.

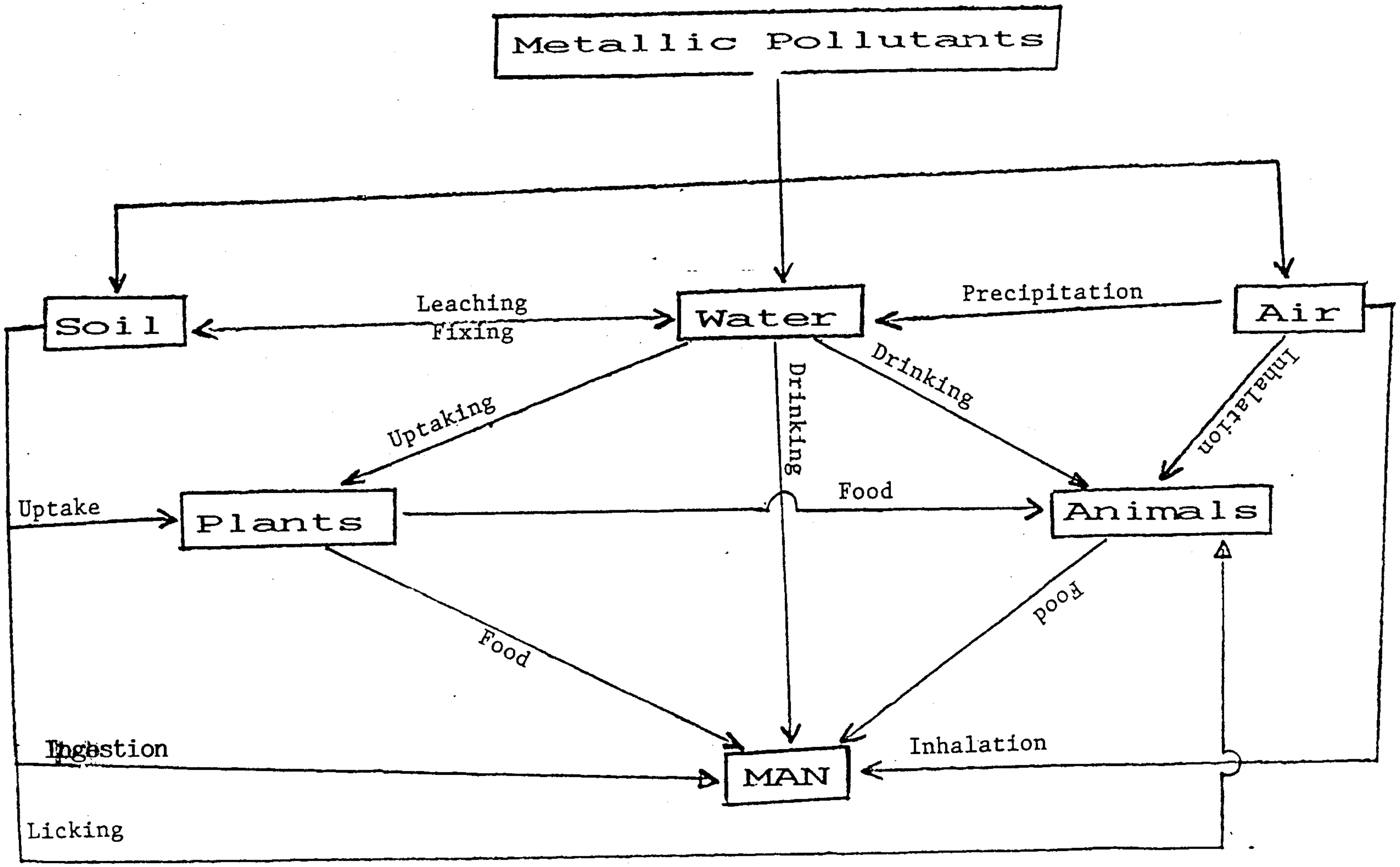


FIG 4.5 Showing Possible Routes of Metallic Pollutants to Man and Other Animals

4.6.1 CADMIUM

The principal source of cadmium appears to be food rather than water or air(90), and cigarette smoking can result in 0.1µg Cd per cigarette and heavy smokers have cadmium intake of 3-5µg Cd per day. Recommended tolerable weekly intake for man is about 400-500µg per man (80,91).

The results for this research showed that an average person living in Kabwe area has an intake of cadmium from the staple food, maize and edible vegetables per week of about 0.85mg Cd which is double more than 0.4mg/kg allowed by FAO/WHO (80).

It should be stressed however that cadmium absorption is greatly increased in diets low in protein and calcium, therefore children, pregnant and lactating women may be at a greater risk as the absorption rate may be doubled due to their demand for protein and calcium (16). In addition, high prices of proteinous foods may worsen this problem. The results also showed that different varieties of maize from Golden Valley Farm take up cadmium differently. MM604 take up more cadmium from the soil than MM502 (Table 3.19).

Other plants in Kabwe did take in more cadmium from the soil such as Chinese cabbage 2.2 mg/kg, soyabean (Hernon variety) 2.3 mg/kg than 0.5 mg/kg which may be allowed (80). Some grasses on which animals feed, within 10km from Kabwe, had cadmium concentration of 4.2 mg/kg. This was higher than 2.4mg/kg which may be generally allowed (5). Beef or diary cattle consuming 12kgDM (92) of this grass can thus ingest about 50mg Cd per day per animal. As the metal is cumulative and that it accumulates in the liver, cadmium content in such an organ could be so high that its consumption by man can greatly increase the body's cadmium content.

Table 6 shows that cadmium content in plant and food samples was decreasing with increase in distance from Kabwe which was a clear indication that the amount of cadmium was strongly affected by the mining activities in the area. The same trend was also shown in the other three areas surveyed. However, there were some anomalies which can be explained by lower or higher average metal concentration in the soil.

4.6.2. COPPER

Toxicity problems occur when soil levels are high and micro-organisms are especially sensitive to high copper levels(6). Copper is about twice as toxic to plants as zinc and sheep are known to be sensitive to high copper levels. Concentrations above 20mg/kg Cu in feed or forage are reported to be toxic for sheep (6,56). The toxicity of copper seems to be worsened by anaerobic environments (13).

In Zambia there seems to be excess of copper. Symptoms of copper toxicity have been reported for many animals and human(12). In man these may be gastric burning, nausea and diarrhoea (12,13). Excess copper can cause Wilson's disease which is characterised by massive accumulation of copper in the liver and brain (13,55,93). Wilson's disease patients may continue accumulating copper in their liver and brain leading to mental illness and pathological lesions in these tissues. In extreme cases, light brown circles called Kayser -Fleischer rings appear surrounding the iris (13). An imbalance of zinc over copper has been linked to an increased Ischaemic heart disease in humans(13,94,95).

There are a lot of diseases based on deficiency of copper in humans. This is not a problem in Kabwe area because there is excess of copper in soil and plants which include vegetables and grain foods. It was found that 3.7mg/kg of copper were present in maize samples from the market in Kabwe, 9.7mg/kg Cu in maize samples collected within 5 km in the eastern part, 5.3 mg/kg Cu in breakfast meal from Kabwe Milling Company, and in MM 752 maize from Mount Makulu Research centre's Golden Valley Farm, 30.1mg/kg Cu. The maximum amount of copper allowed to be in maize by FAO/WHO is 0.4mg/kg(80). It is evident that copper intake in Kabwe area is more than ten times higher than allowed maximum intake per week per a 70kg person. At Kabwe Regional Research Centre, it was found that four different soyabean varieties had amounts of copper which ranged from 5.8 to 9.4 mg/kg which is about 50 to 94 times higher than 0.1mg/kg ADI allowed by FAO/WHO (80). It is possible to observe from the results that the staple food like maize and soyabean contain a large excess of these metals including copper.

4.6.3 LEAD

In Zambia lead poisoning, mostly from the ores which are abundant in Kabwe area and from water and dust from the smelting of lead and zinc ores, could be happening unawares due to the difficulty in recognising the signs of low lead poisoning. These may produce symptoms such as stomachaches, constipation and vomiting (72). In areas like Kabwe where lead is excessive in the soil, it can lead to higher lead levels in grass and fodder crops leading to illness in cattle and other animals which feed on grass with man ingesting contaminated food.

The excess lead in grass is especially toxic to pregnant cattle, goats and sheep which are more sensitive to high levels of the metal (13).

In Zambia leaded petrol is still being used(36) and fumes from automobiles contaminate the soil and vegetation around major roads up to about 500m on either side(9). In large cities like Lusaka there is not enough ventilation especially along the city centre, Cairo road and many other areas and people breathe in excess lead from the auto fumes. High concentration of lead is emitted during traffic rush hours and there is need to measure the amount of lead in such areas.

Fig 3.11 to 3.14 show a decrease in lead concentration as distance increased from Kabwe in both soil and plant samples. This decrease was most pronounced in the west and east of Kabwe. Calculations show that adults may eat food which may contain about 71mg Pb per person per week which is about 20 times higher than 3mg/kg allowed maximum lead intake in food per week(80). Maize grain obtained on the western part of Kabwe may contain as much as 39.7 mg/kg Pb which will go up to 143mg lead per person per week for adults of about 70kg which is about 41 times higher than maximum allowed by FAO/WHO(80).

Toxic effects of lead have been claimed when the diet contains 1mg Pb^{2+} per day (42). It is clear that people in Kabwe area are ingesting more lead in their diets but it should be borne in mind that there is always an individual variation (given a population) in sensitivity to a toxic substance. A certain daily lead intake might cause brain damage in one person but not in another because of variations in absorption rate and/or sensitivity of brain cells. Like cadmium, diets low in calcium or protein increase the absorption rate of lead. Thus in children, pregnant and lactating women the absorption rates of lead may be doubled due to their demand for calcium. Plants grown within 6 km on the western part of Kabwe had very high lead content (Tables 3.2, 3.8, 3.9). Grass samples had lead content ranging between 331 to 806 mg/kg of lead while maize leaves had a content ranging between 597 to 1060 mg/kg of lead. Cattle and other animals feeding on such grass or maize leaves or indeed on silage made from such plants are in extreme danger of being harmed by these toxic materials. Cattle eating 12kg DM(92) of such maize silage can ingest between 7g to 13g of lead daily and between 4g and 10g from grass silage. Consumption of meat obtained from such animals may greatly increase lead body burden due to build up of the metal in higher trophic levels of the food chain(16).

4.5.4 ZINC

Zinc is an essential trace element which plays a key role in numerous essential processes including protein synthesis, DNA and RNA metabolism, lipid and carbohydrate metabolism, energy metabolism and others (13,56,75,76). Zinc is mostly found together with lead and cadmium in zinc-lead mining areas.

There are a lot of diseases associated with deficiencies of zinc (13) but this is an unlikely situation in Kabwe area where zinc is in excess in both soil and plant samples. Adverse effects of excess zinc in diets may include decreased feed intake and growth(97), deprived appetite and anaemia(13). Drowsiness, diarrhoea and lethargy may also be shown in both animals and humans in severe zinc toxicity (97,98) which may occur if zinc content of the diet exceeds 1000 mg/kg (6). Excess dietary zinc is antagonistic to several other elements including iron, copper, calcium and cadmium (56). Large excess of zinc may also raise the content of the metal in plasma, liver, kidney, milk and other vital organs(99,100). In young calves, a dietary zinc intake of 600mg/kg causes a very large increase in the liver and may result in homeostatic breakdown (99,101). The human prostate may contain high zinc levels(56) and individuals with prostatitis have subnormal levels of prostate zinc(13).

Zinc is more soluble in acid than in alkaline solution. Thus a zinc content of plants is often reduced when they are grown on land with high soil pH (56,97). Also the zinc content of the soil affects the zinc content of the plant. High dietary zinc intake in cows of up to 1279 mg/kg may increase milk zinc to 8.4mg/kg(76). It means zinc content in milk of cows is increased or decreased to a small degree by feeding more or less zinc in the diet(97).

The normal daily intake of zinc is about 0.3 - 1.0mg/kg BW(80) but 150 - 600 mg per day is toxic to man and 60 - 400 mg/L is toxic to plants(5). Excess zinc can cause hazardous effects. As mentioned before, zinc is an essential trace element but there is clear evidence that some vegetables and fruits (such as chinese cabbage 115.6 mg/kg, tomato leaves which some people eat as relish 182.5 mg/kg and mango, 434.9 mg/kg zinc) in Kabwe area contain excess zinc as given in examples (see table 3.3 and table 3.9). This may be hazardous as the metal may accumulate in body tissues to such an extent that bad effects may show. Most of these bad effects can get so advanced that they can not be reversed once they manifest.

CHAPTER FIVE

CONCLUSION

5.0 CONCLUSION

This study showed that in Kabwe the probable source of environmental pollution is the mine. This was confirmed by the correlation coefficients(r) between soil metal content and plant metal content and distance, and between soil metal content and plant metal content. The concentration of pollutants decreased with increase in distance but was still high at a distance of 22km west of Kabwe in the direction of the prevailing wind. Plants growing near the smelter contained higher amounts of these metals than those far away. Elevated metal concentrations were partly the result of uptake via the root and partly a result of aerial deposition of metal enriched dust.

Contamination of crops and soils and plants by these metals in Kabwe pose a serious danger to man and other living organisms. Entry of air borne metal pollutants into the body by ingestion of contaminated vegetables and water, in addition to inhalation may contribute significantly to the intake of metals such as cadmium and lead. Lead has the property of producing social effects (hyperactivity) in addition to more conventional disorders of public health. The presence of cadmium and lead in soil is a public health problem and permissible lead levels in soils have been proposed. High average lead content in food is not only bad for adults but also very dangerous to children, pregnant and lactating women. It is for this reason that Smith and Waldron(102) have proposed that lead content of food for children should not exceed 0.01mg/kg.

The results of this research showed that in Kabwe there is a large excess of certain heavy metals in surface soils and in plants. Excess of these metals was found in Zambia's staple foods like maize, rape, cabbage and other vegetables, soyabean and fruits. The excess of cadmium and lead in food is very dangerous and people living in these areas are affected by these metal elements in addition by inhalation of the highly polluted air(38). Thus high levels of these metals in food is and should be of great concern because of the possible health hazards involved in consumption of such metal containing foods. In addition, environmental pollution affects the economy of the country in that contaminated products may not sell and the welfare of the people is affected causing the government to spend more money and other resources trying to repair and/or replace damaged infrastructures and to revitalise the affected persons.

REFERENCES

1. Friberg L., Piscator M., Nordberg G.F. and Kjellstrom T. (1979), Cadmium in the Environment 2nd Ed. CRC press, Inc. Boca Raton. pp 9-227.

2. Mengel K. and E.A. Kirkby (1982), Principles of Plant Nutrition 3rd Ed International Potash Institute, Worblaufen - Bern, Switzerland. pp 501 - 573.

3. Moore J. W. and Moore E. (1976). Environmental Chemistry. Academic Press, Inc. New York. pp 92 - 255.

4. Kabbe F. and Kabbe L. (1976), Chemistry, Energy and Human Ecology Houghton Mifflin Co, Boston.

5. Bowen H.J.M. (1979), Environmental Chemistry of the Elements. Academic Press, New York. pp 109 - 273

6. Bolt G.H. and Brugenwert M.G.M. (1978). Developments in Soil Science: Soil Chemistry: A .Basic Elements Elsevier Scientific Publishing Company, Amsterdam. pp 192 - 271.

7. Miettinen J.K. (1978), The Accumulation and Excretion of Heavy Metals in Organisms in Ecological Toxicology Research. Plenum Press, New York and London. pp215-229.

8. Spiro T.G. and Stiglian W.M. (1980), Environmental Science in perspective. State University of New York, Albany.

9. WHO (1989), Lead-Environmental Aspects Environmental Health Criteria No. 85, WHO ,Geneva.

10. Murdoch W.W. (1972), Environment, Resources, Pollution and Society. Sinaver Associates, Inc. Connecticut. pp213-253.

11. Egan H. (1972), Trace Lead in Food in Lead in the Environment (Hepple P. ed). Applied Science Publishers Ltd Essex, London. pp34-42.

12. Berry J.W., Osgood D.W. and St. John P.A. (1974), Chemical Villains - A Biology of Pollution. The C.V. Mosby Company, St. Louis. pp69-99.

13. Rose J. (1983), Trace Elements in Health. Butterworth and Co (Publishers) Ltd, London. pp1-192.

14. Khan M.A.Q. and Bederka J.P. Jr., (eds.) (1974). Ecological and health effects of pollutants in automobile exhaust in Survival in Toxic Environments. Academic Press, Inc., London. pp497-533.

15. Hepple P. (ed.) (1973), Sources of Lead in the Environment in Lead in the Environment. Applied Science Publishers Ltd Essex, London. pp1-8.

16. Stickel W.H. (1978), Some Effects of Pollutants in Terrestrial Ecosystems in Ecological Toxicology Research. Plenum Press, New York and London. pp25-74.

17. Nriagu J.O. (1979), Copper in the Environment Part 1. Ecological Cycling. John Wiley and Sons, Inc. Toronto. pp1-288.

18. Mellanby K. (1972). The Biology of Pollution. Edward Arnold (Publishers) Ltd, London. pp6-19.

19. Morgan J.M. (1970), Cadmium and Zinc Abnormalities in Bronchogenic Carcinoma. Cancer 25, 1394-1398.

20. Pinta M. (1975), Atomic Absorption Spectrometry. Adam Hilger Ltd.

21. Nwankwo J.N., Elinder C.G., Piscator M. and Lind B.(1977), Cadmium in Zambian Cigarettes: An Interlaboratory Comparison in Analysis. Zambia J.Sci. Technology 2 (4), 1-4.

22. Bazzaz E.A., Carlson R.W. and Rolfe G.L. (1974), The Effect of Heavy Metals on Plants .Environ. Pollut. 7(4), 241-246.

23. Webb M. (ed.) (1979). The Chemistry and Bioinorganic Chemistry of Cadmium in the Chemistry, Biochemistry and Biology of Cadmium. Elsevier, Amsterdam. pp1-43.

24. Wang J. (1985), Stripping Analysis. VCH Publishers, Inc. Deerfield Beach, Florida. pp1-81.

25. Griffin T.B.and Knelson J.H. Z91975), Lead. Georg Thieme Publishers, Stuttgart London. pp6-196.

26. Settle D.M. and Patterson C.C. (1980), Lead in Albacore: Guide to Lead Pollution in Americans. Science 207, 1167-1175

27. Walter H. (1971), Pollution and the African Environment. Pollut. Environ. Zambia Seminar Report. pp60-67.

28. Cannon H.L., Hopps H.C. (1971), Environmental, Geochemistry in Health and Disease. The Geological Society of America, memoir123.

29 Taylor M.G. and Simkiss K. (1984), Inorganic Deposits in Invertebrates Tissues in Environmental Chemistry Vol. 33 pp 102-138. The Royal Society of Chemistry, London.

30. Egan H., Kirk R.S., Sawyer R. (1985), Pearson's Chemical Analysis of Foods. Longman Group Limited, New York. pp113-136.

31. Petterson S. (1966), Bulletin of the American Meteorological Society 47, 950.

32. Biddle G.N. (1982), Toxicology of Lead: Primer for Analytical Chemists. J. Assoc. Off. Anal. Chem. 65, 947-952.

33. John M.K. (1973), Cadmium uptake by eight Food Crops as Influenced by Various Soil Levels of Cadmium. Environ. Pollut. 4, 7-15.

34. Roberts A. (1976), A History of Zambia. Heinemann, London.

35. Zambia(1992), National Report to United Nations Conference on Environment and Development. Ministry of Environment and Natural Resources, Lusaka.

36. Zambia (1990), The State of Environment Report of Zambia. Natural Resources Department October, Lusaka.

37. Chidumayo E.N. (1979), Environment and Development in Zambia pp 9-18. Proc. Natn. Semin. Envir. Dev. Lusaka.

38. Walubita K. (1992), Hon. Minister, Ministry of Environment and Natural Resources on Kwacha Good-morning Zambia, ZNBC T.V. Program, August 2, Lusaka.

39. Kaoma C. and Salter L. (1979), Environmental Pollution in Zambia pp 181-214. Proc. Natn. Semin. Envir. Dev. Lusaka.

40. Perera N.P.(1979), Derelict Land in Zambia pp 217-233. Proc. Natn. Semin. Envir. Dev. Lusaka.

41. Schaefer W. (1992), Public Health Engineering Lecture Notes, UNZA, Lusaka.

42. Ure A.M. and Berrow M.L. (1983), The Elemental Constituents of Soils in Environmental Chemistry Vol.2 pp 94-204.

43. Balaraman T.S. (1971), The Incidence of Air Pollution in Zambia pp 44-49. Pollut. Envir. Zambia Semin. Lusaka.

44. Gough R. (1978), Smoking vehicles must not be allowed on our Roads. Times of Zambia, July 5.

45. Smith J.A. (1971), Pollution by Herbicides pp 23-24. Pollut. Envir. Zambia Semin. Lusaka.

46. Ngwata C. and Phiri J. (1992), Pesticide Inspectors, National Environmental Council Pers. Comm. Lusaka.

47. Mensa S.O.(1971), Water and Sewage Treatment in Lusaka pp13-18. Pollut. Envir. Zambia Semin. Lusaka.

48. Garbrecht G. (1971), Examples of Water Pollution Problems in Zambia pp28-33. Pollut. Envir. Zambia Semin. Lusaka.

49. Mainga A.M. (1983), Analysis of the Nutrient Content of Some Indigenous Zambia Food Plants with some studies on Processing and storage. M.Sc. Thesis, UNZA.

50. Lovelace C.E.A, and Salter L.F. (1979), Environmental Factors which may contribute to the causation of Hepatocellular carcinoma in Zambia: Analysis of fungal toxins in village food samples pp235-242. Proc. Natn, Semin. Envir. Dev. Lusaka.

51. Siame A.B. (1988), Analysis of the Mycotoxins of Fusarium. M.Sc. Thesis, UNZA.

52. Reilly A. and Reilly C. (1972), Patterns of Lead Pollution in the Zambian Environment. Med. J. Zambia 6, 125-127.

53. Matschke H. (1975), Pollution Control in Zambia. The Zambian Nurse 7, 17.

54. WHO(1989), International Agency for Research on Cancer Vol. 46. IARC, Lyon, France.

55. Devlin T.M. (1986), Textbook of Biochemistry with Clinical Correlations. John Wiley and Sons, Inc. Toronto. pp1069-1239.

56. Underwood E.J. (1977), Trace Elements in Human and Animal Nutrition 4th Ed. Academic Press, New York. pp56-423.

57. Tsuchiya K. (1978), Cadmium Studies in Japan: A Review. Kodansha Limited, Tokyo. pp1-305.

58. Menendez-Botet C.J. and Schwartz M.K.(1991), Trace Metals. Anal. Chem. 63, 194-199.

59. Davison A.G., Fayers P.M., Taylor A.J., Venables K.M., Darbyshire. J., Pickering C.A., Chettle D.R., Franklin D., Guthrie C.J. and Scott M.C.(1988), Lancet 1, 663-667.

60. Schroeder H.A.(1971), Metals in the Air. Environment 13 (8), 18-32.

61. Klein C.B., Frenkel K. and Costa M. (1991), The Role of Oxidative Processes in Metal Carcinogenesis Chem. Res. Toxicol. 4(6), 592-604.

62. Chinielnicka A.M. (1990), J. Biol. Trace Elem, Res. 23, 25-53.

63. Kido T., Nogawa K., Tshizaki M., Honda R., Tsuritani I., Yamada Y., Nakagawa H. and Nishi M. (1990), Arch. Environ. Health 45, 35-41. ✓

64. Shaikh Z.A., Ellis K.J., Subramanian K.S. and Greenberg A. (1990), Toxicology 63, 53-62. ✓

65. Whitten M.G. and Ritchie G.S.P.(1991), Calcium chloride extractable Cadmium as an Estimate of Cadmium uptake by Subterranean Clover. Australian J. Soil Research 29(2), 215-221. ✓

66. Nogawa K., Ishizaki A., Fukushima M., Shibata I. and Hagino N.(1975). Environ. Res. 10, 280-307. ✓

67. IARC (1976), Monographs on the Evaluation of Carcinogenic Risks of Chemicals to Man Vol. II. Lyon, France. pp39-74. ✓

68. Sunderman F.W. Jr (1984), Recent Advances in Metal Carcinogenesis. Ann. Clin. Lab. Sci. 14, 93-122. ✓

69. Waalkes M.P. and Oberdorster G. (1990), Cadmium Carcinogenensis in Biological Effects of Heavy Metals Vol. II, Metal Carcinogenesis. Foulkes E.C. ed. CRC Press, Boca Raton. pp129-157. ✓

70. Friberg L.(1979), In Proceedings, First International Cadmium Conference, Metal Bulletin. London. ✓

71. Rowe C.J. (1973), Food Analysis by Atomic absorption Spectroscopy. Varian Techtron, Springvale, Australia. pp20-39. ✓

72. Emerson T., Waldman S., Marshall R., Hall C. and Waldrop T. (1992), Lead and Your Kids. Newsweek Magazine, February 17. pp32-37. ✓

73. Lancranjan T., Popescu H.L., Eavaescu O., Klepsch I. and Serbanescu M. (1975), Reproductive ability of workmen Occupationally exposed to Lead. Arch. Environ. Hlth. 30, 396.

74. Der R., Fahim Z., Yousef M. and Fahim M. (1976), Environmental Interaction of Lead and Cadmium on Reproduction and Metabolism of male Rats. Res. Comm. Chem. Path. Pharmacol. 14, 689.

75. Miller W.J.(1970), Zinc Nutrition of Cattle: A Review J. Dairy Sci. 53, 1123-1135.

76. Nriagu J.O (ed.) (1980), Cellular and Molecular Aspects of Mammalian Zinc metabolism and Homeostasis, in Zinc in the Environment Part II. Health Effects. John Wiley and Sons, New York. pp121-135.

77. David O., Clark J. and Voeller K. (1972). Lead and Hyperactivity, Lancet 2, 900.

78. Willard H.H., Merritt L.L. Jr, Dean J.A., and Settle F.A. Jr (1988), Instrumental Methods of Analysis 7th ed. Wadsworth, Inc. Belmont, California. pp97-784.

79. Oikawa K.(1977), Trace Analysis of Atmospheric samples. Kodansha Limited, Tokyo. pp61-92.

80. UNEP(1986), International Register of Potentially Toxic Chemicals Vol. 1 and 2, Geneva.

81. APHA/AWWA/WPCF(1985), Standard Methods for the Examination of Water and Wastewater 16th Ed. pp 143-261.

82. WHO(1986), Environmental Carcinogens Selected Methods of Analysis. IARC Publication No. 71 Vol. 8, Lyon, France.

83. Cottenie A., Verloo M., Kiekens L., Velghe G. and Camerlynck R.(1982), Chemical Analysis of Plants and Soils. Laboratory of Analytical and Agrochemistry State University, Ghent - Belgium. pp1-63.

84. Preer J.R., Stephens B.R. and Bland C.W. (1982), Sample Preparation in Determination of Lead in Garden Vegetables by Flame Atomic Absorption Spectrophotometry. J. Assoc. Off. Anal. Chem. 65 (4), 1010-1015.

85. Beavington F (1975), Heavy metal contamination of vegetables and soil in domestic gardens around a smelting complex. Environ. pollut. 9 (3), 211-217.

86. Holl W. and Hampp R. (1975), Lead and plants, Residue Reviews 54, 79-111.

87. Voegborlo R.B. (1992), Metal contents of some agricultural crops grown in the Northern Fezzan Desert, Libya. 5th International Chemistry Conference in Africa, Gaborone, Botswana.

88. Adeniyi A.A. (1992), Determination of cadmium, copper, iron, lead, manganese and zinc in dumpsite water leaf (Talinum triangulare). 5th International Chemistry Conference in Africa, Gaborone, Botswana.

89. Sithole S.D., Moyo N. and Macheka M. (1992), An assessment of lead pollution from vehicle emissions along selected roadways in Harare, Zimbabwe. 5th International Chemistry Conference in Africa, Gaborone, Botswana.

90. Fleischer M., Sarofim A.F., Fasset D.W., Hammond P., Shacklette H.T., Nisbet I.C.T. and Epstein S. (1974), Envir. Hlth. Perspect. 7, 253-323.

91. WHO(1989)Cadmium. In : Evaluation of certains food additives and contaminants. Thirty-third Report of the Joint FAO/WHO Expert Committee on Food Additives, Geneva pp 28-31.

92. Cassard D.W. and Juergenson E.M.(1971), Approved Practices in Feeds and Feeding. The Interstate Printers and Publishers, Inc.

93. Alt, E.R., Sternleib, I. and Goldfisher, S.(1990), The Cytopathology of metal overload. Int. Rev. Exp. Pathol. 31, 165-188.

94. Klevay L.M. (1975), Coronary Heart Disease: The Zinc/copper Hypothesis, Am. J. Clin. Nutr. 28, 764-774.

95. Klevay L.M. and Forbush J. (1976), Copper metabolism and the Epidemiology of coronary heart disease, Nutr. Rep. Int. 14, 221-228.

96. Selinger B. (1988), Chemistry in the Market Place. 3rd Ed. Harcourt Brace Jovanovich, Publishers, Sydney. pp423-452.

97. Miller W.J. (1979), Dairy Cattle Feeding and Nutrition Academic press, Inc. New York.

98. Prasad A.S. and Oberleas D. (eds.) (1976), Deficiency of Zinc in Man and its toxicity, in Trace Elements in Human Health and Disease. Vol.1. Zinc and Copper. Academic Press, New York. pp1-20

99. Miller W.J., Blackmon D.M., Gentry R.P. and Pate F.M.(1970), Effects of high but nontoxic levels of zinc in practical diets on ^{65}Zn and zinc metabolism in Holstein Calves. J. Nutr. 100, 893 - 902.

100. Miller W.J.(1975), New concepts and Development in metabolism and Homeostasis of inorganic elements in Dairy cattle: J. Dairy Sci. 58, 1549 - 1560.

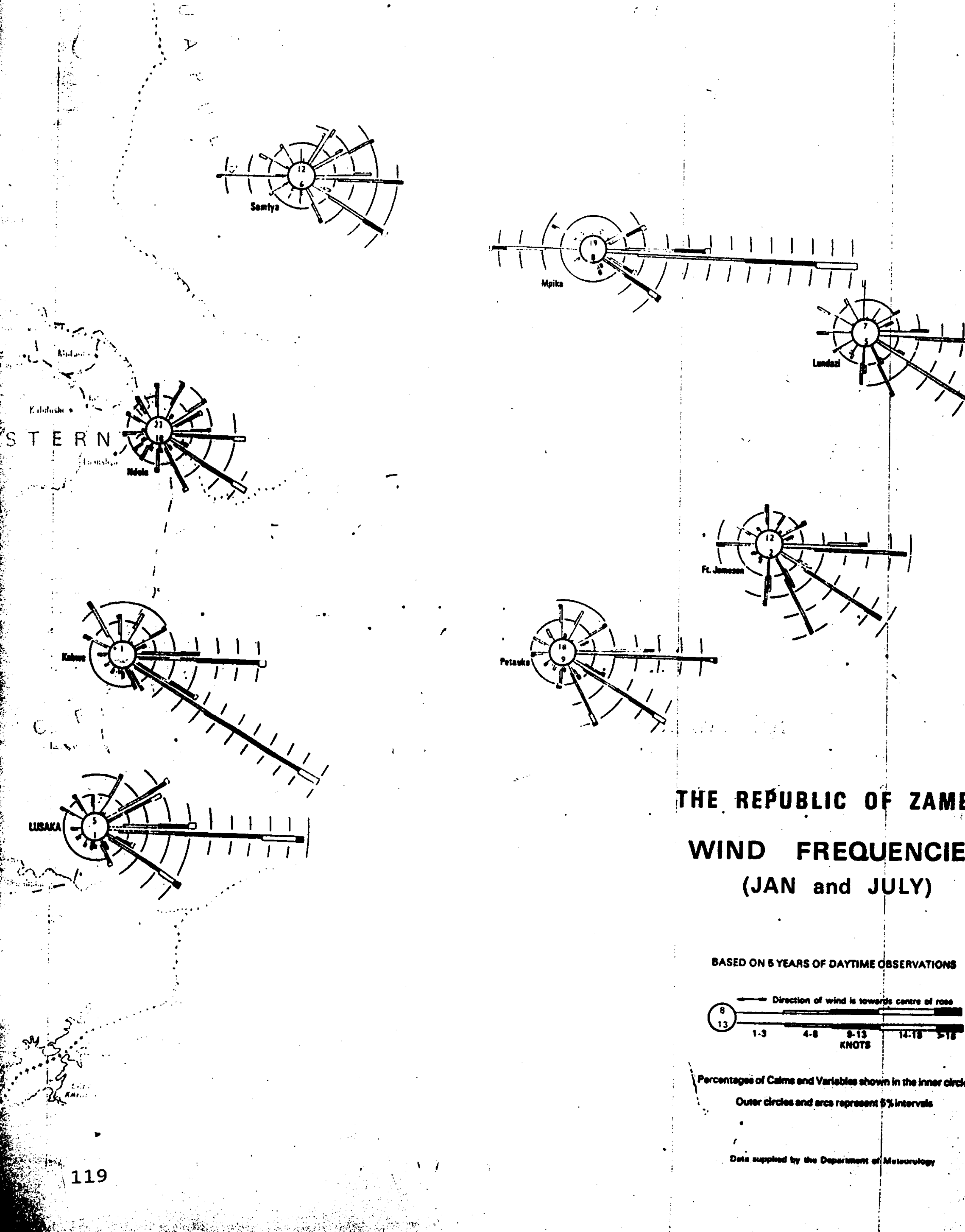
101. Stake P.E., Miller W.J., Gentry R.P. and Neathery M.W. (1975), Zinc metabolic Adaptations in Calves fed on high but nontoxic Zinc level for varying time periods. J. Anim. Sci. 40, 132 - 137.

102 Smith D.B. and Waldron H.A. (1974) Lead in Food-Are Today's Regulations Sufficient? Chem. in Brit. 10, 202.

APPENDIX

APPENDIX A1

Shows the direction of the prevailing winds in and around Kabwe



APPENDIX A2

Shows the direction of the prevailing winds in and around Kabwe