

CHAPTER FIVE

DISCUSSION

5.0 **DISCUSSION**

Zambia derives most of its foreign exchange from mining. Economics and demand dictate that mining is carried out on a very much greater scale. It therefore plays a major part in development of larger areas, moving tonnages of materials and generating larger quantities of waste from more sophisticated processes. Hence the potential for nuisance, pollution and damage is greatly increased. The environmental problems associated with mining are therefore likely to be significant in this area [26].

The purpose of this study was to investigate the influence of the mining activities on selected trace metal pollutants. This report discusses findings on the concentration of cadmium, cobalt, copper, lead and zinc in soils and vegetation near the Nkana smelter in Kitwe. Based on various health studies, limits have been placed on certain contaminants. These limits are highest permissible concentrations of a particular substance in foods, soils, plants, water and others. The limits apply whether the contaminant is from naturally occurring sources such as runoff or from man-made pollution. The results of this report are presented in chapter four.

Generally the results of the heavy metal concentration is significantly higher near the smelter in all the three directions studied, that is, West, North-west and

South-east of the smelter. Moving away from the smelter, the concentrations show lowering values in soils, grass and edible vegetable samples. Figures 4.1– 4.6 shows graphical representation of the metal concentration with increasing distance from Nkana smelter in soils and grass. The correlation coefficient (r) between metal concentration in samples studied and distance from the smelter were quite high, tables 4.8 to 4.10. This indicates that the studied metal concentration in Kitwe area is highly affected by the Nkana smelter. However considering the fact that the area is very rich in minerals, some of the heavy metals could also be coming from the natural sources of weathering.

5.1 CADMIUM

The amount of cadmium metal present could not be detected in soil, grass and vegetable samples analysed in this study from Nkana smelter area. The low concentration of cadmium in this area could be related to the natural occurrence of the metal. Cadmium occurrence is closely associated with the natural occurrence of zinc ore [41, 82] as indicated in Chapter two. A similar research carried out recently by Tembo [27] around a zinc and lead mine in Kabwe area showed the presence of cadmium in soil up to 28mg Cd/kg and in plants up to 7.3mg Cd/kg dry matter. Kitwe town has no zinc mine. Only copper and cobalt are mined and

processed in the area. This could have a bearing to the low amount of cadmium present in the soils and plants.

However, some contamination of the environment is expected in this area of copper smelting because cadmium contamination of air is also associated with copper, lead and zinc smelting [13]. Cadmium deposition rates around smelter facilities are often markedly elevated nearest the source and generally decrease rapidly with distance [83]. High cadmium concentrations in soils are often commonly encountered close to long established smelters [84]. Mines with sulphide ores of copper, lead and zinc in most cases also contain certain amounts of cadmium [82]. Therefore more research need to be carried out here to determine the concentration of cadmium and other metals to lower levels than parts per million (ppm) in soils and vegetation. The instrument used in this research (Atomic Absorption Spectrometer Techtron 1000) was limited to ppm level.

This study shows that the amount of cadmium present in soils and plants does not seem to pose any danger to plant, animal and especially human health. The concentration of cadmium is below the maximum permitted level in soil, that is 0.3mg Cd/kg. Land plants, 2.4mg Cd/kg as given by Bowen [49] and 0.03mg Cd/kg is the maximum permitted level in edible vegetable (Tables 5.1 and 5.4).

The toxic effects of cadmium are not likely to occur in Kitwe area, though this can not be ruled out completely because of the exposure to contaminated air from the mining and other related industries. Cadmium is non-essential and its low concentration is not expected to have any effects on plants and animals feeding on these plants. Reduced dietary intake of this non-essential metal is desirable. Based on these results it can be said that the Nkana smelter area is not polluted with cadmium metal. The levels were found to fall below the maximum allowed concentration in both soils and vegetables analysed.

5.2 **COBALT**

The results for cobalt concentration in soils, grass and vegetables are presented in Tables 4.1– 4.7. The cobalt metal concentration ranged between 0.7 to 43mg Co/kg in soil samples. The highest concentration in soil was obtained in the west nearest the smelter, as expected considering the distribution by prevailing winds of the area (figure 5.1 and figure 5.2). All the soil samples nearest the smelter contained more than 8mg Co/kg that may be allowed in soils. The analysed grass samples had cobalt concentration ranging between 4.3 and 55mg Co/kg dry matter. This is about 55 times higher than 1mg Co/kg dry matter allowed in land plants. The edible vegetable samples had cobalt levels of about 5

– 94.5 mg Co/kg dry matter. The average concentration range according to Bowen [49] should be 0.04 – 4.6 mg Co/kg dry matter. All samples therefore contained more cobalt (up to 20.5 times) than maximum value that may be permitted in vegetables.

Figures 4.1 – 4.9 shows how cobalt content in soils, plants and vegetables reduce with increasing distance from the Nkana smelter in the three directions studied. Generally values from the West are higher than those from the North-West and South-east. This distribution of the metal element provide strong evidence that it is a case of airborne pollution from the suspected source, the Nkana smelter. The high negative correlation coefficient between cobalt concentration in samples and distance from the smelter shown in Tables 4.8 – 4.10 further confirms the undoubted influence of the smelter on the concentration of cobalt in soils and vegetation.

Occurrence of cobalt deficiencies is not expected in Kitwe area because the vegetation contains more than what animal deficient pastures may have, 0.01 to 0.05mg Co/kg dry matter. In forage and pastures the minimum quantity of cobalt required to prevent deficiency diseases has been given as 0.07 – 0.1mg Co/kg of feed. In human diets 0.0002mg Co/day is deficient while 0.005 – 1.8mg Co/day is the normal range [49]. Growing cattle can consume up to 50mg cobalt per 45kg

body weight without ill effects. Cattle eating about 12kg of the grass silage from Kitwe would consume up to a maximum of about 660mg cobalt per day. This is too high even for sheep which can tolerate up to 160mg daily per 45 kg weight for at least 8 weeks without harmful results, with higher dosages being harmful [50]. Cobalt is toxic to man if taken at 500mg Co/day and 0.1–3mg/litre is toxic to plants. Considering the results obtained, the area is polluted with cobalt metal. This is in agreement with the expected results of cobalt contamination of the environment taking into account that it is one of the metals processed at Nkana smelter.

5.3 **COPPER**

The results for copper in soils, grass and vegetables are presented in tables 4.1 – 4.7. The highest concentration was found to be about 5300mg Cu/kg in soil. This is about 265 times higher than the maximum permissible value of 20mg Cu/kg in soils (table 5.4). In grass, the highest value was found to be 2330mg Cu/kg dry matter, that is about 155 times higher than the 15mg Cu/kg that may be allowed in land plants according to Bowen [49]. Vegetable samples had copper concentration ranging from about 12.0 to 311 mg/kg dry matter. Most vegetable samples sampled from the three directions and domestic gardens in residential

areas were found to contain more copper than maximum permissible value of 25mg Cu/kg dry matter. Even at 20km away from the smelter, the copper concentration was still high and above what may be allowed. These values are higher compared to what Beavington [85] found in soil and domestic gardens around a smelting complex in Australia.

The concentration of copper was generally higher compared to the other four metal pollutants studied. The results in soils show very high concentration of copper nearest the smelter. The concentration decreases with increase in distance from the smelter in all the three directions used in the study as expected. The copper concentrate is treated predominantly at Nkana smelter together with cobalt concentrate. The high levels of copper in the area can be attributed to the smelter as the source since results show concentration decrease with increasing distance from the smelter. This is actually supported by the correlation coefficient (r) between copper concentration and distance from the smelter (Tables 4.8 – 4.10). The high negative correlation coefficients means that the smelter contributes greatly to the copper concentration in soil. A similar trend was observed with the levels in grass and edible vegetable samples, demonstrating a drop in copper concentration as one moves away from the smelter. This agrees with the expected effect of the smelter on the copper metal concentration in this environment.

Comparing the three directions studied reveals that on the average levels of copper are higher up to a longer distance in the western than the other two directions in both soils (figure 4.2) and plants (figure 4.5). This can directly be related to the prevailing winds in the Copperbelt area which are predominantly easterlies (figures 5.1 and 5.2).

The study area is highly mineralised and copper seems to be in excess. Therefore copper deficiency problems like skeletal deformation and stunted growth in plants (Chapter 2) are not likely to occur. Copper toxicity problems occur when the copper concentration is in excess. The copper concentration in vegetables were high compared to the 0.1mg Cu/kg allowed daily intake (ADI) by FAO/WHO [86]. The cattle and other animals grazing on grass from this area can take up copper in excess which may accumulate in their liver (Chapter two). This puts the people at risk who depend on these animals for meat protein. Considering the fact that most soil samples, grass samples and all vegetable samples analysed have values of concentration of copper which are higher than the recommended, the area is polluted with copper metal. The pollution is worse near the smelter and seem to be mainly from the copper mining processes. Some of the pollution however could be coming from natural sources.

5.4 **LEAD**

Lead results of all samples analysed are presented in Tables 4.1 – 4.7. Most soil samples have lead concentration below the maximum permitted level of 30mg Pb/kg of soil (Table 5.4). Only samples from one sampling point were found to be above the maximum allowed. This was obtained from Wusakile market (SE₁) nearest to the slag. The highest concentration in soil was 30.5mg Pb/kg. The distribution of lead is similar to that of cobalt and copper, higher concentrations near the smelting complex and reducing as one moves away in the three directions studied. Generally higher values were found in the West and North-western directions than the South-east. This distribution of lead again agrees with the expected dispersion of metal pollutants from the smelter by wind. Soil metal content and distance from the smelter correlates very well. The correlation coefficients (Table 4.8) are negative indicating a positive relationship between metal contamination and the smelter as the source of contamination.

Plants and vegetables showed trace levels of lead. The grass samples were collected during the active growing season, January. This could have had some bearing on the low levels found in grass. The lowest lead content of plants were found to occur during the active growing season in the vicinity of a smelter by Rains [87]. Lead is non-essential element and its absence in edible vegetables and

grass would not pose any deficiency problems. The permissible value in edible vegetables is 0.5mg Pb/kg. 1mg per day is toxic to man while 10mg per day is lethal. From the results of this study it can be deduced that the smelting plant has influenced the concentration of lead in the surrounding environment, especially those near the smelter where the concentration has been elevated more. Therefore lead contamination has occurred in the area. The pollution levels in soils are within accepted standards. However more research is necessary to establish the concentration in vegetation, particularly for mature plants by use of more sensitive methods.

5.5 ZINC

Results of zinc concentration in samples analysed in this study are presented with other metals in Tables 4.1 – 4.7. The zinc soils concentration were ranging from 0.5 – 76.5mg Zn/kg. There was an elevation of zinc concentration in soils near the smelter in all the three directions. The values in soils were found to be above the maximum allowed of 40mg Zn/kg (see Table 5.4) near the smelter. However, away from the smelter, all the values were found to fall within allowable concentration.

Grass samples had concentration ranging from about 22.0 to 167mg Zn/kg dry matter. All the grass samples in the three directions analysed had zinc concentration within what could be allowed in land plants (Table 5.1). The edible vegetable samples contained more zinc than the maximum allowed of 10mg Zn/kg. The concentration range in edible vegetables were between 36.3 – 175 mg Zn/kg dry matter. The highest concentration therefore was about 17.5 times higher than the maximum allowed in vegetables.

The concentration levels of zinc also show general decrease as distance increase from the smelter. This is a similar distribution to the other metals studied in this report. All soil samples in the three directions show negative correlation coefficients (r) between zinc concentration and increasing distance from the smelter indicating possible contamination by the smelting processes. This trend of decrease in zinc concentration with distance was also observed in grass samples to the West, North-west and South-east with correlation between distance and concentration being -0.97 , -0.75 and -0.86 respectively (see Tables 4.8–4.10). In the case of edible vegetables, the different types of vegetables used can also have an effect on the levels of zinc. This is because the general observation is that different species of plants and vegetables take up different levels of different

elements. Despite this effect, the edible vegetables still point to the smelter having an effect on the concentration of zinc and other metals studied.

Zinc seems to be naturally in abundance in Kitwe area and zinc deficiency diseases are unlikely to occur to the people and especially animals grazing on the grass. The Recommended Dietary Allowance (RDA) designed for maintenance of good nutrition of practically all healthy people in USA is 15mg zinc for males and females 11 to 50+ years [56]. However zinc toxicity occurs if zinc content of the diet exceeds 1000 mg/kg. An intake of 150mg per day is toxic to man while 40 to 60 mg per litre is toxic to plants. However, when assessing the potential threat to human health, the intake of any contaminant like zinc via food should not be considered in isolation but should be correlated with data showing the intake of the contaminant by other routes (e.g. through lungs). This is important in assessing human risk. From the results obtained for zinc in soils and vegetation, it can be concluded that the levels of the metal zinc has been influenced by the Nkana smelter and more so near the smelting plant.

In Kitwe area the sources of heavy metals are diverse but commonly associated with industrial and mining discharge as shown in this report. The metal pollutants are released into the streams during waste discharge from industries. Those that precipitate on land from air pollution (figure 1.5) are washed down into

streams during rainy season. Leachate from mine dump like slag (figure 1.4) and slimes dams also reach surface and ground water systems in Kitwe area. Patterson [25] found enhanced concentration of copper, cobalt and other metals in water and sediments from the Kafue river in the Copperbelt mining area. The copper and cobalt concentrations deposited in the Kafue river sediments were classified as very high. Therefore there is need to ensure water is of good quality by protecting against pollution sources such as mining processes, land fills and industries. In January 1981 spillage from Chambishi mine one resulted in the death of several livestock on farms surrounding Mwambashi river from chronic copper poisoning [30]. It must be ensured that pollutants do not get into any of the streams joining the Kafue river where the city of Kitwe's domestic water works is situated (Bulangililo water works). Better protection from dumping sites can be achieved through proper siting for waste disposal in respect to water sources [88].

Heavy metal pollution of surface may create either acute or chronic poisoning in fish and other aquatic life and even man. An epidemic of bone disease associated with kidney damage (*itai-tai* disease) occurred in an area of Japan located along the Jintzu river in Toyama prefecture [13]. Cases of *itai-tai* disease also have been found in other areas of Japan where soil was polluted with cadmium metal. In a recent study Mwase [89] showed high concentration of

copper and cobalt and other metals in sediments, water and fish collected from the Kafue river near Kitwe town. Various types of pathological lesions were recorded from liver and gill from fish, directly related to toxic contamination of sediments in the Kitwe area by mining activities. The effects of various toxicants depends on the water quality and on number, type and concentration of other toxicants. Hence water treatment becomes expensive and control systems are required that can continue to operate for many years during and after commercial mining ceases. Some principal environmental impacts on mining activities and some mitigatory actions we need to take are given in Table 5.5

Table 5.1 Mean values of concentrations of heavy metals in mg/kg [49].

Substance	Cadmium	Cobalt	Copper	Lead	Zinc
Soil	0.35	8	30	35	90
Land plants	0.1–2.4	0.005–1	5–15	1–13	200–400
Edible vegetable	0.005–0.9	0.04–4.6	4–20	0.2–20	1–160
Fresh water	0.0001	0.0002	0.003	0.003	0.015
Air	0.5–620 ng/m ³	0.2–37 ng/m ³	0.036–4900 ng/m ³	0.6–13200 ng/m ³	0.03–16000 ng/m ³

Table 5.2 Toxic Concentration of the five metals

Toxicity	Cadmium	Cobalt	Copper	Lead	Zinc
Toxic to plants	0.2–9 mg/litre	0.1–3 mg/litre	0.5–8 mg/litre	3–20 mg/litre	60–400 mg/litre
Toxic to man	3–330 mg/day	500 mg/day	250 mg/day	1 mg/day	150–600 mg/day
Lethal to man	1.5–9 g/day			10 mg/day	6g/day

Table 5.3: Nutritional classification of zinc content in some vegetables in mg/kg or parts per million (ppm)

	Deficient	Low	Sufficient	High
Apple leaves	0–15	16–20	21–50	>51
Citrus leaves	0–15	16–25	26–80	81–200
Lurcene tops	0–15	16–20	21–70	>71
Maize leaves	0–10	11–20	21–70	71–150
Soybean tops	0–10	11–20	21–70	71–150
Tomato leaves	0–10	11–20	21–120	>120

Table 5.4: Maximum allowed values in soils and some Foods in mg/kg dry matter

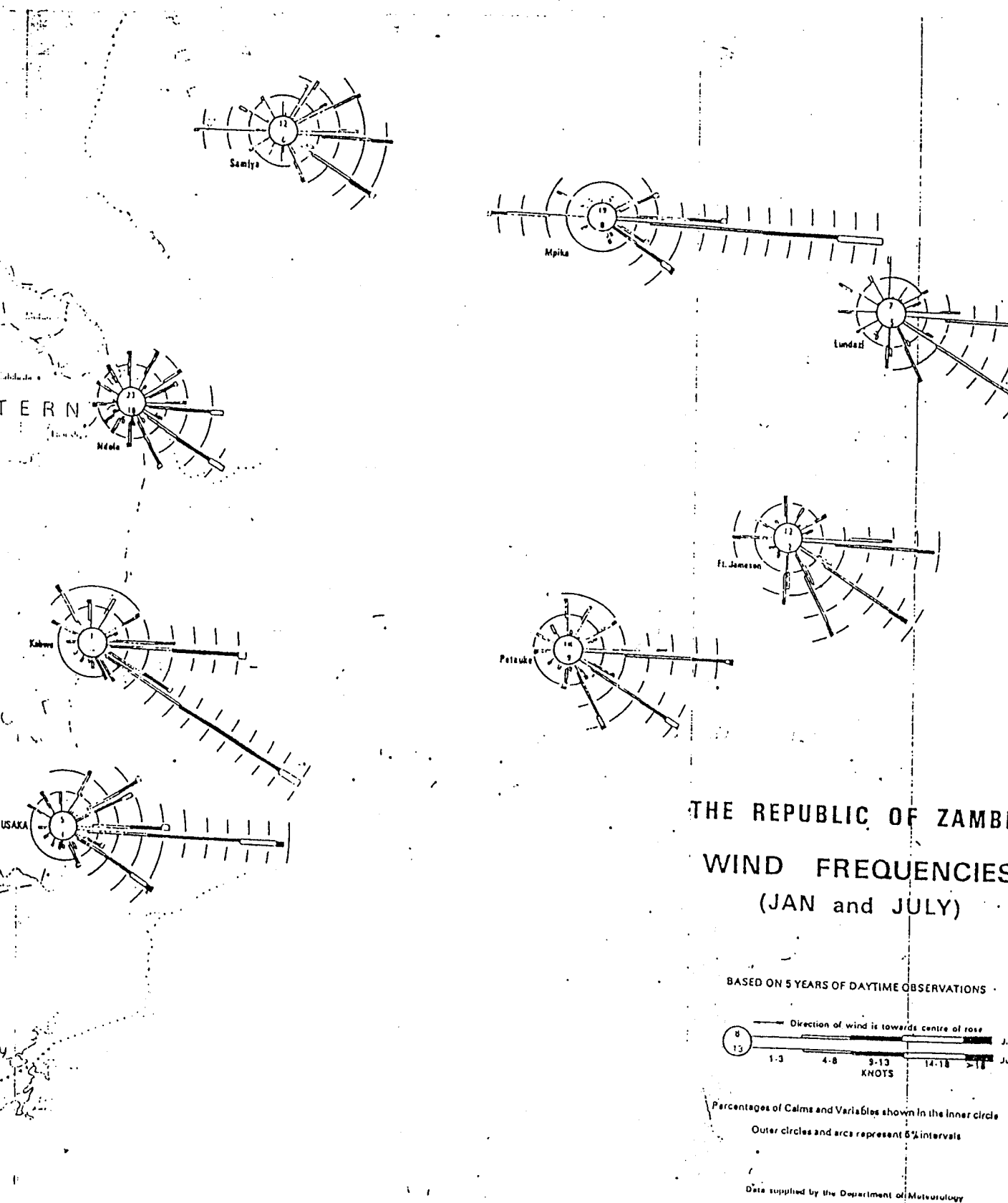
Substance	Cadmium	Copper	Lead	Zinc
Baby food	0.003	0.3	0.05	5
Potatoes	0.05	10	0.3	10
Meat/Meat products	0.05	10	0.5	50
Vegetables	0.03	10	0.5	10
Other foods	0.1	25	1.0	80
Soil	0.3	20	30	40

Source: Ministry of Health, Republic of Slovakia in conjunction with WHO, FAO and EEC 9th May 1994.

Table 5.5: Consideration for Mineral Development [90]

Sources	Receptors	Impacts	Mitigation
Exploration mining and construction	Existing ecosystem	Loss of soil, vegetation Loss of biodiversity	Reclamation of disturbed areas for productive land use and/or habitat creation
	Aquifers	Contamination	Avoidance of aquifers below the mined strata
Soil erosion	surface	siltation and contamination	control of runoff and revegetation of disturbed areas
Waste water mine drainage	surface and - ground water	contamination	Treatment of mine drainage before discharge
Tailings and leach ponds	Wildlife	Loss of birds and animals	cover or fence ponds and drain or close when not in use
Spoil tips solid waste disposal	soil, vegetation and surface	contamination	identification and segregation of toxic rock/ materials
Particulates from blasting and wind erosion	Air	Reduced air quality	correct blasting procedures, revegetation of disturbed areas
Noise and vibration	Humans, wildlife and building structures	Disturbance, nuisance and damage to property	proper blasting procedures. Earth bunds and tree screens

Figure 5.1: Diagram showing prevailing winds in Kitwe area (January and July)



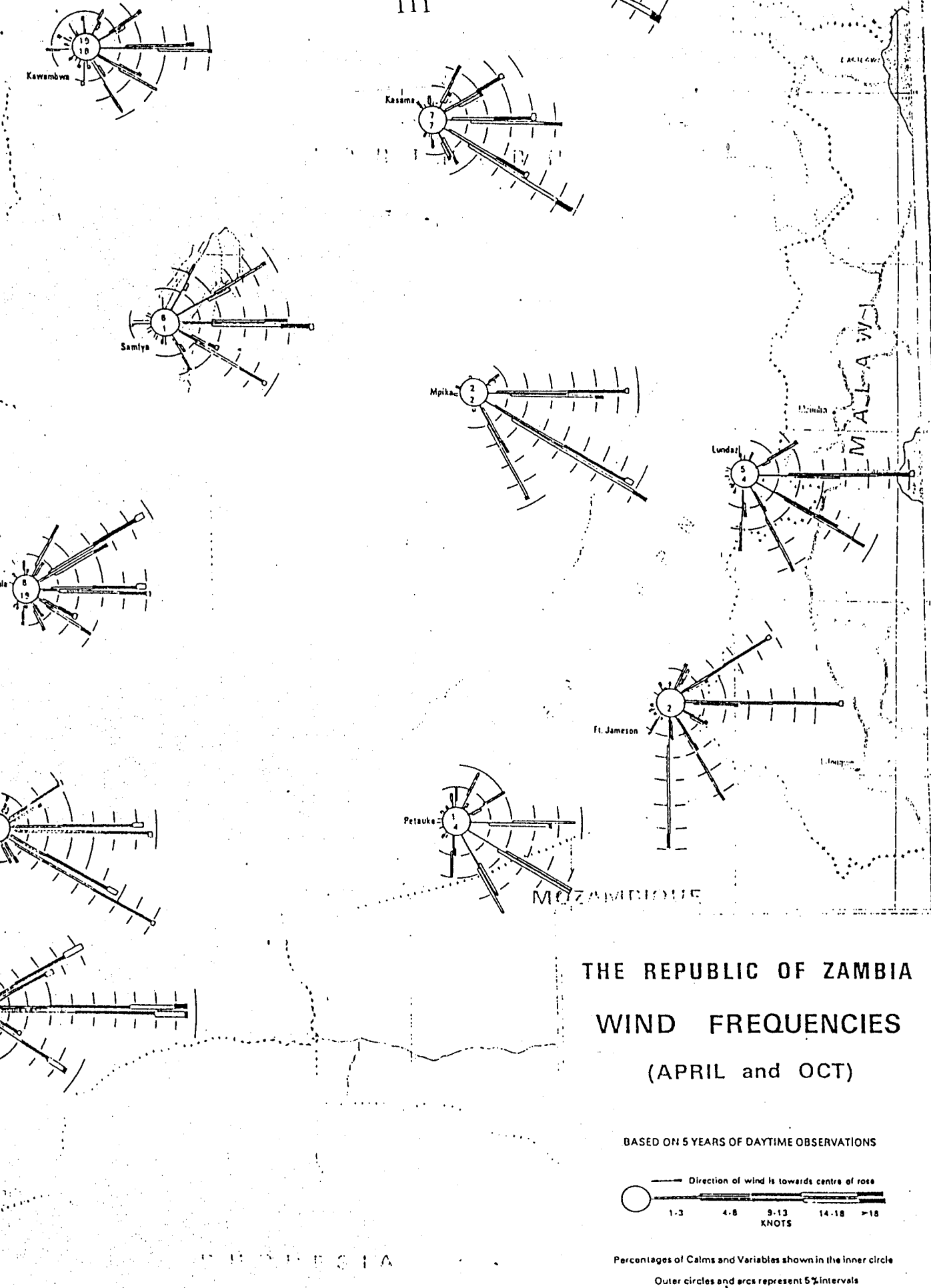


Figure 5.2: Diagram showing prevailing winds in Kitwe area (April and October)

CHAPTER SIX

CONCLUSION

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There various human activities which inevitably and increasingly introduce toxic materials like heavy metals into the Zambian environment. In this study the mining processes at Nkana smelter were found to be the source of heavy metal pollution. The following are the conclusions on each metal

Cadmium : Based on the sensitivity of the instrument used no cadmium was detected in all samples. Cadmium is well below danger levels in both soils and vegetation in Kitwe area.

Cobalt : The concentration of cobalt in all grass and vegetable samples used was found to be more than the recommended values together with the values in soils near the smelter. The area is therefore polluted in cobalt.

Copper: Most soil samples, grass samples and all vegetable samples showed toxic levels of copper. Kitwe area is polluted with copper, the pollution is worse near the smelter.

Lead: The values of lead levels in soils and vegetation were below the danger level to health. However, lead contamination of the environment has occurred. This is evidenced by the enhanced values near the smelter.

Zinc: Zinc contamination has occurred in the Kitwe area. However it would be safe to conclude that the area is not polluted with zinc except nearest the smelter where the levels in soils were more than recommended values.

The results show that the concentration of heavy metals are elevated in soils and vegetation in Kitwe area. The result indicate an inverse relationship between concentration of metals and distance from the smelter. The metal elements are highly concentrated near the smelter and reduce with distance. The high correlation coefficients(r) obtained between metal concentration, in both plants and soils, and distance from the smelter point directly to the smelter as the source of these metals. This spread of toxic metals released from industrial smelters is well recognised [91, 92].

Contamination of the soils and vegetation in urban and industrial areas of Zambia with potentially toxic trace metals as evidenced in this report, is an

important aspect of pollution which can affect the composition of food. This enhancement of potentially toxic metals in soils and vegetation growing in the area could lead to deleterious effects both on plants and on health of those eating them. The effect may occur to biota at considerable distance from the source as a result of long distance plume dispersal or drainage from soil into water bodies. Even at relatively low levels air, water and soil pollution can interfere with wild life and natural vegetation, discolour the atmosphere and water courses, and cause contamination in homes. In addition to indicating the hazard to grazing animals in Kitwe area, these results point out the needs to monitor heavy metal content in meats and vegetables obtained in the area and marketed for human or animal consumption. People of Kitwe may be getting an additional increment of toxic trace metals from cattle and other animals exposed to very high concentration of these metals. This is evidenced by the death of livestock from copper poisoning of farms surrounding Mwambashi river in Kitwe [30].

From this report it is clear that contamination of the environment by the mining industry has occurred, and continues to occur in Kitwe area. However it is necessary to have more extensive study on heavy metal contamination to establish the extent of pollution by the mining industry in all other Copperbelt towns. The study in this mining area need to be continuous and more advanced methods needs

to be used for determination of heavy metals in animals human blood and urine. The next research will be looking at environmental contamination in the mining towns of Chingola, Luanshya, Mufulira and others to complete the Copperbelt.

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