Proc. 3[rd] All Africa Conf. Anim. Agric. & 11[th] Conf. Egyptian Soc. Anim. Prod., Alexandria, Egypt, 6-9 November 2000: 193-196

EFFECT OF ROAD TRAFFIC ON TRACE MINERAL CONCENTRATIONS OF PLANTS

A. A. Aganga, S. Machacha, J.O. Amarteifio and M. Solomon

Botswana College of Agriculture, Private Bag 0027, Gaborone, Botswana

SUMMARY

The concentration of zinc, copper, lead, cadmium and nickel in plants were studied in two seasons (wet and dry seasons) in 1999/2000 in an experiment conducted along the Francistown -Gaborone (the only 2 cities in Botswana) highway with an average daily traffic density of 3.571 vehicles. The experimental plots from which plants samples were collected on monthly basis were located at 40 cm. 10m, 20m, 30m and 1000m away from the major highway.Five sampling areas with three replicates which were 200m apart were evaluated. Each sampling plot was established by a 1m by 1m quadrat.All the 15 sampling plots were established. Sampling was done at the beginning of June, July and August 1999 (representing the dry season)and December 1999, January and February 2000 (for wet season samplings).

Lead concentrations of 13.53ppm were recorded in plants growing at 40cm away from the road while 0.49 ppm was obtained from plants collected a kilometre away from the road. Cadmium concentrations decreased slightly with distance from the road. Cadmium, nickel, and zinc concentrations were low at all experimental sites. Highest concentrations of 0.058 ppm, 0.40ppm and 2.03 ppm were recorded respectively. The trace elements concentrations varied with seasons. Under the current automobile densities in Gaborone. only copper and lead were detected at high levels and copper levels may be toxic to sheep .

Keywords: Road traffic, trace mineral concentration, plants

INTRODUCTION

Trace elements constitute a broad class of elements comprising of about 80% of the periodic table. They are widely distributed in the environment and are not biodegradable. Common physical properties of trace elements include electrical conductivity and thermal conductivity, and they can be deformed without cleaving under stress. Trace elements have a tendency to donate electrons and to form basic oxides. Many exist in different valence state and form a variety of inorganic and organic compounds. Biologically, many trace elements are essential to living systems and are involved in a variety of cellular, physiological, and structural functions.Trace elements are often cofactors of enzymes, and play a role in transcriptional control, muscle contraction, nerve transmission, blood clotting, and oxygen transport and delivery. Although trace elements are potentially toxic at some levels, some are highly toxic at relatively low levels. Moreover, in some cases the same metal can be essential at low levels and toxic at higher levels, or it may be toxic via one route of entry but not another. Toxic effects of some trace elements are associated with disruption of functions of essential metals. Trace elements may have a range of effects, including cancer, neurotoxicity, immunotoxicity, cardiotoxicity, reproductive toxicity, teratogenicity, and genotoxicity (Waalkes, 1998).

Trace elements are not biodegradable, but can be transformed into different chemical forms, often with different valence states. Some of the transformation processes result from activities related to industrialization, including combustion of fuels. or other temperature driven reactions associated with motor vehicle performance. These elements are being emitted into the environment in increasing amounts and sometimes in forms with differing toxicity. Trace elements may also be a part of particulate matter, and are hypothesized to contribute to their toxic effects. Trace elements are used for different purposes in motor vehicles, including; as a part of the structure, (in batteries and in brake pads), as fuel additives to improve engine performance, as fuel additives in conjunction with particle filters to reduce emissions of hydrocarbons, carbon monoxide, and nitrogen oxides (Sawyer, 1998).

There are so many sources of the inorganic chemical contaminants, which can accumulate in soils. The burning of fossil fuels, smelting, and other processing techniques release into the atmosphere tons of these (trace elements), which can be carried for miles and later deposited on the vegetation and soil. Lead, nickel, cadmium, zinc and copper are gasoline additives that are released into the atmosphere and carried to the soil through rain and wind. Contamination of soil and vegetation with lead comes primarily from airborne lead from automobile exhaust and therefore it is most concentrated within

100m of major highways and near urban centers. Some reaches the soils directly (Brady and Weil, 1996).

During the past decade, Botswana has experienced a steadily increase in the number of automobiles (a total of about 136000) (CSO, 1999). This has resulted in a high fuel consumption, hence an increase in exhaust fumes and fuel linkages emitted into soils and vegetation along heavily used roads, and therefore contaminating the latter with trace elements residues such as lead, nickel and cadmium. A high concentration of these trace elements results in chronic diseases and ill health. Despite this, A lot of stray livestock grazing along major tarred roads partly because of poor maintenance of the cordon fence or through farmer's participation and encouragement. Botswana's economy is reliant on beef production; high toxicity levels detected in beef can be of negative impact to the economy in that the world market can reject every beef product produced. This study was done in order to find out the concentrations in plants of lead and some other trace elements such as copper and cadmium that are due to airborne deposition, road traffic in particular. It was also aimed at relating those concentrations with toxicity levels which are harmful to body tissues as a measure of restricting and curbing livestock from utilizing such areas for grazing. Seasonal variation in trace elements concentration was also considered.

MATERIALS AND METHODS

Experimental design

The experimental area chosen for the assessment of trace elements from automobile exhaust was about 600m long. The area of study was in Sebele along the Sebele – Phakalane highway (main road). This area was chosen due to high traffic densities of about 3,571 vehicles per day (CSO, 1999) and easy accessibility.

Three replicates within five areas were established at a distance of 200m apart. In sampling plot was established by a 1m by 1m quadrat. The distance between the first three sample points (main plots) from the road was about 40cm and the next three treatments from each main plot were fixed at a distance of about 10m from the preceding one. The last treatments were used for control measures and were placed at a distance of one kilometre away from the main road (the first three sample points). All the fifteen quadrats or sampling plots were established. Sampling was done in two seasons (that is the wet season and the dry season). December, January, and February represented the wet season while June, July, and August represented the dry season. Sampling was done once at the beginning of each month. Secateurs were used to clip enough forage comprising of grasses, forbs, and shrubs in each quadrant. The sampled material was immediately bagged in brown paper bags and oven dried at 40°C for 72 hours to estimate its dry matter content. The dried forage samples were ground and then stored in tightly covered honey jars for future analysis. A total of 90 samples were collected.

Preparation of sample material for trace elements analysis

One gram of each ground sample was weighed and put in 100ml conical flasks. About 20ml concentrated nitric acid (69%) were added to each sample and left overnight at room temperature to facilitate or enhance digestion. The samples were then digested in a water bath at temperatures of about 90°C for an hour. The digested samples were cooled and filtered into 25ml volumetric flasks. 1% nitric acid was used to fill the volumetric flask up to the mark. The samples were individually shaken to homogenize the mixtures and stored in a cold room for analysis.

All the digested samples were analysed for lead and cadmium using the Atomic Absorption Instrument Varian Spectra AA10 coupled with varian GTA 96. The reference material used for the analysis was bovine – liver. The latter has the following concentration:

298 ± 25 ng / g (ppb) Cd and 501 ± 27 ng / g (ppb) Pb.

Graphite furnace has been widely used in the analysis of petroleum products for trace elements. Yet, flame atomic absorption is still recommended for the determination of major metals (iron, zinc, nickel, copper) and furnace techniques for trace elements (mercury, lead, cadmium) (Rothery, 1996).The collected data were analysed statistically using ANOVA and Duncan's new Multiple Range Test (DMRT) (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Table 1 shows the effect of distance from the main road on the distribution of trace elements in the plants. Cadmium and lead show a significant decrease in concentration as the distance away from the main road increases. Highly concentrated areas are those, which are 40cm away from the road, while those of a kilometer away are low in concentration (0.058) ppm as compared to 0.011ppm for Cd and 13.529 ppm as compared to 0.490 ppm for Pb). Zinc, copper, and nickel show no significance difference between trace element distribution and most spatial distances. The highest concentrations of nickel and copper were detected 30m away from the main road (0.4024 ppm and 36.500 ppm respectively), while that of zinc was observed 10m away from the roadside (2.028 ppm). Zinc, copper and nickel were detected at relatively uniform concentrations without regard to distance.

Table 1. Effect of distance on the distribution of trace elements

Distance (m)	Mean trace element concentration (ppm)				
	Cd	Pb	Zn	Cu	Ni
0. 4	$0.058^a \pm 0.007$	$13.529^a \pm 1.300$	$1.707^b \pm 0.152$	34.222 ± 1.755	$0.3417^b \pm 0.018$
10	$0.045^b \pm 0.0006$	$6.386^b \pm 0.574$	$2.028^a \pm 0.161$	32.667 ± 4.645	$0.3670^b \pm 0.020$
20	$0.035^c \pm 0.0001$	$3.738^c \pm 0.211$	$1.513^b \pm 0.172$	33.222 ± 2.517	$0.3620^b \pm 0.029$
30	$0.024^d \pm 0.002$	$1.654^d \pm 0.192$	$1.546^b \pm 0.103$	36.500 ± 1.860	$0.4024^a \pm 0.0664$
1000	$0.011^e \pm 0.003$	$0.490^e \pm 0.014$	$1.688^b \pm 0.107$	35.778 ± 3.040	$0.2985^b \pm 0.048$

[abcd] column means with different superscripts differ significantly (P<0.05)

Table 2 shows variations in trace elements detected in plants (forages) as a result of fluctuations between the dry and wet seasons. Comparatively, a high concentration of trace elements was detected in the dry season than in the wet season. High concentrations of cadmium, lead, zinc, and nickel were recorded in the dry season as 0.043, 6.947, 2.017, and 0.386 ppm, respectively. On the other hand, copper showed a high concentration of 43.778 ppm in the wet season as opposed to 25.222 ppm in the dry season.

Table 2. Seasonal variation in trace element distribution

Seasons	Mean trace element concentration (ppm)				
	Cd	Pb	Zn	Cu	Ni
Wet season	$0.026^b \pm 0.0018$	$3.372^b \pm 0.496$	$1.376^b \pm 0.119$	$43.778^a \pm 1.633$	$0.323^b \pm 0.021$
Dry season	$0.043^a \pm 0.0009$	$6.947^a \pm 0.548$	$2.017^a \pm 0.231$	$25.222^b \pm 1.528$	$0.386^a \pm 0.018$

[ab] columm means with different superscripts differ significantly (P<0.05)

National Research Council (1980) reported that cadmium toxicosis under most practical conditions in ruminants is highly unlikely, because it would be difficult for ruminants to ingest enough cadmium based on most feeding, management, and environmental conditions. Stebbings and Lewis (1984) proved that a dietary intake of 25ppm cadmium to sheep does not show any clinical effects. According to Table 1, current cadmium concentrations are low to have any toxic effects to animals feeding on such forages. Since a maximal of about 0.058ppm cadmium was detected 40cm away from the road while 0.011ppm was detected a kilometer away from the road.

According to Table 1, the highest nickel concentration detected was 0.402ppm and the lowest nickel concentration detected was 0.299ppm. Comparatively, the detected nickel concentrations are higher than the deficiency levels (0.1ppm) and relatively lower than the minimum toxic level (250ppm). This therefore shows that at current traffic densities, concentrations of nickel are neither toxic nor deficient. A copper content in feed over 20ppm can cause chronic poisoning in sheep (NCMN, 1973). It is estimated that cattle can tolerate 70 – 100ppm of copper over an extended period and higher levels for shorter periods. McDowell (1985), in reviewing copper toxicity concluded that chronic copper toxicity in ruminants is almost entirely confined to sheep. Calves are affected much more than older cattle, but a comparable resistance to the toxicity does not occur with sheep as they mature. Table 1 shows a relatively uniform concentration of copper detected, for instance, the highest copper concentration detected was 36.500ppm while the lowest was 32.667ppm. These levels are highly toxic to sheep but have no chronic effects to cattle. Cattle, sheep, and most mammals exhibit considerable tolerance to high intakes of zinc. The maximum tolerable level of dietary zinc has been set at 500ppm for cattle and 300ppm for sheep (NRC. 1980). According to Table 1. the highest zinc concentration was 2.028ppm and the lowest was 1.513 ppm, . which are comparatively, lower than concentrations above which toxicity results.

Differences in concentrations between seasons (dry and wet seasons) can be attributed to a number of climatic factors dominant at such periods. A relatively low concentration of trace elements was detected in the wet season than during the dry season as shown in Table 2 (for Cd, Pb, Zn, and Ni). During the wet season, a lot of trace elements which are predominately released from automobile exhaust airborne, are either lost through leaching to the water table or as a part of run off through the action of splash which washes off foliar deposits. Unsteady winds coupled with rainfall prevail making it impossible for the plants to actively absorb (either through the stomatal pores or the roots) these trace elements. During the dry season, steady breezes facilitate an easy drift of trace elements from automobile exhaust into the vegetation and soil around major roads. This results in high concentrations of trace elements in plants (forages) as shown from Table 2. During the dry season, overstocked areas especially those under communal grazing systems experience high forage shortages. Thus during this periods, standing hays along roadsides are tempting both to the animals and their embattled owner such that one way or the other, a large number of stray animals are found grazing near roads.

CONCLUSIONS

The study shows that zinc, cadmium, and nickel at highest concentrations of 2.028 ppm, 0.058ppm,respectively and 0.402 ppm, respectively are low at current traffic densities of 3,571 vehicles per day. Trace element concentrations varied between seasons. A relatively high proportion of trace element was detected in the dry season than in the wet season. Roadsides have high concentrations of cadmium and lead as compared to areas further away from major roads. Lead and copper concentrations are high in the evaluated forages, to cattle and sheep respectively under current traffic density levels.

ACKNOWLEDGEMENTS

The authors are grateful for technical assistance of Mr.M. Ramocha of National Veterinary Laboratory (NVL),Gaborone and Mr. M.Mathaio of Botswana College of Agriculture,Gaborone.

REFERENCES

Brady, N.C. and Weil, R.R.,1996. The nature and properties of soils. Prentice –Hall International, Inc. London.

Central Statistics Office (CSO), 1999.Transport and Communications Statistics: 1998. Dept. of Printing and Publishing Services, Gaborone.

McDowell, L.R.,1985.Nutrition of grazing ruminants in warm climates. Animal feeding and nutrition. A series of monographs. Academic Press.Inc. Harcourt Brace Jovanovich Publishers.San Diego.

National Research Council (NRC),1980. Mineral Tolerance of Domestic Animals. Natl. Acad.Sci. Washington, D.C.

Netherlands Committee of mineral nutrition (NCMN), 1973. Tracing and treating mineral Disorders in dairy cattle. Centre for Agricultural Publication and documentation, Wageningen, The Netherlands.

Rothery E.,1996. SpectrAA – 10 and SpectrAA – 20 operation manual. Varian telhtron Pty. Ltd.

Sawyer, R.,1998. Attachment A: Summary of a workshop on metal based fuel additives. University of California, Berkeley. http://204.127.236.248/RFA/RFA.attachmentA.htm

Stebbings, R.S.J. and Lewis, G.,1984. Trace elements metabolism. Man. Anim.Proc. Int.Symp. 5th edition.pp.280.

Steel, R.G.D. & Torrie, J.H., 1980. Principles and Procedures of Statistics: A Biometrical approach. 2nd edition, Mc Graw-hill Publishing Company Incorporated, New York, USA.

Waalkes, N.C.,1998 . Attachment A: Summary of a workshop on metal based fuel additives. National Cancer Institute at NIEHS. http://204.127.236.248/RFA/RFA.attachment A.htm