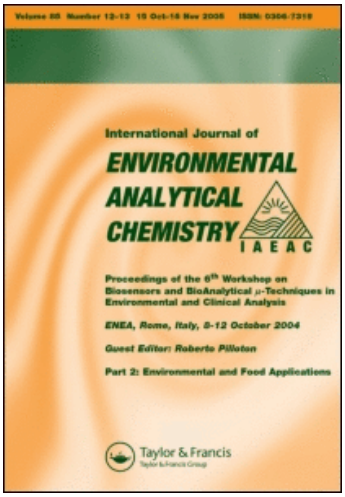
This article was downloaded by:
On: *18 January 2011*
Access details: *Access Details: Free Access*
Publisher *Taylor & Francis*
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



International Journal of Environmental Analytical Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713640455

An Assessment of Lead Pollution from Vehicle Emissions Along Selected Roadways in Harare (Zimbabwe)

S. D. Sithole[a]; N. Moyo[a]; M. Macheka[a]
[a] Department of Chemistry, University of Zimbabwe, Harare, Zimbabwe

To cite this Article Sithole, S. D. , Moyo, N. and Macheka, M.(1993) 'An Assessment of Lead Pollution from Vehicle Emissions Along Selected Roadways in Harare (Zimbabwe)', International Journal of Environmental Analytical Chemistry, 53: 1, 1 — 12
To link to this Article: DOI: 10.1080/03067319308045978
URL: http://dx.doi.org/10.1080/03067319308045978

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Intern. J. Environ. Anal. Chem., Vol. 53, pp. 1–12
Reprints available directly from the publisher
Photocopying permitted by license only

© 1993 Gordon and Breach Science Publishers S. A.
Printed in the United States of America

AN ASSESSMENT OF LEAD POLLUTION FROM VEHICLE EMISSIONS ALONG SELECTED ROADWAYS IN HARARE (ZIMBABWE)

S.D. SITHOLE*, N. MOYO and M. MACHEKA

Department of Chemistry, University of Zimbabwe, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe

(Received, 13 December 1991; in final form, 15 February 1993)

Downloaded At: 14:52 18 January 2011

Vehicle emissions where Pb containing gasoline is used contributes to toxic metal urban air pollution and is still a matter of concern. An assessment of the extent of roadside Pb pollution in Harare (Zimbabwe) was undertaken. Pb was measured in soil and vegetation roadside samples. For busy roads Pb levels in soil and vegetation indicated a significant level of Pb pollution in the environment nearby the road. The Pb levels at the kerb of busy roads (Simon Mazorodze Road) were 1480 and 23.3 $\mu g.g^{-1}$ in soil and vegetation, respectively, and the levels found for less busy roads (Mutare Road) were 404 and 8.0 $\mu g.g^{-1}$ in soil and vegetation samples respectively. The gradual phasing out of the level of Pb in leaded gasoline is suggested.

KEY WORDS: Lead, vehicle emissions, roadside pollution, soil, vegetation.

INTRODUCTION

The sources which discharge particulate trace metallic pollutants into the urban atmosphere are varied and numerous. These sources include industrial processes of smelting, metal recovery and refining, municipal waste incineration and emissions from automobiles that use leaded gasoline. The dispersion of air-borne metallic pollutants is dependent upon the particle size and the prevailing atmospheric conditions.

There is a relationship between levels of environmental pollution and health. The health hazard from exposure to lead from environmental and occupational sources has been adequately documented by WHO[1] and others[2,3]. Urban air pollution from toxic metals affects not only the health of the population but also the cities' amenities as pointed out by Archer and Barratt[4].

The control of air pollution in Harare falls under the jurisdiction of the Harare City Council (HCC). However, the work of the HCC, including the monitoring of urban air

*To whom correspondence should be addressed.

quality, is vast and requires support from other sectors of the community including industries for an effective air pollution control strategy.

Zimbabwe gasoline is imported and contains approximately 0.8 g $Pb.L^{-1}$ depending on the source. With an annual gasoline consumption of ca. 400 x 10^6L an estimated 320 x 10^3 kg Pb are emitted into the environment each year. This gasoline Pb level is higher than is permitted in Europe and USA which ranges between 0.15 – 0.4 $g.L^{-1}$. The trend in these countries is towards the use of unleaded gasoline.

Some of the lead emitted from automobiles is deposited in the vicinity of the roadway because of interception from vegetation and buildings. It is generally recognised[5–7] that in countries where leaded gasoline is used automobile emissions is one of the major contributors of lead pollution in urban areas. Consequently, there is still considerable concern for lead levels in urban environments in these areas.

There has been no measurement of lead accumulated in vegetation and soils alongside roads in Harare as indicators of lead urban air [pollution. However, between 1976–80 Siampsipa[8] carried out a study on the dispersal of heavy metal pollution in Harare. That investigation[8] concentrated on water coarse sediments and dust fall-out and to a limited extent on air samples.

The objective of this investigation was to estimate the extent of lead pollution along selected roadways in Harare through the use of lead levels in vegetation and soils as indicators of lead pollution from motor vehicles.

The study area was Harare, the largest and rapidly growing metropolitan city of Zimbabwe. It has an estimated population exceeding one million. It is, therefore, necessary to evaluate the extent of urban lead pollution in the city. This information, and that to be obtained on the various sources of metal pollution, is of considerable importance to those concerned with pollution control and the development of the city.

Downloaded At: 14:52 18 January 2011

EXPERIMENTAL

Relative traffic densities

Three representative major roads in Harare were selected to cover both residential and industrial areas. The Department of Works of HCC conducts periodic vehicle counts at selected road intersections to determine the necessity of installing traffic lights. The field countings are carried out by traffic enumerators. Each enumerator is assigned an approach at an intersection or T-junction and counts vehicles arriving on his side. The enumerators use mechanical tally counters (MTC) to count straight going, left and right turning vehicles. There are four enumerators at an intersection with three MTCs and three at a T-junction. An enumerator only counts vehicles approaching his side. The counting is done three times a day giving morning, lunch and afternoon peak counts. The traffic census data, and the dates of the counts, are shown in Table 1. The relative traffic densities decreases in the order of Simon Mazorodze, Hatfield and Mutare roads.

Table 1 Relative traffic densities of selected roads in Harare.

Simon Mazorodze Rd		*Hatfield Road*		*Mutare Road*	
Intersection (date)	*Total Counts*	*Intersection (date)*	*Total Counts*	*Intersection (date)*	*Total Counts*
Paisley Road (09:04:91)	8809	Cripps Road (03:03:90)	5355	Harare Drive (11:04:90)	1820
Hobbs Rd (06:07:90)	7868	Boshoff Rd (16:04:91)	4331	Samora Michael Ave[a] (13:08:90)	3621
Willowvale Rd	3705				

(a) Ave stands for Avenue.

Instrumentation

A Varian model AA 1275 series atomic absorption spectrophotometer (AAS) equipped with a single slot burner and a built-in digital read-out was used. The instrument has permanent programmes for data handling controlled by a microprocessor. The instrumental operating conditions that were used are shown in Table 2.

Downloaded At: 14:52 18 January 2011

Sampling sites

Three major roads representing both residential and industrial areas of Harare were selected. The sampling sites were selected so that both soil and vegetation samples could be obtained from the same site to facilitate data correlation.

The first site is about 5.2 km from the city centre along Simon Mazorodze road, a heavily used road with a dual two carriageway, and runs southwards from the city centre. It runs across a mixed residential, and light industrial, area. The sampling site is near Chitsere School which is situated in a densely populated suburb of Mbare.

The second site is about 5 km from the city centre along Hatfield Road. The site is near Sunningdale No.1 School which is adjacent to the road. The road runs south-eastwards from the city centre and there are no major roads in the vicinity. This site is located in a predominantly residential area.

Table 2 AAS operating conditions for the determination of lead in environmental samples.

Parameter	*Condition*
Atomisation	Flame
Lamp Current	7.5 mA
Wavelength	283.3 nm
Atomiser	Air – C_2H_2
Oxidant (air)	1.7 kg. cm^{-2}
Fuel (C_2H_2)	0.3 kg. cm^{-2}
Burner Height	10 mm
Background correction	Deuterium arc lamp

The third site is about 12 km from the city centre along Mutare Road. It is a two lane road running east to west. There is neither a residential nor industrial area in the vicinity and, therefore, it is far away from any possible source of lead pollution except for automobile emissions. The results from this site, therefore, should reflect lead pollution from vehicle emissions and background lead levels in the samples.

Sample collection

Soil and vegetation samples were collected from the sites described above between January-May. Soil samples were collected at 1–2 m intervals in the windward direction. At each sampling location about 1 m square, 5–7 individual subsamples of top soil, about 1.0 cm deep, were randomly collected from the segments in each square and then recombined to give a composite sample mixture. One bulk sample obtained from each location was placed in a polyethylene bag. Large stones, dead leaves and debris and other extraneous substances were excluded. For Hatfield and Mutare Roads the furthest sampling distances were 25 and 22 m, respectively. The second and third sampling locations on the Mutare Road were on an uneven ground. It was only possible to sample as far outward as 10 m on Simon Mazorodze Road due to the presence of the surrounding industry.

For vegetation samples two evergreen plant species *Julbernardia globiflora* and *Parinari curatellifolia* were each sampled from the site on Mutare Road.

Approximately, 10–20 g of both young and old leaves were plucked from each plant type going outward from the road in the windward direction. Samples were obtained from plants of about the same age. The average height of the sampled plants was about 70–95 cm. The leaves were plucked from the top 40 cm taking into account procedures described by Berrow[9] on the sampling of plants and soil for trace metal analyses. The subsamples from each plant were combined into a composite sample. The bulk samples were then placed in properly labelled polyethylene bags taking the necessary precautions to avoid contamination from dust. Since the first 5 m on either side of the local roads are normally cleared of vegetation by the Department of Roads, the first sampling point was about 5 m away from the road. For Mutare Road sampling was extended to 50 m.

There were no suitable sampling sites for vegetation along Simon Mazorodze Road except for a species of grass; *Cynodon dactylon*. This species was ultimately sampled from 1 m squares at 1–2 m intervals. The grass was cut from just above the ground level and then placed in properly labelled polyethylene bags.

Reagents

All reagents used were of analytical grade. Lead nitrate was used to prepare a stock solution of 1000 mg $Pb.L^{-1}$ in deionised water. Standard Pb solutions were prepared by serial dilution. Glassware was soaked in diluted HNO_3 for 4 h prior to use and then rinsed with deionised water. Aqua-regia solution was prepared by mixing concentrated solutions of HCl and HNO_3 in a 3:1 ratio. The specific gravities of HCl, HNO_3 and 70% $HClO_4$ used were 1.18, 1.42 and 1.66 $g.mL^{-1}$ respectively.

Downloaded At: 14:52 18 January 2011

Sample preparation and analysis

Soil samples were first air dried at 25–30°C and sieved through a 2 mm sieve. The sieved sample was thoroughly mixed, coned and quartered and 10–20 g were ground in a pestle and mortar to a size less than 200 μm and then stored in glass bottles.

About 1–3 g of soil that had been brought to constant weight in an oven at 110°C was weighed into a flask, and 10 mL of deionised H_2O was added to form a slurry, and then 7.5 mL of 6 M HCl and 2.5 mL of concentrated HNO_3 were added per gramme of sample. The flask was covered and allowed to digest for 4 h. The flask was then heated and maintained at 180°C. Additional digestion solution was added as necessary. The solution was allowed to cool and then filtered into a 50 mL volumetric flask and diluted to the volume with 2 M HNO_3. The method of standard additions was used to quantify the Pb levels in the samples.

The vegetation samples were sun dried first and then brought to constant weight in an oven at 110°C. They were then ground to uniform size. A 2–4 g-sample size was weighed into a flask and 21 mL of a 6:1 mixture of concentrated HNO_3 and 70% $HClO_4$ per gramme of sample were added. The mixture was gently heated to 70–80°C until most of the sample had dissolved. The temperature was then raised to 140–150°C to achieve complete dissolution. The latter step was repeated after the addition of further digestion mixture where dissolution was not complete. The final solution was made up to 50 mL. Each sample was then subjected to the method of standard additions. The concentration of Pb was expressed as $\mu g.g^{-1}$.

Downloaded At: 14:52 18 January 2011

RESULTS AND DISCUSSION

The data for the relative traffic densities shown in Table 1 indicate that Simon Mazorodze is the busiest road, followed by Hatfield and Mutare Roads, in that order. Simon Mazorodze Road is also the busiest road in the city and yet it runs through a mixed industrial and a densely populated old-style suburb of Mbare. The location of this road contributes to Pb

Table 3 Lead levels in soil samples alongside selected roadways in Harare as a function of distance.

Mutare Rd		*Hatfield Rd*		*Simon Marozodze Rd*	
Distance[a] *m*	*Pb*[b] $\mu g.g^{-1}$	*Distance m*	*Pb* $\mu g.g^{-1}$	*Distance m*	*Pb* $\mu g.g^{-1}$
1.6	320 ± 16.0	1.0	1216 ± 36.5	0.6	1312 ± 39.4
5.6	384 ± 19.2	2.7	488 ± 24.4	1.0	1200 ± 36.0
7.6	456 ± 22.8	5.3	408 ± 20.4	1.8	1152 ± 34.6
8.0	180 ± 9.0	7.3	288 ± 14.4	2.4	664 ± 33.0
9.4	120 ± 6.0	11.6	258 ± 12.9	3.5	720 ± 33.1
13.4	78 ± 4.7	18.2	360 ± 14.4	4.4	640 ± 32.4
15.4	80 ± 4.8	20.5	184 ± 9.2	5.4	668 ± 23.4
17.2	32 ± 2.2	26.1	176 ± 8.8	6.5	456 ± 22.8
19.0	30 ± 2.4	30.0	159 ± 8.1	7.6	276 ± 13.8
22.1	8 ± 0.6				

(a) Distance is measured from the end of the tarmac. (b) Values are reported as the mean of three replicate samples ± standard deviation.

pollution in Mbare. The problem can only be expected to accentuate with time and, therefore, requires monitoring.

Table 3 presents data on Pb levels in soils taken from the vicinity of three roads. These results were plotted in Figures 1 and 2. From Figure 1 it is clear that the amount of Pb deposited alongside both Hatfield and Mutare Roads peaks at the edge of the road and decreases sharply within the first 12 m from the road before falling-off to an asymptote. For both roads most of the Pb deposited onto the soil is found within the first 10–20 m. Lead levels at distances greater than 20 m indicated a general uniform concentration except for the natural variation in the soil. Lead is introduced into the roadside environment as a result of exhaust emission. It then settles on soil and plants. Since the emissions from vehicles are discharged from low level source the extent of roadside Pb pollution in the soil does not extend to great distances.

The decreasing trend in Pb levels in soil as a function of distance from the roadway is in agreement with the results of Skogerboe *et al.*[10] where they found out that the soil Pb levels along an interstate highway levelled off at a distance of 10 m from the edge of the highway. In an extensive review by Scanlon[11] on highway pollution it was found that significant Pb contamination exists up to 50 m from the edges of the road and decreases with distance. Little and Wiffen[12], who measured Pb concentrations in both air, soil and standing grass along the M4 and M40 motorways in London, showed that within a roadside ecosystem there is a gradient of Pb levels in air, soil and grass related to the distance from the road.

The general background levels found for Hatfield and Mutare Roads were 160 and 22 $\mu g.g^{-1}$, respectively, whereas, at the edges of the two roads the levels were 608 and 404 $\mu g.g^{-1}$, respectively, suggesting a level of Pb pollution.

Simon Mazorodze Road (Figure 2) presents a situation where there is a relatively high Pb concentration of 1480 $\mu g.g^{-1}$ at the edge of the road and an extrapolated background level of 160 $\mu g.g^{-1}$. The soil along this road is significantly more polluted than in the other two. This trend is consistent with the traffic census data (Table 1).

The extent of Pb pollution in the vicinity of the road is related to the amount of Pb in gasoline, the age of the car and other factors, as reported by Nriagu[13] who documented the trend in the consumption of leaded gasoline which peaked in 1965–75, and has been declining since then. Byrd[14] *et al.* provided evidence for a decrease in soil Pb levels since the mandatory use of unleaded gasoline in the USA.

The results of Pb levels in vegetation were entered in Table 4 and these were plotted in Figures 3, 4 and 5. The trend of decreasing Pb levels with distance (Figures 3, 4 and 5) in vegetation is similar to that found in soil samples. This agrees with the results of Iqbal *et al.*[5] who found that for a plant species, *Diospyros embryopteris*, Pb levels decreased with increasing distance. The background Pb levels in the plant types, *Julbernardia globiflora* and *Parinari curatellifolia* were 1.2 and 1.0 $\mu g.g^{-1}$, respectively, and the levels near the edges of the road in the same plants were 13.7 and 8.0 $\mu g.g^{-1}$, respectively, which also suggests some level of Pb pollution.

In Figure 5, Simon Mazorodze Road, the graph initially falls-off sharply before becoming an asymptote at 5 m. The background Pb level was 3.0 $\mu g.g^{-1}$ and an extrapolated value of 23.3 $\mu g.g^{-1}$ for the plant type:; *Cynodon dactylon*. The Pb levels found in different plant types in this study are comparable with the values of 2.0–6.0 $\mu g.g^{-1}$ reported by Valerio *et al*[6].

Downloaded At: 14:52 18 January 2011

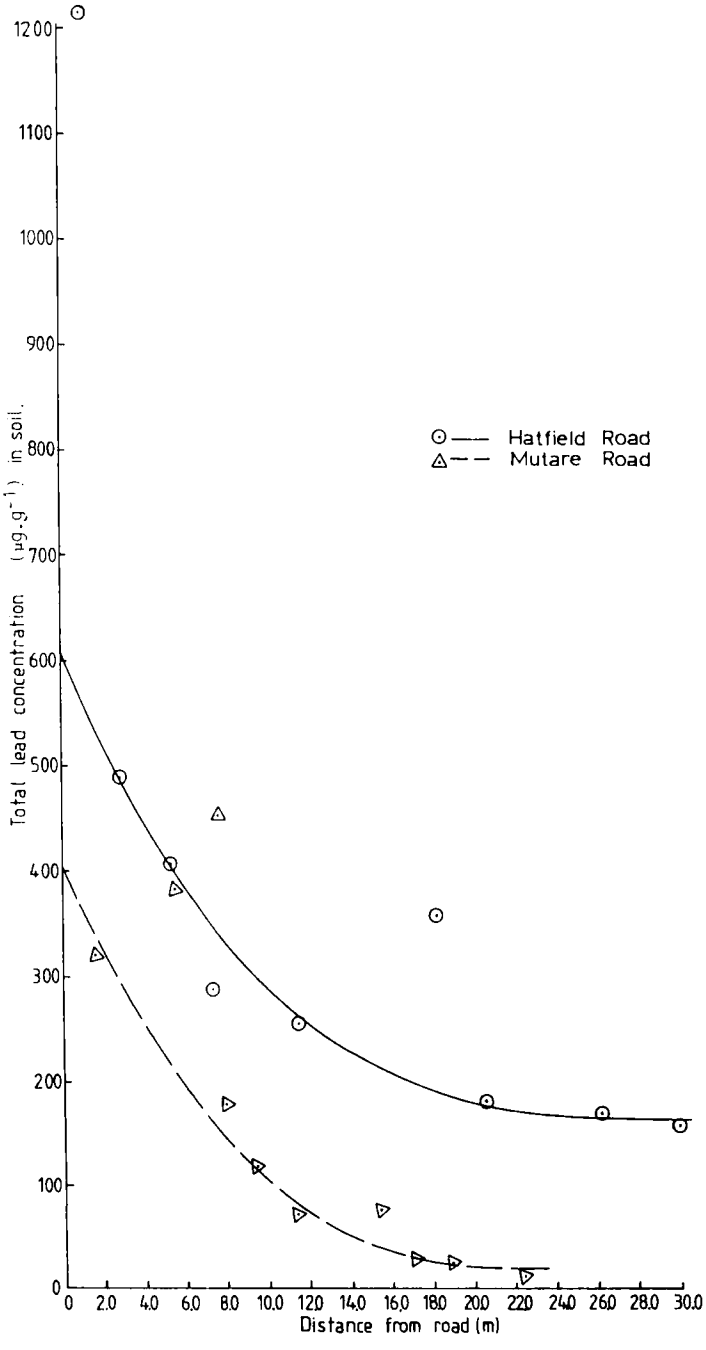


Figure 1 Lead content of soil as a function of distance from road.

Downloaded At: 14:52 18 January 2011

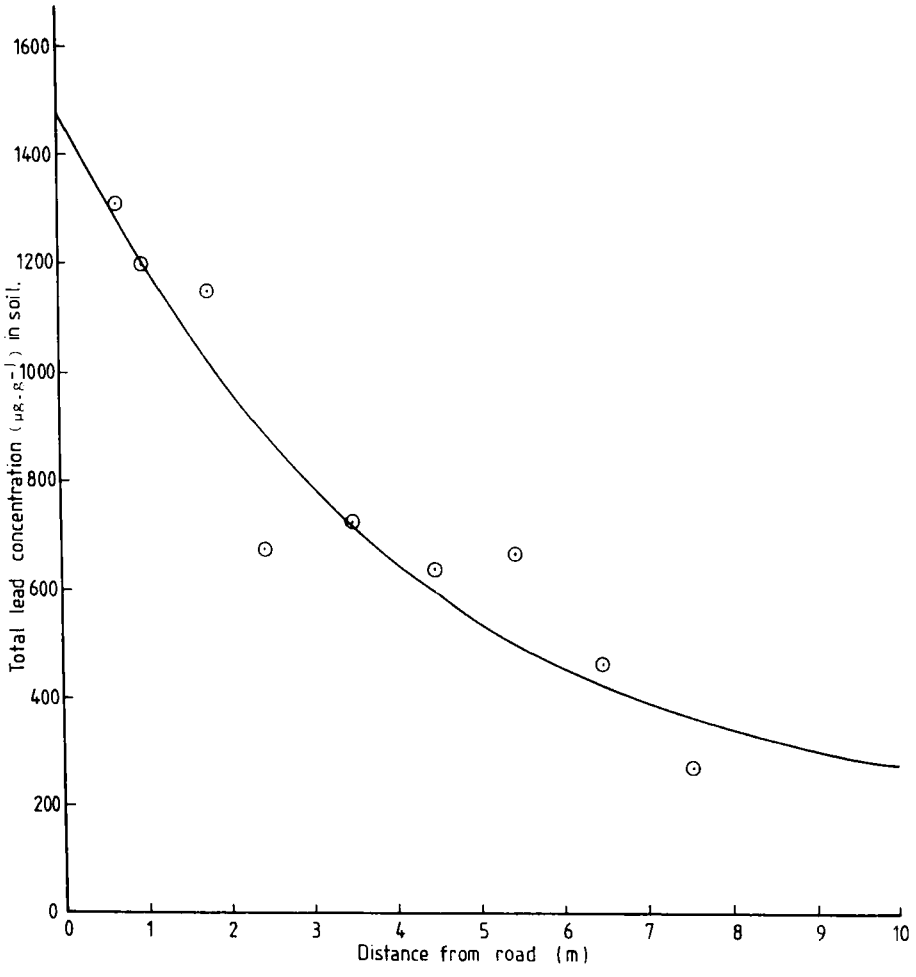


Figure 2 Lead content in soil as a function of distance from road. (Simon Mazorodze)

CONCLUSION

In both soil and vegetation samples a rapid decrease in Pb levels, with increasing distance from the road, was observed, and there is significant Pb pollution at distances close to the busy roadways, such as Simon Mazorodze Road. It is, therefore, suggested that thriving market gardening, usually found near roadways, should be restricted to distances not closer than 40–50 m to the road. It is also time that measures are taken to reduce this wilful Pb pollution from vehicle emissions by gradual phasing out Pb in gasoline, as has been done in Europe and North America.

Downloaded At: 14:52 18 January 2011

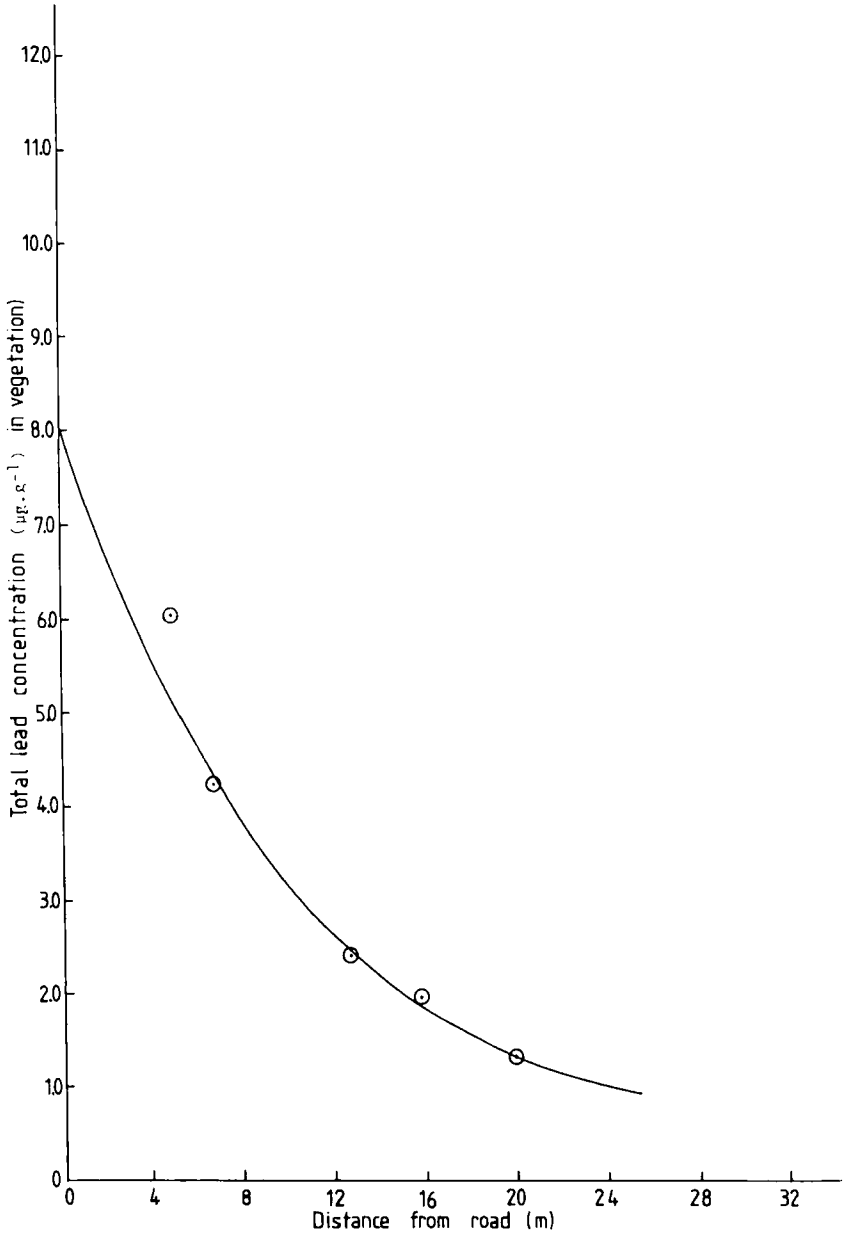


Figure 3 Lead content in vegetation (*Parinari curatellifolia*) as a function of distance from the road. (Mutare Road)

Downloaded At: 14:52 18 January 2011

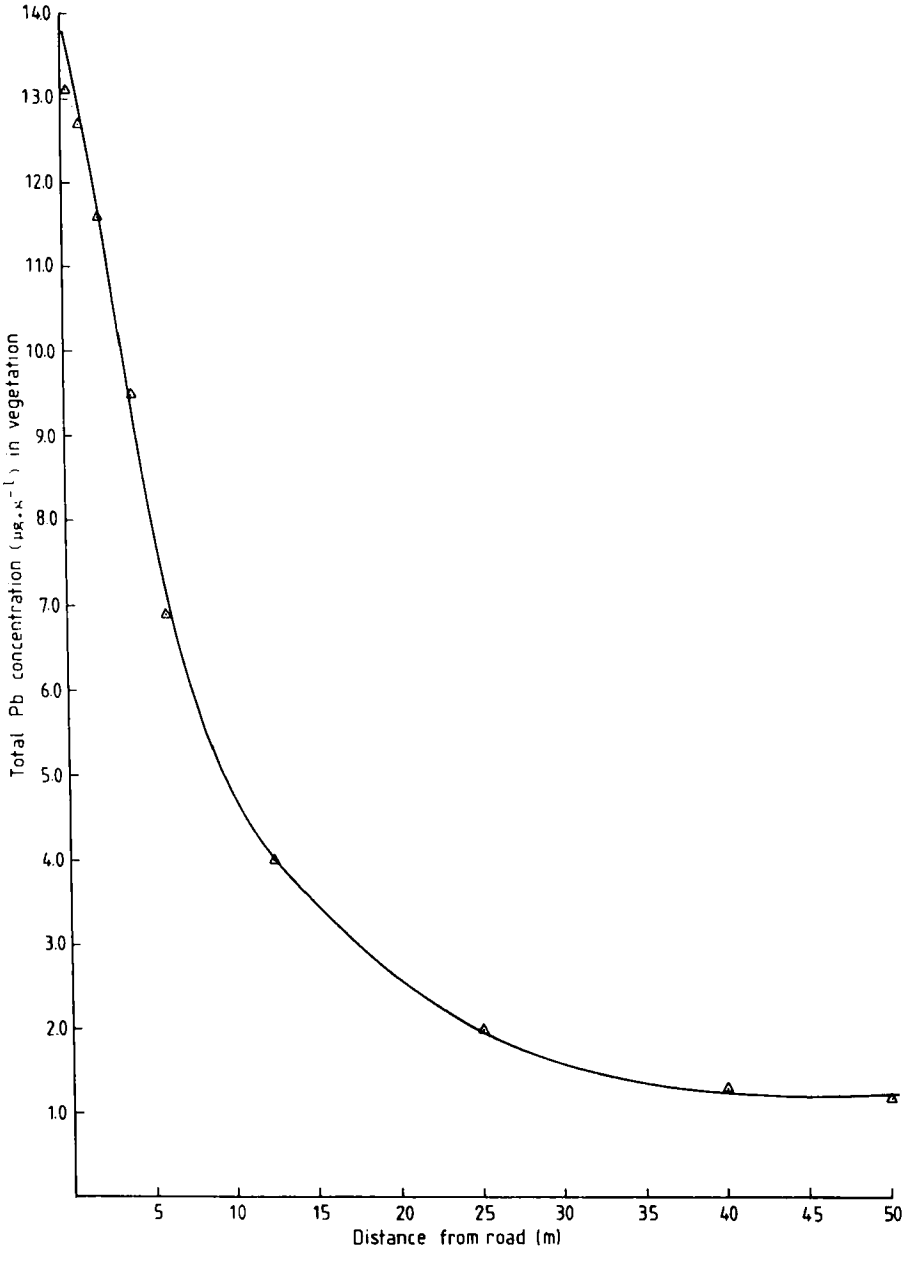


Figure 4 Lead content in vegetation (*Julbernardia globiflora*) as a function of distance from road. (Mutare Road)

Downloaded At: 14:52 18 January 2011

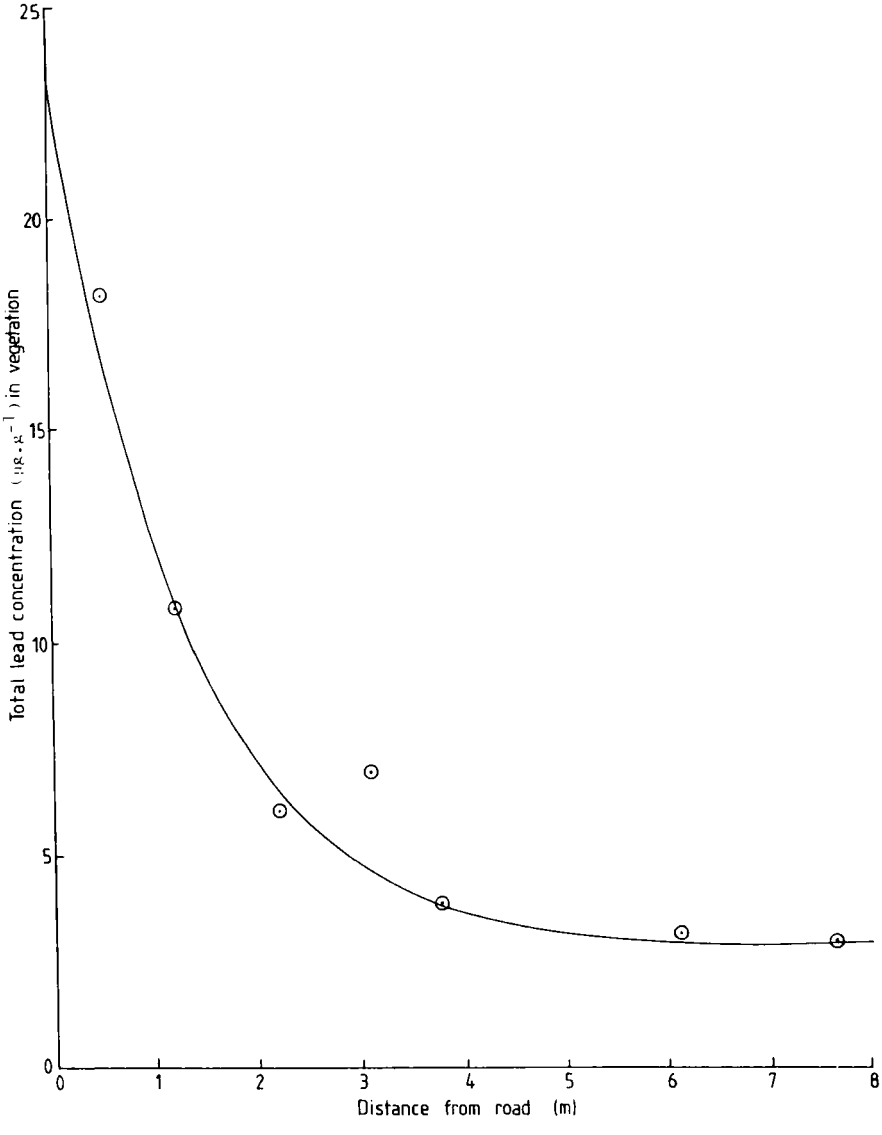


Figure 5 Lead content in vegetation (*Cynodon dactylon*) as a function of distance from road. (Simon Mazorodze)

Downloaded At: 14:52 18 January 2011

Table 4 Lead levels in vegetation samples along side selected roadways in Harare as a function of distance.

Mutare Rd				*Simon Marozodze Rd*	
Plant Type A[(a)]		*Plant Type B*[(b)]		*Plant Type C*[(c)]	
Distance[(a)] *m*	*Pb*[(d)] $\mu g.g^{-1}$	*Distance m*	*Pb* $\mu g.g^{-1}$	*Distance m*	*Pb* $\mu g.g^{-1}$
0.2	13.1 ± 1.03	5.0	6.0 ± 0.60	0.54	18.3 ± 1.5
1.0	12.7 ± 1.02	6.7	4.2 ± 0.50	1.20	10.1 ± 1.0
2.0	11.6 ± 0.93	12.7	2.4 ± 0.29	2.20	6.1 ± 0.67
4.0	9.5 ± 0.77	15.8	1.9 ± 0.23	3.12	7.0 ± 0.77
6.0	6.9 ± 0.59	20.0	1.3 ± 0.16	3.75	3.9 ± 0.50
12.5	4.0 ± 0.36	23.0	N.D.[(e)]	6.12	3.2 ± 0.38
25.0	2.0 ± 0.22	–	–	7.64	3.1 ± 0.38
40.0	1.3 ± 0.17	–	–	–	–
50.0	1.2 ± 0.17	–	–	–	–

(a) The botanical name is *Julbernardia globiflora*. (b) The botanical name is *Parinari curatellifolia*. (c) The botanical name is *Cynodon dactylon*. (d) Values are reported as mean of three replicate samples. (e) N.D. means not detected at the limit of detection of 0.02 $mg.L^{-1}$.

Downloaded At: 14:52 18 January 2011

Acknowledgements

Mr. Tongai Mahachi, Director of the Department of Works and Mr. Motsi of the Traffic and Transportation Section of the Harare City Council are acknowledged for providing the traffic census data. The technical staff of the Organic Section, U.Z. provided technical assistance, Dr. M. F. Zaranyika for ideas and initial helpful discussions. To all these we are very grateful.

The funding for the investigation was provided in part by the University Research Board Grant No.2–9999–10/3461 and by SAREC.

References

1. WHO, *Environmental Health Criteria 3, Lead* (UNEP-WHO, Geneva, 1977) Chapters 8–9.
2. R. L. Boeckx, *Anal.Chem.*, **58,** 274A–287A (1986).
3. J. E. Fielding and P. K. Russo, *New England J. Med.*, **297** (17), 943–944 (1977).
4. A. Archer and R. S. Barratt, *Sci. Total Environ.*, **6,** 275–286 (1976).
5. M. Z. Iqbal and M. A. Qadir, *Intern. J. Environ. Anal. Chem.*, **38,** 533–538 (1990).
6. F. Valerio, C. Brescianini, L. Lastoraioli and S. Coccia, *Intern. J. Environ. Anal. Chem.*, **37,** 245–251 (1989).
7. R. S. Barratt, *Intern. J. Environ. Anal. Chem.*, **40,** 77–97 (1990).
8. F. Siamsipa in Ninth Annual Report, Report No. 26, K. A. Viewing, Institute of Mining Research, University of Zimbabwe, Harare (1978) pp57–60, Project 127 and the subsequent Tenth Report of 1979.
9. M. L. Berrow, *Anal. Proceed.*, **25,** 116–118 (1988).
10. J. L. Seeley, D. Dick, J. H. Arvik, R. I. Zimdahl and R. K. Skogerboe, *Appl. Spectrosc.* **26,** 456–460 (1974).
11. P. F. Scanlon, in *Highway Pollution*, (R. S. Hamilton and R. M. Harrison, Editors, Elsevier, Amsterdam, 1991) Chapter 8, pp. 281–288.
12. P. Little and R. D. Wiffen, *Atmospheric Environ.*, **12,** 1331–1341 (1978).
13. J. O. Nriagu, *Sci. Total Environ.*, **92,** 13–28 (1990).
14. D. S. Byrd, J. T. Gilmore, R. H. Lee, *Environ. Sci. Technol.* **17,** 121–123 (1983).