Bull. Environ. Contam. Toxicol. (1991) 46:782-789

Bulletin of Environmental Contamination and Toxicology

Lead Contamination in Street Soils of Nairobi City and Mombasa Island, Kenya

John Mmari Onyari, S. O. Wandiga, G. K. Njenga, and J. O. Nyatebe

Department of Chemistry, College of Biological and Physical Sciences, University of Nairobi, P.O. Box 30197, Nairobi, Kenya

The advent of modern industrialization and in particular, the motor vehicle, has witnessed dramatic increases in lead usage both as a component of lead-acid storage battery and from 1923 as organic lead alkyl 'anti-knock' additive in petroleum (Ratcliffe 1981). Rodrigues and Castellon (1982) reported the average content of lead in gasoline to be 0.19 g/l and estimated that 70 -80% of the gasoline lead content is emitted to the atmosphere in automobile exhaust fumes. Several workers have established a correlation between increasing lead concentration in roadside soils and vehicular traffic density (Page et al. 1971; Ndiokwere 1984; Yassoglou et al. 1987; Ho and Tai 1988).A wide range of metabolic disorders and neuro-psychological deficits have been associated with environmental exposure to low levels of lead (NAS 1980; EPA 1986; Nriagu 1988). Nriagu (1988) observed that many of the biochemical and neurological changes associated with lead toxicity have been reported at lead blood concentrations as low as 60 mg/l. The threshold for possible medical intervention has been set at 250-300 mg/l (CDC 1985). Of particular concern, lead-contaminated soil may significantly contribute to childrens' risk of blood lead and blood lead levels have been reported for children in Boston, Idaho, Nebraska, New York, Holland and New Zealand (Rabinowitz and Bellinger 1988). Although Onyari and Wandiga (1989) studied the heavy metal content in Lake Victoria sediments, no urban roadside soils were investigated. Since lead is used as a petrol additive in Kenya, it is necessary to document the extent and magnitude of lead contamination of roadside soils in inland and coastal urban environments and evaluate its environmental implications.

MATERIALS AND METHODS

Forty three sites were selected for study from Nairobi City and Mombasa Island as illustrated in Figures 2 to 4.

Send reprint requests to Onyari at above address

A total of 77 samples were collected from the various sites between August and December 1989, so as to cover a wide range of traffic density loads. Also, roadside soils were collected along transects perpendicular to 'Mombasa' and 'Thika' highways at 10 meter intervals starting from the road curb up to 150 meters. Samples were scooped from the top surface of the soil layer (0-2 cm) using a stainless steel spoon. The samples were sifted through a 1-mm plastic sieve, dried in an oven at 105°C for 24 hrs, then crushed and pulverized using an agate mortar. For analysis, the procedure described by Onyari and Wandiga (1989) was used. Two samples from each site weighing two grams each were accurately weighed into digestion tubes, treated with 20 ml of 18 M hydrochloric acid and digested for 3 hours at 100°C in an aluminium heating block. After digestion, 2 ml of 30% H_2O_2 were added to oxidize resistant organic matter. The digests were filtered through Whatman No.1 filter paper and diluted with deionized water to a final volume of 50 ml. A Perkin Elmer Atomic Absorption Spectrometer (AAS) model 2380 was used for analysis of the samples, after preparation of appropriate calibration standards of lead. The reproducibility of the analytical procedure determined by 10 replicate analysis of a selected soil sample yielded good agreement.

Validation of the procedure was evaluated by comparative analysis of a roadside soil sample, using two independent analytical techniques, AAS and Energy Dispersive X-Ray Fluorescence (EDXRF). For the XRF analysis, the soil samples were initially ground to a fine powder using an agate mortar, followed by a fritsch pulverisette type 120, to reduce the size to approximately 50 microns. The soil sample and pure starch were accurately weighed in the ratio 1:2 and thoroughly mixed to ensure homogeneity. An approximate amount of 150-200 mg of the mixture was pressed to obtain five thin pellets of diameter 2.5 cm with the use of a hydraulic press at a pressure of 2 - 3 kilobars.

Finally, each pellet was enclosed in a thin transparent plastic and placed in spectral caps and irradiated using ^{109}Cd (22.6 Kev K_α X-rays) for 1000-2000 seconds. Using a multi-element pellet sample, standard calibration curves were obtained from which absorption correction parameter (apd) values were obtained. These were then used for the calculation of the concentration of each element, using the fundamental parameter technique described by Mangalla (1987).

RESULTS AND DISCUSSION

The typical EDXRF spectra obtained for Nyali Bridge roadside soil, shown in Figure 1, demonstrates the presence of K, Ca, Cr, Mn, Fe, Zn, Ga, Br, Rb, Sr, y, Zr,

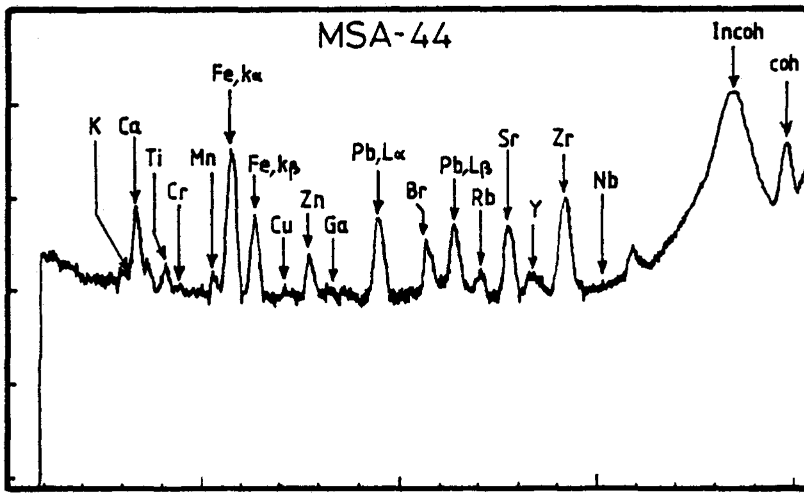


Figure 1. Typical EDXRF spectra for Nyali Bridge (msa44) soil sample.

Nb and Pb. The data in Table 1 illustrate the good agreement obtained between the two independent techniques AAS and EDXRF, attesting to good accuracy. The coefficient of variation, which served as a measure of

Table 1. Comparative analysis of Nyali Bridge soil

Analytical method	Mean lead concentration(mg/kg)	Coefficient of variation(%)
AAS	950 ± 13	1.37
EDXRF	945 ± 30	3.17

precision, ranged from 1.4 to 3.2% demonstrating good precision. The analysis of variance revealed statistically significant differences among the mean lead concentrations from the different sites represented in Figures 2 to 4. The mean lead content in Mombasa Island roadside soils ranged from 23 to 950 mg/kg, as illustrated in Figure 2.

Lead concentrations within Nairobi City (Zone A) varied from 137 - 2196 mg/kg (mean 659) (Figure 3) compared to 148 - 4088 mg/kg (mean 624) in the industrial area (Zone B) region (Figure 4). Generally, a trend of higher lead content was observed in Zone A as compared to Zone B. The city center region generally has a much higher motor vehicle traffic density. Roundabout junctions, bus stations and other areas of the city characterized by traffic jams show high lead values (sites N1, N3, N5, N6, N8 and N17).

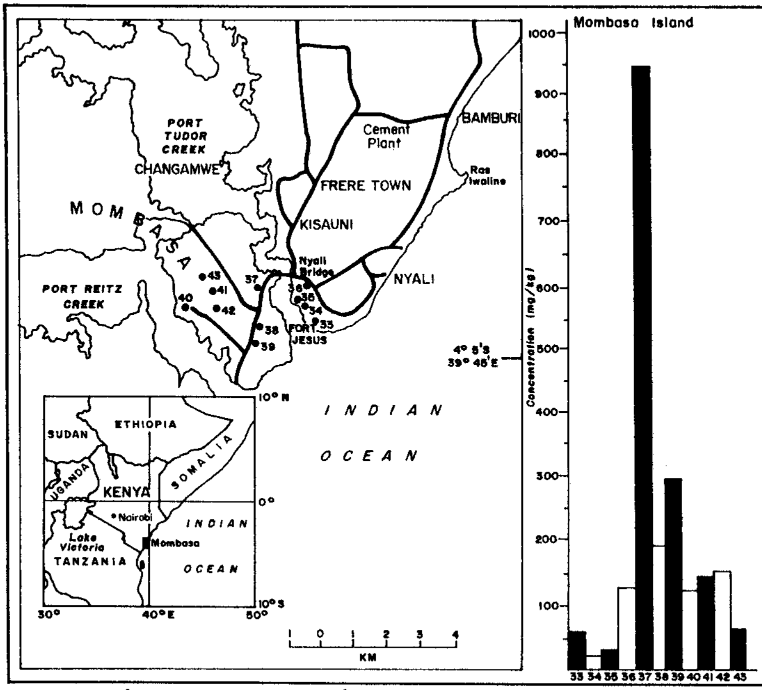


Figure 2. Histogram showing the mean concentration of lead (mg/kg dry weight) in various study locations.

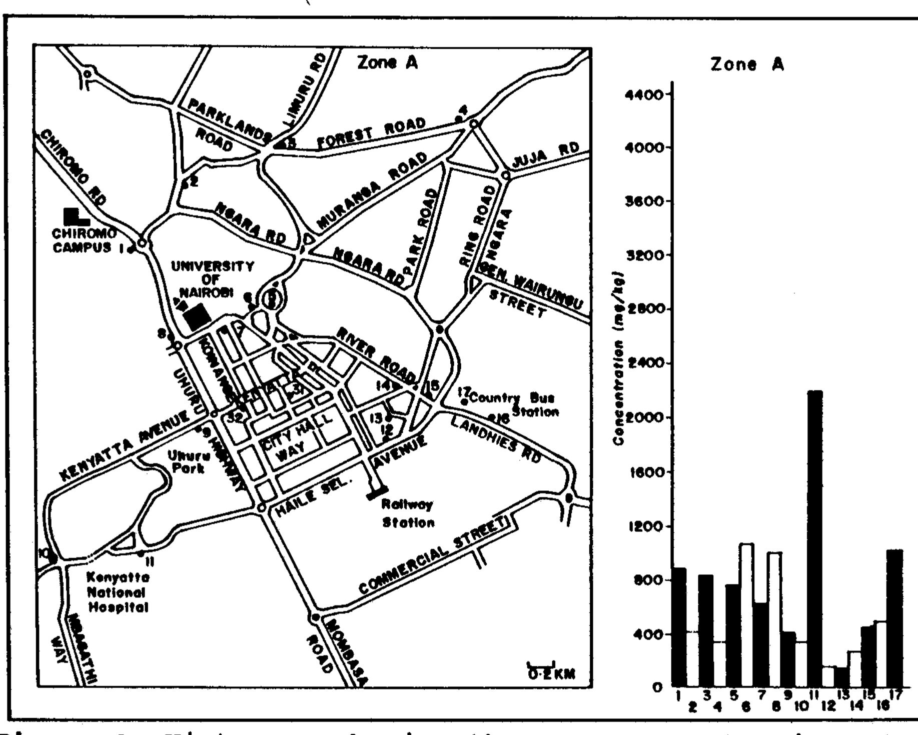


Figure 3. Histogram showing the mean concentration of lead (mg/kg) in various study locations in Nairobi City.

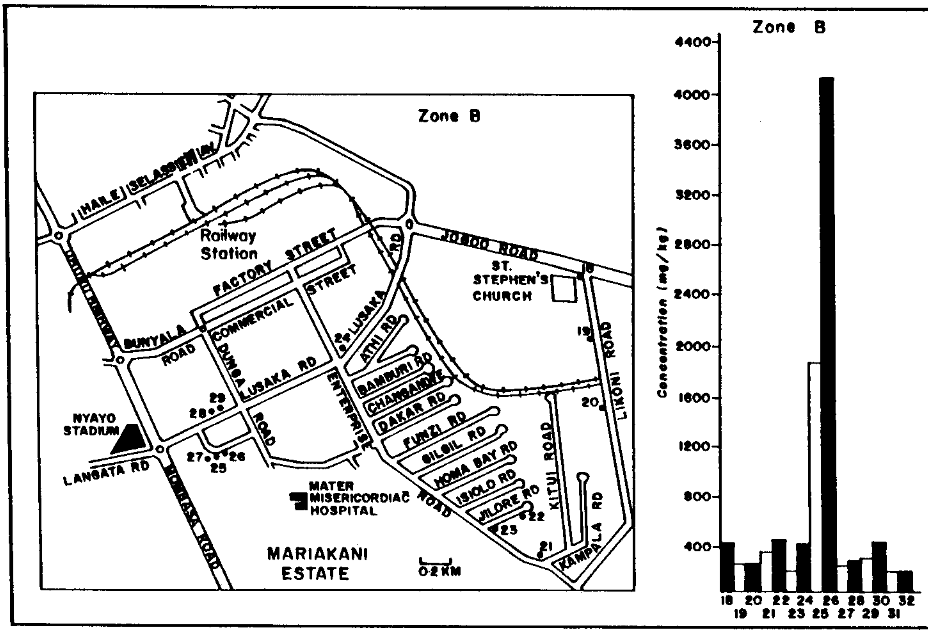
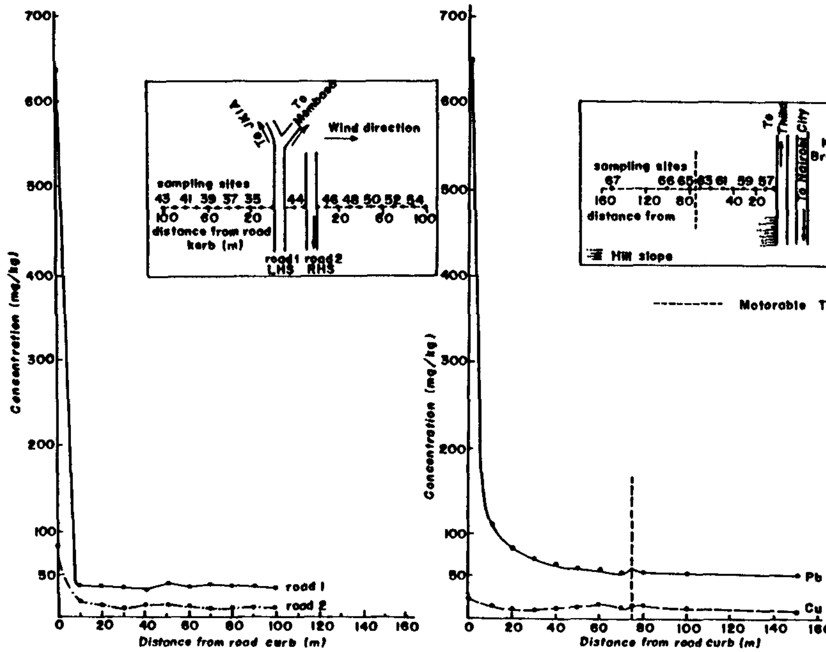


Figure 4. Histogram showing the mean concentration of lead (mg/kg) in various study locations in industrial area (Zone B)

Several workers have demonstrated that the amount of lead emitted as a percentage of lead consumed increases as the vehicle speed increases (Hirschler & Gilbert 1964; Habibi 1970). In our study, a high lead content of 2196 ± 112 mg/kg was obtained at Nairobi hill region (site N11). This is explained by acceleration of motor vehicles due to the steep nature of the hill, as well as the dense traffic volume. High lead values of 1829 ± 556 and 4088 ± 1014 mg/kg were obtained at sampling sites N25 and N26 (Figure 4), respectively, both located near a garage forecourt, which specializes in repair of car radiators, that contain lead alloys.

The lead distribution profiles shown in Figures 5 and 6 demonstrate that lead contamination levels of surface soil drops rapidly with distance from the road curb. In the studies of Ndiokwere (1984), Yassoglou et al (1987), Ho and Tai (1988), similar results were reported. The influence of wind direction on lead fallout is illustrated in Figure 5. It is, therefore, evident from this study that wind direction affects the aerodynamics of dispersion of atmospheric pollutants.

A summary of global comparison of lead content is given in Table 2. Taking into account the elevated lead content



Figures 5 and 6. Relationship between total surface lead and distance from the highway

pattern in urban soil samples in Kenya, established air-blood relationships (Ratcliffe 1981), soil-blood relationships (Rabinowitz & Bellinger 1988) and general epidemiological surveys of blood lead levels, the implications for lead pollution control are clear.

Nriagu (1988) evaluated the role of trace metals as confounding factors in diseases such as cardiovascular ailments, reproductive impairments, immune suppression and allergies and cancer. According to EPA (1986), lead is associated with a wide range of negative pregnancy outcomes including early membrane rupture, low birth weight, spontaneous abortion, complications during pregnancy, increased prenatal mortality, inhibited postnatal growth and development. It is evident from the current study that lead levels in urban soils in Kenya are already too high and city dwellers are currently exposed to high lead burden in some cases. Of major concern is the established link between soil lead-blood and air lead-blood lead relationships and associated undesirable adverse health effects. EPA (1986) animal studies revealed a strong positive correlation between hypertension and exposure to low lead doses over

Table 2. Global comparison of lead content (mg/kg, dry weight) in dust (d) and soils (s).

Study Location	Lead content	Comments	Reference
Mombasa Island	23 - 950	soil	present study
Nairobi (Zone A)	137 - 2196	city center	"
Nairobi (Zone B)	148 - 4088	industrial area	"
'Mombasa' highway	7 - 630		"
'Thika' highway	52 - 649		"
Lancaster U.K.	950-51,900(d)	car park	Harrison(1979)
Lancaster U.K.	410-870(d)	rural roads	Harrison(1979)
Major highways and tunnels(U.S)	10,000-20,000	soil	EPA (1973).
New Haven, CT	30-7,000	soil	Rabinowitz & Bellinger (1988)
Kellogg, ID	50-24,600	Soil	"

relatively long periods. In addition, Ratcliffe (1981) summarized the results of studies on differences in blood lead levels and standard intelligence tests such as IQ scores. The majority of these studies reported lower IQ scores among their higher lead blood subjects. Such studies have awakened many environmentalists towards a lead-free environment. The European community has directed that all cars must be able to run on unleaded gasoline from October 1990. Similar drives towards unleaded gasoline have been implemented by Japan and the U.S. Considering the enormous non-monetary benefits of reducing human exposure to lead, it is suggested that Kenya, along with other countries, should legislate for use of unleaded gasoline.

Acknowledgments. Supported by chemistry department funds. Thanks to Prof. El-Busaidy AHS, Ms Mercy Kamau, Mr. Mangalla MJ and Mr. Kinyua AM for their contributions. EDXRF analysis was done at the Center for Nuclear Science Studies. Thanks to Dr. Kithinji JP and Ms Hilda Munyua for their suggestions and typesetting of the manuscript.

REFERENCES

CDC (1985) Preventing lead poisoning in young children. A statement by the Center for Disease Control, US Dept of Health and Human Services, Atlanta, Georgia, January.

EPA (1973) EPA's position on the health implications of air borne lead, Washington DC. Nov.28

EPA (1986) Air quality control document for lead. Environmental Criteria and Assessment Office, US Environmental Protection Agency, Research Triangle Park, North Carolina

Habibi K (1970) Characterization of particulate lead in vehicle exhaust-experimental techniques. Environ Sci Technol, 4:239-48

Harrison RM (1979) Toxic metals in street and household dusts. Sci Total Environ 11:89-97

Hirschler AA, Gilbert LF (1964) Nature of Pb in automobile exhaust. Arch Environ Health 8:297-313

Ho YB, Tai KM (1988) Elevated levels of lead and other metals in roadside soil and grass and their use to monitor aerial metal depositions in Hong Kong. Environ Pollut 49:37-51

Mangalla MJ (1987) Multi elemental energy dispersive X-ray fluorescence analysis of Kerio Valley fluorite ores and Mrima hill sediments. M.Sc. Thesis, University of Nairobi

NAS (1980) Lead in the Human Environment. US National Academy of Sciences

Ndiokwere CL (1984) A study of heavy metal pollution from motor vehicle emissions and its effect on roadside soil vegetation and crops in Nigeria. Environ Pollut 7:35-42

Nriagu JO (1988) A silent epidemic of environmental metal poisoning? Environ Pollut 50:139-161

Onyari JM, Wandiga SO (1989) Distribution of Cr, Pb, Cd, Zn, Fe and Mn in Lake Victoria sediments, East Africa. Bull Environ Contam Toxicol 42:807-813

Page AL, Ganje TJ, Joshi MS (1971) Lead quantities in plants, soil and air near some major highways in Southern California. Hilgardia 41:1-31

Rabinowitz MB, Bellinger DC (1988) Soil lead-blood lead relationship among Boston children. Bull Environ Contam Toxicol 41:791-797

Ratcliffe JM (1981) Lead in man and the environment. Ellis Horwood Ltd, England.

Rodrigues MF, Castellon (1982) Lead and cadmium levels in soil and plants near highways and their correlation with traffic density. Environ Pollut (B) 4:281-290

Yassoglou N, Kosmas C, Asimakopoulos, Kallinou C (1987) Heavy metal contamination of roadside soils in the Greater Athens area. Environ Pollut 47:293-304

Received August 22, 1990; accepted September 28, 1990.