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Determination of urinary lead in school children in Manzini, Swaziland, Southern Africa

JONATHAN O. OKONKWO,* SALIA M. LWENJE, VICTOR S. B. MTETWA, PATIENCE N. GUMEDZE and MBUSO M. SHILONGONYANE
School of Environmental Sciences, University of Venda, PBX5050, Thohoyandou 0950, South Africa

Summary. Two hundred and fifty-seven urine samples collected from school children living in the Manzini region, Swaziland, were analysed for lead (Pb), using a graphite furnace atomic absorption spectrometer. The mean urine lead concentration for the urban schools ranged from 0.038–0.040 $\mu g \cdot ml^{-1}$, while that for the rural schools ranged from 0.017–0.022 $\mu g \cdot ml^{-1}$. The observed range shown by the urban schools was above the normal (for healthy humans) urine lead concentration of 0.035 $\mu g \cdot ml^{-1}$. However, the mean urine lead concentration for the rural schools was found to be lower than this value. The mean urine lead concentration for the urban schools was significantly higher than that of the rural schools. The differences in the mean urine lead concentrations for boys and girls from both urban and rural schools were found not to be significant, despite the higher values shown by the girls. The difference in lead concentrations between urban and rural schools in Manzini was thought to be due to the traffic density within the urban area.

Keywords: urinary lead, school children, Swaziland

Introduction

Over the last half-century or so, human exposure to lead has changed in origin, but has probably not changed significantly in amount. Thus the decrease in exposure over this period from lead in water pipes, food containers, paints and insecticides has probably been compensated by increased exposure from cigarette smoking and cosmetics, and above all from motor vehicle exhausts, especially in highly motorised, urban communities in developing countries. The recognition of the contribution of lead from vehicles' exhaust has prompted research work on the determination of lead in particulate deposits and plants along roadways (Sithole *et al.*, 1993; Zafar and Mirza, 2000), hair (Kopito *et al.*, 1967; Ahmed *et al.*, 1973; Schuhmacher *et al.*, 1991; Okonkwo *et al.*, 1999) and blood (Gobler *et al.*, 1986), to mention but a few.

The industrial growth that has occurred in Swaziland over the past few decades has generated problems of environmental pollution in the cities. The industrial growth has given rise to, among other things, a massive increase in the number of vehicles using leaded petrol, thus increasing the level of air-borne lead. It is estimated that Swaziland is presently witnessing an increase of 30 percent of newly registered vehicles annually (Swaziland Central Motor Registry, 1997).

In recognition of this problem, the Swaziland government in 1997 introduced unleaded petrol. At present, two types of petrol are in use in Swaziland, the '97 octane' type which contains about 0.7–0.9 g $Pb \cdot l^{-1}$ and the '95 octane'

*Dr Jonathan O. Okonkwo (author for purposes of correspondence) is a Senior Lecturer in the School of Environmental Sciences at the University of Venda, fax: +27 015 962 4749; e-mail: okonkwoj@univen.ac.za. Dr Salia M. Lwenje is a Senior Lecturer, Dr Victor S. B. Mtetwa is an Associate Professor, and Patience N. Gumedze and Mbuso M. Shilongonyane are Research Assistants, in the Department of Chemistry at the University of Swaziland, PB 4, Kwaluseni, Swaziland.

(unleaded) type which contains about 0.1 g $Pb \cdot l^{-1}$. However, among the over 1300 vehicles in Manzini, which is regarded as the industrial hub of Swaziland, more than 80 percent use leaded petrol. Therefore, despite the introduction of unleaded petrol, consumption of leaded petrol is still very high. The air-borne particulate matter has been found to contain about 3.0 $\mu g\ Pb \cdot m^{-3}$ (unpublished). As a large portion of the Swazi population reside in Manzini area, the possible exposure to lead contamination, especially the most vulnerable, the children, should be addressed.

The adverse effect of lead is now well recognised. Lead reportedly interferes with a number of body functions, notably the central nervous system, the haematopoietic system, and the kidney. A series of prospective studies in diverse communities suggests that exposure to environmental lead is associated with a small decrease in intellectual functioning in childhood (Tsuchiya, 1979; Boeckx, 1986). Some workers (Underwood, 1971; Boeckx, 1986) regard the presence of lead in urine as an indirect index of the renal and total body burden of this metal. Therefore, determination of lead in urine is useful for assessing environmental exposure to lead.

Studies on lead as an environmental pollutant in Swaziland are scarce. However, the authors have recently reported on the lead concentration in the hair of school children in the Manzini area in Swaziland (Okonkwo *et al.*, 1999). The present study is on the lead concentration in the urine of school children within the Manzini region. This study was part of a research programme on the determination of trace and essential elements in the urine (Lwenje *et al.*, 1999) and hair (Okonkwo *et al.*, 1999) of school children in Swaziland.

Methods

Sampling procedure

Urine samples, 50–100 ml, were collected directly into 100 ml polythene disposable bottles from 257 school children (urban and rural) aged between 6–12 years. The bottles were sealed immediately, transported to the laboratory and stored in a deep freezer until used. An interview schedule was prepared to cover the basic information on age, sex, parents' occupation, place and duration of residence and health status of each subject.

Reagents and solutions

The ammonium pyrrolidinedithiocarbamate (APDC), methylisobutylketone (MIBK), chloroform and mercury (II) oxide used in the extraction were reagent grades. Nitric acid used was of very high grade (99.9 percent). Lead standard solutions were prepared as previously described (Okonkwo *et al.*, 1999). All glassware used was of Pyrex brand and was soaked overnight in 25 percent chromic acid after which it was thoroughly rinsed with de-ionized water and oven dried.

Sample treatment

50 ml of each urine sample was digested in 3 ml nitric acid (55 percent) in 100 ml beaker. The mixture was then boiled to evaporation leaving a yellow-orange semi-solid deposit at the bottom of the beaker. 10 ml de-ionized water was then added to the deposit and the pH adjusted to 2.8 by dropwise addition of 2 M NaOH.

1.0 ml of freshly prepared solution of 4 percent APDC and 3.0 ml MIBK were added into the digested solution. The mixture was transferred into a 50 ml separating funnel and shaken vigorously for about 10 minutes. After a wait of about 10 minutes to allow for phase separation, the organic phase together with about 5 ml of the aqueous phase were pipetted out from the flask, placed into a Pyrex centrifuge tube and then centrifuged at 350 rpm for 5 minutes in order to recover most of the organic phase. The extraction procedure was repeated three times, each time with fresh APDC and MIBK to ensure complete extraction of lead into the organic phase. The organic phases were transferred into a Beckman polyvial with a fast turn cap. To back extract, 4 ml of 1000 $\mu g \cdot ml^{-1}$ mercury (II) solution was added to the vial. After shaking for about 5 minutes, the aqueous phase was transferred to another vial for atomic absorption analysis.

Lead recovery test

In order to test the efficiency of the digestion and extraction procedures, 50 ml of two urban and two rural samples selected randomly were spiked with 0.1 $\mu g \cdot ml^{-1}$ lead standard solution, digested and extracted as described earlier.

Atomic absorption spectrometer analysis

The apparatus used was a graphite furnace atomic absorption spectrophotometer with an auto-sampler. Details on the instrument operating conditions were described in Okonkwo *et al.* (1999). 20 μl of analyte, standard and spiked solutions were injected into the graphite tube by the auto-sampler. Measurements were conducted in triplicate.

Statistical analysis

One-way analysis of variance (ANOVA) at 95 percentage confidence level was used to evaluate the data.

Results and discussion

Lead recovery test

The lead recovery test result is shown in Table 1. As can be seen from Table 1, the percentage lead recovery is high. The result suggests very negligible loss of lead during the digestion and extraction stages.

Sample analysis

The results in Table 2 show the lead concentration in the urine of school children in the Manzini area. Urine lead concentrations were significantly higher in the urban school children than in rural school children for all the ages ($p < 0.05$). The differences between the urban and rural lead levels may be attributed to the increasing number of motor vehicles within the city of Manzini, where the urban schools were situated.

From the questionnaire conducted, it was found that most of the school children in the urban schools live within the city. In the case of rural school children, the observed low lead levels may be a result of very few motor vehicles within the rural environment. It can also be observed from Table 2 that the mean urine lead concentrations for the urban school children for all the ages were above the normal (for healthy humans) urinary concentration of 0.035 $\mu g \cdot ml^{-1}$ (Underwood, 1971).

This reflects the same trend as previous results on lead in the hair of school children (Okonkwo *et al.*, 1999) This is not surprising since the same children were used in both studies. However, the urine mean lead concentrations for the rural schools were significantly lower than the normal urine lead concentrations. As can be seen in Table 2, the mean urine lead concentrations for the urban schools increased marginally from 6–7 to 10–12 age groups. This trend is in contradiction with previous studies on hair which showed that lead absorption decreases with age and hence lead concentrations in children are higher than in adults (Barry, 1975; Chenard *et al.*, 1987; Okonkwo *et al.*, 1999). With the rural schools, a significant decrease in lead concentrations from

Table 1. Lead recovery test.

Sample code number	Absorbance of sample without Pb standard A	Absorbance of added Pb standard B	Absorbance of sample with added Pb standard C	Percentage recovery	
				C−A	C−A/B
Urban 1	0.07	3.15	3.13	3.06	97
Urban 2	0.14	3.15	3.15	3.01	96
Rural 1	0.07	3.15	3.12	3.05	97
Rural 2	0.05	3.15	3.07	3.02	96

Table 2. Mean lead concentrations* in urine of school children in the Manzini area, Swaziland.

Age group	Urban school (n)	Rural school (n)	Mean concentration of lead ($\mu g \cdot ml^{-1}$) ± SD		
			Urban schools	Rural schools	$p^{\dagger}$
6–7	40	38	0.038 ± 0.010	0.022 ± 0.004	significant
8–9	53	49	0.039 ± 0.009	0.018 ± 0.007	significant
10–12	44	33	0.040 ± 0.007	0.017 ± 0.003	significant

*Arithmetic mean ($\mu g \cdot ml^{-1}$) ± arithmetic standard deviation.
†ANOVA p value.

6–7 to 8–9 age groups and a marginal decrease from 8–9 to 10–12 age groups can be observed from Table 2. This agrees well with previous conclusions on reduced absorption of lead with age (Barry, 1975; Chenard *et al.*, 1987; Okonkwo *et al.*, 1999). The concentration of lead in the samples ranged from 0.019 to 0.056 $\mu g \cdot ml^{-1}$ and 0.01 to 0.027 $\mu g \cdot ml^{-1}$ for urban and rural schools respectively.

The lead concentration in urine according to gender is shown in Table 3. The mean lead concentrations for boys and girls from both urban and rural schools were found not to be significant ($p > 0.05$), despite the higher values shown by the girls.

These results point to essentially similar conclusions from previous studies on hair (Weiss *et al.*, 1972; Chenard *et al.*, 1987; Okonkwo *et al.*, 1999), although some workers have found significant differences between gender (Reeves *et al.*, 1975). No relationship was observed between smoking habits of parents or any adult family member and lead concentrations in the urine of school children studied. This observation also applies to the occupation of parents.

Table 3. Mean lead concentrations according to gender, school children, Swaziland.

Area	Mean ± SD ($\mu g \cdot ml^{-1}$)		
	Boys	Girls	$p^{\ddagger}$
Urban	0.037 ± 0.009	0.045 ± 0.01	NS
Rural	0.019 ± 0.005	0.020 ± 0.008	NS

‡ANOVA p value: NS, not significant.

Conclusions

In this study, the differences in the urine lead concentrations between urban and rural school children in the Manzini area were suggested to be due to traffic density. These findings are supported by studies in which children in cities have been observed to show higher urine lead and blood lead levels than children in rural or small cities (Ahmed *et al.*, 1973; Mahaffey, 1977; Schuhumacher *et al.*, 1991; Okonkwo *et al.*, 1999). The values obtained for the urban schools were higher than the normal urinary concentration of 0.035 $\mu g \cdot ml^{-1}$, and this calls for concern. The introduction of unleaded petrol by the Swaziland government in 1997 is a step taken so far to reduce lead exposure from motor vehicles source.

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References

Ahmed, N.S., El-Gendy, K.S., El-Refaie, S.A., Maecouk, N.A., Bakry, A.H., El-Sebae, H.J. and Soliman, S.A. (1973) Assessment of lead toxicity in traffic controllers of Alexandra, Egypt road intersection. *Arch. Environ. Health* **42**(2), 92–7.

Barry, P.S. (1975) A comparison of concentrations of lead in human tissues. *Br. J. Ind. Med.* **32**, 119–39.

Boeckx, R.L. (1986) Lead poisoning in children. *Anal. Chem.* **58**, 274A.

Chenard, L., Turcotte, F. and Cordier, S. (1987) Lead absorption by children living near a primary copper smelter. *Can. J. Public Health* **78**, 295–98.

Gobler, S.R., Maresky, L.S. and Rossouw, R.J. (1986) Blood lead levels of South African long distance road-runners. *Arch. Environ. Health* **41**(3), 155–61.

Kopito, L., Byers, R.K. and Shwachman, H. (1967) Lead in hair of children with chronic lead poisoning. *New Engl. J. Med.* **276**, 949–53.

Lwenje, S.M., Okonkwo, J.O, Mtetwa, S.B., Gamedze, A., Mavundla, J.A. and Sihlongyane, M.M. (1999) Determination of urinary iodine in school children of the Hhohho region in Swaziland. *International Journal of Environmental Health Research* **9**, 207–11.

Mahaffey, K.R. (1977) Quantities of lead producing effects in humans: sources and bioavailability. *Environmental Health Perspect* **19**, 285–95.

Okonkwo, J.O., Lwenje, S.M., Mtetwa, V.S.B. and Mkhweli, T.B. (1999) Measurement of lead concentration in the hair of school children in the Manzini region, Swaziland. *Intern. J. Environ. Studies* **56** 419–28.

Reeves, R.D., Jolley, K.W. and Buckley, P.D. (1975) Lead in human hair: relation to age, sex and environmental factors. *Bull. Environ. Contam. Toxicol.* **14**, 579–87.

Schuhmacher, M., Domingo, J.L., Libet, J.M. and Corbella, J. (1991) Lead in children's hair as related to exposure to Tarragona Province, Spain. *The Science of Total Environment* **104**, 167–73.

Sithole, N.S., Moyo, N. and Macheka, M. (1993) An assessment of lead pollution from vehicle emission along selected roadways in Harare Zimbabwe. *Intern. J. Environ. Anal. Chem.* **53**, 1–12.

Swaziland Central Motor Registry. (1997) Report of registered vehicles.

Tsuchiya, K. (1979) Lead. In *Handbook of the toxicology of metals* (L. Friberg, G. Norberg and V. Vouk, eds.) Amsterdam: Elsevier-North Holland Publishers.

Underwood, E.J. (1971) *Trace elements in human and animal nutrition*, 3rd ed. New York and London: Academic Press.

Weiss, D., Whitten, B. and Leddu, D. (1972) Lead content in human hair. *Science* **178**, 69–70.

Zafar, I.S. and Mirza, A.A. (2000) Lead in particulate deposits and in leaves of roadside plants, Karachi, Pakistan. *The Environmentalist* **20**(1), 73–7.