International Journal of Paediatric Dentistry 2004; **14:** 175–181

Lead levels in primary teeth of children living in Mexico City

J. C. HERNÁNDEZ-GUERRERO[1], M. D. JIMÉNEZ-FARFÁN[1], R. BELMONT[2], C. LEDESMA-MONTES[1] & A. BAEZ[2]

[1]*División de Estudios de Posgrado e Investigación, Facultad de Odontología and* [2]*Laboratorio de Química Atmosférica. Centro de Ciencias de la Atmósfera. Universidad Nacional Autónoma de México, México*

Summary. *Objective.* The aim of this study was to discover the lead concentration in primary teeth extracted in the peripheral clinics of the Faculty of Dentistry, UNAM (Mexico City).

Design. One hundred healthy primary teeth were collected from 2 to 13-year-old children (52 girls and 48 boys). Sixty-six were maxillary teeth and 34 were mandibular teeth. Lead concentrations were measured by Graphite Furnace Atomic Absorption Spectrophotometry.

Results. Our results indicate that lead concentration in the 10–13-year-old group (7·7 $\mu g/g^{-1}$) was higher than in the other groups. Geometric mean lead concentration was higher in girls than in boys (7·3 $\mu g/g^{-1}$ and 6·3 $\mu g/g^{-1}$, respectively). Maxillary teeth had higher lead concentrations than mandibular teeth and primary canines showed the highest mean lead concentration followed by incisors and molars. Teeth from children living in the south-east area (which according to the Mexico City's Pollution Center data is the more polluted area), presented the highest lead concentration but no statistically significant difference was found among teeth from the different areas.

Conclusions. Our results suggest that age, gender and place of residence are not related to the lead concentration in human primary teeth. This fact seems to indicate the ubiquitous presence of lead in the whole atmosphere of Mexico City and suggests that zones of residence do not appear to influence tooth lead concentration.

Introduction

Lead toxicity to humans has been a field of debate among researchers. Lead intoxication in humans has neurotoxic effects such as encephalitis, behaviour, inattention, IQ deficits and reduced nerve conduction [1,2]. Exposure to this metal can be evaluated by measuring lead in blood, teeth, hair and bone, which are then used to estimate body lead burden [1]. Lead accumulates in bones and teeth [3] but the amount of lead released from teeth is negligible [4], its annual aggregation in hard tissues can be considered to be directly related to blood levels. Thus, teeth are good indicators of environmental lead pollution and have been used by many researchers [4–7].

It has been established that the most important sources of lead to the environment are the emissions from industry and motor vehicles. Considerable attention has been paid to the high air pollution index, including lead, in Mexico City's Metropolitan Zone (MCMZ) during recent years, since it is a highly industrialized city with approximately 3 million motor vehicles. A large percentage of vehicles used leaded-gasoline, although in recent years a decrement of the atmospheric lead levels has been observed in MCMZ due to reformulation of gasolines [8]. In 1994, lead content in gasoline NOVA was 0·06 g/L^{-1}, while a

Correspondence: J. C. Hernández Guerrero, División de Estudios de Posgrado e Investigación, Facultad de Odontología, Universidad Nacional Autónoma de México, Ciudad Universitaria, México D.F., C.P.04510, México. E-mail: jcarlosh@servidor.unam.mx

typical value in 1995 was 0·03 g/L^{-1} [8]. However, in 1995 there had been a reduction of 34% in the consumption of gasoline per day [8]. In spite of the reduction of lead tetraethyl concentration in gasoline due to the introduction of unleaded gasoline (Magna-Sin) in 1990 and the mandatory installation of catalytic converters in new automobiles since 1991, approximately 6 million litres of leaded gasoline are still consumed in MCMZ daily [9]. In view of the enormous quantities of gasoline consumed and the lead liberation to the environment, we presumed that there would be significant lead levels in blood and teeth of children living in different areas of MCMZ.

There are other sources of lead in MCMZ: emission from glass, pigments and paint industries, pottery, non-ferrous metal smelters, accumulator gratings and battery manufacturing plants [9]. On the other hand, some industrial measures have been implemented to eliminate or reduce lead in paints, varnish and canned food [9].

This study was carried out to investigate lead concentration in primary teeth, to compare these concentrations among all types of primary teeth and to determine whether gender, age and place of children's residence have any influence on tooth lead concentration.

Methods

Sampling

One hundred primary teeth were collected from 2–13-year-old children attending any of the 11 peripheral clinics of the Faculty of Dentistry, UNAM.

The selected children had been resident in the same area since birth. Information about age, gender, feeding habits, way of life, address and clinical history were collected. Teeth with fillings, caries or developmental defects were discarded. After careful extraction, each tooth was stored in a high-density polypropylene vial containing a 10% solution of sodium hypochlorite and sent to the Atmosphere Chemistry Laboratory of the Atmosphere Sciences Center (UNAM) for chemical analysis.

Sample preparation

Measurements of the lead concentrations were made in each whole tooth or crown. The sodium hypochlorite solution was discarded and teeth were rinsed several times with deionized water (DW), each tooth was put into a beaker and left in DW overnight. Teeth were then rinsed with DW, dried in an oven at 103 °C for 1 hour and then put into a polycarbonate desiccator with silica gel desiccant (6–18 mesh) and weighed. This procedure was repeated until a constant weight was reached. Each tooth or crown was digested several times with 1 mL of concentrated, twice-distilled nitric acid and beakers were covered with watch glasses. After digestion was complete, the acid solution was cooled and poured into a 10 mL volumetric flask. Beakers and watch glasses were rinsed with DW several times and washings were added to the volumetric flask. Blanks of DW were treated with the same procedure.

Analysis

Lead levels were determined at 283 nm with a GBC Model 932AA Atomic Absorption Spectrophotometer (GBC Scientific Equipment, Gilberts, IL, USA) with a 3000 Graphite Furnace System attachment and PAL 3000 Furnace Auto Sampler. The radiation source was a hollow-cathode lamp. All measurements were made with deuterium background correction.

Quality control Two samples containing known quantities of Pb were prepared and analysed in the same manner. Quantitative recovery in lead percentage was calculated using the differences in concentration with and without the lead addition. Recovery in spiked samples ranged from 106 to 108%.

Statistical analysis After natural logarithmic transformation of lead data, the Kolmogorov-Smirnov test was applied. Data were grouped by gender, age and place of residence. Children were divided in three groups by age: 2–5-year-olds, 6–9-year-olds and 10–13-year-olds. The place of residence was divided in four areas: north-west, north-east, south-west and south-east. To evaluate the effect of gender, age and place of residence on tooth lead concentrations two tests were applied. For gender, the Wilcoxon–Mann-Whitney test large-sample normal approximation with continuity correction was used and for the other two variables, the one-way Kruskal–Wallis test was applied [10]. Comparisons between lead levels of different teeth were made using the Wilcoxon–Mann-Whitney 2-tailed test. Spearman's rank correlation between teeth, lead concentration, age, gender, parent's job, use of pencils and colour crayons, residence area and socioeconomic level was applied. As this test did not detect a correlation between lead concentrations and the different variables, contingency tables were then used to test the association between lead concentrations and the studied variables, except pencils and crayons. With respect to gender, the Yates continuity correction was applied [11]. For age and socioeconomic level variables 3 × 2 tables were calculated, and for children living in different residential areas a 4 × 2 table was made.

To determine the socioeconomic level of the children, data from paint type applied in homes, parent's level of education and job were classified as follows:

- Paint type: enamel, 4; vinyl, 3; others 2, without paint, 1.
- Parent's level of education: professional, 4; college, 3; high school, 2; elementary, 1.
- Father's job: profession, 4; employee, 3; business, 2; other, 1.
- Mother's job: profession, 4; employee, 3; business, 2; home, 1.

The socioeconomic level was calculated by summing the numerical values obtained in all categories, and valves were divided into three intervals: 6–9, 10–13 and > 13.

Results

Of the 100 children sampled, 52 were girls and 48 were boys. Table 1 shows the geometric and arithmetic means and standard deviations of the lead concentrations determined in all types of primary teeth.

Significant differences in lead levels were found between incisors and molars (Z = –2·12), and between canines and molars (Z = –2·11). Lead levels of central and lateral incisors also showed a significant difference (Z = –2·02), lead concentration in central incisors was higher than in lateral incisors. Geometric mean lead concentrations in all types of upper teeth, excepting second molars, were higher than those found for all types of lower teeth. Significant differences were found among upper and lower lateral incisors only (Z = 2·33).

Table 2 shows the geometric means and geometric standard deviations of the lead concentrations corresponding to gender and age. Small differences in lead concentrations were observed by gender ($\chi^2 = 3{\cdot}24$) and the Wilcoxon–Mann-Whitney test showed a non-significant difference (∝ = 0·05). Regarding age, the geometric mean lead concentration in the group of 10–13-year-olds was higher than in the other groups, however, it was found that the group of 2–5-year-old children showed higher concentrations than the 6–9-year-old group. The Kruskal–Wallis test indicated that there were no significant differences between these groups (∝ = 0·05).

Table 3 shows geometric means of lead concentrations in teeth of children living at different areas of MCMZ. The lead concentration in teeth was higher in the group living in the south-east area, but no statistically significant differences between the different residential areas (H = 3·29) were found.

Table 4 shows the results obtained in the analysis of contingency tables, indicating that lead concentration is independent of the different variables tested.

Table 1. Lead concentration (µg/g–1, dry weight) in primary teeth whole or crown.

Type of tooth	*n*	Mean ± SD Arithmetic	Geometric
All teeth			
All	100	8·28 ± 6·18	6·77 ± 1·85
Upper	66	9·19 ± 6·61	7·56 ± 1·85
Lower	34	6·5 ± 4·86	5·46 ± 1·77
Incisors			
All	28	9·10 ± 5·91	7·57 ± 1·88
Lower	8	5·12 ± 2·29	4·55 ± 1·77
Upper	20	10·69 ± 6·19	9·27 ± 1·72
Central	12	11·52 ± 6·89	9·99 ± 1·73
Upper central	10	12·26 ± 7·38	10·49 ± 1·81
Lower central	2	7·82 ± –	7·82 ± –
Upper lateral	10	9·12 ± 4·59	8·20 ± 1·61
Lower lateral	6	4·22 ± 1·85	3·80 ± 1·72
Canines			
All	26	10·44 ± 8·79	8·16 ± 1·99
Upper	20	10·49 ± 8·67	8·43 ± 1·90
Lower	6	10·30 ± 10·00	7·34 ± 2·43
Molars			
First	26	6·33 ± 3·85	5·50 ± 1·69
Second	20	6·84 ± 3·67	5·96 ± 1·73
Upper first	16	7·25 ± 4·51	6·15 ± 1·81
Lower first	10	4·86 ± 1·83	4·59 ± 1·41
Upper second	10	6·73 ± 4·40	5·64 ± 1·86
Lower second	10	6·96 ± 3·00	6·30 ± 1·64

Table 2. Lead concentrations in primary teeth (µg/g–1 dry weight) by gender and age.

	n	Mean
Girls	52	7·3
Boys	48	6·3
2–5	17	7·6
6–9	55	6·3
10–13	28	7·1

Table 3. Lead concentration in primary teeth (μg/g⁻¹, dry weight) by geographical zone.

	n	Mean
North-west	25	6·6
North-east	16	7·3
South-west	44	6·5
South-east	15	6·8

Table 4. Summary of tests of contingency tables.

Variable	χ^2	d.f.	Significance
Gender	3·24*	1	0·071
Age	2·23	2	0·327
Place of residence	5·65	3	0·130
Socioeconomic level	2·75	2	0·252

*With Yates correction.

Discussion

The results of this study indicate that maxillary teeth had higher lead concentration than mandibular teeth. The relationship between lead levels in upper and lower teeth also seems to differ from previous studies [5,12–19]. This could be partly because the maxillary bone is spongy and vascularity is more intense than in the mandible [20].

Lead concentration was found to vary with tooth type and age. Variations in whole-tooth lead concentration related to type of tooth have been found previously [13,17,19,21] and agree with our results. Conversely, it has been reported that mean lead concentration in incisors was higher than in canines and molars [13,14,19,21]. In this study, canines had the highest lead concentration followed by incisors and molars. This could be explained by the difference in morphology and size between canines and incisors and also because, embryologically, the formation of the upper canine enamel and dentin begins during the 5th month of gestation [22] and the crown calcifies during the 4–9th post-natal months. Compared to other teeth, this means a greater exposure time to lead [18]. Upper central incisors begin their mineralization process near to the 3rd foetal month and the coronal dentin is largely completed by the 3rd post-natal month. Usually, lower central incisors lag in their development by one or two months, while molars begin during the intrauterine development and continue calcifying during the first year. Our results suggest that deposition is concurrent with mineralization, and as lead exposure varied during these periods of calcification teeth would show different lead levels. Even if tooth levels represent blood lead at nearest the time of exfoliation [18], differences in exposure patterns could at least partially account for these different trends [23].

It has also been reported that, on average, incisors have higher lead concentrations than molars [13,14]. These differences in lead levels are unlikely to reflect physiological factors, i.e. blood supply to teeth, exposure time or mineralization rates. On the other hand, incisors, canines, and molars calcify at different times [12] and could therefore retain varying amounts of lead. Thus, if a child's blood lead concentrations varied widely during the years of tooth formation, different amounts of lead would be deposited in the teeth at different rates [18].

Some researchers have reported that tooth lead levels increase with age [5,13,24]. However, the results of this study showed that age did not affect tooth lead concentrations. Our results agree with those of Mackie *et al.* [13] who did not find any clear trend between lead concentration and age. When comparisons were made on tooth type, a significant difference was found only in canines between the 2–5 and 10–13-year-old groups of children. Tooth lead levels do not seem to depend on sex [13,24]. Our results showed that tooth lead concentrations were higher in girls than in boys, although no significant differences were observed.

Lead concentrations found in teeth of children living in different residential areas of MCMZ were very similar.

Lead concentrations based on whole-tooth analysis were compared with those reported in other countries. As is shown in Table 5, the arithmetic mean (8·18 μg/g⁻¹) found in Mexico City was lower than those found in other cities [5,8,13,19,25–27,29,30]. These different results show that tooth lead concentration could be related to exposure to lead from the environment.

Acknowledgements

We acknowledge Rocío García M and Ma. del Carmen Torres B. for their help in the analytical work. We are also grateful to Hugo Padilla G. for his review of the English manuscript. This study was partially supported by a grant of the Dirección General de Asuntos del Personal Académico (PAPIIT) Universidad Nacional Autónoma de México, Project No. IN209996.

Table 5. Lead content in the air in different areas.

Author	City	Country	Lead concentration
Altshuller *et al.* (5)	Cincinnati	USA	15·0 µg/g^{-1}
Needlman *et al.* (25)	Philadelphia	USA	11·2 µg/g^{-1}
Mackie *et al.* (13)	Birmingham	UK	11·8 µg/g^{-1}
Van Wick-Grobler (26)	Cape Peninsula	South Africa	16·6 µg/g^{-1}
Grobler *et al.* (27)	Cape Town	South Africa	20·4 µg/g^{-1}
Scharer *et al.* (29)	South-West	Germany	2·8 µg/g^{-1}
Blanusa *et al.* (28)	Not Stated	Yugoslavia	7·4 µg/g^{-1}
Shrivatava *et al.* (30)	AGRA	India	2·7 µg/g^{-1}
Alexander *et al.* (19)	North-West	UK	1·2–4·2 µg/g^{-1}
This study	Mexico	Mexico	8·18 µg/g^{-1}

Résumé. *Objectif.* Cette étude a eu pour objectif de connaître les concentrations en plomb des dents temporaires extraites dans les centres périphériques de la faculté de Dentisterie de UNAM (Mexico City).

Protocole. Cent dents de lait ont été obtenues issues d'enfants âgés de 3 à 12 ans (52 filles, 48 garçons). Soixante-six dents maxillaires et 34 dents mandibulaires. Les concentrations en plomb ont été mesurées par spectrophotométrie d'absorption atomique en four à graphites.

Résultats. Nos résultats indiquent que les concentrations en plomb dans le groupe 10–13 ans (7,7 µg g^{-1}) était plus importante que dans les autres groupes. La concentration moyenne géométrique en plomb était plus importante chez les filles que les garçons (7,3 µg g^{-1} and 6,3 µg g^{-1}, respectivement). Les dents maxillaires avaient des concentrations en plomb plus élevées que les dents mandibulaires et les canines temporaires montraient la concentration de plomb la plus élevée suivies par les incisives et les molaires. Les dents d'enfants vivant dans la zone sud-est (la plus polluée selon les données du Centre sur le Pollution de Mexico City) présentaient la concentration en plomb la plus élevée, mais aucune différence statistique n' été trouvée en fonction des différentes zones.

Conclusions. Nos résultats suggèrent que l'âge, le genre et le lieu de résidence ne sont pas reliés à la concentration de plomb dans les dents temporaires humaines. Ceci semble indiquer une présence ubiquitaire de plomb dans toute l'atmosphère de Mexico-city et suggère que les zones de résidence ne paraissent pas influencer les concentrations en plomb dans les dents.

Zusammenfassung. *Ziele.* Ziel dieser Studie war es, die Bleikonzentrationen in Milchzähnen zu messen, welche in Außenambulanzen der Universitätszahnklinik Mexico City extrahiert worden waren.

Design. 100 gesunde Milchzähne wurden von 2–13 jährigen Kindern gewonnen (52 Mädchen, 48 Jungen). 66 waren Oberkieferzähne, 34 Unterkie-ferzähne. Die Bleikonzentrationen wurden gemessen mittels Atomabsorptions-Spektrophotometrie.

Ergebnisse. Unsere Ergebnisse zeigen, dass die Bleikonzentrationen der Altersgruppe 10–13 Jahre (7.7 µg pro Gramm) höher war als in anderen Gruppen. Die mediane Bleikonzentration war bei Mädchen höher als bei Jungen (7.3 µg pro Gramm versus 6.3 µg pro Gramm). Oberkieferzähne zeigten höhere Konzentrationen als Unterkieferzähne. Am höchsten lagen die Mittelwerte bei Milcheckzähnen gefolgt von Schneidezähnen und Molaren. Zähne von Kindern aus der Südostregion (die nach dem Mexico City Umweltverschmutzungszentrum am meisten belastete Region) zeigten die höchsten Werte, statistisch signifikante Unterschiede bestanden jedoch nicht für Zähne aus den unterschiedlichen Regionen.

Schlussfolgerungen. Unsere Ergebnisse lassen den Schluss zu, dass Alter, Geschlecht und Wohnort keinen großen Einfluss auf die Bleikonzentrationen der Milchzähne haben. Dies könnte darauf zurückzuführen sein, dass die Bleiimmission über die Atmosphäre weit über Mexico City verteilt wird, und so keine deutliche Korrelation der Wohnregion mit den Bleikonzentrationen nachweisbar ist.

Resumen. *Objetivo.* El objetivo de este estudio fue conocer la concentración de plomo en dientes deciduos extraídos en clínicas periféricas de la Facultad de Odontología, UNAM (Ciudad de México).

Diseño. Se recogieron 100 dientes deciduos sanos de niños entre 2 y 13 años (52 niñas y 48 niños).

Los dientes superiores eran 66 y los dientes inferiores eran 34. Las concentraciones de plomo se midieron mediante Espectofotometría de Absorción Atómica en Cámara de Grafito.

Resultados. Nuestros resultados indican que la concentración de plomo en el grupo de niños entre 10–13 años (7,7 µg g^{-1}) fue más alto que en los otros grupos. La media geométrica de la concentración de plomo fue más alta en niñas que en niños (7,3 µg g^{-1} and 6,3 µg g^{-1}, respectivamente). Los dientes superiores tenían concentraciones más altas que los dientes inferiores y los caninos temporales mostraron la concentración media de plomo más alta seguido por los incisivos y molares. Los dientes de los niños que viven en el área del sudeste (según los datos del Centro de Contaminación de la Ciudad de México, es el área más contaminada), presentó la concentración de plomo más alta pero no se encontró ninguna diferencia significativa entre los dientes de diferentes áreas.

Conclusiones. Nuestros resultados sugieren que la edad, género y lugar de residencia no están relacionados con la concentración de plomo en dientes temporales humanos. Este hecho parece indicar la presencia generalizada de plomo en toda la atmósfera de la Ciudad de México y sugiere que la zona de residencia no parece influir en las concentraciones de plomo de los dientes.

References

1 Fergusson JE. *The Heavy Elements: Chemistry, Environmental Impact and Health Effects*. New York: Pergamon Press, 1990: 781–785.

2 Public Health Service Agency for Toxic Substances and Disease. *Toxicological profile for lead*. USA: Registry, US Department of Health & Human Services (USDHH), 1993: 18–21.

3 Elinder CG, Gerhardsson L, Oberdoerster G. Biological monitoring of toxic metals-overview. In: Clarkson TW, Friberg L, Nordberg GJ, Sager PR, eds. *Biological Monitoring of Toxic Metals*. New York/London: Plenum Press, 1988.

4 Steenhout A. Kinetics of lead storage in teeth and bones: an epidemiological approach. *Archives of Environmental Health* 1982; **37**: 224–231.

5 Altshuller LF, Halak DB, Landing BH, Kehoe RA. Deciduous teeth as an index of body burden of lead. *Journal of Pediatrics* 1962; **60**: 224–229.

6 Lappalainen R, Knuuttila M. The concentration of Pb, Cu, Co, and Ni in extracted permanent teeth related to donor's age and elements in the soil. *Acta Odontologica Scandinavica* 1981; **39**: 163–167.

7 Bercovitz K, Helman J, Peled M, Laufer D. Low lead level in teeth in Israel. *Journal of Science of the Total Environment* 1993; **136**: 135–141.

8 Departamento del Distrito Federal (DDF). *Programa Para Mejorar la Calidad Del Aire En El Valle de México 1995–2000*. México: Secretaría de Medio Ambiente, Recursos Naturales y Pesca. Secretaría de Salud, 1996: 10–14.

9 Red Automática de Monitoreo Atmosférico (RAMA). *Informe Anual de la Calidad Del Aire 1996, Zona Metropolitana de la Ciudad de México*. México: Secretaría del Medio Ambiente, Dirección General de Prevención y Control de la Contaminación. Comisión Ambiental Metropolitana, 1997: 4–8.

10 Sprent P. *Applied Non-Parametric Statistical Methods*, 3rd edn. New York: Chapman & Hall, 1989: 78–80.

11 Everitt BS. *The Analysis of Contingency Tables* Monographs on statistics and applied probability, 2nd edn. New York: Chapman & Hall, 1992: 16–19.

12 Shour I, Massler M. The development of human dentition. *Journal of the American Dental Association* 1941; **28**: 1153–1160.

13 Mackie AC, Stephens R, Townshend A, Waldron HA. Tooth lead levels in Birmingham children. *Archives of Environmental Health* 1977; **32**: 178–185.

14 Pinchin M, Massler M, Thompson R. Lead, cooper and cadmium in the teeth of normal and mentally retarded children. *Clinical Chemical Acta* 1978; **85**: 89–94.

15 Fergusson JE, Jansen ML, Sheat AW. Lead in deciduous teeth in relation to environmental lead. *Environmental Technological Letters* 1980; **1**: 376–383.

16 Delves HT, Clayton BE, Carmichael A, Bubear M, Smith M. An appraisal of the analytical significance of tooth-lead measurements as possible indices of environmental exposure of children to lead. *Annals of Clinical Biochemistry* 1982; **19**: 329–337.

17 Grandjean P, Lyngbye T, Hansen ON. Lead concentration in deciduous teeth: variation related to tooth type and analytical technique. *Journal of Toxicology and Environmental Health* 1986; **19**: 437–445.

18 Rabinowitz M, Bellinger D, Levinton A. The blood lead-tooth lead relationship among Boston children. *Bulletin of Environmental Contamination and Toxicology* 1989; **43**: 485–492.

19 Alexander LM, Heaven A, Delves HT, Moreton J, Trenouth MJ. Relative exposure of children to lead from dust and drinking water. *Archives of Environmental Health* 1993; **48**: 392–400.

20 Soehren SE, Van Swol RL. The healing extraction site: a donor area from periodontal grafting material. *Journal of Periodontology* 1979; **5**: 128–133.

21 Lockeretz W. Lead content of deciduous teeth of children in different environments. *Archives of Environmental Health* 1975; **30**: 583–587.

22 Pinkham JR. *Odontología Pediátrica*. México: Interamericana 1991: 33–37.

23 Rabinowitz M, Needleman H, Leviton A. Variability of blood lead concentrations during normal infancy. *Archives of Environmental Health* 1984; **39**: 74–77.

24 Ewers U, Brockhaus A, Winneke G, Freier I, Jermann E, Kramer U. Lead in deciduous teeth of children living in a non-ferrous smelter area and a rural area. *International Archives of Occupational and Environmental Health* 1982; **50**: 132–151.

25 Needleman HL, Tuncay OC, Shapiro MI. Lead levels in deciduous teeth of urban and suburban American children. *Nature* 1972; **235**: 111–112.

26 Van Wyk CW, Grobler SR. Lead levels in deciduous teeth of children from selected urban area in the Cape Peninsula. *South African Medical Journal* 1983; **63**: 559–562.

27 Grobler SR, Rossouw RJ, Katze D, van Wyk CW. Lead levels in different zones of deciduous teeth from various areas. *Journal of Dental Research* 1984; **64**: 810–820.
28 Blanusa M, Ivicic N, Simeon V. Lead, iron, copper, zinc and ash in deciduous teeth in relation to age and distance from a lead smelter. *Bulletin of Environmental Contamination and Toxicology* 1990; **45**: 478–485.
29 Schärer K, Veits G, Brockhaus A, Ewers U. High lead content of deciduous teeth in chronic renal failure. *Pediatric Nephrology* 1991; **5**: 704–707.
30 Srivastava MM, Srivastava S, Vaid A. Tooth lead concentration as an indicator for environmental lead pollution in Agra City, India. *Bulletin of Environmental Contamination and Toxicology* 1992; **48**: 334–336.