Rev. Int. Contam. Ambient. 20 (3) 109-115, 2004

CADMIUM AND LEAD LEVELS IN DECIDUOUS TEETH OF CHILDREN LIVING IN MÉXICO CITY

Armando BÁEZ[1*], Raúl BELMONT[1], Rocío GARCÍA[1] and Juan Carlos HERNÁNDEZ[2]

[1] Laboratorio de Química Atmosférica, Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México, Circuito Exterior, Ciudad Universitaria, Coyoacán D. F. 04510, México. *Corresponding author, e-mail: barmando@atmosfera.unam.mx

[2] División de Estudios de Posgrado e Investigación, Facultad de Odontología, Universidad Nacional Autónoma de México, Circuito Exterior, Ciudad Universitaria, Coyoacán D. F. 04510, México

(Recibido abril 2003, aceptado marzo 2004)

Key words: teeth, children, cadmium and lead exposure, teeth cadmium and lead concentrations, México

ABSTRACT

Cadmium and lead levels in 79 deciduous teeth from children between 5 and 13 years old living in the México City Metropolitan Zone were determined by graphite furnace atomic absorption spectrometry. Lead and cadmium concentrations showed a positively skewed distribution and results were transformed into logarithms. The geometric mean concentrations (GM) in all teeth were 0.22 ± 3.4 and 10.2 ± 2.2 $\mu g\ g^{-1}$ for cadmium and lead, respectively. No statistical differences were observed for cadmium and lead concentrations among tooth type, tooth position, gender, socioeconomic level, and use or no use of color crayons. Cadmium values decreased with children's age and lead levels did not show a clear tendency. Statistical differences were only observed for cadmium according to age.

Palabras clave: dientes, niños, exposición a cadmio y plomo, concentración de cadmio y plomo en dientes, México

RESUMEN

Se determinaron por espectrometría de absorción atómica con horno de grafito los niveles de cadmio y plomo en 79 dientes deciduos de niños de 5 a 13 años de edad que residen en la Zona Metropolitana de la Ciudad de México. Las concentraciones de cadmio y plomo mostraron una distribución sesgada positivamente por lo que se transformaron a logaritmos base 10. Las medias geométricas (GM) de las concentraciones de todos los dientes fueron de 0.22 ± 3.4 y 10.2 ± 2.2 $\mu g\ g^{-1}$ para cadmio y plomo, respectivamente. No se observaron diferencias estadísticamente significativas de las concentraciones de cadmio y plomo entre los tipos de dientes, posición de los dientes, tipo de diente y su posición, sexo, nivel socioeconómico, y el uso o no uso de crayones de color. Los valores de cadmio decrecieron con la edad y los de plomo no mostraron una tendencia clara. Sólo se observaron diferencias estadísticamente significativas entre las concentraciones de cadmio y la edad.

INTRODUCTION

Deciduous teeth have been used as indicators of long-term heavy metal exposure. The concentrations of cadmium and lead in primary teeth have been shown in several previous studies (Triphati *et al*. 1989, Tvinnereim *et al*. 1997, Bloch *et al*. 1998, Eide *et al*. 1998, Bu-Olayan and Thomas 1999, Tvinnereim *et al*. 2000).

Cadmium and lead are air and food contaminants and enter the body by inhalation and ingestion (Nordberg 1978). Cadmium is a toxic metal with a biological half-life of 10-20 years, and is mainly accumulated in the liver and kidneys (more than 50% of the body burden) (Nordberg 1978, Hahn *et al*. 1987). At high levels, it may develop degenerative and inflammatory changes in liver and kidneys (Norén *et al*. 1987). Attrition of plated components, tires wear and exhaust emissions from motor vehicles are sources of cadmium in the urban atmosphere (Harrison and Williams 1982). It has been suggested that fragmentation of automobile tires is a likely source of cadmium (Lagerwerff and Specht 1970, Burton and John 1977). Cadmium seems to be a naturally occurring element in teeth (Ranhkamo and Tuompo 1985). Its concentration in teeth depends on the amount acquired during tooth development (Shearer *et al.* 1980, Shearer *et al.* 1982). Primary teeth may be used as indicators of cadmium exposure (Eide *et al*. 1998).

Lead has greatly attracted researchers' attention due to its toxicity to humans. Lead intoxication in humans has neurotoxic effects such as encephalitis, behavioral disorders and inattention, reduced nerve conduction and IQ deficit (Fergusson 1990, USDHHS 1993). Exposures to this metal can be evaluated by measuring lead content in blood, teeth, hair and bone, which are used to estimate the lead body burden (Fergusson 1990). Lead is accumulated in bones and teeth (Elinder *et al*. 1988) but the amount of lead released from teeth is negligible (Steenhout 1982). Its annual aggregation in teeth can be considered as directly correlated to blood levels. Thus, teeth are good indicators of environmental lead pollution and have been used as such by some researchers (Altshuller *et al*. 1962, Lappalainen and Knnuttila 1981, Steenhout 1982, Bercovitz *et al*. 1993).

Industry and motor vehicles emissions have been established as the most important environmental lead sources, although glass, pigments, paints, pottery, non-ferrous metal smelters, accumulator gratings, and the battery manufacturing industry are other important lead emission sources. Vehicles in the México City Metropolitan Zone (MCMZ) used for many years leaded-gasoline. Lead control strategies have been undertaken to control lead levels in the MCMZ atmosphere. Reduction of lead in paints, varnishes and its elimination from food cans and toys (RAMA 1998), the introduction of unleaded gasoline (Magna-Sin) in 1990 and Premium in 1998, and the mandatory installation of catalytic converters in new automobiles since 1991, are some of these strategies. However, despite them, significant lead levels might still be found in teeth and blood of children living in different MCMZ areas.

This study was carried out to investigate cadmium and lead concentrations in deciduous teeth, to compare these concentrations among different deciduous teeth types and to determine whether gender, and years of residence in the same zone since birth, influenced cadmium and lead concentrations in teeth.

MATERIALS AND METHODS

Teeth collection

Deciduous teeth were extracted from or shed by children who have been living in the MCMZ since birth and attending the Dentistry Faculty peripheral clinics of the National Autonomous University of Mexico in 1997. 100 deciduous teeth, out of 500 obtained indistinctively from boys or girls between 5 and 13 years old, were randomly selected. Twenty-one teeth with fillings, caries or growth defects were discarded. Each child contributed with one tooth. Information on paint type applied to their homes walls, parent's scholarship and job (used to determine socioeconomic level), age, gender, the use or no use of color crayons, home address, and clinical history, was gathered.

Each extracted or shed tooth was placed in a high-density polypropylene vial containing a 10% sodium hypochlorite solution. Samples were immediately sent to the Atmospheric Chemistry Laboratory of the Atmospheric Sciences Center for their chemical analysis.

Sample preparation

All glass and plasticware were soaked in a 20% nitric acid solution for 24 hours and then rinsed thoroughly with deionized water. Upon arrival to the laboratory, teeth were rinsed with distilled water. Fergusson and Purchase (1987), mentioned that it is essential to clean the teeth prior to analysis and that the removal of organic material and surface contamination is the major cleaning stage. Stack and Delves (1981) used hypochlorite solution to remove organic material. In this study, the following procedure was used: each tooth was soaked in 25 ml of a 10% v/v sodium hypochlorite solution for 24 hours, rinsed with deionized water and dried at 103 °C for one hour.

Each tooth was weighed and placed into a 100-mL-beaker and digested with 1-mL of concentrated double-distilled nitric acid and 100 μL of hydrogen peroxide. After complete digestion, the solution was cooled and poured into a 10 ml volumetric flask, and made up to volume with deionized water.

Analysis

Cadmium and lead were analyzed by graphite furnace atomic absorption spectrometry at 228 nm and 283.3 nm, respectively, with a GBC double beam 932AA instrument, equipped with the unique ultra-pulse deuterium arc background correction system and coupled with a System 3000 graphite furnace accessory. Pyrolytically coated furnace tubes and boosted discharge hollow cathode lamps (Photron Super lamp) were used. The detection and quantification limits of the methods were 1.1 and 3.8 $\mu g\ L^{-1}$ for lead, and 0.07 and 0.23 $\mu g\ L^{-1}$ for cadmium.

Quality control

For internal quality control, two teeth were powered in a mortar and divided in two portions that were weighed and placed into a 100-mL-beaker. One of the portions was spiked with known quantities of cadmium and lead, and both portions were digested and analyzed applying the same procedure used for tooth samples. Recoveries in spiked teeth were 106% for cadmium and 107% for lead.

All glassware and plasticware were analyzed to guarantee their cleanness and the no contamination of the sampling material. Blanks of deionized water with reagents were included throughout the entire sample preparation and analytical process. The results indicated that cadmium and lead concentrations were below the detection limits.

The total error of the analytical method was determined by quality control check samples prepared in the laboratory. Ten replicate measurements of each metal were made. The results showed that the total error was 2.3% and 1.1% for Cd and Pb, respectively.

Statistical analysis

The Statistical Package for the Sigma Stat 3.0 was used. Samples were classified according to tooth type, tooth position, gender, age, socioeconomic level, and use or no use of color crayons.

Out of 79 healthy teeth (teeth without fillings, caries or growth defects) used for this study, 38 were from girls and 41 were from boys. Children were divided into seven age groups: 5, 6, 7, 8, 9, 10, and $\geq$ 11 years old.

To determine the socioeconomic level, paint type applied in home walls, parent's scholarship and job were codified as follows:

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

The socioeconomic level was calculated by summing up the numerical values obtained in each classification and divided into two categories, $\leq$ 10 and >10.

The use of color crayons was codified as 1 for yes and 2 for no.

A Pearson's correlation was done to define the relations among teeth cadmium and lead concentrations and weight of tooth, age, gender, use of color crayons, and socioeconomic level.

The association between teeth cadmium and lead concentrations and the studied variables was calculated using a one-way analysis of variance (ANOVA).

RESULTS

Histograms of cadmium and lead concentrations in teeth, show a positively skewed distribution frequency (**Fig. 1**). Data were transformed to logarithms and a

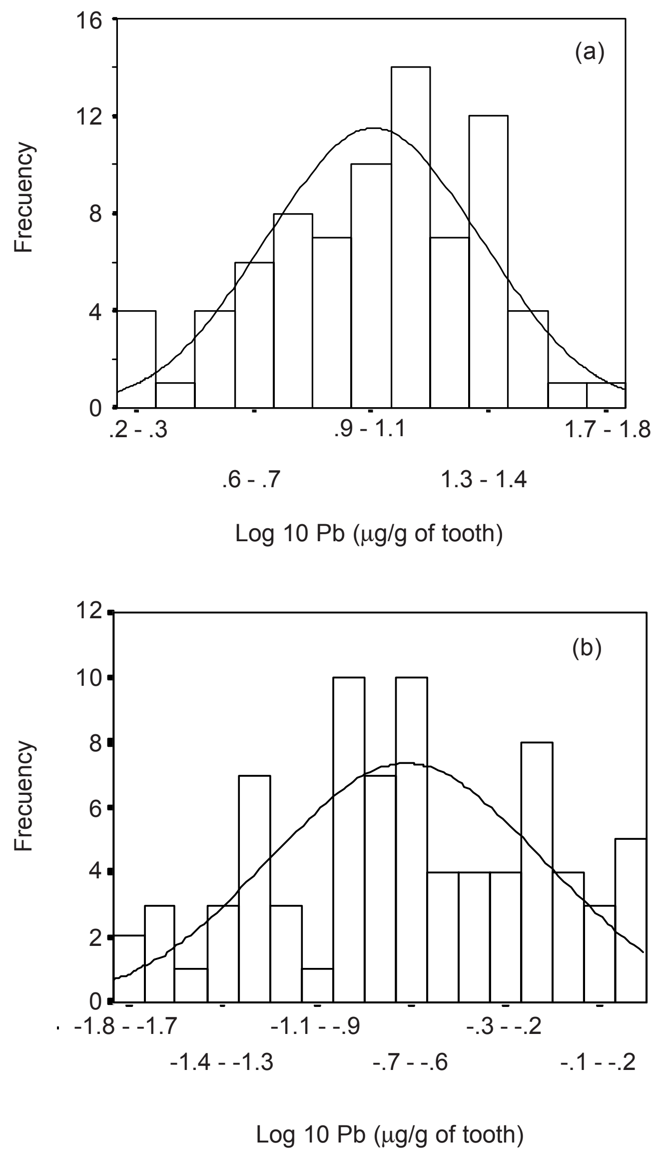

Fig. 1. Frequency histograms normalized by logarithmic transformation: (a) lead concentrations, (b) cadmium concentrations

TABLE I. LEAD AND CADMIUM GEOMETRIC MEANS (GM) AND GEOMETRIC STANDARD DEVIATIONS (GSD), IN µg OF METAL/g OF TOOTH, WITH REGARD TO TOOTH TYPE AND TOOTH POSITION

Tooth	N*	Lead		Cadmium	
		GM ± GSD	Range	GM ± GSD	Range
Type:		F = 0.202 p = 0.818		F = 2.426 p = 0.095	
Incisors	56	10.5 ± 2.1	1.7 – 58	0.27 ± 3.1	0.02 – 1.9
Canines	12	9.2± 3.0	1.8 - 48	0.14 ± 5.1	0.02 – 1.6
Molars	11	9.4± 1.9	3.8 – 22	0.14 ± 2.7	0.02 – 0.6
Position:		F = 0.007 p = 0.935		F = 0.445 p =0.507	
Upper	53	10.1 ± 2.3	1.7 - 58	0.21 ± 3.5	0.02 – 1.8
Lower	26	10.3 ± 2.0	2.0 -29	0.26 ± 3.2	0.05 – 1.9

* Number of samples

TABLE II. LEAD AND CADMIUM GEOMETRIC MEANS (GM) AND GEOMETRIC STANDARD DEVIATIONS (GSD), in µg of metal/g of tooth, WITH REGARD TO TOOTH TYPE AND ITS POSITION

Tooth	N*	Lead		Cadmium	
		GM ± GSD	Range	GM ± GSD	Range
Incisors:		F = 0.056 p = 0.814		F = 0.007 p = 0.935	
Upper	34	10.2 ± 2.2	1.7 – 58	0.27 ± 3.1	0.02 – 1.8
Lower	22	9.7 ± 2.1	2.0 – 29	0.26 ± 3.4	0.02 – 1.9
		F = 0.387 p = 0.537		F = 0.387 p = 0.537	
Central	27	9.8 ± 1.1	2.4 – 27	0.30 ± 3.1	0.02 – 1.5
Lateral	29	11.3 ± 1.2	1.7 - 58	0.25 ± 3.2	0.05 – 1.9
Canines:		F = 0.038 p = 0.850		F = 0.938 p = 0.356	
Upper	11	9.0± 1.4	1.8 - 48	0.12 ± 5.1	0.02 – 1.6
Lower	1	11.4	———	0.65	———
Molars:		F = 2.488 p = 0.149		F = 0.202 p = 0.663	
Upper	8	8.0± 1.2	3.8 – 20	0.13 ± 3.2	0.02 – 0.6
Lower	3	14.8± 1.4	7.9 – 22	0.17 ± 1.3	0.13 – 0.2
		F = 1.304 p = 0.283		F = 0.081 p = 0.783	
Firsts	9	10.4± 1.2	3.8 – 22	0.14 ± 2.8	0.02 – 0.6
Seconds	2	6.0	4.6 – 7	0.11	0.06 – 0.2

* Number of samples

Lilliefors test (Sprent 1989) was done. This test showed that the largest differences $[F(z_i)–S(z_{i-1})]$ were 0.075 and 0.069 for lead and cadmium data, respectively. Therefore, the null hypothesis establishing that the data corresponded to a log-normal distribution, was not rejected at the 1% significance level. Consequently, geometric means (GM) and geometric standard deviations (GSD) were used. The data were transformed into logarithms and used for all statistical calculations.

Concentrations were expressed as µg of metal/g of tooth (dry weight). Tooth weight ranged from 0.0408 to 0.7728 g.

Cadmium and lead concentrations ranged from 0.02 to 2 and from 1.7 to 58 µg/g with GM of 0.22 ± 3.4 µg/g and 10.2 ± 2.2 µg/g, respectively.

No statistical differences were observed for cadmium and lead concentration when comparing teeth type, position and type vs. position. (**Tables I** and **II**). The comparison of cadmium and lead concentrations between first and second molars was not made because only 2 second molars were sampled (**Table II**).

No statistical differences were observed for cadmium and lead concentrations according to gender (**Fig. 2**).

Regarding age (**Table III**), there was a statistical difference between cadmium concentrations GM only; the 5 years old group showed a higher GM concentration than the other groups.

There were no statistical differences between children who used color crayons and those who did not (**Table IV**).

No statistical differences were observed for cadmium and lead concentrations according to socioeconomic level.

The Pearson's correlation coefficient shows that teeth

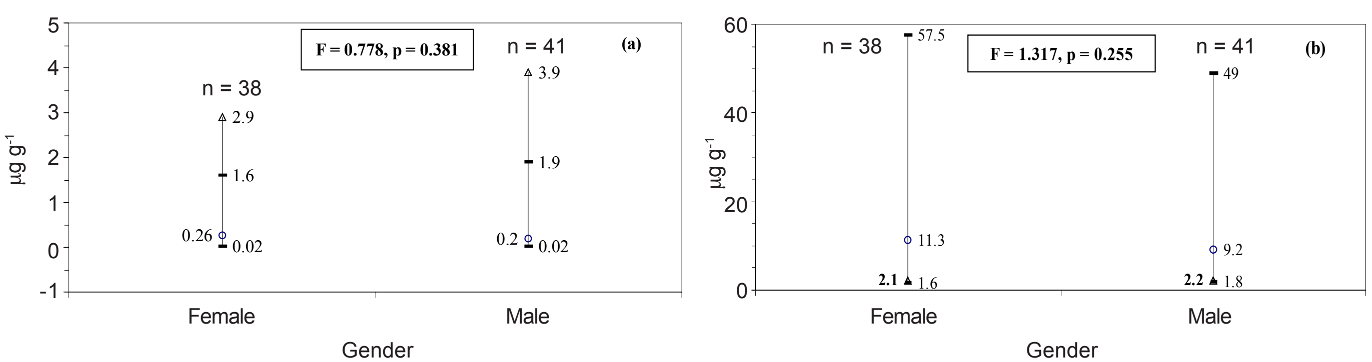

Fig. 2. Plots of cadmium and lead concentrations according to gender: (a) cadmium concentrations, (b) lead concentrations. Circles, triangles and dashes indicate geometric means; standard deviations, and minimum and maximum concentrations, respectively. Values in boxes indicate the results of the ANOVA test

TABLE III. LEAD AND CADMIUM GEOMETRIC MEANS (GM) AND GEOMETRIC STANDARD DEVIATIONS (GSD), IN µg OF METAL/g OF TOOTH, ACCORDING TO CHILDREN'S AGE

Age (yr.)	N*	Lead GM ± GSD	Lead Range	Cadmium GM ± GSD	Cadmium Range
		F = 2.021 p = 0.074		F = 2.838 p = 0.015	
5	6	12.5 ± 1.6	7.8 – 27.5	0.63 ± 2.0	0.26 – 1.6
6	26	9.6 ± 2.2	2.0 – 57.5	0.27 ± 3.4	0.02 – 1.9
7	19	9.2 ± 2.3	1.7 – 31.6	0.22 ± 3.2	0.03 – 1.4
8	13	10.7 ± 1.9	3.1 – 27.5	0.25 ± 2.7	0.04 – 1.1
9	3	35.0 ± 1.3	29.5 – 49.0	0.37 ± 3.8	0.12 – 1.6
10	5	12.6 ± 1.8	5.2 – 23.4	0.08 ± 3.4	0.02 – 0.2
≥ 11	7	6.3 ± 2.8	1.8 – 20.4	0.07 ± 3.3	0.02 – 1.6

* Number of samples

cadmium and lead concentrations correlated (r = 0.552, p < 0.001) and only teeth cadmium concentrations correlated with the weight of tooth (r = -0.395, p < 0.001), type of tooth (r = -0.230, p = 0.042), and age (r = -0.370, p = 0.001).

DISCUSSION

In this study, no statistical differences for cadmium and lead concentrations in molars, incisors and canines were found. The sample size was probably an important factor in the results found. These teeth mineralize at different, but overlapping, times (Schour and Massler 1941). So, they could have retained variable amounts of lead. No statistical differences were observed between lower and upper teeth, nor between the positions of the incisors. The relationship of lead levels and tooth positions seems to vary among different studies (Altshuller *et al*. 1962, Mackie *et al*. 1977, Pinchin *et al*. 1978, Delves *et al*. 1982, Grandjean 1986, Rabinowitz *et al*. 1989, Alexander *et al.* 1993). Tvinnereim *et al*. (2000) did not find cadmium concentration variations, in agreement with our results.

Our results did not show a clear relation between teeth lead concentration and age, this agrees with Mackie *et al*. (1977). In contrast, teeth cadmium concentrations decreased as age increased, agreeing with Bayo *et al*. (2001). The negative correlation between teeth cadmium concentrations and age, confirms this association. No plausible explanation was found on why the 5 years old group had higher cadmium concentrations. The small sample size could have been an important factor influencing the relation between decreasing teeth cadmium and age increase.

Tooth cadmium and lead levels did not seem to depend on gender as established by Mackie *et al*. (1977), Ewers *et al*. (1982), Gil *et al.* (1994), Bu-Olayan and Thomas (1999), and Bayo *et al*. (2001) in accordance with our results.

Regarding socioeconomic level, although no statistical differences were found, our cadmium concentrations results agree with the results of Bayo *et al*. (2001), who found that families with a law socioeconomic status showed no statistically significant higher values.

Bayo *et al*. (2001), have reported significant correlations between teeth cadmium and lead concentrations, and between cadmium levels and tooth weight, tooth type, and age. In this study, only significant correlations for cadmium levels were observed, a fact that cannot be explained.

TABLE IV. LEAD AND CADMIUM GEOMETRIC MEANS (GM) AND GEOMETRIC STANDARD DEVIATIONS (GSD), IN µg OF METAL/g OF TOOTH, ACCORDING TO YEARS OF RESIDENCE, USE OF COLOR CRAYONS, AND SOCIOECONOMIC LEVEL

Variable	N*	Cadmium GM ± GSD	Cadmium Range	Lead GM ± GSD	Lead Range
Use of color crayons:		F = 0.756 p = 0.387		F = 2.722 p = 0.103	
Children who use them	66	0.21 ± 3.6	0.02 – 1.9	9.5 ± 2.3	1.6 – 57
Children who do not	13	0.3 ± 2.4	0.08 – 1.6	14.1 ± 1.6	6.3 – 30
Socioeconomic level:		F = 0.909 p = 0.343		F = 0.116 p = 0.734	
Low	52	0.25 ± 3.3	0.02 – 1.9	10.4 ± 2.3	1.7 -57
High	27	0.19 ± 3.5	0.02 – 1.4	9.7 ± 2.0	1.9 - 32

* Number of samples

CONCLUSIONS

No statistical differences were found for cadmium and lead concentrations between the different tooth types and positions, and between teeth cadmium and lead levels and the studied variables. This was possibly due to the small sample size. Therefore, the sample size should be increased in further investigations**.** Also, the inclusion of other variables such as feeding and smoking habits could aid to understand the variation of heavy metals concentration in teeth.

ACKNOWLEDGMENTS

This study was partially supported by the Dirección General de Asuntos del Personal Académico (PAPIIT), Universidad Nacional Autónoma de México, Project No. IN209996. The authors are indebted to Hugo Padilla G. for the review of the English manuscript and to Delibes Flores Román for his support in computation.

REFERENCES

Alexander L.M, Heaven A., Delves H.T., Moreton J. and Trenouth M.J. (1993). Relative exposure of children to lead from dust and drinking water. Arch. Environ. Health 48, 392-400.

Altshuller L.F., Halak D.B., Landing B.H. and Kehoe R.A. (1962). Deciduous teeth as an index of body burden of lead. J. Pediat. 60, 224-229.

Bayo J., Moreno Grau S., Martínez M.J., Moreno J., Angosto J.M., Guillén Pérez J.J., García Marcos L. and Moreno-Clavel J. (2001). Environmental and physiological factors affecting lead and cadmium levels in deciduous teeth. Arch. Environ. Contam. Toxicol. 41, 247-254.

Bercovitz K., Helman J., Peled M. and Laufer D. (1993). Low lead level in teeth in Israel. Sci. Total Environ. 136, 135-141.

Bloch P., Shapiro I.M, Soule L., Close A. and Revich B. (1998). Assessment of lead exposure of children from K-XRF measurements of shed teeth. Appl. Radiat. Isot. 49, 703-705.

Bu-Olayan A.H. and Thomas B.V. (1999) Dental lead levels in residents from industrial and suburban areas of Kuwait. Sci. Total Environ. 226, 133-137.

Burton K.W. and John E. (1977). Study of heavy metal concentrations in the Rhodda Fawa, South Wales. Wat. Air Soil Pollut. 7, 45-68.

Delves H.T., Clayton B.E., Carmichael A., Bibearm M. and Smith M. (1982). An appraisal of the analytical significance of tooth-lead measurements as possible indices of environmental exposure of children to lead. Ann. Clin. Biochem. 19, 329-337.

Eide R., Tvinnereim H.M., Fosse G., Kjosnes M. and Nyhaug A. (1998). Lead and cadmium in primary teeth from Illinois, USA. Int. J. Environ. Stud. 55, 25-39.

Elinder C.G., Gerhardsson L. and Oberdoerster G. (1988). Biological monitoring of toxic metals-Overview. In: *Biological monitoring of toxic metals* (T.W. Clarkson, L. Friberg, G.J. Nordberg, P.R. Sager, Eds.). Plenum Press, New York, pp. 18.

Ewers U., Brockhaus A., Winneke G., Freier I., Jermann E. and Krämer U. (1982). Lead in deciduous teeth of children living in a non-ferrous smelter area and a rural area of the FRG. Int. Arch. Occup. Environ. Health *50*, 132-151.

Fergusson J.E. (1990). *The heavy elements: Chemistry, environmental impact and health effects*. Pergamon Press, Oxford, New York, Seoul, Tokyo, pp. 569-570.

Fergusson J.E. and Purchase N.G. (1987). The analysis and levels of lead in human teeth: A review. Environ. Pollut. 46, 11-44.

Gil F., Pérez M.L., Facio A., Villanueva E., Tojo R. and Gil A. (1994). Dental lead in the Galician population, Spain. Sci. Total Environ. 156, 145-150.

Grandjean P., Lyngbye T. and Hansen O.N. (1986). Lead concentration in deciduous teeth: variation related to tooth type and analytical technique. J. Toxicol. Environ. Health 19, 437-445.

Hahn R., Ewers U., Jermann E., Freier I., Brockhaus A. and Schlipköter H.W. (1987). Cadmium in Kidney cortex of inhabitants of North-West Germany: its relationship to age, sex, smoking and environmental pollution by cadmium. Int. Arch. Occup. Environ. Health 59, 165-176.

Harrison R.M. and Williams C.R. (1982). Airborne cadmium, lead and zinc at rural and urban sites in North-West England. Atmos. Environ. 16, 2669-2681.

Lagerwerff J.V. and Specht A.W. (1970). Contamination of roadside soil and vegetation with cadmium, nickel, lead zinc. Environ. Sci. Technol. 4, 583-586.

Lappalainen R. and Knuuttila M. (1981). The concentrations of Pb, Cu, Co, and Ni in extracted permanent teeth related to donor's age and elements in the soil. Acta Odontol. Scand. 39, 163-167.

Mackie A.C., Stephens R., Townshend A. and Waldron H.A. (1977). Tooth lead levels in Birmingham children. Arch. Environ. Health 32, 178-185.

Nordberg M. (1978). Studies on metallothionein and cadmium. Environ. Res. 15, 381-404.

Norén J.G., Hulthe P. and Gillberg C. (1987). Analysis of lead and cadmium in deciduous teeth by means of potenciometric stripping analysis. Swed. Dent. J. 11, 45-52.

Pinchin M., Newhan J. and Thompson R. (1978). Lead, cooper and cadmium in the teeth of normal and mentally retarded children. Clin. Chim. Acta 85, 89-94.

Rabinowitz M., Bellinger D. and Levinton A. (1989). The blood lead-tooth relationship among Boston children. Bull. Environ. Contam. Toxicol. 43, 485-492.

RAMA. (Red Automática de Monitoreo Atmosférico). (1998). Informe anual de la calidad del aire en el valle de México

1997. Gobierno del Distrito Federal, Secretaría del Medio Ambiente, Dirección General de Prevención y Control de la Contaminación, Comisión Ambiental Metropolitana. p. 34.

Ranhkamo A. and Tuompo H. (1985). Uptake of cadmium in developing rat teeth in organ culture. Scand. J. Dent. Res. 93, 198-203.

Schour I. and Massler M. (1941). The development of human dentition. J. Am. Dent. Assoc. 28, 1153-1160.

Shearer T.R, Johnson J.R. and DeSart D.J. (1980). Cadmium gradient in human and bovine enamel. J. Dent. Res. 59, 1072.

Shearer T.R., Johnson B.E., Ridlington J.W. and Whanger P.D. (1982). Chemical location of cadmium in developing rat molars. J. Dent. Res. 61, 510-511.

Sprent P. (1989). *Applied non-parametric statistical methods*. Chapman and Hall, London, New York, pp. 87.

Stack M. and Delves H.T. (1981). Tooth lead analysis-An interlaboratory survey. Int. Symp. Harmonization of Collaborative Anal. Studies, Finland, p. 115-118.

Steenhout A. (1982). Kinetics of lead storage in teeth and bones: An epidemiological approach. Arch. Environ. Health 37, 224-231.

Triphati R.M., Khandekar R.N., Raghunath R. and Mishra U.C. (1989). Assessment of atmospheric pollution from toxic heavy metals in two cities in India. Atmos. Environ. 23, 879-883.

Tvinnereim H.M., Eide R., Riise T., Wesenberg G.R., Fosse G. and Steinnnes E. (1997). Lead in primary teeth from Norway: changes in lead levels from the 1970s to the 1990s. Sci. Total Environ. 207, 165-177.

Tvinnereim H.M., Eide R. and Riise, T. (2000). Heavy metals in human primary teeth: some factors influencing the metal concentrations. Sci. Total Environ. 255, 21-27.

USDHHS (US Department of Health and Human Services). (1993). Toxicological profile for lead (UPDATE). Prepared by Clement International Corporation Under contract No. 205-88-0608 for U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. ATSDR/TP-92/12. Atlanta, GA, pp. 6.