Scand J Work Environ Health 1982;8(4):267-272

<https://doi.org/10.5271/sjweh.2467>

Issue date: Dec 1982

Lead levels determined in Swedish permanent teeth by particle-induced X-ray emission.

by [Moller B](#), [Carlsson LE](#), [Johansson GI](#), [Malmqvist KG](#), [Hammarstrom L](#), [Berlin M](#)

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/7170623

This work is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

Lead levels determined in Swedish permanent teeth by particle-induced X-ray emission

by Bengt Möller, DDS, PhD,¹ Lars-Eric Carlsson, MSc,² Gerd I Johansson, DTech,^{2,4} Klas G Malmqvist, DTech,² Lars Hammarström, DDS, PhD,³ Maths Berlin, MD⁴

MÖLLER B, CARLSSON L-E, JOHANSSON GI, MALMQVIST KG, HAMMARSTRÖM L, BERLIN M. Lead levels determined in Swedish permanent teeth by particle-induced X-ray emission. *Scand j work environ health* 8 (1982) 267-272. The determination of lead in permanent teeth is a useful measure of past exposure in early childhood since these teeth are mineralized in early childhood. Particle-induced X-ray emission (PIXE) analysis has been shown to be a method with good applicability for the contamination-free analysis of elements heavier than calcium in dental hard tissues. The method is rapid and nondestructive. The purpose of this study, which used the PIXE technique, was to survey the average level of lead in the coronal dentin of permanent bicuspid teeth collected in three places representing Swedish urban and rural areas. In addition teeth from the New York City area were analyzed. The material comprised 165 teeth from Sweden and, for comparison, 14 teeth from New York City. The median value of lead in the Swedish teeth was 2.9 µg/g, a value indicating an insignificant influence from the environment in comparison to the New York teeth, for which the median value was 9.2 µg/g. There was however a statistically significant difference in the lead concentration of teeth from large and small Swedish cities; this finding may reflect different automobile traffic intensity.

Key terms: dentin, lead, particle-induced X-ray emission (PIXE), tooth, trace analysis.

Environmental lead pollution is a potential health hazard. The involved dangers, which are difficult to survey, mainly concern certain susceptible groups of the population, such as small children and possibly other groups, the susceptibility of which may depend on metabolic defects. According to a report by the National Academy of Sciences (5), about 2% of American children living in slum districts are mentally retarded, presumably because of

exposure to lead levels that are too high. This exposure was ascribed to the use of lead-containing paint in such areas and to the high concentration of lead in the dust of the streets. The former emanates mainly from gasoline engine exhausts [for a review see the article by Hicks (9)].

Lead is always a trace constituent of teeth, and the amount present is both dose-related and virtually permanent (18). During the preeruptive mineralization period, lead, if present, is incorporated into the dental hard tissues. Later, only the outermost enamel layer and the circumpulpal dentin layer are influenced by occasional exposure. Thus the measurement of lead in teeth is a useful measure of past exposure. Lead analyses of tooth material from different parts of the world (6, 7, 11, 14, 17), as well as from different ancient periods (3, 12), have been performed. The highest values were found in tooth ma-

¹ Department of Endodontics, University of Lund, School of Dentistry, Malmö, Sweden.

² Department of Nuclear Physics, Lund Institute of Technology, Lund, Sweden.

³ Department of Oral Pathology, Karolinska Institute, School of Dentistry, Huddinge, Sweden.

⁴ Institute of Environmental Health, University of Lund, Lund, Sweden.

Reprint requests to: Dr B Möller, Department of Endodontics, Tandläkarhögskolan, Carl Gustafs väg 34, S-214 21 Malmö, Sweden.

terial from modern urban areas. Mostly, values from whole tooth measurements are given, and atomic absorption spectrophotometric methods are used. However, whole tooth measurements include parts of the tooth such as enamel and circum-pulpal dentin, which are influenced by occasional changes in lead exposure. Thus, the lead concentration cannot be related to early childhood exposure. Recently, particle-induced X-ray emission (PIXE) analysis has been shown to be a method with good applicability for the contamination-free analysis of elements heavier than calcium in enamel and dentin (1). The analysis is rapid and nondestructive.

The purpose of the present study was to survey, with the PIXE technique, the average level of lead in the coronal dentin of permanent premolars (mineralized during the age period 1.5–6 a) from three different places in Sweden and to determine whether children living in large cities and children from rural areas have different levels of lead exposure. For comparison teeth from New York City were also analyzed.

Material and methods

The Swedish material comprised 165 premolars extracted for orthodontic reasons. The teeth were intact except for a few with superficial caries lesions or amalgam restorations. They belonged to children

aged 9 years 6 months to 17 years 7 months at the time of extraction. The children had grown up in two large cities, Stockholm and Malmö, or in a smaller town, Jönköping, and its surrounding rural area. After extraction the teeth were stored dry. Immediately prior to analysis the teeth were split longitudinally. Two small furrows were made on the buccal and lingual sides of the teeth, and by means of two sharp steel wedges the teeth were split. This method leaves the surfaces uncontaminated, which is necessary for accurate analysis.

The dentin of the tooth crown, which is formed between 1.5 and 5–6 a of age, was analyzed. In addition, five premolars and nine first molars from New York children were analyzed. These children all lived in slum areas.

The principle of the PIXE method is the irradiation of a solid sample with energetic protons (2–3 MeV) from an electrostatic accelerator. The characteristic X rays induced from elements heavier than aluminum are measured in a silicon (lithium) detector. PIXE analysis is a multielement method giving detection limits typically in the range of 0.5–50 $\mu\text{g/g}$ for all heavy elements in a single 5-min irradiation.

Parts of the analyses were performed at the Niels Bohr Institute in Copenhagen, where the teeth were irradiated with a 2-MeV beam in vacuum. The beam diameter was 1.5 mm, and the X rays were detected in a 30-mm² detector positioned with an angle of 90° relative to the beam.

In the analyses performed at the 3-MV tandem-accelerator in Lund, the teeth were irradiated with an external proton beam in pure nitrogen at atmospheric pressure. The proton energy at the sample surface was 2.55 MeV, and the induced X rays were measured with an 80-mm² silicon (lithium) detector positioned at an angle of 135° relative to the beam. When a tooth is irradiated in a gas at atmospheric pressure, the heat convection from the sample surface is increased, and a higher beam current may be used without the sample being damaged. The detection limits are influenced by irradiation time and the proton energy used. The proton beam was collimated to a diameter of 1 mm, and the coronal circum-pulpal dentin was irradiated as shown in fig 1. The teeth were mounted on a target holder which could be translated to

Fig. 1. Position of the beamspot on a tooth half. The total mass analyzed was approximately 0.2 mg. (diam: diameter)

two directions to enable the correct positioning of each tooth. In order that the intensity of X rays from calcium would be decreased, a 1.4-mm Mylar absorber was inserted between the sample and the detector. The number of protons hitting the sample was monitored with measurements of protons back-scattered from the exit window (fig 2).

In this study, irradiation times of 5 to 10 min gave a detection limit for lead at about 2.5 $\mu\text{g/g}$. Together with lead the concentrations of calcium, iron, copper, zinc, mercury, bromine, and strontium were obtained simultaneously. The elemental concentrations were determined from thin target yields, fundamental parameters being used to calculate the effect of proton stopping and X-ray absorption in the sample (4).

PIXE analysis is an absolute method, and no standard samples have to be used. The solid angle of the detector and the ratio of the number of protons back-scattered from the exit foil to the number of protons hitting the sample were calibrated with the use of a thick silver sample (10). The accuracy of a single element determination is about 5 % with this technique (4).

In the calculation of the median lead values, a statistical technique for censored

observations was used (13). This test takes into consideration the variation in the detection limits.

Results

A total of 165 Swedish and 14 New York teeth were analyzed. The distribution of the lead concentrations of the teeth from the three areas in Sweden is shown in fig 3.

Fig 2. External beam PIXE set-up in Lund. The proton beam is brought out from the vacuum system of the accelerator through a thin plastic foil. The characteristic X rays induced in the sample are measured with an energy-dispersive silicon (lithium) [Si (Li)] detector. (N_2 = nitrogen)

Fig 3. The distribution of lead levels in the dentin of permanent teeth from three different areas in Sweden. (det = detection, conc = concentration)

For a large part of the analyses the lead concentrations were lower than the detection limits, which varied from 1.7 to 3.5 $\mu\text{g/g}$. The median values for lead in Jönköping, Malmö, and Stockholm were 2.1, 2.7, and 3.5 $\mu\text{g/g}$, respectively. The p-values for statistically significant differences between the three areas are given in table 1.

In fig 4, cumulative frequency distributions are given for the three Swedish areas. For comparison, two results are given for the New York teeth, one for the five premolars analyzed, and one for the total New York material (14 teeth). The lead levels of the New York teeth (premolars: 3.2, 5.8, 6.1, 10.6, 15.3 $\mu\text{g/g}$; first molars: 3.2, 4.1, 7.3,

8.0, 8.5, 15, 21, 26, 42 $\mu\text{g/g}$) ranged from 3.2 to 42 $\mu\text{g/g}$ and were much higher than those of the Swedish teeth. The median lead value of all the New York teeth was 9.2 $\mu\text{g/g}$, a value higher than any single value in the Swedish material.

Discussion

According to Needleman et al (15), who studied neurophysiological effects of childhood lead exposure, values below 10 $\mu\text{g/g}$ in dentin from deciduous teeth are considered low. We therefore considered a detection limit for lead of about 2.5 $\mu\text{g/g}$ suitable for screening purposes. However, that level turned out to be too high for a detailed analysis of the Swedish material. Though it will be more expensive and time-consuming, a lower detection limit is possible and can be chosen in future studies. For quantifying purposes the PIXE method, being an absolute method, is very reliable. It should be pointed out, however, that the area to be analyzed must be completely situated in the dentin, since the higher lead content on the pulpal walls

Table 1. p-Values of differences in median lead levels ($\mu\text{g/g}$) between three areas of Sweden. The median values are in parentheses.

Areas	p-Value
Stockholm (3.5) — Jönköping (2.1)	0.002
Malmö (2.7) — Jönköping (2.1)	0.035
Stockholm (3.5) — Malmö (2.7)	0.40

Fig 4. Cumulative frequency distributions of lead levels in three Swedish areas in comparison to the distributions for teeth from New York City. Cumulative frequency indicates the number of teeth with a lead concentration in the dentin equal to, or higher than, the lead concentration given on the abscissa.

may obscure the result (1). The detection limit for lead in dentin is relatively high for the PIXE method. The great advantage of the method is the rapidity of analysis (5–10 min per irradiation) and the nondestructive nature of the method.

The coronal dentin of the first premolars is mineralized between 1.5 and 6 a of age, and the crown of the first molars is mineralized from birth to 3 a of age (8). Thus the lead concentration found in the Swedish premolars represents lead exposure during the age period 1.5–6 a. The lead content in the New York first molars represents lead exposure during an earlier, but overlapping, period of childhood. In the case of lead content in deciduous teeth the period of lead exposure is much less definable.

The fact that the lead level in permanent teeth is somewhat lower than in deciduous teeth being taken into consideration (2), the median concentration of dentin lead in Swedish permanent teeth (2.9 µg/g) in this study is comparable to a corresponding value for Icelandic deciduous teeth (16). However, children from suburban areas in Boston showed about three times higher dentin lead levels, which were considered normal and low in comparison with corresponding values from lead-poisoned children (16).

The difference between Malmö and Stockholm on the one hand and Jönköping on the other may reflect different automobile traffic intensity. This opinion is in contrast to what was reported from Norway by Fosse & Berg Justesen (7). They found that large cities such as Oslo and Bergen did not exhibit higher lead levels than smaller cities or whole counties. Of course, at least from a theoretical point of view, other lead sources, such as drinking water, cannot be excluded.

In summary, the lead concentration in Swedish permanent teeth is low and reflects a less-pronounced influence from the environment in comparison to what was found in teeth from New York. However, a difference between small and large cities was noted.

Acknowledgments

We are grateful to Drs R Albert, A Fischbein, N Knutsson, G Koch, and U Tegesjö for referring the teeth to be analyzed, and

to the Van de Graff laboratory at the Niels Bohr Institute, Copenhagen, for the possibility to perform part of this study. For the statistical analysis of the material we thank Mr B Gullberg, Department of Statistics, University of Lund, Lund, Sweden.

The investigation has been supported financially by Produktkontrollnämnden, Swedish Environment Protection Board, Stockholm, Sweden.

References

1. Ahlberg M, Akselsson R. Proton-induced X-ray emission in the trace analysis of human tooth enamel and dentine. *Int j appl radiat isot* 27 (1976) 279–290.
2. Attramadal A, Jonsen J. The content of lead, cadmium, zinc and copper in deciduous and permanent human teeth. *Acta odontol scand* 34 (1976) 127–131.
3. Attramadal A, Jonsen J. Heavy trace elements in ancient Norwegian teeth. *Acta odontol scand* 36 (1978) 97–101.
4. Carlsson L-E, Akselsson KR. Rapid determination of major and trace elements in geological material with proton-induced X-ray and gamma-ray emission. *Nucl instrum methods* 181 (1981) 531–537.
5. Committee on Biologic Effects of Atmospheric Pollutants. Lead: Airborne lead in perspective. National Academy of Sciences, Washington, DC 1972.
6. Ewers U, Brockhaus A, Genter E, Idel H, Schürmann EA. Untersuchungen über den Zahnbleigehalt von Schulkindern aus zwei unterschiedlich belasteten Gebieten in Nordwestdeutschland. *Int arch occup environ health* 44 (1979) 65–80.
7. Fosse G, Berg Justesen N-P. Lead in deciduous teeth of Norwegian children. *Arch environ health* 33 (1978) 166–175.
8. Gustafson G, Koch G. Age estimation up to 16 years of age based on dental development. *Odontol revy* 25 (1974) 297–306.
9. Hicks RM. The threat from air-borne lead. *Int pathol* 14 (1973) 18–30.
10. Johansson GI, Pallon J, Malmqvist KG, Akselsson KR. Calibration and long-term stability of a PIXE set-up. *Nucl instrum methods* 181 (1981) 81–88.
11. Khandekar RN, Ashawa SC, Kelkar DN. Dental lead levels in Bombay inhabitants. *Sci total environ* 10 (1978) 129–133.
12. Kuhnlein HV, Calloway DH. Minerals in human teeth; differences between preindustrial and contemporary Hopi Indians. *Am j clin nutr* 30 (1977) 883–886.
13. Lee D, Desu M. A computer program for comparing K samples with right-censored data. *Comput programs biomed* 2 (1972) 315–321.
14. Mackie AC, Stephens R, Townshend A, Warldron HA. Tooth lead levels in Birmingham children. *Arch environ health* 32 (1977) 178–185.

15. Needleman HL, Gunnoe C, Leviton A, Reed R, Peresie H, Maher C, Barret P. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. *N engl j med* 300 (1979) 689–695.
16. Shapiro IM, Dobkin B, Tuncay OC, Needleman HL. Lead levels in dentine and circumpulpal dentine of deciduous teeth of normal and lead poisoned children. *Clin chim acta* 46 (1973) 119–123.
17. Shapiro IM, Needleman HL, Tuncay OC. The lead content of human deciduous and permanent teeth. *Environ res* 5 (1972) 467–470.
18. Strehlow CD. The use of deciduous teeth as indicators of lead exposure. Doctoral dissertation. New York University, New York, NY 1972.

Received for publication: 1 October 1982