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Red Deer Antlers as Biomonitors for Lead Contamination

F. Tataruch

Institute of Wildlife Research and Ecology, Veterinary University Vienna, Savoyenstrasse 1, A-1160 Wien, Austria

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Changes in human lead exposure were reconstructed by lead analyses of ancient teeth and bones, as lead accumulates in calcified tissues. As a consequence of research on wildlife species as biomonitors for environmental pollution, red deer antlers were considered as indicators for temporal and regional changes of environmental contamination by pollutants such as lead and strontium-90. The chemical composition of the antler is similar to that of other bony tissues in the body. As many hunters keep antlers as trophies even from a long time ago, without any conservational treatment but with an exact listing of the date and place of shooting, the antlers represent valuable samples for environmental research, especially reconstruction of pollution of the past decades when modern analytical techniques did not exist.

The primary focus of this study was to compare pollution by lead before and after the introduction of lead additives to vehicle's fuel and the impact of radioactive strontium-90 to the environment. Results of ^{90}Sr analyses will be published in another paper (Schönhofer et al. 1994).

MATERIALS AND METHODS

Three hundred samples of red deer antlers from 14 different regions in Austria from 1909 to 1990 were collected. Sampling was done by drilling a hole in the back of the shaft at the height of the tray tine. About 1 gram of antler substance (compacta) was obtained (Kutzer and Onderscheka 1973). The resulting hole in the antler was filled with resin material of similar color so that the place of sampling was less obvious.

After drying at 105°C, the material was ashed at 450°C, the ash dissolved in 5 ml HNO_3 suprapur® (E.Merck, Darmstadt, Germany) and the solution was diluted to 10 ml. For the lead analysis a 1:20 dilution with distilled water was prepared and the concentration was measured by AAS (Perkin-Elmer 5000) in a graphite furnace HGA-500 using the method of standard addition (Tataruch and Schönhofer 1992).

Statistical analyses were performed using the SPSS program package (SPSS Inc., Chicago, Ill.) and for tests of significance the Kruskal-Wallis-test was used. As there was no symmetric distribution of the values (ppm d.m.), the medians (x) in the figures are given together with the minima, the first and third quartils, the maxima and the number of samples (n). As the number of samples was different for the regions, the influence of the region on the trend of the lead levels was determined. Calculation of the Kendall Coefficient of Concordance proved the course of lead concentrations in the different areas to be of the same direction.

RESULTS AND DISCUSSION

During the annual period of growth the minerals needed for formation of the antler are mobilized from the skeleton and also derived from the diet. Trace elements, both essential and non-essential, present in food plants are also stored in the antler. Contents of trace elements in the antler proved to correlate significantly with the concentrations of these elements in the local feeding plants (Anke and Brückner 1973). Therefore antlers should also indicate contamination of the biotope by pollutants such as lead and strontium-90.

An animal's burden of lead is mainly caused by two sources; one is respiratory absorption of contaminated air, the other gastrointestinal absorption of lead by uptake of contaminated food plants. Most of the latter results from deposition on the surface of the plants, whereas the amount of lead absorbed by the plant from soils with natural lead concentrations is very small. While grazing, deer ingest some soil too. Lead contained in the soil might add to the body's total burden. As almost the entire lead in the upper surface layers stems from atmospherical deposition (Ewers and Schlipköter 1991) and is not of geogenic origin, it is also a measure for anthropogenic contamination. As a consequence, the lead concentrations in the animal's tissues are an indicator for air contamination.

Very little is known about the exact mechanism of antler's formation, especially about the source of minerals needed. Bubenik and Bubenik (1990) discuss several possible mechanisms how the mineral requirements of antler growth might be met by the animal. Histological investigations by Meister (1956) on bones of white-tailed deer showed hints of mobilization of calcium, the main constituent, from bones during the period of antler growth. It seems plausible that lead, which reacts similar to calcium in animal organisms, is also mobilized from the bones, especially from metabolically active trabecular bone. This would mean that lead levels in antlers not only represent the food burden during the 4 months of antler growth but also the amount of lead previously accumulated in the deer's skeleton.

By calculating the average values for periods of five years, this influence of past exposure was taken into account.

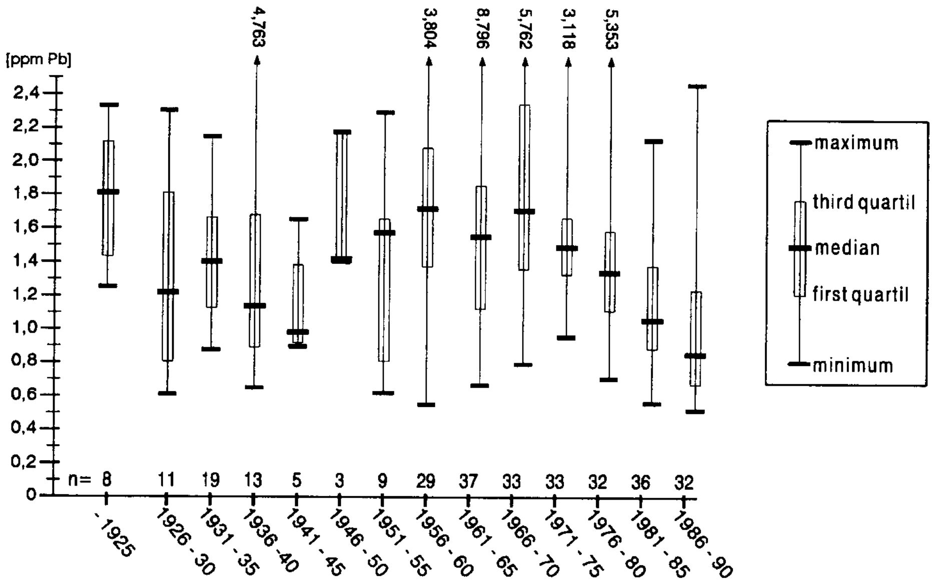

Figure 1. Lead concentrations in red deer antlers from Austria.

All of the samples were taken from typical red deer habitats, consisting of large, unbroken forest areas with very low traffic density. So most of the air lead in these areas is "far fall-out" and "airborne" lead (Ewers and Schlipköter 1991).

Figure 1 shows the course of lead concentrations in the antlers from 1909 to 1990. Values are presented as means of five-year-periods (except 1909 to 1925). The lowest values were registered for the period from 1941 to 1945, the highest medians for the period until 1925 and from 1951 to 1970 and the maximal lead value was determined in the sample from 1961. From the period 1971 to 1975 onwards, a downward trend started that continued even more pronounced during the eighties. The difference between the first and the second five-year-period of this decade was significant on a level of $p \leq 0,0001$ (Tataruch and Schönhofer 1992).

In Austria the addition of organolead compounds to gasoline started in the thirties. During the economic recovery of Austria after World War II traffic density increased, leading to higher lead emissions into the environment. In 1971/72 lead compounds in gasoline were reduced from 0,84 g Pb/l to 0,4 g/l. Calculations of the traffic dependent lead emissions in Austria by Lenz and Akhlagi (1989) proved that this measure resulted in a remarkable decrease of lead emissions although it was partially compensated in the later seventies by a further increase in the number of cars and kilometers driven. The decline of lead in the antlers reflects the reduced amount of lead emissions very well.

The next reduction in the amount of organolead addition to gasoline (to 0,15 g Pb/l) took place in 1982/1983, resulting in a very dramatic drop in lead emissions. These calculated values correspond very well with the results of the antler analyses, showing a more distinct decline in the eighties than in the seventies. A further reduction of lead emissions was achieved by the introduction of unleaded regular and super gasoline in 1982 and 1983. In 1985 the sale of leaded regular was forbidden. These measures resulted in a diminution of lead contamination of the environment also shown by the antler analyses.

Kardell and Källman (1986) analysed concentrations of lead in roe deer antlers from two different areas in Sweden. They found a reduction of 70%, respectively 58% for the period of 1980 - 1983 compared with that of 1968 - 1974. They explain these findings by the reduced addition of lead to gasoline too. Sawicka-Kapusta (1979) analysed roe deer antlers from the Silesian forests from 1938 to 1973. She found much lower lead levels in the samples from 1938 to 1950 compared with those from 1951 to 1973.

Lead levels found for the Austrian samples before World War II were astonishingly high (see figure 1) considering the small number of cars and the fact that addition of organolead compounds to gasoline started in the thirties only. The reason for the high residues is probably found in the higher use of coal for general power production and heating purposes as coal contains varying portions of metals, including lead, which are released to the environment in smoke. The lack of filters resulted in high emissions of dust to which lead particles are adsorbed and thereby dispersed widely around the source.

Interesting results were found when comparing the temporal course of lead levels in 4 study areas in the alpine parts of Austria from which one sample per year was available in the period 1961 to 1990. The geographical sites of these are different: Two areas (L, G) are situated at the northern slope of the Alps, whereas the other two (T, B) are to be found in the central Alps protected against impact of pollutants from the north. Figure 2 shows that the trend of the lead concentrations (medians of 5 years) in the antlers from all 4 areas is about the same, but the levels in the antlers from L and G are significantly higher than in the samples from T and B, indicating a higher lead contamination of these regions. Obviously the Alps represent a barrier for the pollutants from the northern parts of central Europe where centers of heavy industry exist, many of them in a bad condition concerning the amount of emissions. This is proved by the results of the Austrian forest soil monitoring system (Mutsch 1992) which yielded greater concentrations of heavy metals, like lead and cadmium, in the upper layers of soil than in the lower ones, indicating a high anthropogenic input by immissions.

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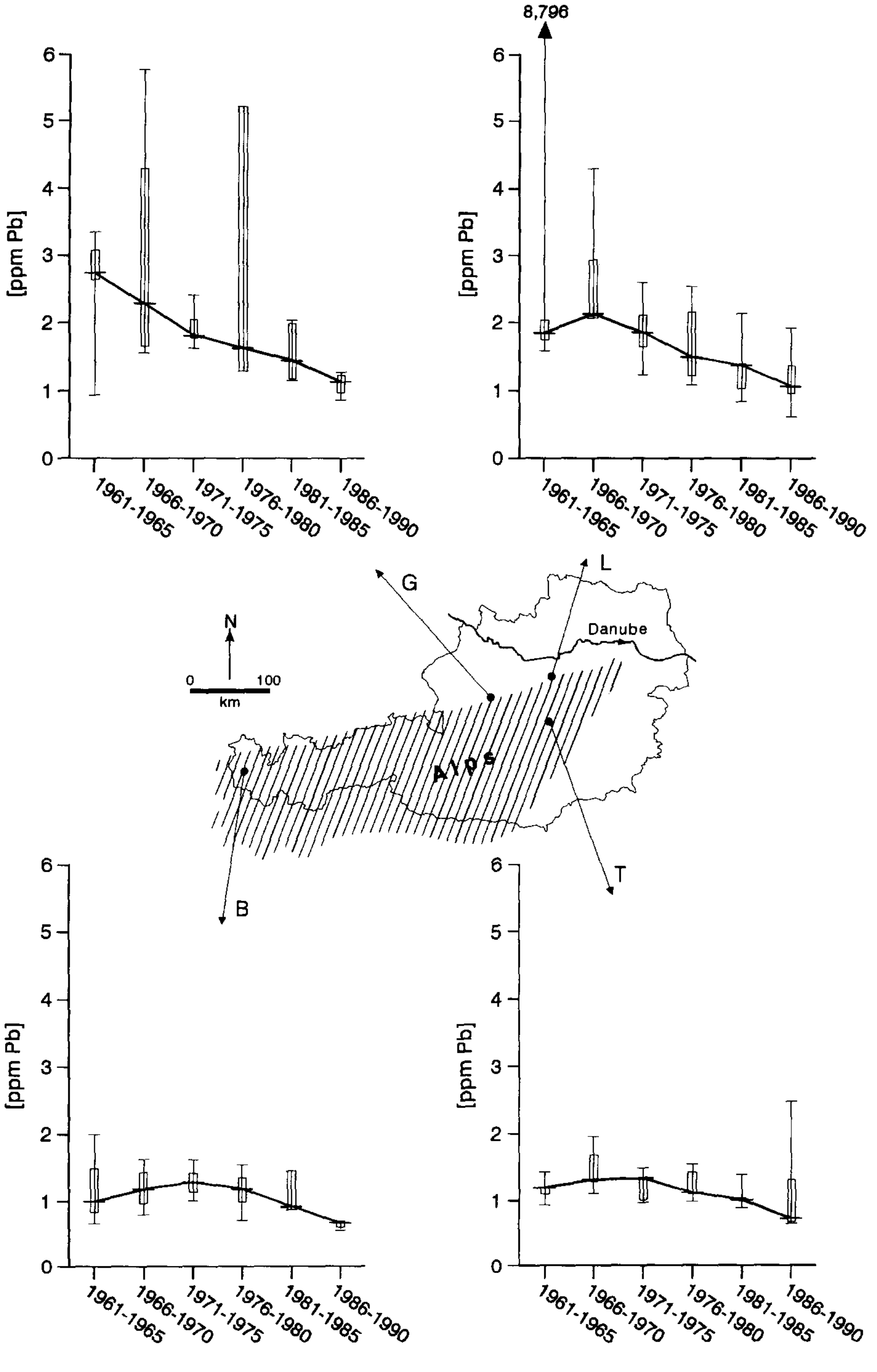

Figure 2. Lead concentrations in antlers from 4 different regions from 1961 to 1990.

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REFERENCES

Anke M, Brückner M (1973) Der Mengen- und Spurenelementgehalt verschieden frequentierter Äsungspflanzen des Rotwildes und des Rothirschgeweihes unterschiedlicher Qualität. Beiträge Jagd- und Wildforschung VIII:21-32

Bubenik GA, Bubenik AB (1990) Horns, Pronghorns and Antlers. Springer, New York, Berlin, Heidelberg, London, Paris, Tokyo, Hong Kong

Ewers U, Schlipköter HW (1991) Lead. In: Merian E (ed) Metals and their compounds in the environment. VCH, Weinheim, New York, Basel, Cambridge, 971-1014

Kardell L, Källman S (1986) Heavy metals in antlers of roe deer from two Swedish forests, 1968 - 1983. Ambio 15:232-235

Kutzer E, Onderscheka K (1973) Einfluß verschiedener Faktoren auf die Geweihentwicklung des Rothirsches. Österreichs Weidwerk 1:42-44

Lenz HP, Akhlagi M (1989) Schadstoffemissionen des gesamten benzin- und dieselbetriebenen Straßenverkehrs in Österreich sowie zu erwartende Entwicklungen 1970 - 2000. Forschungsarbeiten aus dem Verkehrswesen. 60p, 43fig.

Meister W (1956) Changes in biological structure of the long bones of white-tailed deer during the growth of the antlers. Anat Rec 124: 709-721

Mutsch F (1992) Österreichische Waldboden-Zustandsinventur, Teil VI: Schwermetalle. Mitteilungen der Forstlichen Bundesversuchsanstalt 168, Bd.II: 145-192

Sawicka-Kapusta K (1979) Roe deer antlers as bioindicators of environmental pollution in southern Poland. Environ Poll 19:283-293

Schönhofer F, Tataruch F, Friedrich M (1994) ^{90}Sr in Antlers of Red Deer - An Indicator for Environmental Contamination by ^{90}Sr. Sci Tot Environ in press.

Tataruch F, Schönhofer F (1992) Untersuchungen zum zeitlichen Verlauf der Blei- und Strontium-90-Belastung in Österreich anhand von Rotwildgeweihen. Abschlußbericht über das Jubiläumsfondsprojekt Nr.3926 der Österreichischen Nationalbank. 34p.