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Blood Lead Levels in Sheep Exposed to Automotive Emissions

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Elevated lead concentrations in the whole blood of domestic animals as a result of lead poisoning, have been well documented following the original work of BLAXTER (1950). This and later papers (PRIGGE AND HAPKE, 1972; HAPKE, 1973; FICK et al. 1976; VAN GELDER et al. 1973) have been concerned mainly with lead poisoning from contaminated water and other similar sources, and have involved numerous artificial experiments in which lead salts (usually acetates) were fed to domestic animals. Although recent work (BLOOM et al. 1976; WARD et al. 1977) on blood levels in various domestic animals has by inference, taken into account the possibility of poisoning from automotive lead emissions, it is surprising that very little work has been done on blood lead levels in animals grazing or living adjacent to busy motorways. Where such investigations have made, they have mainly involved rodents and other small animals (QUARLES et al. 1974; JEFFERIES AND FRENCH, 1972; WILLIAMSON AND EVANS, 1972).

Because of the sparsity of data on lead uptake by ruminants grazed near roadsides, and because of the potential seriousness of such uptake to a country such as New Zealand, which is heavily dependent on agricultural exports, we have recently carried out a series of studies on the effect of automotive exhaust emissions upon the lead content of the blood of sheep grazing near roadsides. The experiments were designed to simulate real conditions and to avoid feeding artificially with lead salts which can never resemble the end product of motor vehicle emissions. The results of these experiments are reported in this paper.

PROCEDURES

Analytical Methods

Lead levels in whole blood were determined by use of a Varian Techtron Model 63 carbon rod atomizer attachment for a Varian Techtron Model AA5 atomic absorption spectrophotometer. Standard curves were prepared by spiking whole blood (containing about 0.20 µg/ml lead) with incremental amounts of lead and then using the method of addition to calculate the original content in the standards. Beer's Law was obeyed in the range 0.1 to 2.0 µg/ml. To avoid interference from

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matrix effects, Triton X-100 (a detergent) was added in the ratio of 1 volume to 2 volumes of blood before analysis. Corrections for non-atomic absorption were made with a Model BC-6 automatic background corrector. The spectral line at 217.0 nm was used for all lead determinations. The precision of replicates containing about 0.20 µg/ml was about ±5%.

Description of Experiments

A. The lead content of the whole blood of a flock of 62 sheep (Romney breed of various sexes and ages) was determined. This flock had been grazed for nearly six months along the verges of a major highway (5000 vehicles/24 h). Comparative data were obtained for another flock of sheep from the same area but well removed from the effect of motor traffic exhausts.

B. Four sheep (Romney ewes of 2,2,4 and 5 years of age) were removed from the above contaminated area and transferred to a paddock well away from motor vehicles. The lead content of the blood was monitored at regular intervals for 185 days.

C. Four sheep (Romney ewes of 2,2,4 and 5 years of age) from an uncontaminated area were placed in a paddock (at Massey University, New Zealand). This pasture was adjacent to a busy road (8000 vehicles/24 h). The blood lead levels were monitored at regular intervals.

D. Ten sheep (Romney ewes and wethers of varying ages) were kept in a pen well away from motor vehicles and were fed with fresh grass collected from the verge of a busy roadway. The blood levels of lead were monitored over a 9 day period.

E. Four sheep (Romney ewes of 2,5,5, and 5 years of age) were placed in a pen near a busy highway (8000 vehicles/24 h) without access to local forage. The sheep were fed with feed from a non-contaminated area and the blood lead levels were monitored for a period of 5 days.

RESULTS AND DISCUSSION

A. The Blood Lead Content of Sheep Grazing near a Highway

The lead content of whole blood of a flock of sheep grazed for 6 months near a highway at Dannevirke is compared with an adjacent flock in Figure 1. The other flock was from a non-contaminated area. The means and standard deviations of the two populations were 0.90±0.05 µg.ml and 0.20±0.01 µg/ml respectively.

The histogram shows that both populations can be separated completely on the basis of the lead content of their blood. Eighteen sheep had lead levels exceeding 1.0 µg/ml. These concentrations are extremely high and are comparable to levels found in sheep fed artificially with lead salts as reported by

BLAXTER (1950). The same author found a maximum of 1.30 µg/ml in the blood of a sheep fed with 30 g of lead as acetate. This level was reached by one third of the sheep in our study. The mean lead content of the grass was 60 µg/g (dry weight) and corresponds to an ingestion of 7.2 g of lead over a period of 150 days if a daily intake of 800 g of feed is assumed.

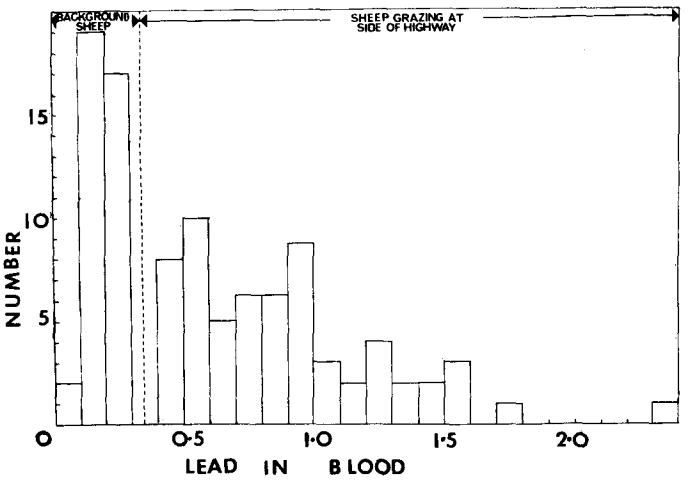

FIGURE 1. Histogram of blood lead levels (µg/ml) in sheep grazing near to, and away from, a major highway.

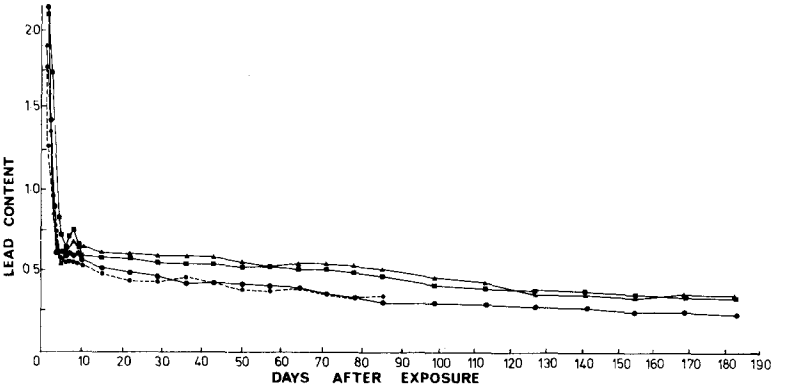

FIGURE 2. Decrease of blood lead levels (µg/ml) in four sheep after removal from contaminated area.

B. Rate of Decrease of Blood Lead Levels after Removal of Animals from a Contaminated Area

When 4 sheep from the Dannevirke experimental area (see above) were removed to a paddock well away from motor vehicle emissions,

the blood lead levels decreased considerably during a period of 185 days. The data are shown in Figure 2.

The concentration decreased from about 2.00 to 0.60 µg/ml during the first 10 days. Background values (0.20 µg/ml), though approached, had still not been reached after 185 days. Lead is known to be stored in the bones of sheep (FICK et al. 1976) and these form a convenient reservoir for gradual release of lead into the blood over a long period.

C. Uptake of Lead by Sheep Brought from an Uncontaminated Area to a Paddock near a Highway

When 4 sheep from an uncontaminated area were placed in a paddock near a major highway (lead content of forage, 19 µg/g dry weight), the lead content of the whole blood rose from 0.20 to about 3.00 µg/ml during the first 24 h. Thereafter there was a gradual decrease over 14 days to a value of about 1.5 µg/ml. This is shown in Figure 3.

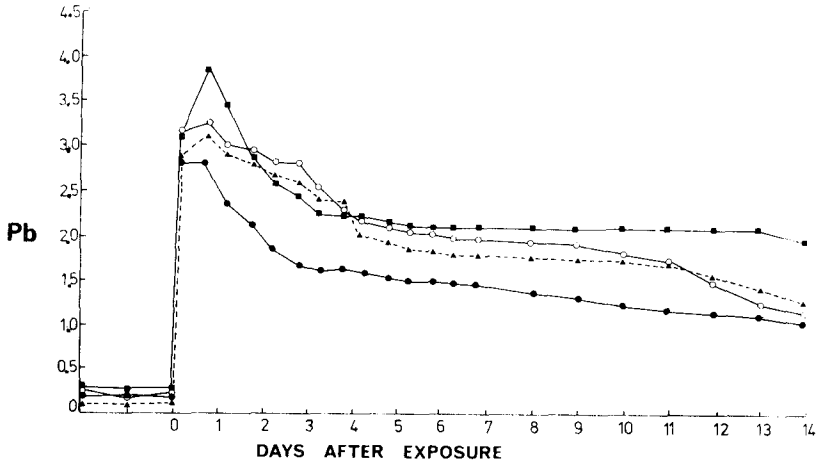

FIGURE 3. Blood lead levels (µg/ml) in sheep transferred from a background area to a contaminated paddock.

The pasture used in this experiment was lucerne (Medicago sativa L.). During the initial period the sheep were consuming leafy material almost exclusively. This had been exposed to lead contamination during the preceding rest period. As the experiment continued, the diet contained a greater proportion of stem material with a lower lead content. It was also likely that intake was reduced slightly as the palatability of the feed declined. The combination of these two factors is suggested as the cause of the post peak reduction in blood lead. It is also possible that lead was being

removed from the blood for storage in other body organs, but further work is required to demonstrate the fate of blood lead in sheep exposed to lead pollution of this type.

D. Uptake of Lead by Sheep Placed away from Motor Vehicle Emissions but Fed with Grass from Roadside Verges

When 10 sheep were placed in a concrete pen well away from motor vehicle exhaust emissions and were fed with grass freshly cut from the verges of a busy highway, there was an immediate rise in the blood lead levels as shown in Figure 4.

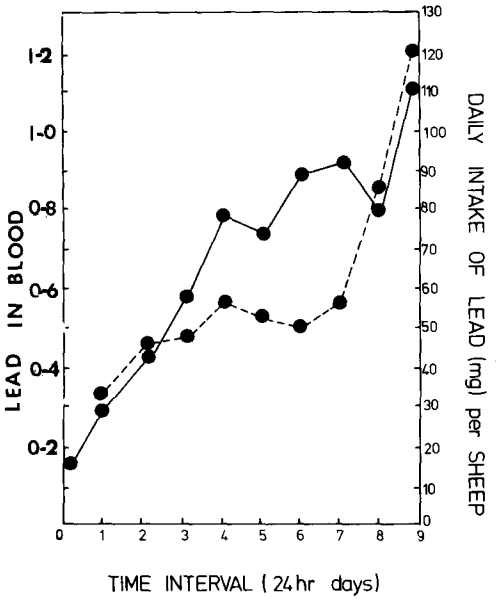

FIGURE 4. Blood lead levels in µg/ml (continuous line) in sheep placed in background area and fed with grass from roadsides. Daily uptake of lead is shown as a broken line.

The mean values increased from 0.17 µg/ml to 1.1 µg/ml over a period of 9 days. The lead content of the feed varied from 40 - 70 µg/g (dry weight basis). Figure 4 also shows (broken lines) the total daily intake of lead. Increased intakes towards the end of the test period are due partly to the higher lead content of later feeds and partly to increased consumption of grass as the animals became used to the new environment. There appeared to be some relation between the lead content of the blood and the daily intake of lead.

E. Uptake of Lead by Sheep Placed near a Busy Highway and Given Feed from an Uncontaminated Area

The experiments so far had shown that the lead content of the feed was an important factor determining the lead content of the blood in the experimental animals. In order to establish whether inhalation of lead particulates was a contributing factor, 4 sheep were placed near a busy highway without access to local feed. The sheep were fed with forage (2.5 µg/g lead-dry weight) from an uncontaminated area. As before there was an immediate increase in the blood lead level as shown in Figure 5.

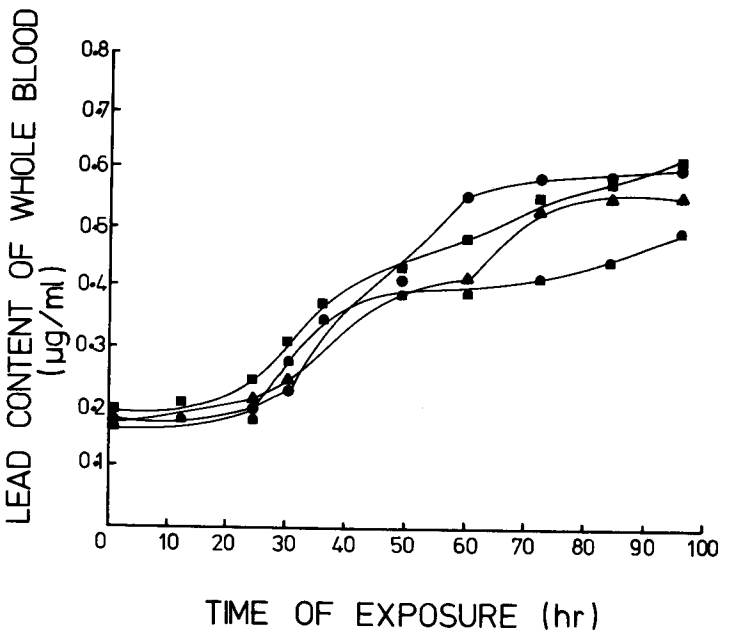

FIGURE 5. Blood lead levels in sheep (four individuals shown as different symbols) placed near roadside but fed with uncontaminated forage.

The rate of uptake was very similar to that of the previous experiment and would seem to indicate that both processes i.e. ingestion by forage and inhalation of lead particulates from air, were equally important in affecting the lead content of the blood.

GENERAL DISCUSSION

Enhanced lead levels in the blood of sheep are in themselves only symptomatic of elevated concentrations in bones and reservoir organs such as liver and kidneys, all of which have been found by FICK et al. (1976) to have enhanced lead levels after feeding artificially with lead salts. Whether or not lead will be found in the same reservoirs after experiments under natural conditions of grazing near highways is somewhat uncertain and is currently being investigated. If this proves to be the case, there will certainly be a need to exclude these organs from sale to the public in the case of animals which have been known to have been grazed close to busy highways.

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SUMMARY

The lead content of whole blood of 62 sheep grazed continuously for 6 months near a major highway was compared with 38 sheep from a nearby uncontaminated area. Mean values of 0.90 and 0.20 µg/ml were obtained. Four sheep from the contaminated area were placed in an uncontaminated paddock and the lead content of the blood decreased rapidly during the first 10 days and thereafter more slowly. After 185 days, blood lead levels had still not quite reached normal levels.

Animals from an uncontaminated area showed an immediate rise in the blood lead levels when placed near a major highway. Sheep placed in a concrete pen away from motor vehicle exhaust emissions showed a rise in lead levels when fed with forage cut from the verges of a busy highway. Sheep placed near a highway and fed with forage from an uncontaminated area showed an increase of lead levels in the blood, comparable to that of the previous experiment. It was concluded that lead uptake by ingestion of polluted forage and by inhalation of airborne particulates are both mechanisms responsible for enhanced lead levels in ovine blood.

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