Absorption of lead from dust and soil

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Summary

The lead burdens for children and mothers exposed to lead-contaminated soils and dusts have been investigated in a rural district with minimal atmospheric pollution. A significant relationship was observed between the lead content of blood and hair of children exposed to soils of mean lead content in the range 420-13,969 p.p.m. The blood lead concentration of children was consistently greater than that of their mothers. No consistent relationship was found between blood lead values and pica for soil. In this situation, lead in soil provided a small additional burden for children but in itself was insufficient to constitute a hazard.

THE hazard to human and animal populations from lead-contaminated soils and street dusts has aroused considerable interest and speculation. Past and present mining and industrial activity and automotive emission have all contributed to increased soil lead content. Entire populations may be unduly exposed by the involuntary inhalation and subsequent ingestion of dust-laden air. Children and livestock may be particularly at risk owing to direct ingestion of soil.

Many cases of lead poisoning in livestock have been observed in high soil lead areas of the United Kingdom. Not only are deaths reported (Thornton, 1973), but also economically important sub-clinical effects such as poor growth and weight gain (Stewart and Allcroft, 1956). This exposure most probably resulted from the direct ingestion of soil, rather than from the lead content of the herbage, as sheep and cattle have been shown to ingest large amounts of soil while grazing. Cattle grazing in the old mining areas of south-western England can ingest ten times as much lead from soil as from herbage (Thornton, 1973).

McNeil and Ptasnik (1974) studied the population adjacent to a lead smelter in an arid, dusty area,

devoid of vegetation, and Lansdowne *et al.* (1974) investigated the human populations near lead smelting activity in London. In both cases, a significant proportion of the increased blood lead values of the local populations was attributed to the ingestion of lead-contaminated dust and soil, although without any direct evidence as to the importance of this source to the acquired lead burdens.

Recent concern about the health hazards of lead additives in gasoline has been centred, not on the inhalation of airborne lead, but on the possible ingestion of lead-contaminated soils and dusts. High concentrations of lead have been found in street dusts and in soils adjacent to highways, and this source of lead has been cited as a potential hazard for children, who may ingest dangerous quantities of lead by the frequent mouthing of dust-contaminated articles, the direct ingestion of soil, and the inhalation and subsequent ingestion of particles from dust-laden air (National Academy of Sciences—National Research Council, 1972; Needleman *et al.*, 1974; Environmental Protection Agency, 1973; Day, Hart and Robinson, 1975). This view has been unsupported by any measurement of the lead burdens derived from this source.

In order to understand more fully this potential hazard, we have studied the lead exposure of children living in an area of high soil lead content and minimal exposure to airborne lead. It has been previously reported (Barltrop *et al.*, 1974) that there was no significant difference in the blood lead concentrations of 2-year-old children and their mothers between two towns whose mean soil lead contents were 900 and 400 p.p.m. Only in the town with the low soil lead content did children with pica for soil have an increased blood and hair lead content. The values recorded were within the normal range, and provided no conclusive evidence for any major hazard to children from lead in soil.

In the course of these studies, several neighbouring villages were found to have soils containing more

than 10,000 p.p.m. (1%) lead. The area is both naturally high in soil lead content, as well as being contaminated by mining activity carried out since the Roman occupation of Britain (Nichol *et al.*, 1970). As these concentrations were much greater than previously studied, a similar investigation was made in these villages, where any effect of high soil lead content on childhood lead burdens should be evident.

Control villages

Since various soil characteristics might influence the intestinal absorption of lead from soil, as has been shown to affect the availability of lead in soil to plants (Mitchell, 1971; MacLean, Halstead and Finn, 1969), careful consideration was given to the selection of the control population. A preliminary survey indicated that the control villages about 10 km from high soil lead villages in the same Carboniferous Limestone area of Derbyshire, had soil lead contents of about 500 p.p.m. While this was a factor of 20 lower than the test villages, it was hoped to find a control area with a much lower soil lead content.

Other limestone areas in the U.K. were investigated, but were also found to be mineralized, and no suitable control villages with a low soil lead content were available. As soil derived from chalk is similar to that derived from limestone, a survey of twelve villages in Hampshire was made in the hope of finding suitable control villages with a lower soil lead content. Samples were taken at a depth 0–5 cm from five gardens in each of the villages. The mean soil lead content of the villages ranged from 232 p.p.m. to 1428 p.p.m., with an overall mean of 504 p.p.m.

As the results were not significantly different from the control villages in Derbyshire, and since the soil type should be as similar as possible in the test and

control areas, no advantage was gained from using any of the villages in Hampshire as control areas.

Methods

The survey and analytical methods were similar to those previously described (Barltrop *et al.*, 1974). Venous blood samples were taken from both the child and the mother at a local clinic, where the mother was asked about the play and pica habits of her child. In addition, a sample of hair and a single stool specimen were obtained from the child. Samples of garden soil and house dust were taken from each of the homes in the study. The biological and environmental data all followed log-normal distributions, and all statistical tests were performed on the log-transformed data.

The lead content in suspended particulate matter and in dust and rainfall were also monitored, the average of monthly samples was 0.28 and 0.34 $\mu\text{g Pb/m}^3$ for suspended particulate matter in the 'low' and 'high' soil lead areas respectively, and 194 and 254 $\mu\text{g Pb/m}^3/\text{day}$ for the dustfall samples. The observed values were low, within the range reported for other rural sites in the U.K. (Peirson *et al.*, 1973) and indicated no significant exposure to lead from these sources.

Results

The preliminary blood and hair lead data for the high and low soil lead areas have been previously reported (Barltrop *et al.*, 1974), and they are now presented in detail in Table 1, together with the corresponding soil and house dust results. In order to investigate more closely the relationship between soil lead content and lead burden, the data were further classified into three groups depending on the soil lead content found at the child's home. The areas chosen contained homes with soil lead content less than 1000 p.p.m., between 1000 and 10,000

TABLE 1. 1973 Derbyshire survey. Lead content: geometric means and ranges*

	Blood lead ($\mu\text{g}/100\text{ ml}$)		Hair (p.p.m.)	Soil (p.p.m.)	House dust (p.p.m.)
	Child	Mother			
All	23.2 (82) 13–45	16.6 (74) 9–44	10.2 (82) 2–62	1978 (72) 130–28000	1189 (64) 190–25000
Low soil lead area	20.9 (34) 15–45	14.7 (30) 9–40	7.5 (34) 2–36	518 (29) 130–3000	565 (23) 190–2450
High soil lead area	25.0 (48) 13–43	18.0 (44) 11–44	12.8 (48) 2–62	4881 (43) 1050–28000	1803 (41) 420–25000
Soil lead < 1000 p.p.m.	20.7 (29) 15–33	14.1 (25) 9–40	7.7 (29) 2–36	420 (24) 130–900	531 (20) 190–2450
Soil lead 1000 p.p.m.–10,000 p.p.m.	23.8 (43) 13–45	18.7 (41) 11–44	10.5 (43) 2–62	3390 (40) 1050–9100	1564 (36) 390–25000
Soil lead > 10000 p.p.m.	29.0 (10) 21–43	14.8 (8) 13–19	20.2 (10) 10–39	13969 (8) 10000–28000	2582 (8) 1000–5100

* Number of cases in parentheses.

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TABLE 2. Mean blood and hair lead content

Soil lead	Blood lead ($\mu\text{g}/100\text{ ml}$)		Hair (p.p.m.)	Soil (p.p.m.)	House dust (p.p.m.)
	Child	Mother			
Less than 1000 p.p.m. N = 29	20.7 ^{a,b}	14.1 ^c	7.7 ^f	420	531
1000–10,000 p.p.m. N = 43	23.8 ^a	18.7 ^{c,d}	10.5 ^e	3390	1564
Over 10,000 p.p.m. N = 10	29.0 ^b	14.8 ^d	20.2 ^{e,f}	13,969	2582

a, a; b, b; etc. significantly different, two tailed *t*-test, $P < 0.05$.

p.p.m. and greater than 10,000 p.p.m. lead, and all statistical tests were applied to these groupings.

The means for these three areas are summarized in Table 2, and the statistically significant differences in blood and hair lead content are noted. The soil and house dust means were significantly different in all areas. The data indicate that absorption, as measured by blood and hair lead contents, does increase with soil lead content. However, the observed increases were small, considering the very high soil lead concentrations encountered, and the values were within the normal range. The mean faecal lead content for all children was 50 μg per single specimen, and there was no statistically significant difference in the results from any area irrespective of the pica history of the child.

As in our previous study, the children were found to have greater mean lead concentrations than their mothers (paired *t*-tests, $P < 0.05$) irrespective of the pica history of the child, or the area in which the child lived. This may reflect the relatively greater dietary intake of the child on a body weight basis.

Comparisons in blood and hair lead concentrations were also made between areas in relation to the pica history of the child (Table 3). Our definition of pica for soil included the habitual mouthing of dirty fingers and toys, as well as the actual ingestion of soil. The data show that there is a general increase in the blood and hair lead concentrations with increasing soil lead content for all children, whether

or not they had current pica. For example, the children with no pica had a mean blood lead of 19.1 $\mu\text{g}/100\text{ ml}$ in the area with soil lead less than 1000 p.p.m. increasing to 23.4 in the 1000–10,000 p.p.m. soil lead area, and to 26.7 in the area with soil lead over 10,000.

Within each area comparisons were made between the blood and hair lead concentrations of those children with no current pica, and those who had current pica for soil (Table 3).

In the area with soil lead of less than 1000 p.p.m. the children with pica for soil had a greater mean blood lead content, 22.5 $\mu\text{g}/100\text{ ml}$, than those with no current pica, 19.1 $\mu\text{g}/100\text{ ml}$, but there was no difference in hair lead content. In the intermediate area, the mean hair lead content was greater for those children with pica for soil, but there was no difference in the mean blood lead content. No differences relating to pica were found in the area with soil lead concentrations over 10,000 p.p.m. (1%).

The mean lead content of the house dust increased with the soil lead content, but was lower in concentration than the soil surrounding the home. Within a given area, there was no significant correlation between individual house dust and soil lead concentrations. A statistically significant concentration is found only if the data from all areas are used reflecting the wide range of values observed.

Statistically significant correlations (both product moment and non-parametric) between the blood and soil lead or house dust data can be shown only if the data from all of the areas are considered. No significant correlations were found within a given area, and for hair lead, significant correlations were found only when the soil lead was over 1000 p.p.m., and when all children were considered.

Discussion

All of the tests between means and the correlation of the individual data indicate that there is a general increase in lead exposure and burden for all children when they live in a high soil lead area. This increase is within the normal range, as indicated by the blood and hair lead concentrations encountered. It would

TABLE 3. Blood and hair lead concentrations—geometric mean

Soil lead area	No.	Blood ($\mu\text{g}/100\text{ ml}$)	Hair (p.p.m.)
Less than 1000 p.p.m.			
No pica	14	19.1 ^{a,1,2}	6.0 ³
Pica for soil	14	22.5 ^{a,3}	8.9 ⁴
1000–10,000 p.p.m.			
No pica	26	23.4 ¹	9.1 ^b
Pica for soil	13	24.3	17.4 ^{b,4}
Over 10,000 p.p.m.			
No pica	5	26.7 ²	22.8 ³
Pica for soil	4	29.0 ³	20.9

Between areas: 1, 1; 2, 2; etc. significantly different, $P < 0.05$. Within areas: a, a; b, b; etc. significantly different, $P < 0.05$.

appear that children who habitually put dirty fingers and toys in their mouths receive little or no extra lead burden when compared with other children living in the same area.

Many factors may influence the absorption of lead in dust and soil. The chemical form and source of the lead, as well as various soil characteristics such as pH, organic matter content, and nature of the parent material, may all influence the bioavailability of lead in dust and soil. Differences in the extractability of lead by various leaching agents were found in the soils from the study area, but the relationship of such results to absorption from the gut is unknown.

No information as to how much soil or dust a child might ingest is yet available. Our present results could be explained if only minute amounts of soil are ingested—even by children who put soil directly in their mouths, or alternatively by very low absorption of lead from soil in the gut. The mean blood lead concentration of 29 µg/100 ml for children living in an area of soil lead content in excess of 1% lead indicates that lead in soil and dust is a relatively minor source and in itself insufficient to constitute a hazard.

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