SIGNIFICANCE OF LEAD-CONTAMINATED SOILS AND DUSTS FOR HUMAN POPULATIONS

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A heavily lead contaminated region in which there was no significant atmospheric pollution was found in the County of Derbyshire in Central England. An initial study of human populations was made in two towns differing in their soil lead content. The contaminated area had a mean soil lead of 900 ppm and the control 400 ppm. Mothers and children aged 2 years were selected and samples of soil obtained from each of their homes. Lead values were determined in the mothers blood and in specimens of faeces, blood, hair and deciduous teeth obtained from the children. Lead was also determined in specimens of soil from gardens adjacent to their homes. No significant differences in lead burdens could be demonstrated between the two populations.

The study was repeated in village populations selected according to the degree of soil contamination $< 1{,}000$ ppm, $< 10{,}000$ ppm, and $> 10{,}000$ ppm. Airborne lead gave mean monthly averages of 0.34 and 0.28 μg Pb/m^3 for the test and control villages. Similarly dustfall lead gave values of 254 and 194 μg Pb/m^2/day.

The blood and hair data showed that there was a general increase in lead content in relation to soil lead irrespective of the presence of pica. The geometric mean values for blood lead in children were 20.7, 23.8 and 29.0 μg/100 ml for each of the three soil groups. No correlation could be found among the corresponding mothers of the children.

The data suggest that contaminated soils and dusts may contribute to body lead burdens, but to a degree unlikely to be of biological significance.

Increasingly, attention has been given to the dispersion of lead in the environment. This differs from many other pollution situations involving synthetic chemicals in that lead is a naturally occurring substance in the

earth's crust with a background concentration of about 16 ppm. Several activities involving lead result in redistribution on the earth's surface on a scale of potential environmental significance and these include:

1. Deposition of mine wastes
2. Primary and secondary smelting
3. The use of lead additives in gasoline

The first two of these activities result in relatively localised contamination problems whereas the latter is more uniformly dispersed and of lesser degree. In spite of this, most controversy has arisen in connection with lead additives to gasoline. Much of this argument was initially based on the assumption that airborne lead itself might be a significant source for human populations. However, it is now apparent that in most urban situations the contribution from this source is relatively small when compared, for example, with the lead content of the normal diet.

Interest has now shifted from atmospheric lead to its ultimate site of deposition on the earth's surface. This has some logic since lead has a transient life in the atmosphere but is thought to be relatively permanent after deposition. It follows that a progressive increase in the lead content of soils and dusts might be predicted in relation to various atmospheric sources.

The question arises as to whether existing or predicted lead concentrations in soils and dusts have significance for man.

Soil and dust concentrations in relation to particular sources have been found to be markedly increased compared with background levels so that a typical city dust might have a concentration of the order of 1—2,000 ppm, whereas soils adjacent to smelters have been found to have concentrations of about 5,000 ppm. Although adults do not normally ingest such contaminated material, children are potentially at risk by virtue of both their mode of play and by direct ingestion through the activity known as pica. Since it is thought that ingestion of about 1,000 μg of lead per day will result in symptomatic poisoning after 4—5 months in a 2-year-old child, it follows that this could result from the ingestion of about 0.1—0.5 g of soil in a similar period. It has not, however, been demonstrated that this actually happens. Few reports of lead poisoning from soil ingestion exist in the world literature and even in those cases, additional sources of lead were not excluded.

Evidence concerning routes of transmission is limited. *Vostal* and coworkers (1) showed that about 200 μg lead could be recovered from a child's hands but its source was not identified and the degree to which it was actually transferred to the child's gastrointestinal tract was not measured. *Day* and coworkers (2) have recently claimed that significant amounts of lead can be transferred from a child's hands to a sticky sweet but again were unable to provide evidence as to whether this was a real as opposed to a potential hazard. *Ter Haar* (3), using naturally occurring Pb 210 as a tracer for atmospheric lead, concluded that this made no significant contribution to symptomatic poisoning in childhood

and although he was able to detect lead derived from this source in two out of three children who were soil eaters, its contribution to daily intake was small.

The problem facing workers investigating this question has been the co-existence of several environmental sources of lead in any given situation so that it has been difficult to determine the fractional contribution of dietary as opposed to atmospheric sources. Thus in El Paso, Texas, raised blood lead values were observed in children living in close relation to a lead smelter but it remains uncertain whether these were due to the contamination of local soils and dusts (about 5,000 ppm) or to atmospheric lead (about 90 $\mu g/m^3$) (4). A similar problem was described by *Lansdown* (5) in Central London in relation to a secondary smelter where contaminated soils, industrial clothing, lead paint, and atmospheric emissions all contributed to the increased blood lead concentrations of local children. In spite of all these uncertainties the contamination of soils and dusts has become a major feature of the views expressed by the U. S. Environmental Protection Agency in their case for the removal of lead additives from gasoline.

In order to resolve this question it is necessary to discover a situation in which most of these variables could be controlled and in particular one in which there was a minimal content of atmospheric lead. Three years ago our attention was drawn to a district in Central England in the County of Derbyshire. This resulted from the findings of a national geochemical survey in which stream sediments were analysed for lead. The composition of stream sediments is thought to reflect the composition of the soils through which they have passed. It was found that the Eastern half of the county was heavily contaminated with lead whereas the Western half, which was otherwise geochemically identical, was relatively uncontaminated. This situation was attributed to surface contamination arising from the mining and smelting of lead which had taken place during the preceding 2,000 years. This industry became virtually defunct, apparat from one small secondary smelter, about 40 years ago. It is now primarily an agricultural area with little traffic or industry and therefore lacks significant atmospheric pollution. This paper describes two successive surveys of populations in that district in which the lead burden of children and mothers inhabiting contaminated and uncontaminated districts were compared (6, 7).

The first study involved the population of towns situated in the east (Matlock) and west (Buxton) sides of tle Country of Derbyshire, representing contaminated and uncontaminated areas respectively. The subjects selected were children aged 2 years together with their determiners. Each mother was interviewed and the child's pica habits determined. Specimens of faeces, blood and hair were obtained from each child and analysed for lead as indices of exposure of varying duration. A blood sample was obtained simultaneously from each mother. The child's home was visited in each case and samples of soil obtained from the adjacent gardens. In view of the potential effect of season the survey,

was conducted initially in the spring, was repeated on the same population in the summer. At the same time in both towns a programme for the collection of extracted deciduous teeth was initiated with the collaboration of local dentists and the school dental service. Throughout the study the lead content of dustfall and suspended particulates was monitored.

The soil analyses are given in Table 1. These showed that the difference in mean soil lead concentration was more modest than might have been supposed from the stream sediment studies. Garden soils in

Table 1

Lead content of garden and grassland soils

Type	Depth cm	Town	Number of samples	Pb, content, ppm		
				Mean	Geo-metric mean	Range
Front garden flower beds	0—5	Matlock	44	1263	925	164—7400
		Buxton	86	817	521	118—3300
Back garden flower beds	0—5	Matlock	36	1367	1028	305—5080
		Buxton	53	557	402	160—3300
Back garden lawn	0—5	Matlock	50	1121	784	230—8000
		Buxton	59	423	326	82—2640
Back garden lawn	30—45	Matlock	51	913	615	92—4400
		Buxton	68	295	217	44—1100
Vegetable garden	0—15	Matlock	8	980	770	270—1830
		Buxton	13	365	287	119— 530
Grasslands	0—15	Matlock	5	1184	1139	660—1575
		Buxton	6	224	218	141— 285
Grasslands	30—45	Matlock	5	1289	1130	555—2695
		Buxton	6	89	82	36— 193

the contaminated district gave a value of 900 ppm whereas the control town had a value of approximately 400 ppm, the difference between these soils was significant ($P < 0.05$) although greater differences were observed in adjacent grasslands compared with the urban soils. Sampling at various depths showed that whereas the lead was relatively superficial in the control town, the contaminated town showed little variation in lead content of soil with increasing depth, suggesting that soils in that district were more highly mineralised. Atmospheric lead values were 0.61 $\mu g/m^3$ and 0.29 $\mu g/m^3$ for the test and control towns respectively, confirming that this did not represent a significant source of exposure for either population.

The blood lead data are given in Table 2. These showed no difference between children or mothers in the two towns. However, it was noted that children invariably had greater blood lead concentrations than their mothers and that both mother and child showed increased values in the summer compared with the spring months. In both cases the difference was significant ($P<0.05$).

Table 2
Blood lead results

	Children			Mothers		
	No.	Geom. Mean	Range	No.	Geom. Mean	Range
Matlock						
Spring	47	20.1	11—38	47	17.0	7—42
Summer	28	24.7	9—48	24	21.0	10—36
Buxton						
Spring	69	22.1	11—46	70	18.1	10—39
Summer	36	28.1	15—65	34	22.6	13—43

The data were further analysed by comparison of those children who had no current pica (Table 3), those who had non-specific pica, and those who had pica for soil. In the contaminated district no significant difference could be found between the lead values for these groups in either the spring or summer sample. However, in the control town a significant difference was found in the summer sample only for children with pica for soil compared with those who had no current pica ($P < 0.05$). For the purpose of this study pica was defined as the ingestion of any non-food substance and pica for soil included those children who habitually mouthed fingers or toys which were soil-contaminated, in addition to those actually ingesting soil as such. Using these definitions, 51 of the 119 children in both towns had pica for soil but only 11 (9.2%) had been observed to ingest soil. Examination of the data showed that although the soil-eating children had a greater blood lead content than those without pica, the mothers of the children also showed a similar difference, suggesting that the increased values observed were due to factors other than soil ingestion.

Hair lead data were based on analyses of the proximal 2 cm of hair adjacent to the scalp. The data (Table 4) showed no evidence of a soil-related effect between the two towns. In the control towns, children with pica for soil had a significantly greater hair lead content than those without a pica history, but the values were all low and within the normal

Table 3

Blood and faecal results

	April			July			Surface soil. μg/gm dry soil
	Blod lead μg/100 ml Child	Mother	Faeces μ/sample	Blod lead μg/100 ml Child	Mother	Faeces μ/sample	
Matloch All	20.1 (47)[a]	17.0 (47)	67.8 (47)	24.7 (28)	21.0 (24)	65.8 (27)	909 (47)
No or past pica	19.0 (19)	17.0 (19)	75.6 (19)	24.2 (13)	22.9 (11)	73.1 (12)	904 (19)
Present pica	20.9 (28)	16.9 (28)	63.0 (28)	25.2 (15)	19.5 (13)	60.4 (15)	912 (28)
Present pica for soil	20.4 (14)	15.3 (14)	64.0 (14)	25.2 (8)	18.4 (7)	54.0 (8)	709 (14)
Buxton All	22.1 (69)	18.1 (70)	69.4 (68)	28.1 (36)	22.6 (34)	67.8 (39)	398 (72)
No or past pica	21.5 (15)	16.8 (15)	60.2 (15)	22.5 (7)[b,c]	19.9 (7)	56.6 (7)	380 (15)
Present pica	22.2 (54)	18.5 (55)	72.3 (53)	29.8 (29)[c]	23.4 (27)	70.5 (32)	403 (57)
Present pica for soil	22.6 (37)	18.9 (37)	81.0 (36)	31.5 (16)[b]	22.4 (14)	78.0 (19)	406 (38)

a Number of samples
b, b Significantly different at 95% confidence levels
c, c Significantly different at 90% confidence levels

range. Analyses of faeces and teeth showed no significant difference between the two districts. It was concluded, therefore, on the basis of this initial study, that soil lead contents of 900 ppm did not result in any demonstrable burden compared with the control district with a mean value of 400 ppm.

Table 4

Lead in hair (Pb μg/g hair)

	Spring		Summer	
	Geometric Mean	Range	Geometric Mean	Range
Matlock				
Al	6.7 (47)[a]	3.1—21.2	8.1 (33)	2.3—45.7
No or past pica	5.7 (19)	3.1—17.2	8.3 (15)	2.3—45.7
Present pica	7.7 (28)	4.0—21.2	8.1 (18)	2.5—38.7
Present pica for soil	6.5 (14)	4.0—15.8	6.8 (9)	2.5—38.7
Buxton				
All	5.0 (71)[a]	0.8—36.0	7.4 (40)	2.1—47.5
No or past pica	3.6 (15)[b, c]	0.8— 6.9	4.4 (8)[d, e]	2.1—11.3
Present pica	5.5 (56)[b]	2.7—36.0	8.0 (32)[d]	2.1—47.5
Present pica for soil	5.7 (38)[c]	2.9—36.0	8.2 (19)[e]	3.7—47.5

a, a b, b; etc. significantly different at 95% confidence level.

During the course of the preliminary studies we discovered villages situated in the eastern half of the country in which greater soil lead contents could be found. Values of up to 30,000 ppm (3%) were detected but the distribution between even closely adjacent villages was non-uniform. The source of the contamination was again previous mining and smelting in some areas but it should be noted that the soil in that district has a naturally high lead content. A second survey was therefore designed to take advantage of these more extreme values.

In view of high values in control towns, an initial attempt was made to find control populations elsewhere in the British Isles situated in a similar geochemical area but with lesser degrees of lead contamination. Other limestone areas in the United Kingdom were therefore investigated and a survey was made of 12 villages in Hampshire in the South of England. However, soil samples from gardens in each of these villages gave a mean lead content of 504 (232-1428) ppm. It was concluded that it was unlikely that control populations exposed to lesser degrees of soil lead could be found in the United Kingdom. For this reason closely adjacent villages to the contaminated district were selected as controls.

The survey and analytical methods were similar to those previously described with the exception that on this occasion venous as opposed to capillary blood samples were obtained. No attempt was made to conduct a survey of deciduous teeth since the population size was limited. The lead content of suspended particulates and dustfall were monitored and gave mean monthly averages of 0.28 μg and 0.34 μg/lead/m^3 for suspended materials, and 194 μg and 254 μg/lead/m^2/day for dustfall in the »low« and »high« soil lead areas respectively. These observed values were low and within the range reported for other rural sites in the United Kingdom (8).

Preliminary soil lead analyses for the area allowed the villages to be grouped into contaminated districts with a mean soil lead of 10,000 ppm and control villages with a mean soil lead of 500 ppm. The preliminary blood and hair results showed marked differences between the two districts (Table 5). Children in the high soil area had a mean blood lead of 25.0 μg/100 ml whereas those in the low soil lead area had a mean blood lead of 20.9 μg/100 ml. The corresponding hair lead values were 12.8 μg/g and 7.5 μg/g. A similar difference was observed between the mothers with values of 18.0 and 14.7 μg/100 ml blood respectively. These differences were all statistically significant ($P < 0.05$).

Examination of the data in histogram form showed that the differences were due to a displacement of the distribution curve for the whole population of children rather than the occurrence of high sporadic values (Figs. 1, 2.) The observed blood lead values in the high lead area

Table 5

Preliminary blood and hair results

	Geometric means		
	Blood μg Pb/100 ml		Hair μg Pb/g
	Child	Mother	
High soil lead area			
All	25.0 (48)[a]	18.0 (44)[b]	12.8 (48)[c]
No current pica	23.6 (27)[d]	18.1 (26)	10.8 (27)[e, f]
Present pica	26.8 (21)	17.6 (20)	15.8 (21)
Present pica for soil	26.4 (16)	17.5 (16)	21.1 (16)[f]
Low soil lead area			
All	20.9 (34)[a]	14.7 (30)[b]	7.5 (34)[c]
No current pica	19.9 (17)[d]	14.6 (16)	5.7 (17)[e]
Present pica	21.9 (17)	14.6 (15)	9.8 (17)
Present pica for soil	22.1 (16)	14.5 (14)	9.0 (16)

Numbers of individuals in parentheses
a, a; b, b; etc. significantly different at 95% confidence level.

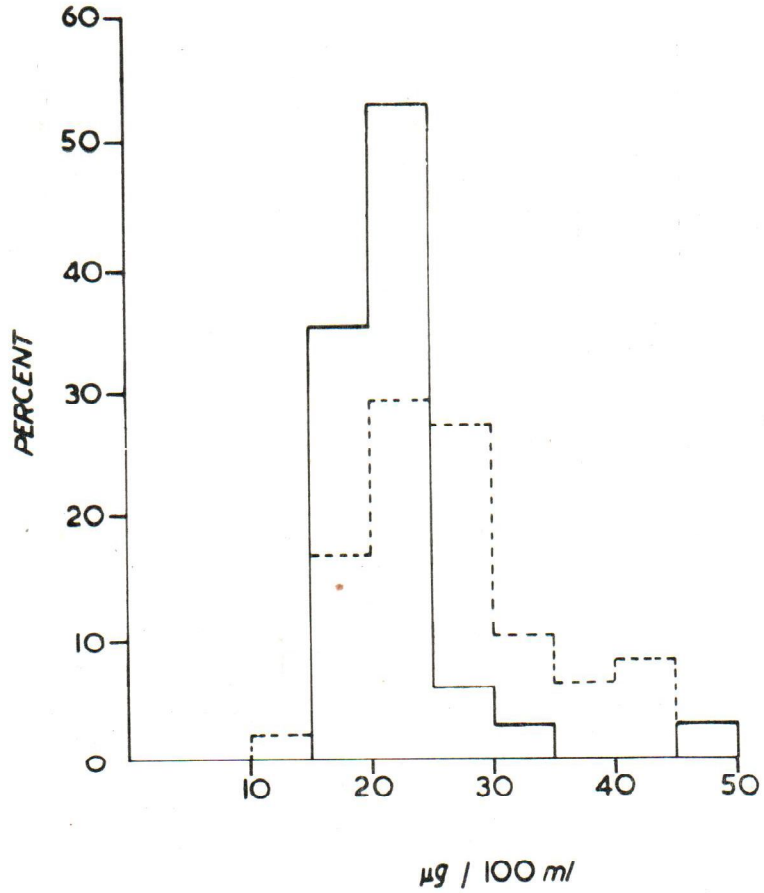

Fig. 1. *Children's blood lead concentrations* (Reference No. 6)
(— —) high soil lead area, N = 48;
( ) low soil lead area, N = 34.

suggested that although soil lead had contributed to the child's lead burden, it was not associated with increases of pathological significance.

Children with pica for soil had significantly greater hair lead values than those who did not. However, these were not associated with significant differences in blood lead values.

Subsequently, more detailed soil sampling data became available and it was possible to classify the selected population into three groups depending on soil lead content at the child's home. The selected values were less than 1,000; between 1,000 and 10,000; and greater than 10,000

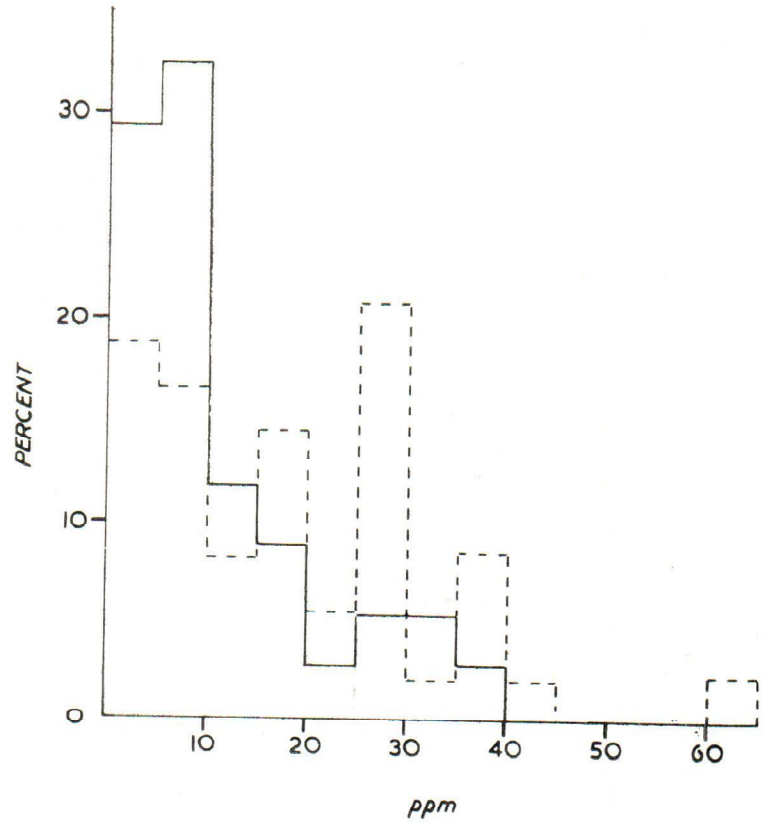

Fig. 2. *Children's hair lead concentrations* (Reference No. 6)
(— —) high soil lead area, N = 48;
(——) low soil lead area, N = 34.

ppm. All the subsequent statistical tests were applied to these three categories. Findings are given in Table 6 in which it is shown that the blood lead concentration of children increased progressively from 20.7 μg/100 ml to 29.0 μg/100 ml in relation to increasing soil lead content. The corresponding mean soil lead contents ranged from 420 to 13,969 ppm.

Although the lead content of house dust from individual homes increased *pari passu* with soil lead, the absolute values for house dust lead in the low soil lead district were greater than those for the corresponding soils. For other districts the values were considerably less than those found in the soil adjacent to the home. The hair lead data for the children showed a similar progressive range from 7.7 to 20.2 ppm. Blood lead data for the mothers, however, did not show any significant relationship.

Table 6

Mean blood and hair lead content

Soil Lead	Blood lead μg/100 ml Child	Mother	Hair ppm	Soil ppm	House dust ppm
Les than 1000 ppm N = 29	20.7[a,b]	14.1[c]	7.7[f]	420	531
1000—10,000 ppm N = 43	23.8[a]	18.7[c,d]	10.5[e]	3390	1564
Over 10,000 ppm N = 10	29.0[b]	14.8[d]	20.2[e,f]	13969	2582

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

The faecal lead data for the children were unremarkable and the mean lead content per single specimen of stool was 50 μg corresponding in most cases to the 24-hour excretion rate. No statistically significant difference could be found in faecal lead content between the various soil areas investigated. As before, children invariably had greater blood lead contents than their mothers. The data were further analysed with respect to the presence or absence of pica but no consistent relationship could be demonstrated between this activity and blood or hair lead content (Table 7) so that although greater blood lead values (pica) were observed in the low soil lead areas, no significant differences could be demonstrated for those inhabiting the high soil lead area.

It should be emphasised that statistically significant correlations (both product moment and non parametric) could be shown between blood and soil lead/house dust data only if the data from all of the area was considered collectively. No significant correlations could be found within a given area for blood lead and for hair lead — significant correlations for hair lead could be found only when soils of lead content greater than 1,000 ppm were considered.

The data presented in this paper suggest that there is an increased exposure to lead for children living in areas of high soil lead content. This effect is small and the maximum displacement of the distribution curve related to soils of approximately 14,000 ppm lead compared with soils of 400 ppm lead amounted to 8 μg/100 ml. It must, however, be recognised that many factors may influence the absorptions of lead from ingested soils and dusts. These may include the chemical and physical form of the contaminated material, variations in soil characteristics such as pH, organic matter content, and nature of the parent material and perhaps, in addition, the nutritional status of individuals within the study groups.

Table 7

Blood and hair lead concentrations

Soil lead area	No.	Geometric mean Blood µg/100 ml	Geometric mean Hair ppm
Less than 1000 ppm			
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 ppm			
No pica	26	23.4[1]	9.1[b]
Pica for soil	13		17.4[b, 4]
Over 10,000 ppm			
No pica	5	26.7[2]	22.8[3]
Pica for soil	4	29.0[3]	20.9

Between areas: 1, 1; 2, 2; significantly different, $p < 0.05$
Within areas: a, a; b, b; significantly different $p < 0.05$

Some evidence has recently come to light concerning this in animal studies which have recently been reported (9, 10). Thus it has been shown that marked enhancement of absorption can occur as a result of dietary modification involving decreased mineral and increased fat content of animal diets. These effects are additive so that after only 48 hours exposure in animals receiving a modified diet, a combination of high fat and low mineral diet will result in a 50-fold increase in blood lead values in exposed animals compared with controls receiving the same daily intake of lead.

Furthermore, the absorption of lead is modified by its chemical form and a 12-fold variation in absorption has been shown in a limited range of compounds including metallic lead. Even particle size modifies absorption so that it has been possible to demonstrate a 5-fold variation in uptake of metallic lead powders of varying particle size in the range 0 to 250 μ. It follows that our findings might not be readily extrapolated to other climatic or even to urban situations. The study areas were characterised by appreciable rainfall throughout the area and by profuse vegetation which would, of course, tend to bind surface lead and limit its dispersion. The situation in an arid region devoid of vegetation or in the more barren areas of large conurbations may be associated with different dispersal patterns. Furthermore, varying cultural and nutritional practices in the exposed populations may modify the degree to which lead is absorbed from the gut and hence its potential hazard.

It is probable that no single environmental standard can be devised to cover all the situations likely to be encountered. Separate environmental studies of this type may have to be repeated in relation to each particular source so that the effect of these variables can be determined.

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Sažetak

ZNAČENJE KONTAMINACIJE TLA I PRAŠINE OLOVOM ZA LJUDSKU POPULACIJU

Disperzija olova iz industrije i prometala ima za posljedicu povećanu koncentraciju olova u tlu u svim razvijenim zemljama. Te se vrijednosti u Velikoj Britaniji kreću oko 400 ppm u poljoprivrednom području do 2000 ppm u nekim gradovima. Zbog ovih se podataka došlo do pomisli da bi djeca, zbog navike da nečiste predmete stavljaju u usta a i da jedu zemlju ili prašinu, mogla biti znatnije eksponirana negoli opća populacija.

Da bi se proučio ovaj problem, odabrana su u Velikoj Britaniji dva područja: jedno s visokim sadržajem olova u tlu (u prosjeku 900 ppm) i drugo s niskim sadržajem olova (400 ppm), a s podjednakom koncentracijom atmosferskog olova. Iz jednog i drugog područja odabrane su majke s djecom između 2 i 5 godina. Sakupljeni su uzorci tla iz njihovih vrtova kao i uzorci kućne prašine te analizirani na sadržaj olova. Ujedno su uzeti uzorci krvi majki i uzorci krvi, kose, mliječnih zubi i stolice njihove djece. Posebnim upitnikom majke su davale podatke o običajima djece da stavljaju predmete u usta i da jedu zemlju i ti su podaci analizirani u odnosu na koncentraciju olova izmjerenu u pojedinim uzorcima.

Rezultati su pokazali da nije bilo značajnih razlika u opterećenju olovom između dviju proučavanih skupina. Djeca su međutim imala konstantno veći sadržaj olova u krvi nego majke.

Slična su proučavanja ponovljena u seskoj populaciji odabranoj na temelju stupnja kontaminacije tla olovom: do 1 000 ppm, < 10 000 i > 10 000 ppm. Prosječni sadržaj olova u zraku bio je 0,34 $\mu g/m^3$ u ispitivanom području i 0,28 $\mu g/100$ ml u navedena tri područja. Nije bilo korelacije prema vrijednostima olova u krvi majki ispitivane djece.

Ovi podaci upozoravaju na to da kontaminirano tlo i prašina pridonose opterećenju organizma olovom, ali u takvom stupnju da nije vjerojatno da bi to bilo od biološkog značenja. Očito je da ima mnogo različitih činilaca koji mogu utjecati na apsorpciju olova iz crijeva uključujući osobine progutane zemlje, kemijski oblik olova i nutricijsko stanje djeteta.

DISCUSSION FOLLOWING THE PAPER

WILLIAMS: Has Dr Barltrop any evidence that asking the mother if her child has pica produces a meaningful answer? All children explore the world with their mouths, and as a father I would not like to say whether my own children have exhibited pica or not.

BARLTROP: The mother is usually a more reliable witness than the father in this respect: Our approach was influenced by my studies on the prevalence of pica in some 400 children in the United States 10 years ago. It is a common activity which all children show at the age of one year but it is still present in about 10% of 5 year old children. The mother's response will depend on the skill within which the enquiry is constructed and although it is not claimed that every case was discovered our data show a remarkably high proportion of children in whom this activity was recognized.

EDWARDS: The information presented for several inorganic lead compounds indicates that the rate of lead absorption is dependent upon the chemical form of lead added to the diet. Do you have similar information on addition of organic lead compounds to the diet?

BARLTROP: We have studied several of the organo-lead compounds used as diers in the paint industry. They are well absorbed and compare with lead acetate in this respect. Many of them have to be dissolved in a lipid such as corn oil before incorporation into the animal's diet. Since we have shown that lipids enhance absorption of lead it is important that the reference diet, which in our work contained lead acetate, is similarly treated.

MOORE: In a 3-month feeding study in rats where the animals were maintained on a synthetic diet (low in Pb) and fed 4 different lead compounds (lead chlorobromide, lead acetate and two chemical forms of lead oxide) we could not detect any significant differences in organ concentrations of lead. There was a tendency for slightly higher lead levels in organs from rats receiving lead chlorobromide.

BARLTROP: We have not studied lead chlorobromide. However, our data also showed little difference in absorption between one form of lead oxide and lead acetate. Marked differences in absorption can be found with a wider range of lead compounds. It should be emphasized that our studies were of limited duration (48 hours) so that the possibility of adaptive changes in long-term studies might have been avoided.

STANKOVIĆ: Hair has long been recognized as a metal-containing metabolic end product. Recently, more attention has been paid to the determination of the trace metals in the hair as an index of a prolonged exposure. Hair, by some investigators reflects better the total body pool of some elements than either blood or urine.

In our study analysis has been applied to two classes of elements: the toxic elements lead and cadmium, for which no evidence of essentiality has been found and the essential nutrients, such as zink and copper.

The studied population consisted of three different groups of male and female inhabitants:

1. A group of farmers far from any pollution (30 subjects as a control group)
2. A group of residents of Belgrade (40 subjects)
3. A group of inhabitants living at least 10 years in the vicinity of a lead smelting plant (50 subjects) and
4. of a group of workers from the mentioned lead plant (50 subjects)..

Hair was washed with 1% detergent solution, warm deionized water and 1% nitric acid. By our washing procedure metals adhering to the surface of the hair were efficiently removed leaving only the metals contained within the hair structure for the subsequent analysis.

Hair samples were digested with nitric acid and hydrogen peroxide and prepared as 2% nitric acid solution for atomic absorption determination of metals.

The results for lead, cadmium, copper and zink summarized as the arithmetic means with standard deviations for each group are presented in the following table.

Trace metal content in hair, μg/g
The mean values with standard deviations

Group	Lead		Cadmium		Copper		Zinc	
	Mean	s	Mean	s	Mean	s	Mean	s
1st	3,76	2,30	0,22	0,17	9,54	3,15	153	51,5
2nd	7,16	4,41	0,30	0,22	9,28	2,76	137	41,1
3rd	33,13	18,84	0,33	0,14	7,71	2,90	154	49,8
4th	71,90	30,80	0,78	0,82	10,70	3,52	158	39,6

The mean values for the two non-essential, toxic trace elements, cadmium and especially lead, show differences between groups, which are in accordance with exposure. The uptake of lead by hair was very marked and gradually increased with the degree of exposure. The differences in arithmetic means between group 1 and 2 are statistically significant (t-test) at $P < 0.05$ and among all other groups at $P < 0.001$. On the other hand, means for the two essential trace elements, copper and zinc, do not differ significantly among people in village, city, arround lead plant, and the lead workers.

Our results show that

— the mean hair Pb level and also Cd level reflect community exposure and might be a useful biotoxicological index of a prolonged exposure

— the content of the essential elements, Cu and Zn in hair, did not differ significantly between farmers, urban population and workers.

KOSTIAL: I am pleased to see how much attention is being paid by you and some other speakers to the influence of nutritional factors on lead absorption.

I want to mention our results concerning a striking increase — by a factor over 50 — in lead absorption in rats on a milk diet. This effect, however, cannot be explained by either a difference in fat or calcium intake compared to control animals.

Some of our other results indicate that the absorption of all chelated forms of lead is higher from the intestine. This might also have a practical significance since various chelating agents are being added to our food and beverages.

This is only to point out that much more work is needed to understand factors which might influence lead absorption from the intestine. These factors, however, seem to be very relevant to estimation of lead exposure in a population group.

BARLTROP: We have recently studied the effect of the food additive sodium alginate and some related compounds. They all enhanced the absorption of lead which is interesting in that they are thought to have metal binding properties.

BARRY: Hair lead estimates are of doubtful value as a parameter for the estimations of lead exposure relative to absorption. Hair samples obtained from a group of 32 of our lead workers gave mean values of 400 ppm in hair proximal to the scalp and 500 ppm in hair distal to the scalp. The mean blood lead value of the group was 32 μg/100 ml and urinary lead concentration was 81 μg/l.

Atmospheric lead would appear to attach to hair probably by the affinity of lead for SH groups of which there is an abundance in hair. Washing with a detergent solution fails to wash off the attached lead. Hair lead concentrations do not seem to represent systemic lead uptake in situations of raised atmospheric lead concentrations.

BARLTROP: Atmospheric lead may contaminate hair samples and this increases from the proximal to the distal end of the hair. Hair samples are thus of limited value in conditions of heavy atmospheric contamination; however these conditions did not apply to the districts which were the subject of this report.