Lead: Levels in Roadside Invertebrates and Small Mammals

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A number of recent studies have revealed significant accumulations of lead in soils adjacent to major roads. The sources of contamination are the inorganic lead compounds from the exhaust gases of petrol engines, as confirmed by isotopic studies(1-7). There is general agreement that (i) the amount of lead in excess of natural soil levels is a function of traffic density and the time for which contamination would have occurred, (ii) the majority of contamination occurs within 100 ft. of the edge of the road, and (iii) penetration of lead does not usually extend below the topsoil. Concern that crops grown adjacent to well-used roads might contain levels of lead that are dangerous to human consumers has prompted several workers to study the accumulation of lead in vegetation (5,6,8-10). They have shown that the amounts present in plant material are more variable than those found in the soil; they depend not only on the distance from the road, but also on the nature of the vegetation and the time of year (11). Concentrations of several hundred parts per million are not uncommon, and levels may reach 1,000 parts per million (0.1%) in the semi-natural vegetation of roadside verges. Very little is known of the levels of lead in animals feeding on and living amongst such vegetation, or of the effects that such contamination might have on their survival and distribution. We report here the initial findings of a study of lead levels in roadside faunas, taken from north Yorkshire and Co. Durham, England in June 1971.

Methods

Samples of ground-living invertebrates were collected for analysis by means of pitfall traps, glass jars of about 5 cm. diameter, containing a small quantity of 2% formalin. They were set in rows parallel to the edge of the road and left in position for 7 days. By comparing the size of catches, this sampling technique was also used to measure changes in relative abundance, with increasing distance from

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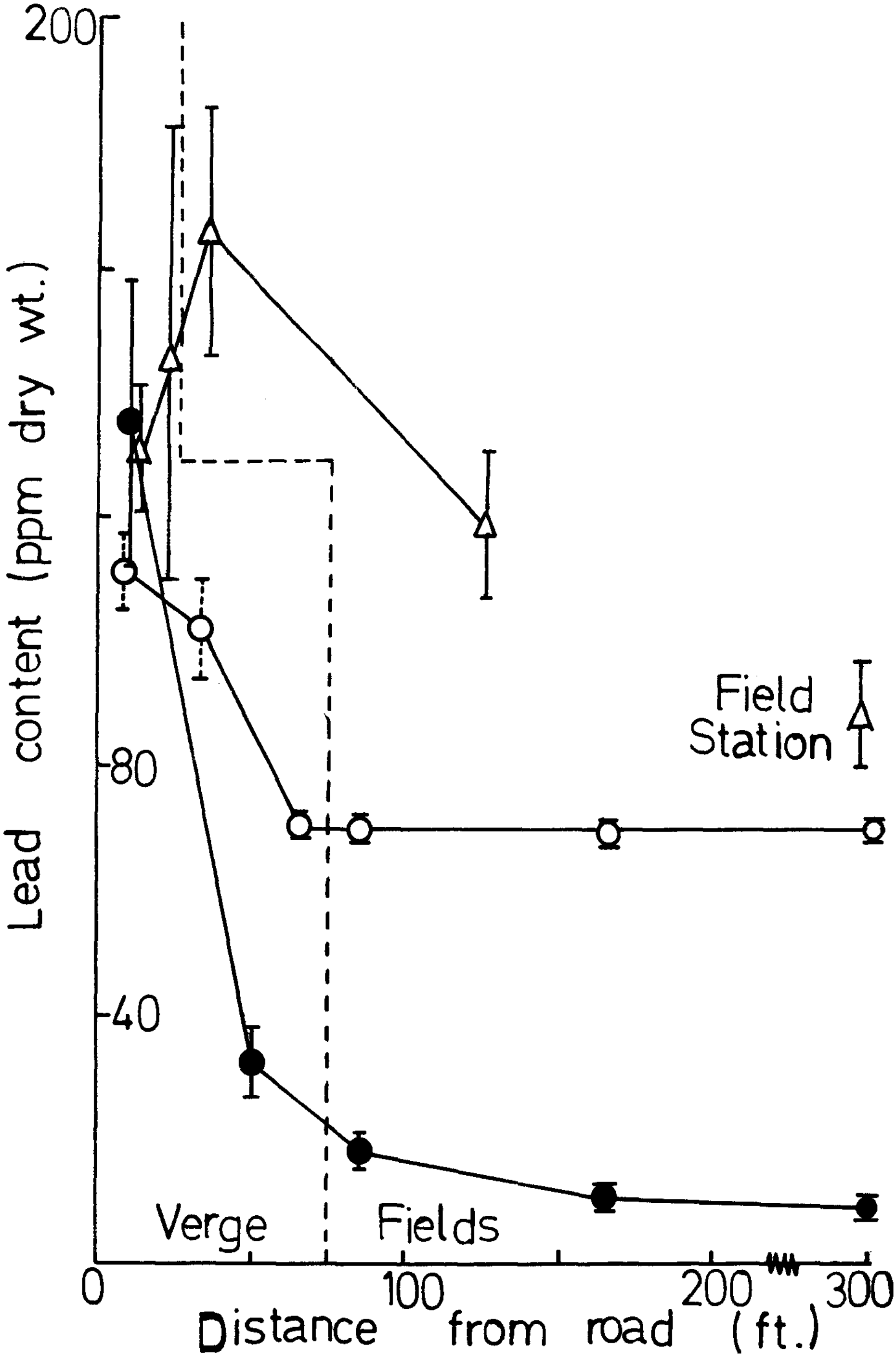

Figure 1. Lead content of soil (open symbols) and vegetation (filled symbols) from roadside verges and adjacent fields. Circle = Catterick, Yorkshire; triangle = Durham. Values are mean ± s. error (4 samples).

the edge of the road, within each invertebrate group. (Pitfall trapping is unsuitable for measuring absolute abundance since the numbers caught depend on the behaviour and activity of the species concerned. Even within a species, these vary with temperature and physiological state (12). However, all comparisons given below are of catches made over the same date period and in the same limited area.)

Lead levels in soil, plants and animals were measured by a Pye-Unicam SP 90 Atomic Absorption Spectrophotometer, at a wavelength of 283.3 nm. using an acetylene/air flame. Soil and vegetation samples were digested with a mixture of AR perchloric, hydrochloric and nitric acids before estimation; animal material required digestion only with nitric acid. Prior to digestion, animals were shaken in 70% ethanol to remove external contamination by soil.

Results and Discussion

The results from a sloping verge (gradient 1 in 4) and a field of permanent pasture bordering the Catterick by-pass road, north Yorkshire, are shown in Fig. 1 and Table 1. Levels of lead in the top 5 cm. of soil and in samples of unwashed mixed vegetation declined with increasing distance from the road, as expected from the findings of other workers. Similarly, in all animal groups, lead body burdens were highest close to the road and lowest in the field. We believe that contamination by soil did not contribute significantly to the amounts of lead found in the animals, since at the top of the verge, 65 ft. from the road, lead levels in the soil were down to background, whereas in the fauna they were still well above normal. Furthermore, across the transect from field to road, the lead content of the soil increased by only half the background level, whereas that of the fauna more than doubled.

Levels of lead in most groups analysed were below 50 p.p.m., but reached 80 p.p.m. in millipedes (Diplopoda) and nearly 700 p.p.m. in woodlice (Isopoda, chiefly *Philoscia muscorum*). Nevertheless, both millipedes and woodlice were at their most plentiful within a few feet of the road (Table 2.). For most invertebrate groups, the habitat change from roadside verge to pasture field, via a low hawthorn hedge, affected their abundance much more than the effects (if any) of variation in lead levels in soil and vegetation. Catches of ground beetles (Carabidae) and most groups of spiders (Araneae, excluding Lycosidae and Thomisidae) were much higher in the field than on the verge; the reverse was true of ants (Formicidae), woodlice and harvestmen (Opiliones).

TABLE 1

Lead content (p.p.m. of dry weight) of roadside invertebrates from Catterick, North Yorkshire.

	Verge			Field	
	Distance from edge of road (feet)				
Invertebrate group[1]	9	33	65	85	165
Beetles (Coleoptera)	11.5	11.0	7.75	4.7	5.0
Millipedes (Diplopoda)	82	80	69	42	-
Woodlice (Isopoda)	682	665	467	288	-
Harvestmen (Opiliones)	45		-	12	
Spiders (Araneae)	23		-	11	

1 Standard errors are available only for analyses of beetles from the three stations at 33-85 ft.; these are 1.0, 0.75 and 0.2 respectively. Too little material was available for duplicate analyses of other groups.

TABLE 2

Total number of invertebrates caught in 13 pitfall traps at each of 5 roadside sampling lines at Catterick, north Yorkshire.

	Verge			Field	
	Distance from edge of road (ft.)				
Invertebrate group	9	33	65	85	165
Staphylinidae	120	125	114	111	97
Carabidae	48	46	55	163	147
other Coleoptera	60	79	45	74	51
Coleopteran larvae	31	26	39	60	41
Dipteran larvae	2	4	-	-	-
Lepidopteran larvae	3	-	2	-	2
Symphytan larvae	3	4	1	11	23
Formicidae	39	81	300+	1	1
other Hymenoptera	3	5	5	3	5
Hemiptera	64	27	11	32	18
Lycosidae	53	42	29	14	8
Thomisidae	13	17	11	8	2
other Araneae	47	45	42	205	159
Opiliones	173	206	119	51	29
Isopoda	165	155	188	9	3
Diplopoda	58	34	39	13	27
Chilopoda	5	4	3	2	1
Gastropoda	1	2	-	2	2
Orthoptera	-	1	4	-	-
Oligochaetae	2	1	1	2	3

Only the ants (*Myrmica ruginodis*) show a consistent and significant decrease in numbers across the verge, in parallel with increasing lead levels in soil and vegetation. However, their distribution is more likely to be governed by such factors as soil texture and microhabitat, since they were almost absent from the uncontaminated field. Other invertebrate groups show decreases across the region of greatest increase in soil lead levels (between 65 and 33 ft. from the road) but these decreases are not significant (X^2 test). In contrast, two groups, millipedes and bugs (Hemiptera), show significant increases ($p < 0.01$) with increase in soil lead levels; presumably the microhabitats are more favourable for them near the roadside.

Further investigations were made on a sloping roadside verge at South Road, Durham. This was superficially very similar to, but only a third the width of, the verge of Catterick. At the Durham site, however, regrading of the verge after road improvements 3 years ago, and disturbance of the top-soil of the adjacent field, have markedly upset the lead profile of the soil. At all stations, even within the field, the soil contained more lead than found in the grounds of the Zoological field station, about ½ mile away. Also, the concentrations varied widely between samples taken a few feet apart at a given distance from the road. (Compare the standard errors at the Catterick and Durham sites, shown in Fig. 1.)

The lead body burdens of invertebrates, collected on the verge and at two positions in the field, are given in Table 3. Unlike the results from Catterick, there is no consistent decline in levels with increasing distance from the road, and the standard errors (where estimated) are high. This suggests that transfer of lead from the soil via vegetation to the fauna is more important than uptake from direct 'fall-out'. (Unfortunately both field and verge were mown soon after collection of the animals, but before data on the lead content of the vegetation had been obtained.) Whilst most groups of animals contained similar body burdens at the two sites, both woodlice and millipedes at Durham contained only half of the concentrations of lead found at Catterick. These animals feed chiefly on decaying vegetation, for which we have no lead estimates. Thus it is not known whether their body burdens reflect differences in the lead content of their food at the two sites. Since woodlice carry about 8 times the lead burdens of millipedes at either site, it is clear that differences in feeding habits are not necessarily responsible for the variation in lead levels between invertebrate groups.

TABLE 3

Lead content (p.p.m. of dry weight) of roadside invertebrates from Durham

Invertebrate group[1]	Verge: Distance from edge of road (ft.) 10 + 22 (combined)	Field: 36	Field: 125
Beetles (Coleoptera)	16.0 ± 3.4	16.5	21.0
Millipedes (Diplopoda)	43.0 ± 9.7	40.5	47.5
Woodlice (Isopoda)	380	280	-
Harvestman (Opiliones)	30.5	40.0	30.0
Spiders (Araneae)	17.5 ± 1.8	22.0	25.8
Ants (Formicidae)	14.5 ± 3.5	-	-
Earthworms (Oligochaetes)	18.1	-	-

[1] Standard errors are given where duplicate analyses were possible with the amount of material available. Earthworms were degutted before analysis.

We could find no evidence for concentration of lead from one trophic level to the next. Tissues from four species of small mammals, caught on the roadside verge at Durham, contained the lead concentrations summarized in Table 4. While the carnivorous shrews had marginally higher lead burdens than the herbivores, the shrews contained less lead than many of their invertebrate prey (which presumably included woodlice). Also, assuming that lead levels in the roadside vegetation at Durham were similar to those found at Catterick, the herbivorous mammals contained substantially lower levels than did their food. Nevertheless, they carried even smaller lead burdens away from the roadside, in the grounds of the Zoological Field Station. Similar results for lead contents of small herbivorous mammals have been reported (13).

TABLE 4

Lead content (p.p.m. of dry weight) of vertebrate tissues from Durham

Tissue[1]	South Road: Verge	South Road: Field 200 ft. from road	Field Station ½ mile from road
LIVER:			
Common Shrew *Sorex araneus*	14 ± 3.3	11	-
Bank Vole *Clethrionomys glareolus*	13.5 ± 2.6	10	7.5
Short-tailed Vole *Microtus agrestis*	10.5	5	5
Wood Mouse *Apodemus sylvaticus*	12	9.5	9
KIDNEY:			
Common Shrew	27	17.5	-
Bank Vole	13	5	5
Short-tailed Vole	9.5	5	9
Wood Mouse	-	6.5	5

[1] Spleens were also analysed, but no concentrations higher than 8 p.p.m. were detected. Standard errors are given for analyses made in duplicate.

The distribution of invertebrates at Durham (Table 5) once again indicates that changes in microclimate and microhabitat, e.g. between verge and field, are of greater importance than any effect of lead contamination. Ants, woodlice and millipedes again decreased in passing from the roadside verge to the field, but weevils (Curculionidae) increased. At the top of the sloping verge, 22 ft. from the road, catches of many groups were minimal; at this station, the soil was driest. There is thus no evidence that aerial lead, or any other gaseous exhaust product, is limiting the numbers of animals living closest to the road.

TABLE 5

Total number of invertebrates caught in 20 pitfall traps at each of 4 roadside sampling lines at Durham

Invertebrate group	Verge Distance from edge of road (ft.) 10	 22	Field 36	 125
Staphylinidae	133	74	144	111
Carabidae	28	11	19	19
Elateridae	7	9	4	4
Curculionidae	235	237	321	323
Other Coleoptera	25	14	20	9
Coleopteran larvae	35	47	66	65
Dipteran larvae	96	75	91	67
Lepidopteran larvae	1	6	4	7
Symphytan larvae	2	4	3	3
Formicidae	c.2,500	c.3,000	440	59
Other Hymenoptera	-	5	3	3
Hemiptera	63	55	66	40
Lycosidae	96	75	91	67
Other Araneae	231	143	147	156
Opiliones	121	96	102	136
Isopoda	57	112	45	2
Diplopoda	120	48	61	27
Chilopoda	16	6	2	1
Gastropoda	5	6	12	5
Orthoptera	2	-	1	-
Dermaptera	1	4	-	-
Oligochaetae	6	-	5	3

Those invertebrates found to contain the highest concentrations of lead are also those which possess calcareous exoskeletons. It is highly likely that the mineral metabolism needed for formation of these structures also accounts for the heavy uptake of lead; but the exoskeletons may also act as a safe place for its disposal. Woodlice are known to concentrate calcium by about 20 times, from the 1% or so in the litter on which they feed to the 20% in their bodies (14). If they concentrate lead similarly, and their food contains 30 p.p.m. of lead (as it might well have done at Catterick), then the observed body levels of about 600 p.p.m. are readily explained. Millipedes (feeding on similar food) also concentrate calcium about 20 times. However, they clearly do not accumulate lead so readily (Tables 1 and 3). The biochemical differences responsible for the greater degree of discrimination against lead by millipedes are not known.

Summary

Concentrations of lead in the bodies of roadside invertebrates were generally below 50 p.p.m., but reached nearly 700 p.p.m. in woodlice (Isopoda). Lead levels in tissues of small mammals caught on roadside verges did not exceed 30 p.p.m., and were thus less than the levels found in many of their prey. No evidence was found of decreases in abundance of invertebrates with increasing levels of lead in soil and vegetation close to roads.

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