The Uptake of Lead by Vegetables from Soil

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Determinations have been made of the lead content of vegetables and of the soil in which they were grown—mainly in the Matlock area of Derbyshire. Results do not prove that there is any significant increase in lead content of these vegetables as a result of uptake from the soil.

As additional information, some figures for cadmium and zinc contents of soils are also tabulated.

Previously, we have reported that vegetables grown in composts to which lead was added showed little evidence of absorption of lead[1]. It is well known that Derbyshire has many lead-bearing areas. In addition, there is a lead processing works in one of these areas. Publicity given by press, radio and television to the dangers of lead to human beings has caused much public alarm in the County. Statements have said or implied that harmful amounts of lead are taken up by vegetables from lead-bearing soils. This survey examines soil from ordinary (local) gardens, and vegetables grown in those soils, in an attempt to establish for the benefit of domestic and commercial growers the truth or otherwise of the allegations.

Sampling

SOIL

Samples were taken from gardens by a three-inch diameter P.V.C. pipe as 5–6 in. cores. Four to five cores were taken. Generally, the cores from one garden were mixed and the results obtained on the composite sample taken as representative of the soil in which the vegetables analysed were grown. In some instances, analyses were made on individual cores taken from the immediate vicinity of the vegetables analysed. These individual cores also served to give some indication of the variation in different parts of one garden. Vegetables were not analysed from all sources of soil.

The soil was spread out on clean paper and dried under an infra-red lamp. Large stones were rejected and the sample was quartered to an analytical portion of about 500 g. This was ground in a mortar until it passed through a B.S. No. 7 sieve and stored in an air tight jar for analysis.

VEGETABLES AND FRUIT

(*a*) *Peas and Broad Beans*—seeds and pods separated, weighed and analysed separately, unwashed.

(*b*) *Kidney Beans*—beans washed with distilled water and washings and beans analysed separately.

(*c*) *Lettuce, Brussels and Cabbages*—outer leaves separated from inside heart, each weighed and analysed separately, unwashed. The inside of the stalk of cabbages was also separately weighed and analysed.

(*d*) *Cauliflower and Broccoli*—outer leaves, inner leaves, head and stalk separated, weighed and analysed separately, unwashed.

(*e*) *Potatoes, Carrots, Parsnips and Beet*—washed with distilled water to remove soil as far as possible. Peeled. Peelings and inside flesh weighed and analysed separately.

(*f*) *Onions*—roots rejected, tops and bulbs weighed and analysed separately. The inside layers of bulbs were taken for analysis.

(*g*) *Tomatoes and Grapes* (*greenhouse grown*)—washed with dilute nitric acid. Fruit and washings analysed separately.

(*h*) *Gooseberries and Blackcurrants*—Tops removed and weighed; fruit weighed and washed with dilute nitric acid. Tops, fruit and washings analysed separately.

Apparatus

1. Infra-Red Lamps.
2. British Standard Test Sieve No. 7.
3. Shandon Southern A3000 Atomic Absorption Spectrophotometer (or equivalent instrument)
4. Silica and glass apparatus hot alkali/acid-washed before use.

Reagents

1. *Nitric Acid* (*lead-free*).
2. *Hydrochloric Acid* (*lead-free*).
3. *Dilute Hydrochloric Acid Solution:* A 1·0 N solution.
4. *Ammonium Citrate Solution:* A 25 per cent. solution of the lead-free salt in water.
5. *Hydroxylamine Hydrochloride Solution:* A 1 per cent. solution in water.
6. *Ammonia Solution:* Sp. Gr. 0·880 (lead-free).
7. *Dithizone Solution:* A 0·1 per cent. solution in chloroform.
8. *Standard Solution of Lead:* Containing 40 parts of lead per million in 1·0 N hydrochloric acid.
9. *Standard Solution of Cadmium:* Containing 2 parts of cadmium per million in 1·0 N Hydrochloric acid.
10. *Standard Solution of Zinc:* Containing 2 parts of zinc per million in 1·0 N hydrochloric acid.

Method

With the method described it is very convenient to determine lead, zinc and cadmium simultaneously, and this was done, some of the results for zinc and cadmium being recorded in the Tables.

Take about 5 g of soil, weighed to nearest 0·1 g in a 85-mm diameter silica basin. Add 10 ml of lead-free nitric acid, and evaporate the mixture to dryness on a water bath. Ignite gently to destroy organic matter. Cool, add 10 ml of lead-free hydrochloric acid and again evaporate to dryness. Add a further 10 ml of lead-free hydrochloric acid and evaporate to dryness a third time. Extract the residue with hot, 1·0 N hydrochloric acid and filter the mixture through a No. 42 Whatman paper into a 100-ml graduated flask. Repeat the extraction with 1·0 N acid, thoroughly washing the residue and passing the washings through the same filter. Cool and dilute to volume with 1·0 N hydrochloric acid, mixing well.

Transfer to a 250-ml separating funnel, with mixing after each addition, 20 ml of sample solution, 30 ml of water, 5 ml of 25 per cent. ammonium citrate solution, 10 ml of 1 per cent. hydroxylamine hydrochloride solution, and 3 ml of 0·880 ammonia solution. Cool, add 10 ml. of 0·1 per cent. dithizone in chloroform; shake the funnel and transfer the chloroform after separation to a 100-ml separating funnel containing 30 ml of 1·0 N hydrochloric acid solution. Shake the mixture until the dithizone is regenerated (green). Return the chloroform to the 250-ml separating funnel and repeat the extraction process until all the metals are extracted, (no colour change in the dithizone). Then extract once more.

Transfer the hydrochloric acid solution to a 50-ml calibrated flask and dilute to volume with the same solvent.

Run a blank determination through the whole of the above process.

Determine the metals in this solution using the atomic absorption spectrophotometer under the following conditions.

Lead: Absorption line 283·3 nm., acetylene 2·4 litres/minute, air 7 litres/minute; slit width 2; burner height 4; lead lamp current 5 milliamps; meter full scale for 40 p.p.m. of lead.

Cadmium: Absorption line 228·8 nm., acetylene 1·5 litres/minute: air 7 litres/minute; slit width 1; burner height 3; cadmium lamp current 6 milliamps; meter full scale for 2 p.p.m. of cadmium.

Zinc: It was usually necessary to dilute the sample solution at least tenfold with 1·0 N hydrochloric acid solution. Absorption line 213·9 nm; acetylene 1·2 litres/minute; air 7 litres/minute; slit width 1; burner height 1; zinc lamp current 12 milliamps; meter full scale for 2 p.p.m. of zinc.

The method used will determine lead down to a level of 20 p.p.m., and zinc and cadmium to 1 p.p.m. By suitable adjustment of volumes and instrument settings these sensitivities could be further improved.

VEGETABLES AND FRUIT

The well-established process was employed, in which samples are digested with the nitric and sulphuric acids. Lead was extracted with dithizone with final colorimetric measurement. The lower limit of estimation was about 0·01 p.p.m.

Results

SOIL

Table I gives the results of single core samples from two gardens. They were both remote from the lead bearing area of Derbyshire, but were old well-established gardens in which lead sprays could have been used at some time.

TABLE I

THE VARIATION OF LEAD, CADMIUM AND ZINC CONTENTS OF GARDEN SOILS

Garden No.	No. of Samples	Lead		Zinc	
		Range	Mean	Range	Mean
		parts per million		*parts per million*	
22	5	271–347	302	143–223	180
23	6	259–574	367	191–222	207

The cadmium content was below the level of detection in all cases. (1 part per million)

Table II gives results of analysis of composite samples from gardens in Derbyshire and elsewhere. Metals other than lead occur naturally in and near Matlock and there is a lead processing works in the vicinity of gardens 1–7.

VEGETABLES AND FRUIT

Tables III to IX give the results of analysis for lead in vegetables and a few fruits grown in some of the soils listed in Tables I and II. The figures for lead in soil are repeated for easy reference.

Discussion

There is evidence of lead in whole samples of root-vegetables, but these are difficult to wash free from soil. The peeled roots contained very little lead.

The atmosphere is clearly a source of lead. This is seen in results on the tops of gooseberries and blackcurrants and in the washings from these fruits. It is also seen from the tests on the outer leaves of lettuce and the brassicas.

The results afford no evidence that the plants analysed take up lead from the soil. They confirm previous findings from this department[1]. Similar results on vegetables have been reported by Thomas, Roughan and Watters[2], but these authors give no figures for lead in the soil. Of course, from this survey, it is not possible to say that no plant can take up lead in any quantity from any soil under any circumstances, but the evidence collected so far, indicates that lead assimilation from the soil is unlikely to be a danger to the public.

TABLE II

LEAD, CADMIUM AND ZINC CONTENTS OF SOME MIDLAND SOILS

Garden No.	Location	Lead *p.p.m.*	Cadmium *p.p.m.*	Zinc *p.p.m.*
1	1–16 lead bearing area of Derbyshire in and near Matlock	250	2	180
2		315	3	210
3		680	4	315
4		935	3	250
5		1140	40	2680
6		1450	11	545
7		1475	16	845
8		300	0	110
9		315	2	175
10		555	0	175
11		3520	3	235
12		260	0	100
13		4320	17	1150
14		6680	44	515
15		1385	18	495
16		1020	21	6750
17	Other parts of Derbyshire not known to be lead bearing	135	0	420
18		200	0	375
19		225	0	280
20		330	0	230
21		695	0	305
22		300	0	180
23		365	0	205
24	Lincolnshire	65	0	100
25	Cheshire	200	0	125
26	Greenhouse	200	0	115
27		985	0	230
28		1820	39	2120

TABLE III

LEAD CONTENT OF ROOT VEGETABLES GROWN IN LEAD BEARING SOILS

Crop	Garden No.	Lead content of soil *p.p.m.*	Lead content of: Peel *p.p.m.*	"Flesh" *p.p.m.*	Whole sample *p.p.m.*
Potatoes	24	65	0·22	0·01	0·04
	22	295	0·81	0·02	0·11
	21	695	0·46	0·13	0·18
	4	935	0·41	0·06	0·10
	14	6680	4·00	0·17	0·86
Carrots	24	65	0·43	0·04	0·11
	23	495	1·17	0·12	0·49
	21	695	0·38	0·05	0·11
	14	6680	2·60	2·05	2·22
Beet	24	65	0·11	0·06	0·07
	1	250	0·38	0·10	0·14
	23	260	0·58	0·04	0·11
	21	695	1·37	0·18	0·25
Parsnips	19	225	0·22	0·12	0·14
	21	695	1·50	0·97	1·10
Radishes	4	935	—	—	0·43

TABLE IV

LEAD CONTENT OF ONIONS GROWN IN LEAD BEARING SOILS

Crop	Garden No.	Lead content of soil *p.p.m.*	Lead content of		
			Peel *p.p.m.*	"Flesh" *p.p.m.*	Whole sample *p.p.m.*
Spring Onions	22	350	0·30	0·16	0·27
	21	695	0·23	0·13	0·19
Larger Onions	23	325	0·04	0·02	0·03
	21	695	0·53	0·02	0·10

TABLE V

LEAD CONTENTS OF PEAS AND BROAD BEANS GROWN IN LEAD BEARING SOILS

Crop	Garden No.	Lead content of soil *p.p.m.*	Lead content of		
			Seeds *p.p.m.*	Pods *p.p.m.*	Whole sample *p.p.m.*
Peas	24	65	0·01	0·04	0·03
	24	65	0·01	0·63	0·49
	17	135	0·03	0·15	0·09
	1	250	0·02	0·25	0·16
	1	250	0·02	0·24	0·11
	1	250	0·02	0·17	0·12
Young Peas	1	250	0·01	—	—
Mature Peas	1	250	0·01	—	—
Old Peas	1	250	0·01	—	—
	12	260	0·02	0·14	0·10
	20	330	0·02	0·15	0·11
	10	555	0·08	0·54	0·42
	23	575	0·02	0·12	0·10
	3	680	0·03	0·31	0·22
	21	695	0·01	0·35	0·17
	4	935	0·05	1·11	0·86
	11	3520	0·17	0·22	0·20
	13	4320	0·02	0·16	0·12
	14	6680	0·03	0·30	0·21
Broad Beans					
(early)	1	250	0·01	0·29	0·23
(late)	1	250	0·01	2·48	1·76
	23	275	0·04	0·13	0·11
	10	555	0·03	0·71	0·54
	3	680	0·03	0·72	0·52
(early)	4	935	0·12	1·58	1·08
(late)	4	935	0·04	0·50	0·39
	13	4320	0·04	0·62	0·44
	14	6680	0·04	0·68	0·51

TABLE VI

LEAD CONTENT OF KIDNEY BEANS GROWN IN LEAD BEARING SOILS

Crop	Garden No.	Lead content of soil *p.p.m.*	Lead content of		
			Washings *p.p.m.*	Beans *p.p.m.*	Total *p.p.m.*
Kidney Beans	24	65	<0·01	0·01	0·01
	24	65	<0·01	0·02	0·02
	17	135	—	0·56* (inside 0·15 outside 0·67)	—
	20	330	0·02	0·11	0·13
	21	695	0·03	0·03	0·06
	21	695	0·14	0·28	0·42

* Contamination with soil suspected.

TABLE VII

LEAD CONTENTS OF LETTUCE, CABBAGE AND BRUSSELS SPROUTS GROWN IN LEAD BEARING SOILS

Crop	Garden No.	Lead content of soil *p.p.m.*	Lead content of: Inner leaves *p.p.m.*	Outer leaves *p.p.m.*	Stalk *p.p.m.*	Total *p.p.m.*
Lettuce	24	65	0·01	0·48	—	0·20
	1	250	0·12	1·06	—	0·76
	23	345	0·05	1·32	—	0·87
	21	695	No heart—whole sample tested			1·26
Cabbage	22	270	0·05	0·38	0·22	0·28
	21	695	0·04	0·84	0·04	0·59
	14	6680	0·59	1·18	0·61	1·01
Brussels Sprouts	19	225	0·06	1·04	—	0·68
	1	250	0·05	4·35	—	1·72
	4	935	0·05	13·7	—	5·67
	14	6680	0·04	5·37	—	3·13

TABLE VIII

LEAD CONTENT OF CAULIFLOWER AND BROCCOLI GROWN ON LEAD BEARING SOILS

Crop	Garden No.	Lead content of soil *p.p.m.*	Lead content of: Outer leaves *p.p.m.*	Middle leaves *p.p.m.*	Inner leaves *p.p.m.*	Head *p.p.m.*	Stalk *p.p.m.*
Winter Broccoli	1	250	3·95	0·61	0·49	0·10	0·14
Cauliflower	1	250	—	0·34		0·05	0·12
Cauliflower	22	295	—	0·06		0·03	0·01

TABLE IX

LEAD CONTENTS OF SOME SOFT FRUITS GROWN ON LEAD BEARING SOILS

Crop	Garden No.	Lead content of soil *p.p.m.*	Lead content of: Tops *p.p.m.*	Washings *p.p.m.*	Washed fruit *p.p.m.*	Whole sample unwashed *p.p.m.*
Blackcurrants	1	250	39·0	0·41	0·13	1·70
	22	300	19·5	0·10	0·07	0·37
	8	300	21·0	0·26	0·23	1·26
Gooseberries	1	250	16·0	0·21	0·12	0·47
	1	250	11·5	0·78	0·11	0·36
Tomatoes	26	200	—	0·05	0·02	0·07
	28	1820	—	0·02	0·01	0·03
Grapes	27	985	—	0·05	0·07	0·12

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