Lead in potatoes

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SUMMARY. There are specific environments where potatoes contain much larger amounts of lead than is generally realised. Nevertheless, if we accept the hypothesis that human adults are only likely to be harmed if they absorb more than 100 micrograms of lead daily for extended periods[10] then only in rare instances are they apt to be adversely affected by eating potatoes. Medical data suggest that where children are involved the acceptable amounts of lead are significantly less. However, where potatoes do show evidence of contamination by virtue of their high lead content, the possibility of more general contamination should be investigated. The intake of lead from potatoes, if supplemented by lead provided from other foodstuffs, from air, and possibly from water, can well reach unacceptable amounts.

Patterson's[12] claim that most people in industrialised countries are suffering from a chronic lead insult, does seem justified but, because of the remarkable ability of humans to adapt to some conditions, but how much this insult constitutes a menace to heath must be dealt with by medical men.

Introduction

Not only are comparisons odious, as Dr Johnson once remarked, but they are also misleading. The wisdom of this remark becomes clear when attempts are made to relate trace element studies carried out on vegetables in different laboratories. Some vegetables, after routine washing, are analysed shortly after being harvested: others are prepared as they would be by a prudent housewife, either for cooking or for eating raw. Yet again, in other investigations not only are the vegetables suitably prepared for consumption, but they are also cooked before being analysed. It seems probable that cooking may alter the trace element content of vegetables. If so then this could explain why some studies report much lower trace element contents in vegetables than do others.

Also some vegetables may be consumed either raw or cooked, as with cabbage, celery, and carrots. Some reports do not indicate whether or not a particular vegetable has been cooked and, if so, under what conditions.

Furthermore, the trace element content of some vegetation varies greatly according to which period of the growing season the sample has been harvested. Studies of this kind have largely been carried out on forage crops, but it seems reasonable to assume that the trace element content of vegetables also varies seasonally.

General practitioners will be interested to learn that during the coming year preliminary studies on this important aspect of the trace element content of vegetables should be completed. Greater knowledge of seasonal variations and of the effects of cooking on the concentration and availability of various trace elements in different vegetables will help to extend our understanding of the role of trace elements in nutrition.

There is a general consensus that possibly only between five and ten per cent of the lead ingested from potatoes and other vegetables is absorbed. Nevertheless the data presented later in this paper suggest that in some instances the amount of lead contained in potatoes, if added to the lead contributed by other sources, may be large enough to be significant for some specific diseases.

With the object of collecting reliable data which would enable general practitioners and others to asses the importance of lead contamination in different localities, and assured of the co-operation of Dr Pinsent and his associates of the Royal College of General Practitioners, I decided to collect potatoes from various areas. In some areas I hoped that contamination would be minimal, but in others a significant degree of contamination was anticipated.

Journal of the Royal College of General Practitioners, 1967, **25**, 66—72

Thus, this study deals principally with the lead content of many potatoes collected from widely separated areas chosen primarily not with the intention of establishing average or normal values, but with the idea of showing the effect that different geological, and geographical environments may have.

In many instances, the lead content and pH of the soils in which the potatoes have been grown have been studied. Enough data have been collected to demonstrate that, important though these factors may be, they alone do not determine the lead content of potatoes. The data do suggest that by suitable agricultural practice it may be possible to modify the uptake of lead by potatoes from some soils. Those wishing better to assess the significance of the results presented in this paper may refer to any one of several papers and symposia which deal with the medical aspects of lead ingestion.[3,4,5,8,20].

Preliminary results

When we first tried to discover what might be taken as the normal or average lead content of potatoes, we found little data in the literature.

In 1962 we published[17] our first findings, which were based on 15 samples taken at random in British Columbia, nine from widely separated points in the United Kingdom, and 30 from various localities in the United States and the United Kingdom. These last samples were provided by Professor D. J. Wort, Professor of Botany at the University of British Columbia. Although we were well aware that some of these samples had been collected from areas subjected to one form of pollution or another, we were, nevertheless, surprised at the varying results obtained from the three collections.

All these analyses were by colorimetry, and the techniques involved have been described elsewhere.[16] Professor Wort's samples were given to us in oven dried form, but all the other samples were prepared as they would be by ' a prudent housewife.' However, at the time this work was being done most results were being expressed in terms of oven 'dried' and 'ashed' material.

TABLE 1
LEAD IN POTATOES (in p.p.m.)

	Wet		*Dry*		*Ash*	
Preliminary results 1962	*Average*	*Range*	*Average*	*Range*	*Average*	*Range*
(a) British Columbia[17] 15 samples	1	0·07–2·2	5	0·4–12	112	8–240
(b) United Kingdom[17] 9 samples	0·2	0·07– ·3	0·6	0·3–1	18	8–32
(c) United Kingdom[17] and U.S.A. 30 samples	0·4	0·01–2·2	2·1	0·05–11	47	1–240
Intermediate results 1966 *						
(a) United Kingdom (General practitioners) 16 samples	0·4	0·04–4·6	1·8	0·2–17	48	4–510
(b) Suggested normals in[18] absence of contamination		0·02– ·2		0·1–1		2–20
Summary of ten year study[19]	0·4	0·04–6·0	2	·2–30	40	4–600

* Not previously published

Today results are more and more being presented in terms of 'wet' vegetables. Because originally we did not attempt to determine results on a wet weight basis we have, for purposes of comparison, used average conversion factors as determined by the U.S. Department of Agriculture[15] and ourselves.[19] In converting from parts per million ' ash ' to p.p.m. ' wet ' weight, we have assumed that the ash weight of potatoes is 0·9 per cent of the wet weight. Obviously the ' wet ' results of these exploratory studies must be regarded only as estimates.

However, after dealing with many hundreds of potato samples we have observed that relatively few deviate by more than 15 per cent from this average figure. Table 1 presents in summary form these earlier results, and also shows how our conclusions have been modified from time to time as newer and more recent data became available.

Relationship between lead content of potatoes and associated soils

Because there is obviously some relationship between the lead content of vegetables and the soils and stream sediments in the vicinity, it seems prudent at this juncture to remind medical men, dieticians, and epidemiologists that the relationship is by no means simple. The data presented in table 2 illustrate this.

The determinations of lead in these soils are by hot sulphuric acid, or by aqua regia extraction, depending on whether or not the subsequent determinations were to be by colorimetry or by atomic absorption. The proportion of total lead extracted from the different samples, therefore, varies somewhat, but not to any significant extent as far as the overall relationships are concerned.

TABLE 2

RELATIONSHIPS BETWEEN LEAD IN ASH OF POTATOES AND OF THE SOIL ON WHICH THEY ARE GROWING (In ppm)

LOCALITY	A. *Lead in Ash of Potato*	B. *Lead in Soil*	*Ratio* $\frac{A}{B}$
Glamorganshire	7	800	0·009
Devonshire	13	534	0·02
Isle of Man	4	400	0·01
Warwickshire	200	700	0·3
Quebec	255	890	0·3
Yorkshire	125	290	0·4
Stirlingshire	510	300	1·6
British Columbia	106	22	4·8
Ontario	43	8	5·4
Jersey	621	58	10·7

The above examples are not necessarily representative. They were selected at rando for illustrative purposes only.

At one period during our investigations we believed that the varying pH's could explain these apparent discrepancies. Although soil pH plays an important part in the ability of potatoes to pick up lead from a soil, it can by no stretch of the imagination explain all anomalous relationships. Probably lead in the atmosphere and in ground water is of more importance than has previously been realised.

Conclusions

As a result of these and related studies, some of which have been published elsewhere, the following facts have emerged:

(1) The amounts of lead in potatoes vary much more than is generally realised.

(2) Contamination is widespread in Great Britain and Canada, and presumably in the United States. Thus, it is virtually impossible to determine what is normal at the present time. Even areas generally considered agricultural and rural are seldom free from some degree of contamination.

(3) Although the total lead content and the pH of a soil affect the uptake of lead by potatoes it is, as yet, not possible to predict the lead content of potatoes growing on any particular soil.

(4) There is some evidence to show that the lead content of potatoes varies with the time of harvesting.

Expanded studies

An expanded programme was carried out between 1970 and 1971. Some of the results could have

been predicted, but others could not, and indeed, may provide food for thought for the future.

Table 3 presents in summary form the results of these investigations.

TABLE 3
LEAD IN POTATOES (in p.p.m.)

A. *Areas believed to be uncontaminated*	*Number of samples*	*Wet average*	*Range*	*Dry average*	*Range*	*Ash average*	*Range*
1. Cortez Island, British Columbia	7	0·3	0·1 –0·35	1·3	0·5– 1·5	26	9–41
2. Hebrides—Argyllshire	4	<0·53	<0·16–1·3	2·7	<1·0– 6·5	58	<18–145
B. *Areas of probable industrial contamination*							
1. Trail, British Columbia	7	1·0	0·6 –1·6	4·8	2·7– 8·7	97	59–158
2. Sudbury, Ontario	5	0·7	0·5 –1·0	4·3	3·0– 5·3	57	42– 79
3. Noranda, Quebec	6	1·2	0·15–2·9	6·5	0·8–16·1	114	14–255
4. Teesside, Bradford, Leeds, Birmingham, and Coventry, England.	9	2·7	0·6 –7·0	12·2	2·8–31·7	272	60–704
C. *Random gardens (England and Wales)*							
1. North Wales	6	1·4	0·13–3·2	6·5	0·6–13·8	158	15–375
2. Central Wales	3	0·9	0·5 –1·3	3·9	2·4– 5·4	104	61–139
3. Jersey	4	2·3	0·7 –5·6	11·3	3·3–26·7	262	81–621
4. Kent	4	0·17	0·08–2·0	0·9	0·6– 1·4	22	9– 27
5. Wiltshire and Dorset	6	1·1	0·09–3·1	5·0	0·5–13·3	102	9–342
6. Devonshire and Somerset	7	0·15	0·08–2·0	0·8	0·2– 1·6	17	6– 32
7. Yorkshire and Derbyshire	7	0·9	0·4 –1·6	4·3	2·2– 6·8	101	46–174
D. *Random gardens (British Columbia)*							
1. Oyama (1970)	11	·7	0·1 –1·4	3·9	0·6– 7·6	74	9–139
2. Oyama (1971) (Different gardens from above)	6	0·6	0·3 –1·1	3·3	1·7– 4·8	55	29– 86
3. Vernon	11	0·9	0·6 –1·4	4·8	3·5– 8·4	91	55–153
4. Kelowna	10	1·0	0·7 –1·3	5·4	3·6– 6·7	95	72–131
5. Penticton	11	1·0	0·6 –1·6	5·3	2·6– 7·7	104	53–145
6. Kimberley	5	0·7	0·3 –1·1	4·2	2·1– 5·9	78	27–113
7. Kamloops	10	0·5	0·3 –0·9	2·5	1·2– 4·7	49	21– 97
8. Vancouver	8	0·7	0·2 –1·0	3·4	0·8– 4·7	75	24–111
9. Campbell River	5	0·4	0·2 –0·7	3·1	1·9– 4·6	46	31– 71
E. *Random city gardens (England)*							
1. Exeter	5	0·55	0·14–0·8	2·4	0·7– 3·7	54	13– 80
2. Birmingham	8	1·7	0·8 –2·9	9·6	5·5–15·0	179	70–315
3. Leeds	11	0·9	0·14–1·4	4·1	1·0– 7·0	96	20–160
4. Manchester	9	1·2	0·3 –2·5	6·8	1·5–11·5	131	40–270
F. *Rural area in Nova Scotia* Pugwash–Tatamagouche	8	1·5	1·0 –1·9	7·2	4·3–10·0	155	101–213

Relative importance of lead intake from potatoes and root crops

Many estimates have been made of the total lead ingested from food. Most commonly they fall between 100 and 300 micrograms per day. Recent studies in Canada[9,7] and in the United Kingdom[14], have ranged between 100 and 200 micrograms from a total daily food intake of

1·78 and 1·5 kilograms respectively. These data suggest that the lead content of food in Canada and the U.K. averages 0·06 and 0·13 p.p.m. respectively. These estimates are definitely low compared with means of 0·49, 0·21, 0·37, and 0·21 as given for the U.S.A. by Schroeder for sea foods. meats, grains and grain products, and vegetables respectively [13]. Probably different methods of preparation, and the fact that most of the Canadian analyses have been on cooked foods, can explain what appear to be serious discrepancies.

Early studies by Monier Williams in Great Britain[11], and Kehoe[6], in the United States, suggested daily intakes of lead from food amounting to 220 and 310 micrograms respectively. Assuming daily intakes of food amounting to 1·5 and 1·78 kilograms in Great Britain and the United States, we arrive at estimates of lead concentrations in their overall food supply of 0·15 and 0·17 p.p.m. respectively.

Only the Canadian studies deal with potatoes separately from root crops in general. In the more recent British study referred to above, the lead intake from root crops is given as 42 micrograms which amounts to 21 per cent of the total daily intake of lead. By comparison, the Canadian study shows only 14 micrograms of lead coming from root crops out of a total lead intake of 106 micrograms or 13 per cent, potatoes alone contributing somewhat less than one third of the 14 micrograms.

Attempts to explain these variations in the absolute and relative importance of the lead that is contributed by potatoes, are apt to be abortive until more data become available. At present little appears to be known about the form in which lead is present in potatoes, and whether or not cooking removes any of this lead or make it more or less absorbable after ingestion. Do baked or boiled potatoes contain more digestible lead?

Discussion

Many of the above results could have been anticipated but some were entirely unexpected. Areas where heavy industry is prominent certainly reflect varying degrees of contamination. Samples from Cortez Island—an isolated area in British Columbia, the Hebrides—an area where there was once lead mining—Kent, Devonshire, and Somerset, all provided some samples pleasingly low in lead, and this in spite of the fact that many soils in Devonshire and Somerset contain large amounts of that element. What need to be explained are the occasional high lead samples found in Jersey, Wiltshire, and Dorset, where no contamination was anticipated.

In British Columbia, where epidemiological studies were initiated two years ago, it was determined that in areas where there are thought to be above normal prevalences of multiple sclerosis, namely in parts of the West Kootenays and Okanagan, the potatoes there certainly have a lead content approximately double those from Kamloops which has a lower than normal prevalence of multiple sclerosis.

However, the area in the vicinity of Pugwash and Tatamagouche in Northern Nova Scotia provides the biggest surprise of all. In a section of this area, containing only a few hundred people, eight cases of multiple sclerosis were known when our collection was made. In this district there is no heavy industry, limited automobile travel, and no record of lead mining. Possibly the black shales that occur in the district may be responsible, but this suggestion has yet to be substantiated.

It may be pointed out that because so few samples have been taken from each area that no sound conclusions can be drawn. This comment is justified. However, it must be explained that the resources available to us were extremely limited, most of our collections were made by volunteers, and a portion of the analyses were performed on time 'borrowed' from mineral exploration projects. However, it is hoped that the data will be of enough interest to justify more extensive and detailed investigations.

The data presented in tables 2 and 3 provide ample evidence to confirm the two facts suggested by our earlier studies. First, there are greater variations in the lead contents of raw potatoes than are generally realised. Second, these variations cannot be related solely or directly to the lead content of the soils in which the potatoes are growing, but result from many factors of which urban and industrial contamination are of particular interest.

Significance of anomalous lead concentrations in potatoes

For simplicity let us assume a daily intake of 200 grams of potatoes and 1·3 kilograms of all

other foods, including milk. Further, let us assume an average concentration of lead, as postulated in the latest British Survey[14], for all foods except potatoes. By examining varying contributions of lead from potatoes to reflect the differing concentrations reported in this paper, we may compare the relative importance of the amounts of lead ingested from potatoes under varying circumstances.

TABLE 4

LEAD INTAKE FROM 1·3 Kg. OF AVERAGE FOOD SUPPLEMENTED BY LEAD CONTRIBUTED BY 0·2 Kg. OF POTATOES WITH VARYING CONCENTRATIONS OF LEAD (in micrograms)

Concentration of lead in potatoes (wet weight) (in p.p.m.)	*Lead from 0·2 Kg. of potato*	*Lead from 1·3 Kg. of all other food*	*Total* (a) *Ingested*	(b) *Absorbed* 5%	10%
0·02	4	160	164	*8*	*16*
0·2	40	160	200	*10*	*20*
1·0	200	160	360	*18*	*36*
1·5	300	160	460	*23*	*46*
2·0	400	160	560	*28*	*56*
2·5	500	160	660	*33*	*66*
5·0	1000	160	1160	*58*	*116*

If the above intakes were all that had been considered, there would be little cause for concern because only in the unlikely case of an individual eating potatoes with an unusually high lead content for a long period of time need there be any concern as to his health.

Unfortunately, where potatoes contain an unusually high lead content there is more than a possibility that other food crops, the atmosphere, and possibly the water supply, may also contain abnormal amounts of lead. In this connection it is well to remember that possibly as much as forty per cent of the lead taken from the air by humans is absorbed. Thus, anomalous amounts of lead in potatoes although they may not be thought a serious threat to health when considered alone, may be of greater significance in suggesting that particular attention should be given to monitoring the lead content of air, dust, soil, and water in the vicinity.

Monier Williams[11] suggested an intake of 100 micrograms daily from water and 80 micrograms from inhaled dust. Kehoe[6] proposed a more modest figure of 20 micrograms from each of these sources. However, it has been claimed that, in a general way, the assimilation of from 50 to 100 micrograms of lead daily by a human would result in whole blood with lead contents of the order of 0·2 to 0·4 p.p.m. respectively.

We may sum up by suggesting that when the potatoes in an area contain from 2·0 to 5·00 p.p.m. (wet weight) the possibility of that area offering a lead insult should seriously be considered.

Corroborative evidence

In our earlier studies we used exclusively dithizone and colorimetric methods. During the last four years atomic absorption methods have been introduced. When dealing with values below 4 p.p.m. (dry weight) we are more inclined to rely on colorimetry.

We frequently compare the results obtained by the two methods using aliquots from the same sample. However, when, after taking all reasonable precautions, we found out results " seemingly " outside the orbit of the experiences of some other workers, we arranged to have representative samples checked in other laboratories.

Thanks to the co-operation of Professor W. M. Langille, Professor of Chemistry at the Nova Scotia Agricultural College at Truro, Nova Scotia, and Dr E. Somers, Head of Food and Drugs Directorate, Department of National Health and Welfare, Ottawa, some two dozen samples ranging from our lowest to our highest in lead were checked. Although the checked analyses were by no means perfect they were most gratifying. When, in terms of oven dried material, results were near 20 p.p.m., extreme variations were seldom as much as 20 per cent.

On the other hand results in the range of 0·01 to 0·04 p.p.m. might differ by as much as 100 per cent. In short, although our lowest results may be open to question, the higher values

may be relied on. Furthermore, we are confident that our results are, if anything, on the low side.

We were very surprised at the high lead content of many British soils but our findings are supported by two other recent studies[1,2]. It appears that many British soils suffer from serious lead contamination.

Acknowledgements

Early data were acquired by virtue of grants from The Geological Survey of Canada, The National Research Council of Canada (Grant No. A1805), The Defence Research Board of Canada (Grant No. 7510–16), and The Donner Canadian Foundation. A Canada Council Grant (Killam Award) was given in 1970 for the study of environmental problems. This grant made possible much of our more recent work of which only a small part is dealt with in this paper.

Dr and Mrs L. E. Lefevre and Mr E. Wilks collected many of the potatoes from localities in Great Britain and North America respectively. Many university colleagues in the Faculties of Medicine and Agriculture have contributed advice and criticism, but none more than Drs R. E. Delavault and K. Fletcher who paid particular attention to analytical problems. The analyses have been largely carried out by Mr A. S. Dhillon and Miss Anne Baxter, whose keen interest in these studies has made this project truly a team effort.

Support by The Royal College of General Practitioners in Great Britain, and the College of Family Physicians in Canada, epitomised by the sympathy and understanding of Drs R. J. F. H. Pinsent and W. A. Falk respectively, has encouraged us to carry on this work in a field superficially far removed from our usual task of mine finding.

We also acknowledge the help of those municipal authorities in Birmingham, Exeter, Leeds, and Manchester, who provided the allotment and potato material which comprise such a valuable portion of this work.

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