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May 15, 1967

To: All Members Lead Health and Safety Committee

Re: Macaulay Institute, Aberdeen, Scotland

This Institute has been doing some very interesting work in the field of lead, soils and plants. As an example, we attach for you a copy of their recent paper which shows that certain forage crops concentrate to a marked degree lead in the leaf. As you will see, this concentration is so great that as the crop dies off in the fall, the lead content of the top soil increases many times.

This is for your information.

Very truly yours,

Don G. Fowler

Don G. Fowler

DGF:bgb
Attachment

Look Ahead with Lead

LIA12144

take to England

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THE LEAD CONTENT OF PASTURE HERBAGE

By R. L. MITCHELL and J. W. S. REITH

On soils in north-east Scotland derived from quite diverse parent materials, including granitic gneiss, sandstone, slate and mixed acidic and basic igneous rocks, the normal lead content of rotational mixed pasture herbage during the period of active growth is between 0·3 and 1·5 ppm in the dry matter. In autumn, at a date possibly determined by the cessation of active growth and therefore by climatic conditions, the lead content of the above-ground portion of the plant begins to rise, reaching 10 ppm in late autumn, and may reach 30–40 ppm in late winter or early spring before growth recommences. At this stage, young shoots with a low lead content appear and the senescent foliage withers away. The increase in lead content of the above-ground portion when the plant is dormant may indicate movement from the root rather than active uptake of lead from the soil. The possibility of surface contamination by petrol-engine exhaust fumes or other industrial materials has been ruled out, and soil contamination of the herbage cannot account for the effect observed. The level of lead in pasture herbage in late winter appears sufficiently high to justify consideration of possible effects on the health of the animal consuming appreciable quantities during this period.

Introduction

No evidence of a biological requirement for lead has been established, and interest in the lead content of vegetation has arisen because of possible hazard to animal or human health. Deaths in livestock have frequently been attributed to lead poisoning resulting from the ingestion of paint or other materials containing lead, and the effects of lead poisoning, both acute and chronic, in man are well known. The possibility that lead might be involved in such disorders as swayback in sheep[1] or multiple sclerosis and cancer in man[2] has been discussed by several workers, but not confirmed. Warren & Delavault[3,4] have directed attention to the marked variation which can occur in the content of lead in vegetation from different locations and pointed out the need for further investigation. These authors showed that vegetation adjoining busy highways was contaminated with lead from the exhaust fumes of motor vehicles using leaded petrol. This effect has been confirmed by Cannon & Bowles[5] and other workers.

In Scotland, Swaine & Mitchell[6] have pointed out that the surface horizons of most soils are higher, often considerably higher, in lead than the lower horizons. This was considered to be due to accumulation through the plant, the possibility of contamination from motor traffic or industrial activity being ruled out because the most marked instances occurred in areas remote from such sources. One uncultivated Scottish soil which contained 20–30 ppm of Pb in the lower horizons had a total content as high as 550 ppm of Pb in the A_1 horizon.

Numerous factors must be considered in the study of the content of lead in the plant and its availability to the animal consuming it. Apart from surface contamination, these include the distribution of lead in different plant parts and seasonal changes in lead content. Investigations covering these effects have been in progress at the Macaulay Institute for a number of years, and at this stage the findings regarding the lead content of rotational pasture herbage on arable soils in areas remote from effects of industrial contamination or motor traffic exhaust fumes appear to warrant wider consideration.

Lead has been determined spectrographically as described elsewhere[7] using cathode layer direct current arc excitation following chemical concentration by mixed organic reagents. Contents below 1 ppm of Pb in plant dry matter have been assessed by means of recording microphotometry, thereby extending the limit of determination in herbage to below 0·1 ppm of Pb.

It has been found that practically all samples of pasture herbage taken in late autumn or winter have lead contents very appreciably higher than those taken in spring or summer. Contents within the range 0·3–1·5 ppm of Pb in dry matter are usual during the period of active growth. Results from four locations in north-east Scotland, obtained over a number of years, have been selected to illustrate the effect. The only earlier suggestion of such an effect appears to be that by Shearer *et al.*,[8] who reported that the lead content of grass collected from four fields in Derbyshire in January showed a large increase over grass collected from the same fields in November. The lead contents quoted from this lead-rich area are exceedingly high, up to 350 ppm in dry matter, but these authors considered the results to be too scanty to enable definite conclusions to be drawn.

Experimental

Comparison of summer and autumn samples

In Table I are presented the lead contents of mixed pasture herbage and two of its constituents, cocksfoot and clovers, sampled prior to cutting in mid-June and mid-October 1956 at an experimental site at Logierieve in Aberdeenshire on a freely drained soil of the Foudland association[9] derived from slate. The results are from ten treatments, each replicated in four randomised plots, which had involved different trace- and major-element applications not including lead. The variations between plots at one time of sampling may be due, at least in part, to these treatments. They are in any case insignificant compared with the results at different dates of sampling, the lead contents being ten times as great in October as in June. The contents in cocksfoot and clovers indicate that different species are equally affected.

Mean values for the contents of iron, titanium and cobalt at both dates are also given in Table I. The levels of these elements in the June samples indicate that these samples are essentially free from soil contamination.[10] On the assumption that the relatively small increases in the contents of these elements in the October samples, compared with those taken in June, were entirely due to soil contamination, the amount of possible soil contamination can be assessed and the lead content of the soil necessary to produce an increase of some 10 ppm in the herbage estimated. It appears that a total lead

TABLE I

The content of lead and other trace elements in pasture herbage grown on a soil of the Foudland Association and sampled in June and October, 1956

(results as ppm in dry matter)

	Mixed herbage		Cocksfoot		Mixed clovers	
Lead	June	October	June	October	June	October
Plots 5/34	0·35	11·4	0·43	7·9	0·29	7·9
6/32	0·36	9·2	0·38	6·5	0·36	11·0
2/33	0·83	10·4	0·58	7·1	0·32	6·9
1/35	0·31	10·8	0·81	10·7	0·46	8·5
8/31	0·51	9·5	0·37	12·2	0·18	5·3
7/37	0·39	9·0	0·67	9·3	0·34	7·2
9/38	1·3	8·8	0·92	8·0	0·80	5·8
10/36	0·68	10·0	1·1	9·5	0·84	8·1
3/39	0·94	16·6	0·87	7·7	0·89	6·9
4/40	1·5	13·1	0·79	10·1	0·44	9·1
Mean of all plots						
Lead	0·72	10·9	0·73	8·9	0·49	7·7
Iron	48	113	44	89	57	105
Titanium	2·7	7·1	2·5	5·4	1·4	4·5
Cobalt	0·055	0·13	0·052	0·078	0·077	0·14

content in the soil of over 1% would be required. The content in the soil is in fact only 15 ppm, so that soil contamination cannot be responsible for the observed increase in the lead content of the October samples. There are good grounds for believing that at least part of the increases in iron, titanium and cobalt in autumn is in fact due to an increase in the actual content in the plant.

A similar increase in the lead content of herbage in autumn was observed by Davy[11] while working in this laboratory. The soil was on the poorly drained series of the Tarves Association[9] derived from mixed acidic and basic rocks, on the Aberdeen University farm near Udny, Aberdeenshire, containing around 10 ppm of lead. The results in Table II, taken from Davy's thesis, refer to herbage cut every 3-4 weeks to simulate grazing conditions. The lead contents of mixed herbage, cocksfoot and white clover increase from around 1 ppm in summer to 10 ppm in late autumn; for rye grass, the levels are about half those for the other species. The sharp rise occurred in clover prior to the October sampling, while it was later in the other species. Senescence occurred earlier with clover, and by the end of November it was not possible to obtain a satisfactory sample on which to carry out a lead determination. Comparison of the lead contents with those of iron and titanium again indicates that soil contamination cannot explain the increase in lead. The mixed herbage sample taken on 19 August was probably somewhat contaminated by soil and gives an indication of the relative rises in lead, iron and titanium to be expected from this cause. This soil type has been found to carry vegetation which is higher than normal in titanium, possibly because of the presence of some organically-bound titanium which is available to plants, but this has not been experimentally established.

Variation in lead contents throughout the year

Following these and similar findings and because some very high lead contents had been observed in random herbage samples taken during winter months, a more detailed study was carried out at two locations, with sampling of mixed herbage, periodically throughout the year. The soils, both reasonably freely drained, were from an arenaceous Old Red Sandstone till of the Stonehaven association at Brigtanks in Kincardineshire and a granitic gneiss till of the Countesswells association[9] in the Institute grounds at Craigiebuckler, Aberdeen. The Stonehaven soil has a lead content of 30 ppm of which 1·1 ppm is soluble in 0·5 M-acetic acid and 7 ppm is extracted by 0·05 M-EDTA. The respective values for the Countesswells soil are 50, 1·6 and 12 ppm. The results from composite samples from replicated plots are presented in Table III. Unfortunately, a few samples were not obtainable because of snow cover or animal invasion of the plots. A sample from the granitic soil in March 1963 would have been of particular interest. In 1962, the herbage on the Stonehaven soil was in its first year after seeding, while on the Countesswells soil it was already 4 years old. In each case the plots were mown immediately after each sampling from May to October.

The results from both locations again demonstrate an appreciable rise in the lead content of pasture herbage in late autumn. They further indicate that the effect persists throughout the winter and indeed tends to increase until early spring. In one instance a content of 37·4 ppm in the dry matter, or almost 400 ppm in the ash, was obtained in March.

TABLE II

The content of lead and other trace elements in pasture herbage grown on a soil of the Tarves Association and sampled at intervals from May to November, 1955

(results as ppm in dry matter)

Date of sampling	Mixed herbage			Cocksfoot			Rye grass			White clover		
	Pb	Fe	Ti	Pb	Fe	Ti	Pb	Fe	Ti	Pb	Fe	Ti
23.5.55	1·0	182	17	0·7	61	3·1	0·3	60	6·3	2·4	341	41
13.6.55	1·2	161	19	1·1	81	4·4	0·6	74	7·9	3·9	241	29
6.7.55	1·4	158	14	0·8	83	3·3	1·3	118	8·0	1·8	210	11
21.7.55	1·2	150	16	0·4	90	5·8	0·6	74	7·1	0·3	141	12
19.8.55	2·6	331	42	0·8	91	7·3	1·5	148	11·0	1·7	201	19
26.9.55	2·2	197	18	1·6	142	3·9	1·4	136	17·9	1·3	118	8
13.10.55	1·8	156	13	1·6	99	4·3	1·6	121	7·7	9·3	136	7
22.11.55	9·7	292	22	11·9	163	16·8	3·1	196	15·9	*	*	*

* No sample available

TABLE III

The content of lead in mixed pasture herbage grown on soils of the Stonehaven and Countesswells Associations and sampled at intervals from May 1962 until August 1964

(ppm Pb in dry matter)

Date of sampling	Stonehaven association	Date of sampling	Countesswells association
21.5.62	0·29	8.5.62	0·33
2.7.62	0·68	6.6.62	0·57
9.8.62	0·22	28.6.62	0·63
29.10.62	1·1	1.8.62	0·60
20.12.62	1·5	31.8.62	0·47
29.3.63	16·2	19.10.62	12·4
9.5.63	3·4	20.12.62	10·9
24.6.63	0·71	29.3.63	†
9.8.63	1·5	8.5.63	1·4
30.10.63	9·2	7.6.63	1·9
30.11.63	21·4	1.7.63	2·5
8.1.64	25·7	8.8.63	1·9
7.2.64	17·8	8.9.63	5·3
16.3.64	21·8	16.10.63	2·6
21.4.64	5·7	8.1.64	22·4
25.5.64	2·1	7.2.64	27·0
30.6.64	1·0	16.3.64	37·4
10.8.64	2·4	21.4.64	*

† Sample unobtainable * Area ploughed

A sample from an adjoining series of plots contained 39·6 ppm of Pb. By this date, the contents of iron and titanium were high, but were in fact twice as high in the plots with the slightly lower lead content, so again soil contamination can be disregarded as far as the lead contents are concerned. The reduced lead contents of samples taken in April, early May and later, can be attributed to the presence of increasing amounts of new growth with a low lead content.

The low lead contents in the 1962–63 samples from the Stonehaven soil can probably be related to the fact that the plants are young, but possibly climatic factors are also involved.

Discussion

This variation of up to 100-fold in the lead content of pasture herbage at different stages of growth is the largest that has been found in the study of some 25 elements at the Macaulay Institute. Increases of two- to three-fold may occur for some elements, as shown, for instance, by iron, cobalt and titanium in Table I, others such as zinc, molybdenum, manganese and copper generally show little or no change when the lead increase occurs. There is undoubtedly an increase in the lead content of the whole above-ground portion of the plants when active growth stops. The distribution within the plant at different stages of growth and during senescence is at present being studied. Differences in the magnitude of the increase in autumn may be due to weather conditions. At the location reported in Table I, for which results are available over a number of years, the highest lead contents of mixed herbage in mid October 1953, 1954 and 1955 were 8·0, 2·6 and 2·5 ppm respectively, compared with 16·6 ppm in 1956. As an actual uptake from the soil by the senescent plant during the winter seems improbable, although not impossible, a translocation might be a movement to the above-ground portion of lead accumulated in the roots during the period of active growth. No evidence regarding this is at present available, but the possibility is being investigated.

Two other possible explanations of the increase in lead content appear most unlikely to be applicable. The effect might arise because of a decrease in the dry weight of the plant at senescence and after. A loss in organic matter alone would necessitate a corresponding rise in all the inorganic constituents, and this does not occur. There is little change in ash content throughout the year, the values being within the range 10 ± 2% at both centres reported in Table III. It would in fact be necessary to postulate a loss of some 95% of all the constituents of the dry matter except lead in order to explain the effect on this basis. The second possibility is contamination from rainfall, but this is equally improbable. In fact, the very abrupt rise in late autumn, with, as shown in Table II, different times of occurrence for different species, appears to rule this out. On the basis of a one ton per acre plant cover and a rainfall of 4 in (a typical October monthly figure), a content of lead in the rainwater of around 0·1 ppm would be required, assuming some 20% retention in the plant material. The normal lead content of precipitation would appear not to exceed 0·002 ppm.

Results for other types of vegetation indicate that increase in lead content at maturity is not confined to the constituents of pasture herbage. Guha & Mitchell[11] report a marked increase in the lead content of deciduous tree leaves at senescence; zinc and sodium also show increases, most other elements decrease. Hunter[13] quotes results showing some increase in the lead content of bracken fronds in autumn. Unpublished findings on various species of crops and deciduous shrubs confirm the effect. The increase in the lead content of vegetation prior to its deposition on the soil surface provides an explanation for the high lead content of the surface horizon of soils mentioned above.

This marked increase in lead content of herbage at senescence may have practical significance. It can render somewhat uncertain the comparison of materials from different areas sampled at [illegible] dates, in investigations on the correlation of the lead content of vegetation with the incidence of human or animal disorders. It also raises questions regarding the ingestion of lead by [illegible] grazing herbage during the winter months, particularly in open winters, but this is not a matter which can be discussed here.

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FERMENTATION PRODUCTS IN BREAD FLAVOUR AND AROMA

By DOROTHY M. COLLYER

Products of yeast fermentation are widely believed to be important in bread flavour, although there is little evidence for this.

In taste panel triangular tests, bread made from dough with a high level of fermentation products was compared with control bread. The difference in crumb flavour was fairly statistically significant (5% level) although bread odour was affected. There was no effect on crust flavour.

Where fermentation products did have an effect, this was an adverse one according to panel preference figures.

The sensitivity of the panel was tested and considered to be satisfactory with respect to salt, sugar and quinine levels in bread.

Introduction

There exists a widespread and long standing assumption that the products of yeast fermentation play an important part in the flavour and aroma of white bread. Many of these substances have pronounced odour and flavour and have been detected in bread,[1] but there is little scientific evidence to link them directly with bread flavour. Recently the conventional standpoint has been questioned.[illegible]

Visser't Hooft & de Leeuw[illegible] correlated acetylmethylcarbinol with fermentation procedures and also with flavour quality, but their organoleptic methods were not described. Baker *et al.*[illegible] referred to experiments which showed that fermentation was necessary for full flavour development, but no details were given of the flavour assessment side of the experiments.

In early work by Dutterworth[illegible] the totalled scores by [illegible] judges showed fermentation time of the bulk dough below [illegible] to be unimportant in production of taste and aroma unless cut drastically. Cornford's statistically based taste panels[illegible] assessed as equal the flavour intensities of 3 or 18 h bulk-fermented bread and bread made by the Chorleywood Bread Process in which bulk fermentation is eliminated by the application, amongst other features, of a controlled amount of intense mechanical work during mixing.[illegible] Even conventionally mixed dough with no bulk fermentation gave bread which had the same flavour intensity as fermented bread and bread made from a 6-h brew or pre-ferment in place of the normal dough water. Panels failed to distinguish Chorleywood Process bread from conventional bread in duo-trio tests, indicating a close similarity in flavour quality as well as intensity. Similar tests by de Ruiter[illegible] employing the triangular method also strongly indicated that there was no difference in flavour amongst bread with normal, shortened and very short fermentation.

New, economically advantageous, short fermentation methods use brews successfully to bring the flavour up to that of conventional bread, as well as for other reasons.[illegible] Satisfactory brew bread flavour has been reported[illegible] and brew buffering has been mentioned as influencing the flavour of the bread.[illegible] However, direct comparisons between brew bread and bread made by a comparable method but without