SOME ASPECTS OF LEAD POLLUTION IN PERSPECTIVE*

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LEAD was one of the earlier metals to be won by man from its natural state in the earth's crust. Lead sulphide, the principal mineral from which lead is recovered, is easily smelted, and the separation of this lead from its associated sulphur requires much less skill and energy than is the case with many of the other metals used by man.

Thus, it is not surprising that lead has been used by man for more than 5,000 years. Its malleability, ductility, and resistance to many types of chemical attack have resulted in many uses, amongst which one of the earliest of interest to us was the making of pipes for the transmission of water, an application that only recently has fallen into disfavour in some districts. We pay unintentional tribute to the Roman use of lead piping every time we call a plumber, this word being derived from the word ' plumbum ', the Latin for ' lead '.

However, it is something of a paradox that lead, a most useful servant of man since antiquity, has also been known to form compounds that are toxic. Lead, like fire, may be said to be a good servant but a bad master.

Lead pollution

Much has been written on lead in industry, but it is not intended to report on these papers except where they indicate, or supplement, evidence as to what may generally be accepted as being a normal or an anomalous amount of lead in vegetation, and in some food products that are consumed by humans.

In British Columbia, interest in lead stems from the fact that from the Sullivan Mine at Kimberley has come for the past 40 years, from five to ten per cent of the world's supply of lead. Attempts to find another 'Sullivan' have captured the dollars and imagina-

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tion of many, so far without success. For decades geologists, geophysicists, and prospectors have failed in this quest. It is hard not to believe that another ' Sullivan ' awaits discovery, and it was this belief, or hope, that stimulated an attempt to apply biogeochemistry in this search. So far, biogeochemistry has failed to find a ' Sullivan '. Nevertheless, many new data have been discovered, and some seem to be of sufficient interest to justify being reported in the pages that follow.

Incidentally, the earliest biogeochemical work to be reported in North America (Warren and Howatson, 1947; Warren and Delavault, 1949), dealt with the zinc content of trees in the vicinity of the Sullivan mine. This paper deals primarily with lead, a metal that was not investigated during the earlier studies.

Research work on lead has been carried out in many countries, particularly by Lounamaa (1956) in Finland, and Cannon (1960) in the United States. It appeared that the new growth of trees and lesser plants, normally carried in its ash from 50 to 100 p.p.m. of lead.

For purposes of practical prospecting, it is advisable not to use new growth, the metal content of which varies widely during a growing season, but rather older growth which, although it does not provide such marked variations during a growing season, does reflect more consistently variations from what may be considered normal, whether these variations are caused by lead present in soils derived from rocks anomalously rich in lead, or by soils, water, or air that have been polluted in one way or another by abnormal concentrations of lead. Where practical, one should collect growth initiated during the season prior to collection. In practice, this means that leaves of deciduous trees normally are excluded, and that emphasis is placed on twigs whose growth commenced the year previous to collection. Where evergreens are involved, needles may be used. For the sake of brevity and simplicity, only the ash content of last season's twigs are dealt with in this report until food products are discussed.

The ash of these last season's twigs normally carries from 25 to 50 p.p.m. of lead. Variations, either up or down, of as much as 50 per cent, are not unusual, but usually can be explained by factors that are becoming better known as biogeochemical knowledge expands, such as an abundance or scarcity of humus, and its resulting humic acids in the soils on which the vegetation that is being sampled is growing.

Some rocks, although they do not contain ore bodies, do contain abnormal amounts of lead, and trees growing in these areas may carry from 50 to 250 p.p.m. of lead. Such amounts of lead in vegeta-

tion may point to a geochemical area or province that justifies further examination.

Where economic, or potentially economic occurrences of lead underlie soil, one finds wide variations in the lead content of the overlying vegetation.

The causes of these variations are not yet understood, but in four different lead mining areas of western Canada, there are trees that carry from 200 to 2,000 p.p.m. of lead in their ash.

Thus it may be seen that in some areas biogeochemistry may be used in searching for buried lead deposits. In many areas, particularly those where there are well-developed residual soils, soil sampling may provide a more practical prospecting tool than ' twig ' sampling. However, where soil is lacking, or where soil profiles are poorly developed, biogeochemical techniques may usefully be employed, and, in some areas, may actually be more practical than soil sampling.

Biogeochemical anomalies resulting from pollution

When trying to establish what could be considered to be a normal lead content for the ash of various organs of different trees and lesser plants, collections were made from several British Columbian areas that were believed to be normal, that is, it was thought that these areas were not contaminated either by nature or by man.

Quite unexpectedly, consistently high results came from three sets of samples. These results were high enough to make laboratory technicians think that lead mineralization had been inadvertently discovered. Trees from these suites carried variable amounts of lead, but several had from 100 to 1,000 p.p.m. of lead, and one specimen of hemlock (*Tsuga heterophylla*) actually contained 2,400 p.p.m. Eventually, it was shown beyond doubt that the anomalous lead in these three suites had been introduced by automobile exhausts. However, before publishing these results, two further suites of samples were collected from areas close to much travelled highways. The ash of these trees carried amounts of lead that, in general, ranged from 250 to 3,000 p.p.m. At first it was thought that this lead came from lead compounds merely sprinkled on the surface of the vegetation. Surprisingly enough, careful washing of the samples, and comparisons between the lead content of different organs of various ages, established beyond doubt that in most instances 80 per cent or more of the lead was in and not on the leaves and twigs involved in the pollution.

Since the above work was completed, it has been established that lead arsenate sprays, and smelter fumes, can introduce comparable amounts of lead to soils and vegetation.

' Natural ' occurrence of lead in soils, cereals and vegetables

In a recent Symposium on lead (1963) de Treville, in several tables summarizes the present state of knowledge concerning the lead content of soils, beverages and various food products. A large number of representative analyses are quoted, amongst them a few emanating from the laboratories of the University of British Columbia. Unfortunately, probably by oversight, the author neglected to state that the high lead content in one soil (Warren and Delavault, 1960, p. 18), namely 1,000 p.p.m., came from a soil derived from a limestone containing greater than normal amounts of lead. Indeed, had not some exceptionally high lead-bearing soils been included in it, it would appear that the lead in British Columbian soils was of the same order of magnitude as found by other workers. It has been found that where a soil contains anomalously high amounts of lead, there is usually an understandable cause, either a geological anomaly, or pollution in some form. At this juncture it may be wise to point out that geological anomalies can cause cereals and vegetables to carry lead in amounts comparable to what is found in some badly polluted areas. This is a matter of fact. Whether or not these geologically ' inspired ' lead anomalies should be termed ' natural ' is a moot question.

Similarly, in dealing with vegetables and cereals, some with moderately high lead contents were reported, but in the case of the British Columbian samples the following footnote appeared:

> All these samples were collected when it was assumed that the ' normal ' lead content of food was well known: all the samples with the exception of some trees, and two of cereals, were collected solely in an effort to find out if abnormally high lead content did occur in these places where either geological or medical evidence suggested that high lead might be anticipated. The two cereal samples taken under normal conditions, and referred to above, contained 0.3 and 0.5 p.p.m. of lead (Warren and Delavault, 1962, p. 97).

It is not surprising, therefore, that British Columbian analyses were higher in lead than most of the others that were cited, and furthermore, the majority of these British Columbian analyses were not of samples that should be termed ' natural '.

The normal lead content of some cereals and vegetables

After making a large number of analyses of the lead content of trees and lesser plants, and finding that all contained lead and that a few had much greater than normal amounts, and knowing that medical men regarded the presence of too much lead in food, drink, or air with some suspicion, and had in consequence, made some detailed studies of lead in food products, further investigations seemed justified.

Such results as are available indicate that the normal lead content of both ash and oven-dried edible portions of cereals and vegetables,

is lower than that of the trees and lesser plants that were dealt with in prospecting.

Although not possessing sufficient data to consider any conclusions statistically sound, it seems reasonable to suggest, as a working hypothesis, that oven-dried cereals and vegetables normally contain from 0.1 to 1.0 p.p.m. of lead, and their ash from 2 to 20 p.p.m. Incidentally, recent analyses of cereals or vegetables all contain measurable amounts of lead. Most analyses that have reported ' no lead ' were made more than 20 years ago.

In general, it has been the experience in British Columbia that potatoes tend to carry less lead than normal, and lettuce somewhat more. Overall these conclusions seem to be in line with those of Schroeder and Balassa (1961) and Kehoe (1960).

The normal lead intake from food by humans

If the reports of Kehoe and his associates in the United States (1959) and the United Kingdom Ministry of Food in Great Britain (1954), may be taken as acceptable, then one may assume that humans have a normal daily intake of lead of from 0.25 to 0.50 milligram, with 0.4 milligram probably representing an acceptable average. Most of this lead normally comes from food.

The U.K. Ministry of Food (1954) points out that " the consumption of two pounds of food containing one p.p.m. of lead would contribute 0.9 milligram " ... and that " the daily intake of lead by a normal individual has been estimated at about 0.4 milligram."

Abnormal lead intake by humans

Kehoe (1960) has carried out a series of highly sophisticated experiments on human volunteers, and has shown that they could survive for many weeks with no obvious ill effects a diet supplemented by two milligrams of lead daily. However, adding three milligrams a day soon built up a lead content in the recipient's body that suggested it would be prudent to discontinue the experiment.

Near main highways in southern British Columbia and southern England, cereals and vegetables grow with from five to ten times what may be taken as a normal lead content: occasionally even higher lead concentrations may be found. This would suggest that under an unusually bad combination of circumstances—such as much pollution, poor drainage, and a high organic content in the soil—foods might be produced which could bring about the ingestion by an individual of from two to five milligrams a day if he ate solely from this contaminated food.

The facts make any assumption based on this possibility highly speculative. In the first place, in our more highly developed societies, where pollution is most apt to be a problem, the food supply is drawn

from a great variety of sources, and the possibility of any one person or group of persons consuming in their food the aforementioned amount of lead is most unlikely. In the second place, Kehoe fed his volunteers lead in aqueous solutions in the form of lead acetate. Not only do we not know the form in which lead is present in food products, but also we can find no evidence to suggest that any lead ingested from cereals and vegetables would affect humans in the same manner as the lead acetate administered by Kehoe.

It may be that negligible amounts of the lead in cereals and vegetables are absorbed by humans. Whether or not this is so is outside our sphere of knowledge. One obvious comment must follow. If the lead in cereals and vegetables is not absorbed, why should somebody of the calibre of Monier-Williams (1950) attempt to set up 'acceptable standards' for the lead content of foods? We have been told that maple sugar from at least two Canadian districts has had unacceptable amounts of lead, caused incidentally by 'natural' lead occurrences in the soils and underlying rock, and not by any man-made pollution. By what means were the standards of safety for lead in maple sugar established?

To sum up, it appears that either standards for the lead content of food should be modified, or it must be accepted that in some instances man may be getting dosages of lead which, although not demonstratively serious, cannot be viewed with equanimity. Certainly there is no need for undue alarm but, equally, there is no justification for complacency.

Incidental to the above remarks, it seems clear that anomalously high lead contents in cereals and vegetables can be of the same order of magnitude whether they are caused by pollution or by excesses of lead in underlying geological formations.

Confirmation from other scientists

Fortunately, the above findings have been supported by other investigators working in Finland, the U.S.S.R., and the United States of America.

In Finland, Salmi (1963) has demonstrated that vegetation exposed to automobile exhaust may carry many times its normal content of lead.

In the U.S.S.R., Dubrovskaia (1960) has reported that in some streets in Chelysbinsk and Tula, the air was heavily charged with lead, so much so that " medical examinations of traffic controllers have demonstrated some changes in their nervous and cardiovascular systems, and in the gastro-intestinal tract. Blood analyses have revealed the presence of reticulocytes and erythrocytes with basophylic granules".

However, particularly convincing and well-documented evidence showing how much pollution there may be in severe cases comes from Cannon and Bowles (1962). They have demonstrated how fodder and food crops growing close to much travelled highways in some parts of the United States contain from 4–20 times their normal complement of lead.

Summary and conclusions

Cereals and vegetables with from 5–20 times their normal quota of lead do occur. Their anomalous lead content may stem from the lead content of the rocks primarily responsible for the soil on which the vegetal matter is growing or from some man-made pollution. In either case the lead anomalies may be of the same order of magnitude.

Until much more is known about the form in which lead occurs in cereals and vegetables, and how it is dealt with in the human digestive system, it is impossible to make a realistic appraisal of the seriousness or otherwise of the problem posed by those foods that are abnormally high in lead.

In view of evidence presented in this paper, it would appear that although the problem of anomalous lead is probably not critical, it may well be serious and deserves further critical investigation. Critical investigation should include those aspects of the problem that are geological: these aspects appear largely, if not entirely, to have been overlooked by medical men.

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ON AIRS, WATERS AND PLACES

'. . . Whoever wishes to investigate medicine properly should proceed thus: in the first place to consider the seasons of the year and what effects each of them produces (for they are not at all alike but differ much from themselves in regard to their changes). Then the winds, the hot and the cold, especially such as are common to all countries, and then such as are peculiar to each locality. We must also consider the qualitites of the waters, for as they differ from one another in taste and weight, so also do they differ much in their qualitites. In the same manner, when one comes into a city to which he is a stranger, he ought to consider its situation, how it lies as to the winds and the rising of the sun; for its influence is not the same whether it lies to the north or the south, to the rising or to the setting sun. These things one ought to consider most attentively, and concerning the waters which the inhabitants use, whether they may be marshy and soft, or hard and running from elevated and rocky situations, and then if saltish and unfit for cooking; and the ground, whether it be naked and deficient in water or wooded and well watered, and whether it lies in a hollow, confined situation, or is elevated and cold; and the mode in which the inhabitants live and what are their pursuits, whether they are fond of drinking and eating to excess, and given to indolence, or are fond of exercise and labour, and not given to excess in eating and drinking.

From these things he must proceed to investigate everything else. For if one knows all things well, or at least the greater part of them, he cannot miss knowing, when he comes into a strange city, either the diseases peculiar to the place, or the particular nature of common diseases, so that he will not be in doubt as to the treatment of the diseases, or commit mistakes, as is likely to be the case provided one had not previously considered these matters.'

The Genuine Works of Hippocrates. Francis Adams translation. London. 1849. **1**, 190.