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CONCENTRATIONS OF LEAD, CADMIUM, COPPER AND ZINC IN TEETH FROM A CAVE USED FOR ROMANO-BRITISH BURIALS: EFFECT OF LEAD CONTAMINATION

by

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ABSTRACT

Deposits in the fourth chamber of Wookey Hole Cave were found to contain up to 0.5% lead, more than 30 times as much as in other Mendip caves (Stenner, 1978). Ten teeth recovered, with other skeletal material, from this deposit, were analysed for lead, cadmium, copper and zinc, using flame atomic absorption spectrometry. Comparing with local data for modern teeth, cadmium levels were high, and lead levels very high. However, some values (zinc and copper) and relative standard deviations (zinc, copper and cadmium) were within expected limits. The range of values for lead was unusually narrow in relation to concentration. Post-mortem exposure of the teeth to a lead-rich environment may have contributed the bulk of the 75 p.p.m. lead typical of these teeth.

INTRODUCTION

Lead uptake by bones during interment for centuries in soil has been considered unlikely since it was reported by Zimdall and Skogerboe (1977) that lead is mobile only when soil acidity is low, a condition unfavourable to bone preservation. As Waldron (1983) states, this argument seemed to have been endorsed by the demonstration that there was no significant correlation between the concentrations of lead in bones and soil taken from the same graves at a Romano-British cemetery at Poundbury, Dorchester (Waldron *et al.*, 1979). However, Waldron (1983) has recently shown a high correlation between rib lead and soil lead levels in skeletal material recovered from abbey burials. The soil lead levels were ten times those typical of the earth's crust; moreover, nearly ten times as much lead was found in these bones as in modern bones.

Additional evidence on interaction between trace metals in the burial environment and those in bones and teeth would therefore contribute to this aspect of archaeological chemistry, particularly if a more uniform environment with unusual heavy metal levels had been demonstrated. The specimens analysed in the present limited survey were recovered from human skeletal remains submerged in sedimented layers in the Fourth Chamber of a well-known show cave (Wookey Hole Cave) in the south-west of England (University of Bristol Spelaeological Society, 1973-75 excavations). The burials were considered to represent

at least 28 individuals, mostly aged 10-25 (Rogers, 1978) from a Romano-British group dated from pottery and pewter ewers to the 2nd to 4th centuries A.D. During the last century water reached this site from a fast flowing stream draining disturbed ground where lead mining had been undertaken from pre-Roman times until the beginning of the present century (Gough, 1967). Samples of the sedimented layers which contained the skeletal material, together with layers above and below this (also samples from other, dry caves) were analysed for lead, zinc and copper by Stenner (1978). High concentrations of lead (3-5 mg/g) and zinc (1-2 mg/g) were found in the relevant layers sampled.

Ten premolar teeth from the documented skeletal material found in this chamber were made available. They were analysed for lead, zinc, copper and cadmium contemporaneously with fresh specimens from patients living in the Bristol area (Coles, 1979).

METHOD & MATERIALS

The teeth were scrubbed in 2% nitric acid and the pulpal cavities reamed out with a stainless steel needle. They were dissolved in a 1 : 1 mixture of nitric acid (70%) and perchloric acid (60%), using 4 cm^3 per gram of specimen (0.7-1.0 gm). The digests were evaporated nearly to dryness and sufficient water added (final pH adjusted to 2.5) for reaction with an organic salt (ammonium pyrollidine dithiocarbamate) in order to form 'chelates' with trace metals, these being soluble in non-aqueous media. Trace metal chelates were extracted into iso-butyl methyl ketone (4-methylpentan-2-one) and the ketone solutions aspirated into an atomic absorption spectrometer. Concentrations of lead, cadmium, zinc and copper were determined at appropriate wavelengths, using automatic background correction. Standards contained all four metals in similar proportions to those present in contemporary teeth.

RESULTS

Concentrations of the four trace metals analysed in the Wookey Hole Cave teeth are shown in Table 1. Copper and cadmium levels varied between 0.1 and 2.3 p.p.m. The mean value for copper was less than typical values for contemporary teeth from the Bristol area, that for cadmium was considerably greater. Zinc concentrations matched those in modern teeth, although the scatter was greater. Except for lead, the differences between the highest values and the medians were greater than those between the lowest values and the medians. Normal distributions were therefore not assumed, and two types of data transformation were tested. Values were converted both to natural logarithms and to square roots. Both transformations yielded sets of values appearing to be normally distributed, but a slight superiority was seen in the square root transformation (SRT), in that there was better matching between means and medians. Relative standard deviations (RSD) were then 27% for zinc, and 35-36% for cadmium and copper. For consistency only, data for lead were similarly examined (SRT) but the RSD was below 10%, an exceptional value. The mean was 75 p.p.m., a level about twenty times those typical of modern teeth. Additional analyses of two teeth from the Slitter Cave, a dry site also in the Mendip Hills and also in use during the Romano-British era, showed lead concentrations only one-fifth as much as those typical of the Wookey Hole Cave teeth.

DISCUSSION

Features of the analyses calling for comment were the high lead and cadmium values coupled with what, for lead, was thought likely to be a rather low variability. Further evidence was gathered from the literature in order to determine the level of variability to be expected within relatively small groups of teeth. These values were expressed in RSD form, and shown to be unrelated to the lead concentrations reported (Table 2). For groups of data representing ten investigations the RSD (square root transformations of data) fell within the range 15-35%. Three of these groups were from archaeological populations, and RSD values for these were at the upper end of the range. But the low RSD for the Wookey Hole Cave tooth lead data was more than three standard deviations below the RSD for the means for the ten studies surveyed. The mean value for lead concentrations of the cave teeth was twice the next highest value encountered (Waldron, 1983), for premolars recovered from Corinium (Cirencester).

A distinctively low RSD was not seen for the cadmium analyses, although the mean for the Wookey Hole Cave group was much above that for modern teeth (Table 3). It is not known, however, whether unusual concentrations of cadmium were present in the silt surrounding the teeth. Variability in copper analyses matched that for cadmium analyses, and was similar to that calculated for the data of Oehme, Lund and Jonsen (1978). Variability in zinc analyses was somewhat greater than those for other groups, although the mean value was within expected limits.

The uptake of trace metals from soil may depend upon the type of metal as well as its availability. Evidence on this point may be seen in the analytical data on teeth recovered from beneath the 12th century *stave* church at Uvdal, Buskerud, Norway (Fosse and Wesenberg, 1981). Half of the teeth were recovered in jaw fragments, the others separately. However, only half as much lead and copper was recovered in teeth (2-6 specimens) from the jaw fragments as in single teeth; the ratio was 3 : 4 for cadmium and zinc analyses. It may be surmised that metal concentrations were higher in single teeth because of their greater exposure to the burial environment. The Wookey Hole Cave teeth were associated with mandibular fragments, but comparatively few skulls were recovered; a number were found downstream (Hawkes, Rogers and Tratman, 1978).

The high lead values, coupled with their low variability, are explicable when the data of Stenner (1978) are taken into account. He reported levels for lead, copper and zinc in sediments from which bones and teeth were recovered (Table 4). Some thirty times as much lead was present in these strata as was typical of samples from sixteen caves with no known association with lead-contaminated streams (mean lead and zinc 140 and 170 p.p.m., resp.). Coincidentally, the lead levels in teeth from Wookey Hole Cave were also thirty times those to be expected in modern populations living in rural areas. Subtraction of an arbitrary 50 p.p.m. from the lead concentrations found in the cave teeth results in a notional mean of 25 p.p.m. and a RSD of nearly 30%, a value falling

within the range of those listed in Table 2. It may therefore be suggested that much of the lead determined as present in these teeth was acquired post-mortem and was not removed by the initial scrubbing in 2% nitric acid. Waldron (1983) reported that a tooth from the Cirencester Roman site showed very little lead in the circumpulpal dentine, in which lead levels are (in modern teeth) typically at ten times the level in bulk dentine, but that the lead level was high at the surface. Lead was not acquired post-mortem from all the teeth in the group of over 100 analysed, for minimum levels for the several types of teeth matched those to be expected in modern teeth.

In an attempt to compare lead levels in deciduous and permanent teeth from the same jaws, surface contamination can only be substantially reduced by rather drastic abrasion. This was the course adopted in studying the second group of teeth from the Poundbury Romano-British cemetery (Whittaker and Stack, 1983). On average, as much as one-tenth of the tooth material was thus rejected. The lead levels were lower but not significantly so, in permanent teeth of this group than in teeth from the first group in which the cleaning had been by light abrasion. However, the heavily abraded deciduous teeth contained only half as much lead as the lightly abraded teeth when these two sub-groups were compared. There was a rather wider contrast in cadmium levels in the differently prepared sub-groups of teeth from this site, but not in the much greater zinc levels. It had been considered unlikely that superficial contamination would have been a problem in the analysis of lead in these teeth, for soil lead levels were of the same order as those in the teeth (12-15 p.p.m. in three of the four sub-groups).

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TABLE 1

Concentrations of lead, copper, cadmium and zinc in teeth from the Fourth Chamber of Wookey Hole Cave.

Ref. No.	Metal concentrations in p.p.m.†			
	Lead	Copper	Cadmium	Zinc
579	63	0.37	0.15	81
546	93	0.47	0.42	53
1001	84	1.20	0.57	189
M31.12/19	80	2.19	0.72	253
1975	56	2.25	0.44	191
1976	99	1.14	1.14	215
307	81	2.32	1.45	404
366?	76	0.96	0.90	277
162M?	93	1.22	1.62	147
1950	64	0.26	0.20	79
Mean§	75	1.1	0.7	155

§ Square root transformation of data

† Values from a pooled sample of modern teeth:

Method*	Lead	Copper	Cadmium
AAS	7.3	2.4	0.14
DPASV	5.7	2.9	0.14

(Zinc concentration was c. 150 p.p.m.)

* Atomic Absorption Spectrometry is more widely used than Differential Pulse Anodic Stripping Voltametry.

TABLE 2

Lead concentrations in small groups of teeth, and their relative standard deviations. Means and RSD based on square root transformations: Contemporary teeth and teeth from archaeological sites.

Study No.[a]	Location		RSD% [b]	Mean Pb (p.p.m.)	No. in [d] group
1	Uvdal, Buskerud, Norway		33	1	14
2	Tønsberg and Gimsøy, Vestfold, Norway		35	28	8
3	Poundbury, Dorset, U.K.		29	10	10
4	Wookey Hole Cave		9	75	10
5	Bristol	(1979)	17, 21, 19	4	10 x 3
6	Bristol	(1983)	30, 34, 31	3-4	12 x 3
7	London	(1981)	25, 20, 26	5	12 x 3
8	Plymouth	(1980)	30, 32	4	11 x 2
9	Oslo	(1974)	27	2	13
10	Tokyo	(1974)	35	11	22
11	Hachijo	(1974)	32	5	13
12	Oxlo	(1978)	18	3	13

a Ref. 1-4: Archaeological material; Ref. 10 & 11: Data from Fig. 3 (Hachijo Isl., S. of Tokyo, E. of Kyushu Isl.)

b Standard deviation as percentage of mean (SRT data)

c To nearest p.p.m., based upon SRT data

d 1, 2 or 3 groups (square root transformation of data)

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TABLE 3

Cadmium concentrations in small groups of teeth, and their relative standard deviations. Means and RSD based on square root transformations. Contemporary teeth and teeth from archaeological sites.

Location[a]	RSD%[b]	Mean[c] (p.p.m.)	No. in[d] group
Uvdal, Buskerud, Norway	23	0.69	10
Tønsberg and Gimsøy, Vestfold, Norway	37	0.14	8
Poundbury, Dorset, U.K.	34	0.25	11
Wookey Hole Cave	25	0.68	10
Bristol (1983)	34	0.13, 0.14, 0.10	10 x 3
Oslo (1974)	47	0.67	10
Tokyo (1974)	44	0.08	19[d]
Hachijo (1974)	36	0.49	16[e]

a References as for Table 1

b Standard deviation as percentage of mean (SRT data)

c To nearest 0.01 p.p.m., based upon SRT data

d 5 zero values excluded e Highest value excluded

TABLE 4

Concentrations of copper, lead and zinc in sections through a mud bank in the Fourth Chamber of Wookey Hole Cave containing skeletal material (samples collected 1973-75).

(Part of Table 3 (Stenner 1978) comprising data on stratified layers)

Thickness of sample analysed § cm. (approx)	Metal concentration, p.p.m. † Copper	Lead	Zinc
0.9	71	26000	1600
0.8	38	24000	2100
1.6	29	5200	1800
0.5	38	5100	1700
0.9	37	4800	780
0.6	31	3600	860
0.5	34	5100	1500

§ The first two samples represented hard deposits

Remaining samples contained charcoal or skeletal fragments. Two further samples (4-5 cm) showed similar analyses; below these were compact unstratified layers with much lower lead levels.

† Samples from other caves having no known associations with metal-contaminated streams provided further data:

Copper 20 (S.D. 10), Pb 140 (S.D. 90), Zn 170 (S.D. 120)

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