

**Chapter 7: History of Trace Metal Deposition at Bleham
Tarn Since 1800**

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7.0 History of Trace Metal Deposition at Blelham Tarn Since 1800

This chapter presents a 200 year history of trace metal deposition at Blelham Tarn determined from the results of this study. Reconstructing the record of atmospheric deposition to Blelham Tarn requires the following data:

- (i) direct measurements of atmospheric flux from rainfall,
- (ii) records from soil cores,
- (iii) records from the peat bog, and
- (iv) records from the sediment cores.

Environmental tracers such as ^{210}Pb are useful tools in the process of correcting indirectly measured fluxes. Normalising against ^{210}Pb is often used to correct for erosive inputs, sediment focussing and post-depositional transport. In this simple approach, we assume that the pollutant has the same transport coefficient as ^{210}Pb and subtract the background to calculate the anthropogenic component. If P_a = atmospheric flux of ^{210}Pb (known), P_s = flux of ^{210}Pb to sediments (known), F_a = atmospheric flux of pollutant (unknown), F_s = flux of pollutant to sediments (known),

then:
$$\frac{F_a}{F_s} = \frac{P_a}{P_s} \quad \text{eqn. 7.1}$$

and the atmospheric flux can be estimated from the formula,

$$F_a = F_s \times \frac{P_a}{P_s} \quad \text{eqn. 7.2}$$

7.1 Direct Measurements of Contemporary Trace Metal Fluxes

Direct measurements of trace metal deposition via rainfall are available from the surrounding area adjacent to Blelham Tarn. *Table 7.1* shows mean annual Pb, Zn, Cu, and Ni fluxes for the period 1975-1996. Samples were collected using a bulk sampling method followed by filtration through 0.45 μm Whatman filter paper and analysis via A.A. Spectroscopy (Baker, *pers. comm.*). Ratios between mean atmospheric fluxes of trace metals for the period 1975-1996 are shown in *Table 7.2*.

Lead: There is a general decline from *c.* 1980 in the depositional flux of Pb with a mean flux of 1.183 $\mu\text{g cm}^{-2}$. Maximum fluxes are 4.9 $\mu\text{g cm}^{-2}$ for 1980 and a smaller peak of 1.5 $\mu\text{g cm}^{-2}$ in 1988.

Zinc: The Zn flux is relatively uniform with a mean of 6.428 $\mu\text{g cm}^{-2}$. There are two peaks of 29.380 $\mu\text{g cm}^{-2}$ in both 1982 and 1983 and a further maximum of 25.583 $\mu\text{g cm}^{-2}$ in 1993.

Copper: The flux of Cu is the most irregular of the four metals under investigation. Cu flux increases to a maximum value of 2.398 $\mu\text{g cm}^{-2}$ in 1981, followed by a decrease to 0.259 $\mu\text{g cm}^{-2}$ in 1991 and further increasing to 1.726 $\mu\text{g cm}^{-2}$ in 1996.

Nickel: Ni deposition is relatively uniform with a mean flux of $0.579 \mu\text{g cm}^{-2}$, and a maximum value of $3.323 \mu\text{g cm}^{-2}$ in 1987.

Year	Pb ($\mu\text{g cm}^{-2}$)	Zn ($\mu\text{g cm}^{-2}$)	Cu ($\mu\text{g cm}^{-2}$)	Ni ($\mu\text{g cm}^{-2}$)	Rainfall (mm)
1975	1.515	2.959	1.166	0.719	1572
1976	1.003	6.006	1.063	0.748	1657
1977	0.927	4.059	1.571	0.758	1898
1978	1.567	3.263	2.237	< 0.416	1768
1979	< 1.741	2.988	1.034	0.705	1917
1980	4.943	5.520	1.378	< 0.513	1966
1981	< 1.619	3.266	2.398	0.380	1989
1982	1.151	29.380	1.428	0.194	1930
1983	1.164	29.380	1.692	0.630	1732
1984	0.823	2.875	1.307	0.231	1739
1985	0.757	2.563	1.065	0.255	1926
1986	0.949	4.068	1.174	0.830	2113
1987	0.896	2.782	0.820	3.323	1918
1988	1.502	3.982	0.582	0.674	2139
1989	0.962	2.483	0.782	0.296	1722
1990	1.054	2.702	0.656	< 0.189	2030
1991	0.757	1.956	0.259	0.177	1913
1992	< 0.745	2.236	0.765	< 0.203	1992
1993	< 0.870	25.583	0.550	< 0.348	1740
1994	0.557	1.805	1.379	0.117	2162
1995	0.270	1.433	1.013	< 0.189	1750
1996	0.369	2.822	1.726	< 0.716	1537
Mean	1.118	6.550	1.184	0.573	1869

Table 7.1: Annual trace metal deposition data from Wraymires, Cumbria 1975-96 (AEA, *pers. comm.*). Samples were collected using a bulk sampling method followed by filtration through $0.45 \mu\text{m}$ filter paper and analysis via A.A. Spectroscopy (Baker, *pers. comm.*).

	Pb	Zn	Cu	Ni
Pb	-	0.17	0.94	1.95
Zn	5.86	-	5.53	11.43
Cu	1.1	0.2	-	2.1
Ni	0.51	0.09	0.48	-

Table 7.2: Ratios between mean atmospheric fluxes of Pb, Zn, Cu and Ni for the period 1975-96.

7.2 ²¹⁰Pb Flux

The results of the analytical work enable us to compare both indirect and direct measurements of ²¹⁰Pb flux to Blelham Tarn. The indirect measurements include data from three types of collectors; sediment, soil and peat cores. Soil cores have previously been used to calculate mean ²¹⁰Pb fluxes at this site and are a useful basis for comparison. Soil cores enable us to calculate a mean flux over a long period of time, whereas results calculated from direct measurements of rainwater can provide a monthly flux with a high degree of accuracy.

7.2.1 Indirect Measurements

Table 7.3 gives the unsupported ²¹⁰Pb inventories for the 1996 Blelham Tarn soil cores. Indirect ²¹⁰Pb flux (P) is calculated by multiplying the decay constant of ²¹⁰Pb (yr^{-1}) by the ²¹⁰Pb inventory, A , (Bq m^{-2}) (Beninger *et al.*, 1975):

$$P = \lambda_{\text{pb-210}} \times A . \quad \text{eqn. 7.3}$$

The annual flux of ²¹⁰Pb to the Blelham Tarn catchment measured by the seven soil cores in this study was found to be $148 \text{ Bq m}^{-2} \pm 25$.

1996 Core	²¹⁰ Pb Inventory		²¹⁰ Pb Flux	
	(Bq m^{-2})	(\pm)	($\text{Bq m}^{-2} \text{ yr}^{-1}$)	(\pm)
BLS 96/1	4048	363	126	11
BLS 96/2	3575	324	111	10
BLS 96/3	4905	164	153	5
BLS 96/4	6009	212	187	7
BLS 96/5	4430	128	138	4
BLS 96/6	5071	189	158	6
BLS 96/7	5239	157	163	5
Mean	4754	220	148	25

Table 7.3: Blelham Tarn soil core ²¹⁰Pb inventories and associated indirectly measured fluxes.

Radionuclide inventories and calculated fluxes from Blelham Tarn sediment cores and the Foulshaw Moss peat core are presented in Table 7.4. The inventories and corresponding fluxes of the cores vary markedly over the Blelham basin.

Core	²¹⁰ Pb Inventory		²¹⁰ Pb Flux	
	Bq m ⁻²	±	Bq m ⁻² yr ⁻¹	±
BLT 96/A	9063	254	282	8
BLT 96/D	8012	263	249	8
BLT 96/J	15157	992	472	31
BLTW 97/A	6024	215	188	7
BLTW 97/B	5993	206	187	6
FLM 95	3163	68	98.3	2.1

Table 7.4: Sediment core radionuclide inventories.

7.2.2 Direct Measurements

Mean monthly concentrations of ²¹⁰Pb and ⁷Be in rainwater samples for the period from April 1997 to August 1998 are given in Table 7.5 whilst Fig. 7.1 shows a comparison between monthly ²¹⁰Pb and ⁷Be depositional fluxes. Investigations into the atmospheric fallout of ²¹⁰Pb and ⁷Be in many places around the world indicate that there are seasonal variations in the depositional fluxes. They tend to be high in winter in a few places while in most places the high occurs in spring (Baskaran, 1995). This data seems to fit both of these patterns.

The annual deposition from April 1997 to March 1998 of ²¹⁰Pb and ⁷Be was found to be 165 ± 8 Bq m⁻² and 3912 ± 120 Bq m⁻² respectively.

7.2.3 Comparison between Indirect and Direct ²¹⁰Pb Flux Measurements

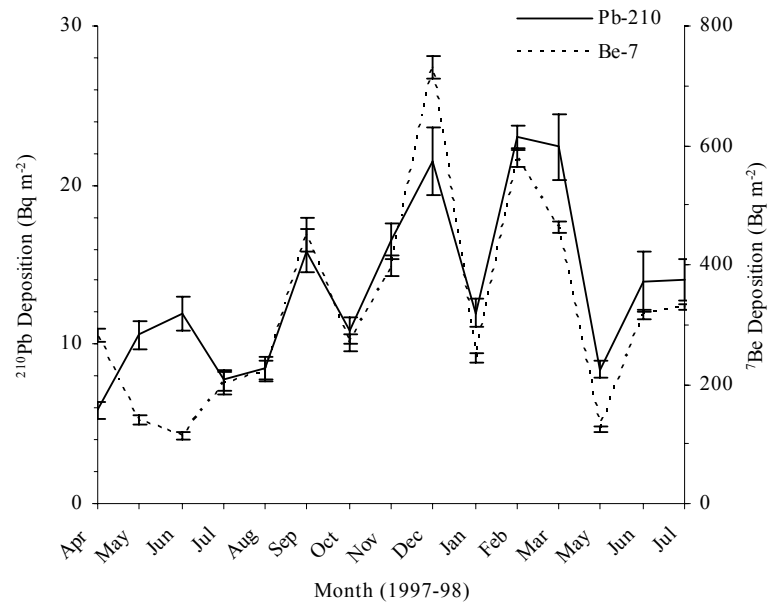
The mean ²¹⁰Pb concentration in rainfall of 91 ± 5 Bq kl⁻¹ is comparable to the value of 82 ± 9 Bq kl⁻¹ determined from three earlier UK studies compared in Smith *et al.* (1997).

The mean ²¹⁰Pb flux determined from soil cores of 148 ± 25 Bq m⁻² yr⁻¹ is remarkably close to the value of 165 ± 8 Bq m⁻² yr⁻¹ obtained from rainfall measurements. Smith *et al.* (1997) gave a lower value of 115 ± 40 Bq m⁻² yr⁻¹ determined from soil cores from the same locations, though in that particular study the detector system was such that there were difficulties in accurately determining the supported ²¹⁰Pb (Appleby *et al.*, 1999).

Since the mean annualised rainfall for the study period of 1946 mm yr⁻¹ is a little higher than the long term mean (1814 mm yr⁻¹), the mean annualised direct flux of 165 Bq m⁻² is perhaps a little higher than the long-term mean. Correcting for the difference, the mean annual ²¹⁰Pb flux from rainfall measurements is calculated to be 154 ± 7 Bq m⁻². This value is in good agreement with the soil core flux determined as part of this study.

Collection Period		^{210}Pb		^7Be		Rain
Start	Finish	(Bq kl^{-1})	\pm	(Bq kl^{-1})	\pm	(mm)
07/04/97	05/05/97	56	6	2686	93	105
06/05/97	02/06/97	129	30	1843	236	83
03/06/97	30/06/97	130	14	1233	69	92
01/07/97	28/07/97	89	18	2304	543	87
29/07/97	28/08/97	94	28	2425	238	91
29/08/97	29/09/97	85	22	2386	247	187
30/09/97	03/11/97	78	7	1909	115	140
04/11/97	01/12/97	85	7	2037	94	195
02/12/97	05/01/98	63	8	2072	139	341
06/01/98	02/02/98	85	11	1734	160	143
03/02/98	02/03/98	143	4	3552	91	162
03/03/98	06/04/98	87	8	1774	36	260
07/04/98	04/05/98	NS		NS		
05/05/98	01/06/98	119	8	1763	62	71
02/06/98	06/07/98	60	7	1350	64	233
07/07/98	01/08/98	58	5	1346	24	244
Annual Mean		90.7	4.7	2028	62	
Annual Flux		Bq $\text{m}^{-2} \text{yr}^{-1}$	\pm	Bq $\text{m}^{-2} \text{yr}^{-1}$	\pm	mm yr^{-1}
		165	8	3912	120	1967

Table 7.5: Radionuclides concentrations and fluxes in rainwater.

Fig. 7.1: ^{210}Pb and ^7Be deposition at Esthwaite Water vs. calendar month 1997-98.

Since the flux determined from the soil cores represents a weighted mean value over *c.* 50 years, the consistency of these results is evidence for a relatively constant ^{210}Pb flux over this period of time when measured on annual time-scales. There are however significant variations on shorter (monthly) time-scales.

Table 7.6 shows $\text{Pb}/^{210}\text{Pb}$, $\text{Zn}/^{210}\text{Pb}$, $\text{Cu}/^{210}\text{Pb}$, and $\text{Ni}/^{210}\text{Pb}$ direct deposition ratios. These have been rainfall corrected to the long-term mean.

	<i>Direct Flux Ratio $M/^{210}\text{Pb}$ (mg Bq^{-1})</i>	
	<i>Nominal</i>	<i>Corrected to 1814 mm</i>
Pb	0.07	0.07
Zn	0.40	0.40
Cu	0.07	0.08
Ni	0.03	0.04

Table 7.6: $\text{Pb}/^{210}\text{Pb}$, $\text{Zn}/^{210}\text{Pb}$, $\text{Cu}/^{210}\text{Pb}$, and $\text{Ni}/^{210}\text{Pb}$ direct deposition ratios.

7.3 Total Deposition to Blelham Tarn

Comparing the total anthropogenic deposition of metals on a unit area basis (g cm^{-2}) eliminates the biases from dilution effects that occur when comparing concentrations. The total anthropogenic deposition of an element per unit area (or inventory) is calculated according to the following formula:

$$Q_s = \sum_{i=1}^n (C_i)(D_i)(B_i) \quad \text{eqn. 7.4}$$

where

Q_s = the total inventory stored in the sediments,

C_i = the concentration of substance C in the i th section of the core minus the background concentration of that metal ($\mu\text{g g}^{-1}$),

D_i = the density of the i th section of core (g cm^{-3}), and

B_i = the thickness of the i th section of the core (cm).

Trace metal inventories, in soil cores, peat bogs, and sediment cores associated with this study are shown in Table 7.7. All things considered, the sediment core inventories (excluding BLT 96/J) are fairly consistent. Cores 96/A and 97/A have similar trace metal inventories but differing ^{210}Pb inventories showing evidence of focussing.

The rainfall at Foulshaw Moss is much lower than at Blelham Tarn, 1100 mm y^{-1} compared to 1814 mm y^{-1} . For comparison, it is therefore useful to correct Foulshaw Moss data to Blelham Tarn rainfall levels.

For the soil cores, the total deposition of Zn, Cu, Ni, cannot be calculated since there is no obvious background, possibly due to remobilisation of these redox sensitive elements within the cores.

	^{210}Pb (Bq m^{-2})	Pb ($\mu\text{g cm}^{-2}$) (post-1900)	Zn	Cu	Pb ($\mu\text{g cm}^{-2}$) (post-1800)	Zn	Cu
Foulshaw Moss							
Actual	3163	550	189	51	810	225	64
Rain corrected	5216	907	312	84	1336	371	106
Blelham Tarn							
Soil cores							
BLS 96/1	4048				369		
BLS 96/4	6009				893		
BLS 96/5	4430				356		
BLS 96/7	5239				1810		
Sediment cores							
BLT 96/A	9063	591	1130	108	915	1541	147
BLTW 97/A	6024	557	971	97	853	1291	140
BLT 96/D	8012	553	1247	94			
BLTW 97/B	5993	596	1088	155	963	1489	214
BLT 96/J	15157	954	1621	144			

Table 7.7: Trace metal inventories in soil cores, peat bogs, and sediment cores.

7.4 Reconstruction of the Historical Data

Table 7.8 shows ^{210}Pb and trace metals fluxes since 1975 to the study sites. The mean Blelham Tarn values (excluding BLT 96/J since it is heavily influenced by catchment inputs) have been corrected for sediment focussing by multiplying by the ratio of the atmospheric flux to the mean ^{210}Pb flux to the sediment. The Foulshaw Moss values have been corrected for the rainfall difference.

The ^{210}Pb flux at Foulshaw of $98 \text{ Bq m}^{-2} \text{ yr}^{-1}$ becomes $162 \text{ Bq m}^{-2} \text{ yr}^{-1}$ when scaled to the Blelham Tarn rainfall. This is in quite good agreement with the estimated value for Blelham Tarn of $151 \text{ Bq m}^{-2} \text{ yr}^{-1}$ (average of direct and indirect measurements from this study) and suggests that the peat bog is a good collector of atmospheric deposition.

Comparing the ^{210}Pb corrected sediment flux for the period > 1975 with the rainfall measurements for 1975-96 the fluxes determined from the lake sediments are somewhat higher. This may be due to leaching from the catchment since correcting the rainfall measurements for the dry deposition component of rainwater (an increase of between 20-40%) is insignificant. The apparently higher lead flux at Foulshaw Moss may be due to the closer proximity to heavy traffic from the neighbouring villages of Town End, Millside and Ulpha, all approximately 1 mile away, or more likely from the main road (A590) which runs alongside the bog (Fig. 3.1).

	^{210}Pb ($\text{Bq m}^{-2}\text{y}^{-1}$)	Pb	Zn	Cu
		($\mu\text{g cm}^{-2}\text{y}^{-1}$) (>1975)		
BLT 96/A	254	6.6	13.2	1.7
BLTW 97/A	215	7.9	12.5	1.8
BLT 96/D	263	5.9	16.6	1.7
BTW 97/B	206	8.4	16.4	3.8
BLT 96/J	992	15.4	20.9	2.2
Mean (excluding 96/J)	235	7.2	14.7	2.3
Corrected*	151	4.4	9.1	1.4
Foulshaw Moss				
Actual	98	4.4	4.3	0.6
Corrected**	162	7.3	7.1	1.0

Table 7.8: Mean Post-1975 Fluxes for sediment and peat cores. Corrected* = ^{210}Pb corrected, corrected** = corrected for rainfall variations.

Atmospheric deposition histories at Blelham Tarn can be estimated by

- averaging all the sediment records (excluding BLT 96/J) and correcting for focussing (eqn. 7.2),
- correcting the Foulshaw Moss record for rainfall difference, and
- averaging the above two.

The following table summarises these calculations. (c) is probably the best estimate of the record of atmospheric deposition at Blelham Tarn.

Date	(a)			(b)			(c)		
	Sediment record			Foulshaw Moss			Mean		
	Pb	Zn	Cu	Pb	Zn	Cu	Pb	Zn	Cu
	($\mu\text{g cm}^{-2}\text{y}^{-1}$)			($\mu\text{g cm}^{-2}\text{y}^{-1}$)			($\mu\text{g cm}^{-2}\text{y}^{-1}$)		
1995	3.7	7.8	1.4	5.1	5.3	1.0	4.4	6.5	1.2
1985	4.2	8.8	1.3	6.0	6.8	0.7	5.1	7.8	1.0
1975	4.5	8.4	1.0	10.8	7.1	0.9	7.6	7.8	0.9
1965	4.4	8.7	0.9	11.6	4.5	0.8	8.0	6.6	0.8
1955	3.9	8.4	0.7	10.9	2.8	0.8	7.4	5.6	0.8
1945	3.6	7.6	0.6	10.8	2.2	1.0	7.2	4.9	0.8
1935	3.5	6.9	0.5	10.7	1.8	1.1	7.1	4.4	0.8
1925	3.3	5.9	0.5	10.7	1.8	1.1	7.0	3.8	0.8
1915	3.5	5.9	0.4	8.3	0.9	0.8	5.9	3.4	0.6
1905	3.6	5.6	0.5	8.3	0.8	0.8	5.9	3.2	0.6
1887	2.9	3.8	0.4	6.7	0.6	0.4	4.8	2.2	0.4
1867	2.0	2.2	0.3	4.9	0.6	0.2	3.4	1.4	0.2
1825	1.8	1.8	0.3	2.8	0.6	0.1	2.3	1.2	0.2

Table 7.9: Estimates of atmospheric fluxes at Blelham Tarn ($\mu\text{g cm}^{-2}\text{y}^{-1}$) for the period 1825-1995.

7.5 Source Indicators

While lead isotope ratios can be used to provide information on the geochemical origins of anthropogenic lead pollution (Chow *et al.*, 1975), they are also useful markers for looking at changes in the anthropogenic or excess lead flux over time. Here they are used to identify key periods in the history of Blelham Tarn.

7.5.1 Modelling Anthropogenic $^{206}\text{Pb}/^{207}\text{Pb}$

For each of the sections above the background value, the $^{206}\text{Pb}/^{207}\text{Pb}$ ratio was corrected with background values to derive an excess $^{206}\text{Pb}/^{207}\text{Pb}$ ratio, representing anthropogenic input of lead using the formula (Farmer *et al.*, 1996):

$$\left[(\text{Pb}_{\text{excess}}) \times \left(\frac{^{206}\text{Pb}}{^{207}\text{Pb}} \right)_{\text{excess}} \right] = \left[(\text{Pb}_{\text{meas}}) \times \left(\frac{^{206}\text{Pb}}{^{207}\text{Pb}} \right) \right] - \left[(\text{Pb}_{\text{bg}}) \times \left(\frac{^{206}\text{Pb}}{^{207}\text{Pb}} \right)_{\text{bg}} \right] \quad \text{eqn. 7.5}$$

Although there is no direct proof of this relationship it has been empirically tested using the lead isotope sediment core data gathered for this study (Fig. 7.2).

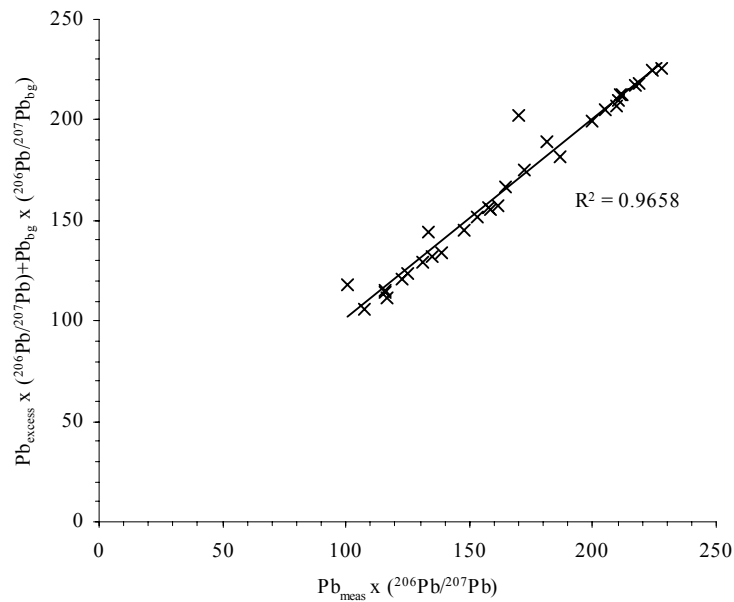


Fig. 7.2: Empirical evidence for the relationship presented in equation 7.5, calculated from BLT 96/A sediment core measurements.

The normalised anthropogenic lead flux for core 96/A was then plotted along with the corresponding excess $^{206}\text{Pb}/^{207}\text{Pb}$ ratio against calendar year. Similarly, the anthropogenic lead flux for the bog and excess $^{206}\text{Pb}/^{207}\text{Pb}$ ratio was plotted against calendar year.

7.5.2 Sediment Core Excess $^{206}\text{Pb}/^{207}\text{Pb}$

Using the value of 1.176 for the $^{206}\text{Pb}/^{207}\text{Pb}$ ratio below 51 cm, the $^{206}\text{Pb}/^{207}\text{Pb}$ ratio of the anthropogenic derived lead for each section was calculated from the formula, results are shown in Fig. 7.3.

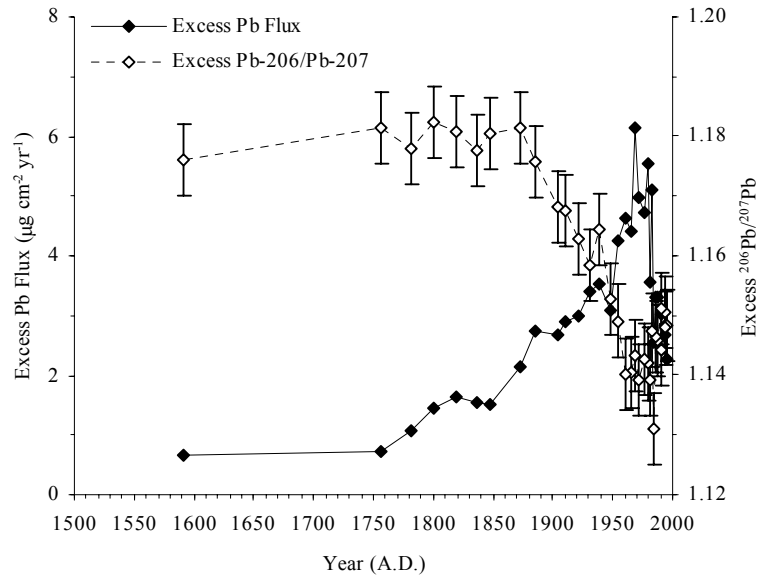


Fig. 7.3: Excess (*i.e.* anthropogenic) normalised lead fluxes and associated excess $^{206}\text{Pb}/^{207}\text{Pb}$ ratios at Blelham Tarn site A vs. calendar year (1591-1996).

Three key periods can be identified from the excess $^{206}\text{Pb}/^{207}\text{Pb}$ ratio for the sediment core. (i) From pre 19th century to 1872 it was constant at 1.180 ± 0.007 during which time the flux slowly increased. The total excess Pb deposited during this period was $529 \mu\text{g cm}^{-2}$, 42% of the inventory for the core of $1247 \mu\text{g cm}^{-2}$. (ii) From 1872-1931 the ratio fell to 1.159 ± 0.006 , whereas other lakes in the UK show stabilised (*i.e.* non-decreasing) isotope signatures here (Farmer *et al.*, 1996). The total excess lead deposited during 1872-1931 was $277 \mu\text{g cm}^{-2}$, 22% of the core inventory. (iii) From 1931, soon after the introduction of leaded petrol, the isotopic ratio decreased steadily to 1.140 by the mid-1980's, although the flux of lead remained $\geq 5.19 \mu\text{g cm}^{-2} \text{ yr}^{-1}$, peaking at $10.34 \mu\text{g cm}^{-2} \text{ yr}^{-1}$ in 1969, and was still as high as $8.60 \mu\text{g m}^{-2} \text{ yr}^{-1}$ in 1983. Thereafter, at the same time as steps were introduced to reduce the lead content of petrol in the UK, the ratio increased slightly to 1.15 as the flux fell sharply to $3.83 \mu\text{g cm}^{-2} \text{ yr}^{-1}$ by 1996. Overall the excess lead deposited from 1931 to 1996 was $441 \mu\text{g cm}^{-2}$, 35% of the core inventory. The influence of catchment derived minerogenic Pb in the sediment core record is apparent in the unstable 'industrial' $^{206}\text{Pb}/^{207}\text{Pb}$ record *c.* 1940 (Fig. 7.3 above).

7.5.3 Peat Core Anthropogenic $^{206}\text{Pb}/^{207}\text{Pb}$

Using the value of 1.154 for the $^{206}\text{Pb}/^{207}\text{Pb}$ ratio below 35 cm, the $^{206}\text{Pb}/^{207}\text{Pb}$ ratio of the anthropogenic lead for each section was calculated from the formula (Fig. 7.4).

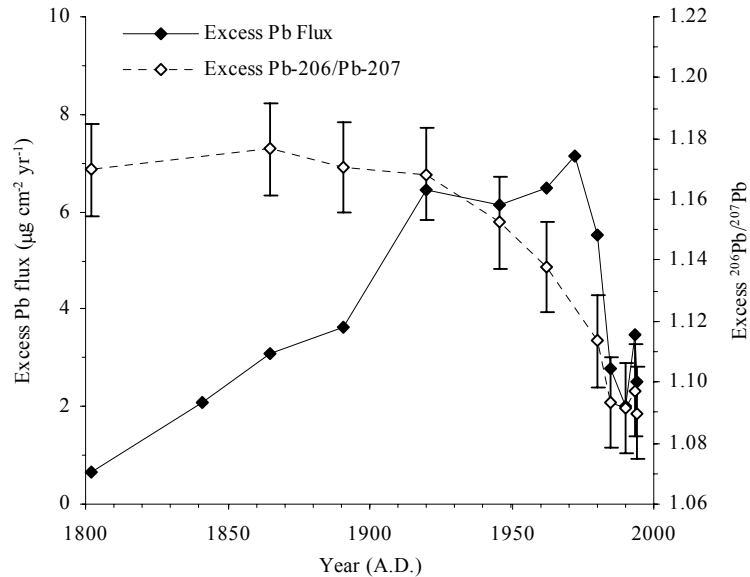


Fig. 7.4: Excess (*i.e.* anthropogenic) lead fluxes and associated $^{206}\text{Pb}/^{207}\text{Pb}$ ratios at Foulshaw Moss vs. calendar year (1802-1996).

Two key periods can be identified from for the excess $^{206}\text{Pb}/^{207}\text{Pb}$ ratio from the peat core. (i) From 1800 to 1920 the ratio was very steady at 1.171 ± 0.09 despite, as the industrial revolution flourished, a dramatic increase in flux which peaked at $6.44 \mu\text{g cm}^{-2} \text{yr}^{-1}$ in 1920. The total excess Pb deposited during this period was $376 \mu\text{g cm}^{-2}$, 46% of the inventory for the core of $815 \mu\text{g cm}^{-2}$. (ii) From 1920, soon after the introduction of leaded petrol, the isotopic ratio decreased steadily to 1.093 ± 0.07 by the mid-1980's, although the flux of lead remained $\geq 6.12 \mu\text{g cm}^{-2} \text{yr}^{-1}$ prior to 1980, peaking at $7.15 \mu\text{g cm}^{-2} \text{yr}^{-1}$ in 1972. Thereafter, at the same time as steps were introduced to reduce the lead content of petrol in the UK, the ratio increased slightly to 1.092 as the flux fell sharply to $2.00\text{-}3.48 \mu\text{g cm}^{-2} \text{yr}^{-1}$ by 1990-1995. Overall the excess lead deposited from 1920 to 1995 was $439 \mu\text{g m}^{-2}$, 54% of the core inventory.

The shift in the $^{206}\text{Pb}/^{207}\text{Pb}$ ratio of excess lead in these environmental compartments occurring in the 1920's, after a century of stability (Farmer *et al.*, 1996), was due to the introduction of leaded petrol with a low $^{206}\text{Pb}/^{207}\text{Pb}$ value. This is reflected classically in the peat record which is thought to compose of an entirely atmospheric record (Fig. 7.4 above).