Kinetics of lead in blood after the end of occupational exposure

SCHUTZ, A. SKERFVING, S. RANSTAM, J. CHRISTOFFERSSON, J-O. Kinetics of lead in blood after the end of occupational exposure. Scand J Work Environ Health 13 (1987) 221—231. The sum of two exponential functions was fitted to the decay of blood lead (PbB) level after the end of lead exposure. For two subjects who had not formerly been occupationally exposed to lead but who had been exposed to a single short heavy dose, the fast compartment (probably soft tissues) had a biological half-time of 37 and 44 d, respectively. For 20 lead workers after the end of occupational exposure, the corresponding median was 29 (range 7—63) d. For 21 ex-lead workers, the median biological half-time of the slow compartment was 5.6 (range 2.3—27) years. There was significant interindividual variation in both the fast and the slow half-time. This finding probably means a considerable variation in risk at a certain exposure level. In the lead workers, the PbB fraction corresponding to the slow compartment had a median as high as 1.3 (range 0.7—2.7) μmol/l, which constituted more than half of the total PbB. This fraction was associated with exposure history, and with the lead level in the skeleton, the latter determined in vivo by an X-ray fluorescent method. The data thus indicate a rather rapid turnover of the skeletal lead pool, a phenomenon which may affect the PbB level considerably.

Keywords: half-time, metabolic model, two-compartment model.

Exposure is common in industry. The blood lead level is the main parameter used for the biological monitoring of lead exposure (74). However, knowledge on the kinetics of PbB is incomplete, as it regards the metabolism of lead in the other tissues of the body (74), which is a phenomenon that PbB does not mirror.

In the present article we report a study of the decay of lead in the blood of lead-exposed subjects after the end of exposure. This decay pattern could be interpreted by a metabolic model.

Methods and sampling

The first group to be studied was 23 male ex-lead workers (table 1). Their mean age was 55 years and their mean exposure time was 23 years. The PbB was usually determined at the end of exposure and then at varying intervals. For 10 subjects PbB was determined once a year. For one worker (number 101), no further determinations were available concerning the first year after the end of exposure. For 12 subjects (numbers 10 to 115), several determinations were made during the first year, then at year seven, and then again from nine on about twice a year. For one subject (number 102) there was a lack of data between 3.5 and 9.6 years after the end of exposure.

In addition 17 male lead workers temporarily removed from exposure were investigated (table 2). Their mean age was 49 years, and their mean exposure time was 11 years. The reason for removal from exposure was high PbB levels (generally about 3.0 μmol/l or more). Twelve of the workers were transferred from a smeltery to a nearby plant, the work in which did not involve lead exposure. The PbB level was generally determined when the workers left the smeltery and then once a week for three weeks; later PbB measurements were made once every two to four weeks.

Furthermore, two male volunteers, who had been unexposed occupationally, but who had been exposed to a single short heavy lead dose, were included (table 2). Details on these two subjects have been published elsewhere (56).

Spot determinations of "background" PbB levels were made for 47 healthy workers not occupationally exposed to lead. They lived in the same county as the exposed subjects and were all blue-collar workers. Their average PbB level was 0.3 μmol/l. In this connection, it may be mentioned that, for 15 workers in a glue production plant located close to the nonlead resort of the temporarily removed smeltery workers, the average PbB level was 0.5 (range 0.3—0.7) μmol/l.

Medical examinations

For most of the subjects, an occupational and medical history, including alcohol habits, was obtained. Venous blood samples were analyzed for lead (see the section Blood Lead Determinations), hemoglobin, sedimentation rate, red and white cell counts; calcium,
phosphate, and creatinine concentrations; and alkaline phosphatase and gamma glutamyl transferase activities in serum. A urine sample was analyzed for albumin and glucose.

Among the ex-lead workers, detailed medical information was lacking for four. Among the 19 remaining, 12 had earlier been removed (at least once) temporarily from lead exposure because of a high PbB level and/or a high delta-aminolevulinic acid level in the urine. One subject was clinically diagnosed as lead poisoned (upper abdominal pain, constipation, neuropathy, and slight anemia) at the time when his exposure ended. No one else had been treated in a hospital because of lead poisoning. One worker had a clinically silent chronic lymphatic leukemia, and one had a type 2 diabetes treated with diet only. Three persons had slight increases in their serum creatinine levels, and two others showed slight albuminuria. Three subjects had somewhat increased gamma glutamyl transferase activities in their serum, two of whom were known to abuse alcohol.

Blood lead determinations
Blood was obtained from the cubital vein. During the first years of the study, acid-washed heparinized sampling tubes were prepared at our laboratory. Later on, evacuated, metal-free Vacutainer® tubes were used. Almost all of the PbB determinations were made in the same laboratory and by the same method. The samples were wet-ashed, and lead was complexed with dithizone, extracted, and determined by flame atomic absorption spectrometry (AAS) (55, 56). The detection limit was 0.05 μmol/l (<10 μg/l). The accuracy was tested twice each year in a Nordic interlaboratory calibration program with 6–19 (mean 12) accepted laboratories participating on each occasion. The regression function of our results (Y, μmol/l) on the average result of the other laboratories (X, μmol/l) was Y = 1.008X - 0.052. Our results for the 115 samples (range 0.2–5.6 μmol/l) averaged 96.3 % of the corresponding results obtained in the laboratories. Furthermore, we participated in the External Quality Assessment Scheme during the first part of the study. In the 29 samples analyzed, our results by single analysis averaged 99 % of the mean of the results obtained in the laboratories.

During the first year of observation of subject 104—115, the first three years of subject 102, and the first six years of subject 116, PbB was determined by a colorimetric method after extraction with diethylether in chloroform. The detection limit was about 0.2 μmol/l, and the method was shown to be about 10 %.

Mathematical analysis
Three models corresponding to the sum of one, two, and three exponentials were considered for the decay curves of each individual worker. A first order rate (transformed and quoted as half-time T1/2) was fitted to each compartment (Y(l), Y(2), and Y(3)), and the concentration corresponding to the "background" value of 0.3 μmol/l was subtracted from each parameter. The two parameters and their associated standard deviations were estimated as elements of the asymptotic covariance matrix of the estimates. The fit of the three models was judged from comparison of the fraction of total variance in the PbB values explained (R²). Likelihood-ratio tests were used for checks of the validity of the models and for the accuracy of the individual curve fittings.

To describe accumulation, a function of the form 

\[ Y(t) = A(t) - B(t) \times e^{-B \times t} \]

where \( A \) is a scale constant, \( B \) an elimination constant, and \( t \) time, was fitted to the data by use of the nonlinear regression procedure in BMDP (21).
in vivo from the middle phalanx of the left forefinger of 37 subjects by an incident light fluorescence method, as described earlier (16). The detection limit was 20 µg/g, and the method error about 15%. Readings below the detection limit were assigned a value of 10 µg/g in the calculations. Most cases, levels derived either at duplicate determinations (16) or calculated from a series of measurements (15) were employed.

General, nonparametric tests were employed. For regressions the Spearman’s rank correlation (r_s) was used, and for comparisons of duplicate measurements the same individual the Wilcoxon’s matched-pairs signed-rank test was used. Comparisons between groups were made by the Mann-Whitney U-test. In a few instances, a single or multiple linear regression analysis was made. For establishing interindividual variations, normal tests were employed. When more than one regression series was available for a particular individual, the value corresponding to the calculations of the best fit (R^2) of the compartment analysis was used. All P-values are two-tailed. "Statistically significant" denotes P<0.05.

The fit of the two-compartment model (median 97%, range 35–99%) was considerably and significantly (P<0.0001, Wilcoxon) better than that of the one-compartment model (median 86%) (tables 1 and 2). The fit of the three-compartment model was similar (medians 97 versus 97%) (table 1), though significantly (P<0.01, Wilcoxon) better.

When the three-compartment model was employed, the median of Y(1) was 0.6 (range 0.0–2.3) µmol/l, that of Y(2) was 1.4 (range 0.0–2.5) µmol/l, that of T(1/2) was 3.7 (range 0.3–16) years, that of Y(3) was 0.3 (range 0.0–2.6) µmol/l, and that of T(1/2) was >100 (range 4.9–00) years.

In the following presentation, only the simplest model with a good fit, i.e., the two-compartment one, will be discussed.

With the use of the two-compartment model, the decay rate in the remaining 21 ex-lead workers (table 1) had a median biological half-time of the slow compartment (T(1/2)) of 5.6 years during a median post-exposure period of 13 years. There was a considerable range for T(1/2), i.e., 2.3–27 years (table 1).

The data were sufficient for an estimate of the half-time of the fast compartment in three of the ex-lead workers. For subject 104, T(1/2) of 30 d was employed. The fit of the two-compartment model (median 97%, range 35–99%) was considerably and significantly (P<0.0001, Wilcoxon) better than that of the one-compartment model (median 86%) (tables 1 and 2). The fit of the three-compartment model was similar (medians 97 versus 97%) (table 1), though significantly (P<0.01, Wilcoxon) better.

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Figure 1. Decline of the blood lead level (PbB, logarithmic) after the end of exposure for three ex-lead workers. A two-compartment model was fitted to the data. Both compartments and their biological half-times (T(1/2)) are indicated. For subject 104 and 117, the half-time of the fast compartment (T(1/2)) was assumed to be 30 d (y = years).
Table 1. Kinetics of the decrease of lead in blood (PbB) after the end of the occupational exposure of 23 ex-lead workers observed for more than one year. (% = degree of explanation, TW(1) = half-time of fast compartment, TW(2) = half-time of slow compartment, 95% CI = 95% confidence interval, Y(1) = Y-intercept for the fast compartment, and Y(2) = Y-intercept for the slow compartment)

| Subject | Age (years) | Exposure duration (years) | First post-exposure observation (d) | Number of samples | One-compartment model (%) | Two-compartment model (%) |
|---------|-------------|--------------------------|-----------------------------------|------------------|--------------------------|--------------------------|
| 101     | 44          | 4.5                      | 1.6                               | 2.9              | 5                        | 58%                      |
| 102     | 60          | 4.2                      | 15.0                              | 39               | 87                       | 29%                      |
| 103     | 49          | 5.9                      | 51                                | 40               | 38                       | 23%                      |
| 104     | 54          | 2.7                      | 13.0                              | 11               | 87                       | 20%                      |
| 105     | 41          | 3.0                      | 12.9                              | 10               | 86                       | 20%                      |
| 106     | 48          | 2.9                      | 12.9                              | 10               | 91                       | 20%                      |
| 107     | 54          | 3.3                      | 13.0                              | 13               | 94                       | 20%                      |
| 108     | 30          | 3.7                      | 12.9                              | 12               | 91                       | 20%                      |
| 109     | 58          | 2.6                      | 12.9                              | 12               | 79                       | 20%                      |
| 110     | 58          | 3.6                      | 12.9                              | 12               | 51                       | 20%                      |
| 111     | 65          | 4.5                      | 12.8                              | 12               | 58                       | 20%                      |
| 112     | 51          | 3.3                      | 12.8                              | 10               | 95                       | 20%                      |
| 113     | 68          | 4.6                      | 11.2                              | 9                | 96                       | 20%                      |
| 114     | 31          | 4.2                      | 10.4                              | 9                | 96                       | 20%                      |
| 115     | 40          | 4.2                      | 9.4                               | 9                | 96                       | 20%                      |
| 116     | 60          | 10                      | 4.3                               | 9                | 82                       | 20%                      |
| 117     | 59          | 27                      | 4.2                               | 14               | 31                       | 19%                      |
| 118     | 58          | 22                      | 4.9                               | 10               | 78                       | 20%                      |
| 119     | 65          | 30                      | 4.8                               | 13               | 86                       | 20%                      |
| 120     | 85          | 33                      | 4.6                               | 14               | 54                       | 20%                      |
| 121     | 65          | 14                      | 4.3                               | 17               | 78                       | 20%                      |
| 122     | 61          | 24                      | 3.6                               | 12               | 9                        | 20%                      |
| 123     | 65          | 38                      | 1.7                               | 12               | 27                       | 0%                       |

Note: Numbers 101 and 201 are identical with numbers 201 and 217, respectively, in Table 2.

Table 2. Kinetics of the decrease of the blood lead (PbB) levels during a temporary cessation of occupations exposure among 12 fast workers observed for less than one year and among two volunteers who had a short, heavy exposure. (*= degree of explanation, TW(1) = half-time in fast compartment, TW(2) = half-time in slow compartment, 95% CI = 95% CI = confidence interval, Y(1) = Y-intercept for the fast compartment, and Y(2) = Y-intercept for the slow compartment)

| Subject | Age (years) | Exposure duration (years) | First post-exposure observation (d) | Number of samples | One-compartment model (%) | Two-compartment model (%) |
|---------|-------------|--------------------------|-----------------------------------|------------------|--------------------------|--------------------------|
| 201     | 43          | 3                        | 6.7                               | 189              | 20                       | 57%                      |
| 202     | 59          | 23                       | 4.5                               | 209              | 12                       | 87%                      |
| 203     | 59          | 22                       | 4.2                               | 172              | 10                       | 84%                      |
| 204     | 53          | 14                       | 3.8                               | 12               | 80                       | 87%                      |
| 205     | 60          | 5.5                      | 3.0                               | 112              | 82                       | 87%                      |
| 206     | 58          | 25                       | 3.0                               | 12               | 73                       | 87%                      |
| 207     | 58          | 5.5                      | 3.4                               | 114              | 94                       | 84%                      |
| 208     | 49          | 4.0                      | 3.2                               | 115              | 94                       | 84%                      |
| 209     | 48          | 7.5                      | 3.6                               | 171              | 78                       | 84%                      |
| 210     | 58          | 5.5                      | 3.9                               | 180              | 92                       | 84%                      |
| 211     | 58          | 13                       | 3.6                               | 158              | 84                       | 84%                      |
| 212     | 49          | 4.0                      | 3.5                               | 238              | 50                       | 77%                      |
| 213     | 51          | 1.5                      | 3.9                               | 120              | 67                       | 77%                      |
| 214     | 40          | 1.0                      | 3.5                               | 155              | 97                       | 70%                      |
| 215     | 50          | 1.0                      | 3.3                               | 147              | 94                       | 70%                      |
| 216     | 29          | 0.3                      | 3.5                               | 63               | 11                       | 68%                      |
| 217     | 58          | 28                       | 3.0                               | 111              | 96                       | 63%                      |
| 218     | 53          | 0.001                   | 2.1                               | 215              | 94                       | 62%                      |
| 219     | 37          | 0.001                   | 2.3                               | 100              | 67                       | 44%                      |

Note: Numbers 201 and 217 are identical with numbers 101 and 117, respectively, in Table 1.

All the end of exposure.

At the end of exposure.

A volunteer.

* Two subjects were studied twice, as the statistical calculations, the decay pattern with the best fit was used.

Sample obtained 1 d after the end of exposure.
I'll 102, 103, and 123) (table 1) and in temporarily removed lead workers (table 2). The time period in the latter group was too short for an accurate estimation of the half-time of the slow compartment (TV(2)). Thus, in the calculation of TV(2) for these subjects, an approximate TV(2) of 27 years (see the preceding text) was used as being the median TV(2) for the 20 subjects in the former group. The median observation time was 155 d.

The decay pattern was studied during two periods of temporary removal from exposure, 0.5 and 5 years apart, the decline rates of PbB were considerably shorter and next longest TV(1), respectively, are shown in figure 2.

For temporarily unexposed subjects (numbers 203 and 208) (table 1), the decay pattern was studied during two periods of temporary removal from exposure, 0.5 and 5 years apart, the decline rates of PbB were considerably shorter and next longest TV(1), respectively, are shown in figure 2.

The median TV(1) for the 20 subjects in the latter group was 27 years (range 0.5—5 years) (table 1), and 1.2 years (range 0.5—2.6 years) for the 17 workers temporarily removed from exposure (table 2). The difference was statistically significant (P = 0.007, Mann-Whitney).

The intercept of the slow compartment (Y(2)) had a median of 0.8 (range 0.0—3.0) umol/l for the 21 ex-lead workers (table 1), and 1.3 (range 0.5—3.6) umol/l for the 17 temporarily removed ones (table 2). The difference was statistically significant (P = 0.007, Mann-Whitney).

The intercept of the fast compartment (Y(1)) had a median of 1.8 (range 0.7—2.6) umol/l for the 21 ex-lead workers (table 1) and a median of 1.8 (range 0.9—2.6) umol/l for the 17 workers temporarily removed from exposure (table 2). The groups were, of course, significantly different. For both of the two temporarily unexposed subjects, Y(2) was 0.1 umol/l for the 21 ex-lead workers, Y(2) made up for a value of 68 (range 33—100) % of the combined compartments (Y(1) plus Y(2)), whereas for the workers temporarily removed from exposure, Y(2) was 100 % of the combined compartments.

The relationship between the half-time (TV(1)) and the intercept (Y(1)) of the fast compartment in a two-compartment model fitted to the decline of the blood lead level after the end of exposure (subject 212) is shown in figure 3A. Closed circles and open circles denote lead workers and volunteers, respectively. In figure 3B, open circles and triangles denote ex-lead workers in two subjects (numbers 203 and 208) (table 1).

The relationship between age and the half-time of the slow compartment (TV(2)) in a two-compartment model fitted to the decline of blood lead levels after the end of exposure (subject 212) is shown in figure 4. Figure 5 is a scatter plot of the slow compartment half-time (TV(2)) versus the median observation time for the 20 subjects in the latter group. The median TV(2) for the 20 subjects in the latter group was 27 years (range 0.5—5 years) (table 1), and 1.2 years (range 0.5—2.6 years) for the 17 workers temporarily removed from exposure (table 2). The difference was statistically significant (P = 0.007, Mann-Whitney).

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temporarily removed from exposure it was 57 (95% confidence interval: 27—80)%. The difference was statistically significant (P = 0.02, Mann-Whitney). For all the 38 lead workers, the mean was 65%, while the fractions were 7% for the two occupationally unexposed subjects.

T'/j(1) correlated significantly with Y(1) (r = 0.8, P = 0.03) (figure 3), but not with age, time of exposure, initial PbB, Y(2), or the serum creatinine levels. The correlation between T'/j(1) and Y(1) [T'/j(1) = 5.4 x Y(1) + 23] did not run through the 95% confidence interval of T'/j(1). This result showed that T'/j(1) was an independent variable.

The T'/j(2) of the ex-lead workers correlated significantly with Y(2) (r = 0.5, P = 0.01) (figure 4), not with age, observation time, initial PbB, Y(1), Y(2), or the serum creatinine levels. For all 38 lead workers, the linear regression line T'/j(2) = 0.15 x age - 1.7 did not run through the 95% confidence interval of T'/j(2). This finding showed that there was an interindividual variation for T'/j(2) (P < 0.0001).

When Y(2), for all 38 lead workers and the two unexposed subjects, was plotted against exposure time (figure 5), there was no significant nonparametric association. Neither was there any linear correlation. However, when an exponential accumulation of PbB was fitted to the data, there was a reasonable fit (R² = 0.49, P < 0.001). The elimination constant was 1.2, corresponding to a half-time of 0.6 years, and the levels off at 1.8 μmol/l.

Moreover, there was a tendency for the workers temporarily removed from exposure to have a higher Y(2) at a particular exposure time than the ex-lead workers. However, the difference was not statistically significant for T'/j(2) (P = 0.003) (figure 6). The T'/j(2) of the ex-lead workers correlated significantly with age (r = 0.50, P = 0.01) (figure 4), not with exposure time, observation time, initial PbB, Y(1), Y(2), or the serum creatinine levels. In 10 out of the 21 subjects, the linear regression line for T'/j(2) upon age [T'/j(2) = 0.15 x age - 1.7] did not run through the 95% confidence interval of T'/j(2). This finding showed that there was an interindividual variation for T'/j(2) (P < 0.0001).

For the 35 lead workers and the two unexposed subjects, there was a significant correlation between PbB and bone lead content (r = 0.36, P = 0.01) (figure 7). Multiple linear regression analysis displayed that there was an increase in Y(2) of 0.008 μmol/l per 1.0 μmol/l bone-Pb (P = 0.005). Furthermore, the temporarily removed workers had a Y(2) that, on the average, was 1.0 μmol/l higher than that of the ex-lead workers. The finding was also obvious from the decrease in Y(2) of 0.09 μmol/l per year of the postexposure observation time (P < 0.0001). Among the active workers, there seemed to be a leveling off of Y(2) when the bone Pb content increased. There was no such clear corresponding tendency among the retired workers.

Discussion

A multiple exponential model fitted well the data pattern of PbB. However, there are other possibilities in power functions. Indeed, data indicating a nonlin
tion between the air lead level and PbB (eg, in re-
verses 12, 13, 19), between PbB and plasma lead (20,
23, 33), and between PbB and the lead level in urine
(13, 26, 67) could favor the choice of a nonlinear
model. However, elimination rates similar to ours have
been reported earlier, both for subjects for less (11,
13) and far more (14, 40) exposed. In addition there
was no indication in the present data that the elimina-
tion rates were faster in subjects with a high initial PbB,
indeed the T1/2(1) was similar with and without Y(1). This
shows that initially no serious objections against the
multiple exponential model, at least not in the PbB
concentration range that we have studied.
For a few subjects, the fit was not as good. For five
subjects the R2 was < 80%, and for one of them it
was 0%. This result may be due to the fact that, in
some subjects, the PbB was low during a major part
of the observation period and thus the analytical
results had a great impact.
It is relevant to consider whether the number of com-
partments is two. Different authors have proposed one,
two (1, 7, 63, 64), three (4, 33, 43, 53, 66), ten (23, 44, 45, 60), and even five (6) compart-
ments in human metabolic models. The simplest mod-
fications to a good fit in the present study was the two-
compartment one. Thus there was no reason to choose
a more complicated model. Of course, from a theo-
etical point of view, a larger number of compartments
would have been preferable. Thus data from the two subjects exposed
to a single heavy lead dose may indicate an initial
decay of PbB (56). For most of the subjects in the present study, such a phenomenon would have
been detected. There was probably a continuous
absorption of lead from the lungs and gastrointestinal
tract for some time after the end of exposure. (See the
following discussion.) In addition the early observa-
tions were few. However, for the two subjects (num-
ber 28 and 216) from whom frequent observations
were made during the first few days after the end of
exposure, the data did not indicate any rapid initial
absoption. Moreover, in addition to the relatively small
number of observations, the limited observation period
over which the analytical method error may obscure other
compartment, especially small or very slow ones. In-
dividuals with a high PbB concentration may indicate
that the slow compartment really has more than one
compartments. (See the following discussion.)
Parts of the body which constitute the two com-
partments must also be considered. The only organ
which might influence much of the PbB was the bone lead.
Most of the bone lead amounts sufficiently large to cover the
average excretion associated with the decay of the PbB
 Empresa (on the order of 0.05-0.1 mg/24 h
or even, for several years (60)) is the skeleton.
In humans, the skeleton contains hundreds of milligrams (1, 13, 16, 39,
55, 60), and the equilibrium between the slow compartment and
the lean body pool is also strongly supported by the as-
sumption that mean value of 25) and the bone lead content. The
average value was 10.9 mg, an amount which fits with the excre-
tion during the emailing of the fast compartment.
The median half-time of the fast compartment was about one month. There may be errors that affect this
estimate. It is difficult to be absolutely sure that the
observation did stop totally at a fixed date; some exposure
may have continued after the formal end of exposure.
For example, for the temporarily removed smelter workers,
the worksite after removal was located only a few hundred meters from the plant. Also, the homes
of the workers may have been contaminated. In addi-
tion, a worker may have a pool of lead in the lungs
and the gastrointestinal tract and thus continue to ab-
sorb lead for some time after lead inhalation and in-
gestion have ceased. The limited data on hand — fre-
quent measurements of two subjects — may indicate
such an absorption, but mainly up to one week after
the end of exposure, which is in accordance with ear-
lier observations (9, 12, 13, 31, 32). This delayed ab-
sorption is probably the reason of the present weak
positive correlation between T1/2(1) and Y(1). These
possible sources of error all tend to give a somewhat
too long an estimate as compared to the true half-time.
Furthermore, the workers temporarily removed from
exposure were not randomly selected. They were re-
moved from exposure because of high PbB levels, and
this occurrence might partly be the result of a slow
elimination rate in those particular individuals. An-
other possible explanation of the slight positive as-
sociation between T1/2(1) and Y(1) is a bias introduced
by the disregarding of possible intermediate compart-
ments.
PbB is mainly present in the red cells. It could thus be
suspected that the lifetime of these cells would determine the T1/2(1). However, the calculated T1/2(1)
is considerably shorter than would be expected if lead
were eliminated from blood only at the normal death
rate of these cells. But lead is known to cause hemolysis,
and the question can be raised of whether it could have
affected the T1/2(1). Hardy, at least not considerably,
as there was no correlation between T1/2(1) and the
initial PbB. A negative correlation would be expected
if hemolysis were important. For the lead workers tem-
porarily removed from exposure, we had to employ an
estimated T1/2(2) of five years. However, this proce-
dure did not affect the T1/2(1); even a T1/2(2) as short
as one year, or as long as 10 years, would cause only
small changes in the T1/2(1).
Having taken these possible errors into considera-
tion, we still find it is fully justified to conclude that the
average T1/2(1) is about one month. This assumption
is also compatible with various kinds of earlier data on
the elimination (1, 11-14, 20, 27-29, 36, 37, 40,
46, 50, 51, 54, 56, 65), if a second, slow compartment
is taken into consideration, and on the accumulation (5, 24, 27, 28, 37, 38, 48, 65, 67) of PbB.
There was a considerable interindividual variation in
T1/2(1). To some degree this occurrence may be expa-
nled by various errors in the estimates of individual
decay curves. Thus the two subjects studied twice had
...ular for cancellous bone pool may be more im-
portant (57). But, in addition, in the active workers,
the amount may also be affected by a small, intermediately
fast pool, perhaps contained mainly in the liver, the
skeletal turnover in the trabecular bone. When the data of subject 103
were closely examined, one may, in fact, note more than one component in the slow
component. In the samples of organs other than the skeleton on Y(2)
were indicated by the accumulation pattern of Y(2)
for a particular exposure time. A steady state was
reached already within a couple of years. This period
was much faster in the trabecular bone (57); the turnover of
the trabecular bone is much slower (15, 61). The accumul-
ation pattern may also be affected by the nonlinear be-
...the accumulation pattern may also be the cause of the apparent
peak of Y(2) upon lead in finger bone in active
workers (but not in the retired ones, who had lower
lead levels).
There was a considerable interindividual variation
in particular exposure time. One obvious ex-
planation for the variations in the intensity of exposure. An
individual explanation may be the interindividual var-
ingen in lead metabolism seen in this study, as well
as earlier ones (8, 32, 60). The variation in the kinetics of lead metabolism
...of lead metabolism in the workers who were followed for a long
...the workers had a Y(2) of more than 1.7 µmol/l. A short time had elapsed to affect the slow com-
ponent. On the contrary, a long time had elapsed before the PbB con-
centration decreased to a "safe level" ("return level"), as the result of a rapid excretion, is probably
...the "safe level." These assumptions are in
 agreement with observations of workers removed
from exposure (69).

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