Kawasaki Journal of Medical Welfare Vol. 5, No. 2, 1999 47–54

Original Paper

Changes over Time in Lead Concentration in a Factory's Air and in the Blood of the Workers

Hiromi MICHITSUJI*, Yukio FUJIKI* and Masana OGATA**

(Accepted Nov. 10, 1999)

Key words : lead in the air, lead in the blood, trend, environmental monitoring, biological monitoring

Abstract

In order to know the trend of the results on ambient monitoring and biological monitoring in the three shops A, B and C, using lead for manufacturing leaded glass, regression analyses between lapsed months and the concentration of lead in the air (PbA) and the concentrations of lead in the blood (PbB) of workers handling lead were investigated. The results indicated that decreases in the concentration of PbB paralleled decreases in the concentration of PbA. This was confirmed by the negative values of the slopes in the regression equation between the elapsed time and the lead concentration in the air and between the elapsed time and the lead concentration in the blood. The negative slopes of regression lines between the elapsed time and of the concentrations of PbA or PbB are significant against the zero values which were found in the A, B and C shops. In Shop "A" the decreased concentration of PbA and PbB in the early stage is higher than those in the later stage.

Introduction

Lead is absorbed via the lungs and the gastrointestinal tract and is eliminated in urine, feces, sweat and hair. Lead concentration in blood rises immediately after the first exposure, levels off after a month of occupational exposure and then reaches a steady state. Ninety percent of blood-borne lead is bound to the erythrocytes. Blood lead represents about 2% of the body burden and is used for biological exposure monitoring of lead [1] and also biological effect monitoring using urinary delta amino levulinic acid [2].

The threshold value of lead is recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) to be 0.05 mg/m^3 while the biological exposure indices of lead in the blood is 30μg/100ml except for women of child bearing potential [3]. In Japan, large scale biological monitoring of lead and eight other essential organic solvents was begun by the Ministry of Labor in 1989 [4, 5], resulting in decreasing incidences of lead in the air and blood since then which has been reported by the authors [6-10].

This report describes the case of decreasing presence of lead in the air accompany a decreasing presence of lead in the blood.

* Matsushita Science Center of Industrial Hygiene
7-6 Tonoshima-cho, Kadoma, Osaka, Japan.
** Kawasaki University of Medical Welfare
Kurashiki, Okayama, 701-0193, Japan

Material and Method

Workshops:

Electric bulbs made from leaded glass were manufactured in factories A, B and C by melting a cylindrical tube of glass and cutting it with burners generating a small flame.

The operators were mainly engaged in the melting process while machine keepers brushed out small pieces of leaded glass attached to the machines.

In Workshop "A" workers 1 and 3 were machine keepers while worker 2 was an operator. In Workshop "B" worker 4 was a machine keeper and worker 5 was an operator. In the Workshop "C" workers 6 and 7 were machine keepers and worker 8 was an operator.

This survey was started in December of 1982 and, at that time, the average age of the workers was in their thirties.

Methods used to improve the lead concentration in the workshop:

Vinyl curtains were hung in order to increase the efficiency of the local ventilation by making the working environment smaller in volume.

Analysis of the lead in the air:

Lead was collected on the surface of a quartz filter (Watman, Q-MA 37 mmϕ) by vacuum sampling using a mini-pump (Sibata Co. MP-303 CFT) under the condition of 3 l/min for 10~20 min by the A sampling method [11].

For personal sampling, a quart filter was attached to the collar of the workers and air in their breathing zone was sucked through the filter by a mini-pump over a 2~3 hour period.

Sample and blank filters were reduced to ashes in 15 ml of a mixture of ($HCl:HNO_3:H_2O$ = 1:1:15) in a water bath at 100°C. After cooling, the specimens were filtered through a No. 7 filter after shaking and analyzed with a graphite furnace atomic absorption spectrophotometer (AAS) with an auto sampler (Perkin Elmer 4100ZL).

The sample size was 10μl. The wave length used throughout study was 283.3 nm. The lamp current was 10mA and slit width was 0.7nm. Standards were linear from 25 to 100ng.

Analysis of the lead in the blood:

About 3 ml of blood was collected from each subject by venipuncture. Blood samples were collected, heparinized in polypropylene tube which were sealed immediately and then transferred to the laboratory. For the blood lead analysis, 0.2 ml of blood was added to 0.1 ml of deionized water followed by 0.7 ml of 1% Triton X-100 in 2% of $(NH_4)H_2PO_4$ and hemolyzed, 20μl of the mixtures were applied on AAS [12].

Blood lead analysis was carried out using a graphite furnace atomic absorption spectrophotometer with an auto sampler (Hitachi 180-80). Triton X-100 and $(NH_4)H_2PO_4$ were used as matrix modifiers.

Analytical conditions of the two kinds of atomic absorption spectrophotometers are shown in Table 1.

Results

Trends in results of biological and ambient monitoring over time:

Variations in the lead concentrations in the air of the three shops and the lead concentrations in the blood of workers are listed in Table 2.

A time study of the lead concentrations in the air and blood is shown in Fig. 1.

Table 1 Analytical method

AAS*	Hitachi 180-80	Perkin Elmer 5100ZL
Compensated method for Spectroscopic analysis	vertical magnetic field type Geman	parallel magnetic field type Geman
Graphic furnace	Tube	Cross type
Sample volume	10 μl	20μl
HCL current	6mA	10mA
SLIT	1.3nm	0.7mA
Measurement mode	Peak Height Absorbance	Peak Area Absorbance area

Furnace heating program	Temp. (°C)	Time (sec.)	Ar (ml/min)	Ramp (sec.)	Temp. (°C)	Hold (sec.)	Ar (ml/min)
Dry	40→ 90	30	200	1	110	30	250
Dry				5	130	30	250
Ash	100→ 400	10	200	5	600	30	250
Ash	500→ 500	30	200				
Atom	1800→1800**	5	off	0	1600	3	50
Clean	2200→2200	3	200	1	1800	3	250

* Atomic absorption spectra photometer ** A light control facility is turned on. Ar = Argon gas

Trends in results of biological and ambient monitoring over time using equations set up by the least square method:

Trends in lead concentration in the air of the workshops and the blood of workers handling lead were investigated from 1982 to 1994 in Shop "A", from 1982 to 1989 in Shop "B" and from 1983 to 1987 in Shop "C" .

The equation of the first degree is calculated by the least square method as follows; $c = \alpha + \beta t$, where t is month and c is the concentration of lead in the air or blood. The factors of the equations set up are

Table 2 Change in the concentration of lead in the air and in the blood with time

Shop	A				B				C			
	Real No		Log		Real No		Log		Real No		Log	
mon.	PbA	PbB	PbA	PbB	PbA	PbB	PbA	PbB	PbA	PbB	PbA	PbB
1	29	29.5	1.46	1.47	36	27.3	1.56	2.44	-	-	-	-
7	24	28.4	1.38	1.45	24	24.1	1.38	1.38	26	22.6	1.41	1.39
13	19	27.3	1.28	1.44	21	23.3	1.32	1.37	17	20.7	1.23	1.35
17	20	25.4	1.30	1.40	18	22.4	1.26	1.35	17	19,7	1.23	1.29
29	15	25.4	1.17	1.40	18	23.2	1.26	1.36	14	18.0	1.15	1.26
39	12	21.4	1.07	1.33	8	17.4	0.90	1.07	12	16.2	1.08	1.21
50	12	17.4	1.07	1.24	10	15.3	1.00	1.18	11	14.4	1.04	1.15
89	9	16.4	0.95	1,21	-	-	-	-	-	-	-	-
100	9	15.7	0.95	1.19	-	-	-	-	-	-	-	-
106	9	14.5	0.95	1.16	-	-	-	-	-	-	-	-
112	9	15.5	0.95	1.18	-	-	-	-	-	-	-	-
125	7	12.0	0.85	1.08	-	-	-	-	-	-	-	-
142	6	11.9	0.78	1.08	-	-	-	-	-	-	-	-

Log=common logarithm, mon=month, PbA=lead concentration in the air,
PbB=lead concentration in the blood. Data of PbB are from workers 1, 2, 5 and 8.

listed in Table 3.

Data in the table indicate that the decreasing concentration of lead in the blood parallels the concentrations of lead in the air.

In Shop "A", the concentration of lead in the air (PbA) decreased 0.13μg/m^3 per month with a standard error of sample regression slope (sb) of 0.019. The lower 95% confidence interval is calculated to be 0.088, suggesting that the slope is significant against zero at a 5% level.

The concentration of lead in the blood (PbB) also decreased 0.12μg/dL per month with 0.010 of sb and -0.12 $\pm$ 0.010 of 95% confidence interval. The decrease of lead concentration per month expressed as β/α (rate of decrease) was calculated to be -0.59% per month for concentration of lead in the air (PbA) and -0.43% for concentration of lead in the blood (PbB) by the regression equations in the months from 1 to 142 weeks.

The trend lines in Shop "A" are separated into lines showing the early stage (1-39 week) and of showing late stages (50-142 week). The rates of decrease were compared. The rates of decrease in the early stage and late stage for PbA are -1.54% and -0.33%, respectively, indicating that the rate of decrease of the former is higher than the latter. And, the rates of decrease in the early stage and late stage for concentration of

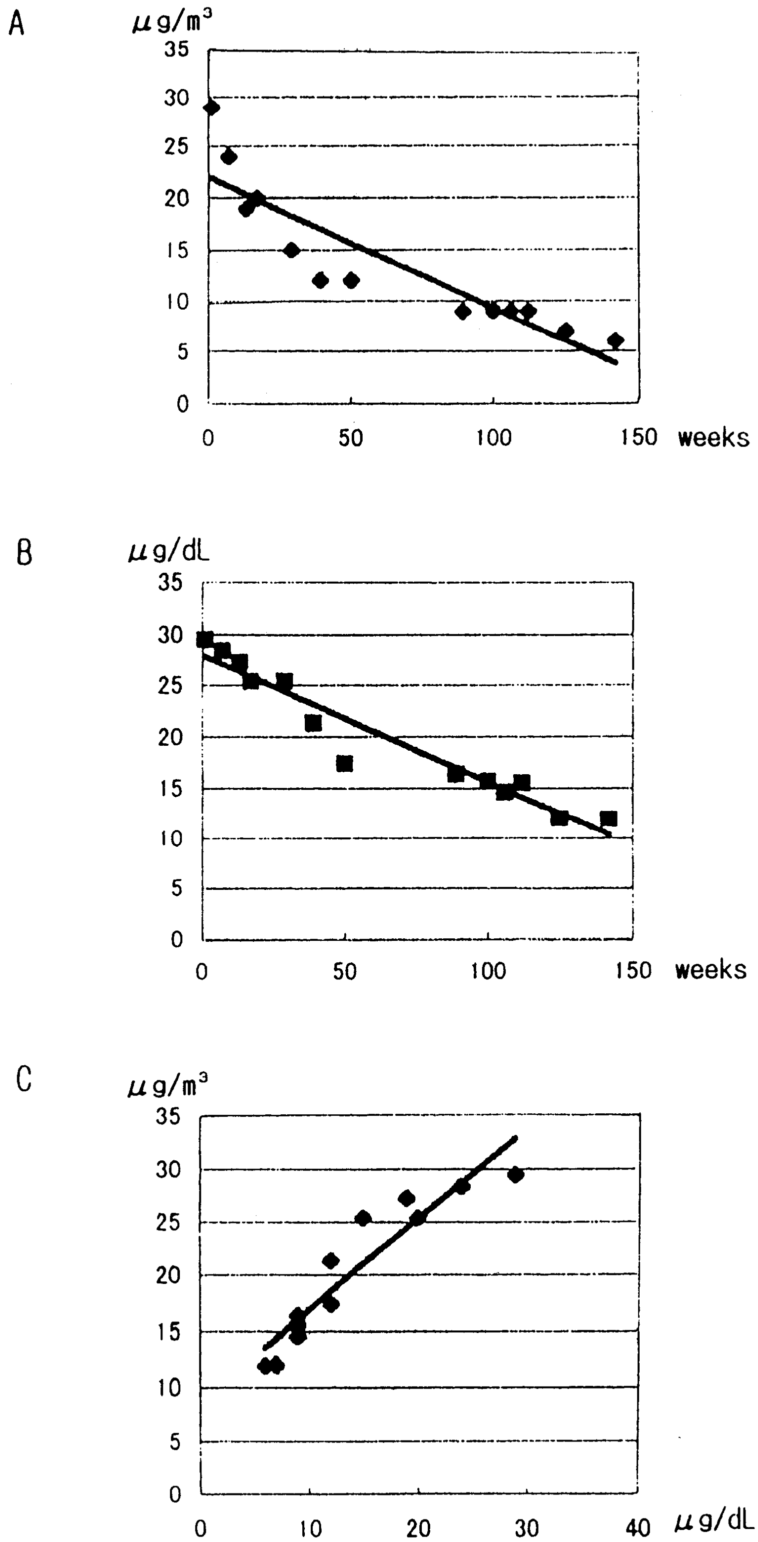

Fig. 1 Change in the lead concentration in the air (PbA) in the workplace (A) and the blood (PbB) in the workers (B) and the regression line between PbA and PbB (C).

PbB were 0.67% and 0.39%, respectively, indicating that the former is also higher than the latter. The data indicate that the rate of improvement in the early stage is higher than the later stage.

When common logarithmic scales are used for the concentrations of PbA and PbB in Shop "A" in 1 to 142 months, linearity of the regression line is a little improved than with real numbers of concentration as expressed correlation coefficient.

Table 3 Factors of straight lines depicted between lead concentration in air and blood with time by the least square method

shop	R/Log	PbA. B	α	β	β/α (%)	R	s_b	Conf. int.	test
A-1	Real No	T-PbA	22.0	-0.13	-0.59	-0.90	0.019	±0.042	*
N=13		T-PbB	28.0	-0.12	-0.43	-0.97	0.010	±0.022	*
M=1~		Pb. A-B	8.4	0.85	-	-0.94	-	-	
142	Log	T-PbA	1.35	-0.0041	-	-0.95	0.004	±0.009	*
		T-PbB	1.46	-0.0028	-	-0.98	0.002	±0.004	*
A-2									
N=6	Real No	T-PbA	27.2	-0.42	-1.54	-0.96	0.060	±0.017	*
M=1~		T-PbB	29.7	-0.20	-0.67	-0.96	0.029	±0.080	*
39		Pb. A-B	17.8	0.43	-	0.91	-	-	
A-3									
N=7	Real No	T-PbA	21.5	-0.07	-0.33	-0.90	0.013	±0.033	*
M=50~		T-PbB	15.2	-0.06	-0.39	-0.96	0.015	±0.037	*
142		Pb. A-B	5.8	0.10	-	0.92	-	-	
B	Real No	T-PbA	29.8	-0.47	-1.35	-0.90	0.010	±0.027	*
N=7		T-PbB	26.7	-0.22	-0.82	-0.94	0.034	±0.089	*
M=1~		Pb. A-B	14.0	0.41	-	0.92	-	-	
50	Log	T-PbA	1.50	-0.012	-	-0.92	0.002	±0.006	*
		T-PbB	1.84	-0.018	-	-0.69	0.001	±0.002	*
C	Real No	T-PbA	22.5	-0.23	-1.02	-0.85	0.070	±0.193	*
N=6		T-PbB	22.8	-0.15	-0.66	-0.98	0.016	±0.044	*
M=7~		Pb. A-B	9.4	0.55	-	0.92	-	-	
60	Log	T-PbA	1.36	-0.0062	-	-0.92	0.001	±0.004	*
		T-PbB	1.40	-0.0046	-	-0.97	0.0006	±0.002	*

The names of shops are A-1, A-2, A-3, B and C, respectively.
No=number, M=month, s_b=standard error of sample regression slope,
conf. int. = confidence interval, T= time in months
* = $p < 0.05$ against slope is zero

In the Shop "B", the rates of decrease of the concentrations of PbA are similar to the rates of decrease of the concentrations of PbB from 1 to 39 months, respectively. The β/α value of PbA and PbB is -1.35% and -0.82%, respectively. The sb value of PbA and PbB is 0.01 and 0.034, respectively. The rate of decrease is similar to the early stage of shop A.

In Shop "C", the rate of decrease of PbA and PbB is a little less than the rates of Shop "B" but the slopes of decreasing concentration of PbA and PbB are significant against zero at 5% levels.

Discussion

Previously, the authors reported that the urinary hippuric acid concentrations decreased parallel with decreased concentration of toluene in the air. This first report described improvement of solvent concentration in a shop resulting in decreased concentration of metabolite in the urine of workers when the air ventilation was controlled [13].

In the previous report [10], the authors also described that data from seven major laboratories showed the percentage of exposed workers in distribution 3 for lead in blood and delta-aminolevulinic acid, and metabolites of eight organic solvents decreased with time. In ambient monitoring, the percentage of work places in control class 3 for lead and styrene also decreased with time after large scaled biological monitoring began according to a regulation issued by the Ministry of Labor of Japan.

The results of this report described that improvement of concentration of PbA in the work place reduced the concentration of PbB in the workers.

The improvement of environmental and biological monitoring in Japan will be the results of accumulation of improvement of each shop. However, the results in this shop were at an early stage compared with the large-scale biological monitoring already begun in Japan.

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