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Lead Exposure and Blood Lead Level of Workers in a Battery Manufacturing Plant in Thailand

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Abstract: This study was conducted in a battery manufacturing plant where lead was used in the processes of production, to survey the working conditions and safety behaviors, and to measure the airborne lead level contaminated in the workplace and the blood lead level of workers. The survey of working conditions showed that the workers were directly exposed to lead in sections e.g. grid casting, spreading, forming and polishing, assembly and special battery production sections. Some workers in these sections used a cotton mask to protect dust exposure, but most workers did not use any masks. High airborne lead level more than 0.2 mg/m^3 was frequently measured in these sections. Geometric average of blood lead level slightly increased from 17.9 μg/dl to 22.3 μg/dl during 1998 and 2001. However, the geometric average of blood lead level dropped to 17.4 μg/dl in 2002. No workers had blood lead level above 60 μg/dl. Workers with different age groups had no significantly different average blood lead level. Workers whose duration of work was between 20–29 years had average blood lead level of 21.5 μg/dl. This group of workers had slightly higher blood lead level than those whose duration of work was 19 years or less, but with no significant difference. 21 subjects underwent annual health examination and exposure monitoring in 2002. There was no significant relation between airborne lead level and blood lead level.

Key words: Lead exposure, Blood lead level, Airborne lead level, Battery manufacturing plant, Working conditions, Safety behaviors

Introduction

Lead is a heavy metal and toxic to human. However, it is a useful material in industry and is still now utilized in various industries in Thailand. Especially the battery manufacturing plant is one of the leading source of occupational lead poisoning, because lead exposures can occur through a variety of ways in the battery manufacturing processes. Workers in a battery manufacturing plant are easily exposed to lead. Thus, we should grasp the conditions of exposure to lead and the blood lead level, clearly identify the problems and find out the effective control measures.

The objectives of this study were to find out the manufacturing processes, to survey the working conditions and safety behaviors, to measure the airborne lead level contaminated in the workplace, to measure the blood lead level of the workers and to determine the correlation between blood lead level and airborne lead level.

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Materials and Methods

This study was conducted in a battery manufacturing plant in Bangkok, Thailand. It has produced automotive batteries, industrial batteries, electrolytes for lead - acid battery, deionized water, battery plates and small parts. The number of workers ranged from 245–282 in these five years (1998–2002). Subjects in this study were the workers who took the annual health examination during 1998–2002. The number of the subjects was shown in Table 1. Subject characteristics of workers were examined by an interview using a questionnaire.

The manufacturing processes, working conditions and safety behaviors of workers were examined by walkthrough survey, interview and observation by team of researchers in July–August 2002.

The airborne lead level was measured by both area and personal sampling as follows.

—Area sampling: Two instruments for air sampling, (1) gravimetric pump (SKC, Airchek sampler Model 224-PCXR4) of which flow rate was adjusted to 2 L/min and (2) filter holder containing a mixed cellulose ester membrane filter (pore size 0.8 μm), were set to a tripod. They were put in 5 sections, grid casting, spreading, forming and polishing, assembly, and special battery production sections. This procedure was done at height of approximately 1.50 meters (breathing zone level) as standing working conditions. All samples were analyzed under NIOSH 7105[1].

—Personal sampling: Personal sampling was performed in a manner same as area sampling. This procedure was done at breathing zone level of workers.

The blood lead level of workers was performed under NIOSH 8003[2].

Descriptive analysis was used for explanation of manufacturing processes, working conditions and safety behaviors. One-way analysis of variance (ANOVA) was used to compare average blood lead level by age and duration of work. Independent samples T-test was used to compare average blood lead level by sex. The correlation between airborne lead level and blood lead level were evaluated with Pearson's correlation. Statistical analyses were conducted with SPSS for Windows, version 9.0. Any P values less than 0.05 were considered statistically significant.

Table 1. Number of subjects who took the annual health examination during 1998–2002

Year	Total number of workers	Number of subjects (%)
1998	282	193 (68.4)
1999	270	183 (67.8)
2000	261	175 (67.0)
2001	255	183 (71.8)
2002	245	182 (74.3)

Results

Manufacturing processes

The manufacturing processes of the battery for engines composed of:

1. Casting grid by sending mixed metal to an automatic grid casting machine at grid casting section to make it plates.
2. Pasting the plates by spreading muddy mixture of lead oxide, sulfuric acid and water on the grid. Then the plates were brought to an oven to dry. This process was conducted at spreading section.
3. Forming the plates into positive and negative plates at forming section. After that these formed plates were polished at the plate polishing section.
4. Assembling the polished plates to a battery cell. The battery cells were then put into the cell compartment of battery case unit. The poles of each cell were sealed and the battery cover was closed. This process was performed in assembly section.
5. In special battery production section, the polished plates were assembled to a battery cell of a big size battery for locomotives and 10-wheel trucks. The manufacturing processes of the polished plates for the big size battery were same as ones of the battery for engines, excepting the different places for pasting.

In other sections, distilled water, mixed acid and case unit were produced.

Working conditions and safety behaviors

In this study, we surveyed the working conditions in the sections where workers were directly exposed to lead e.g. grid casting section, spreading section, forming and polishing sections, assembly section and special battery production section. Most workers in the grid casting section and the spreading section did not use any masks. Some workers used a cotton mask to protect themselves from dust exposure. The floor at the grid casting section was dirtied by lead dust, because no one cleaned the floor after finishing his work each day.

Most workers in the forming and polishing sections were mainly in the control room, but one of them was occasionally outside to check the plates. Most workers in these sections did not use any masks. Some workers used a cotton mask to protect dust exposure in a manner same as in the grid

Table 2. Airborne lead level (area sampling) by sections in 1998–2002

Section	Airborne lead level (mg/m^3)				
	1998	1999	2000	2001	2002
Grid casting	–	0.056	0.517	0.001	0.062
Spreading	–	–	1.822	0.063	0.101
Forming and polishing	0.692	2.370	61.172*	0.874	0.052
Assembly	–	0.430	2.617	0.156	0.197
Special battery production	0.331	–	1.360	0.014	0.022

*Exhaust ventilation system was out of order.

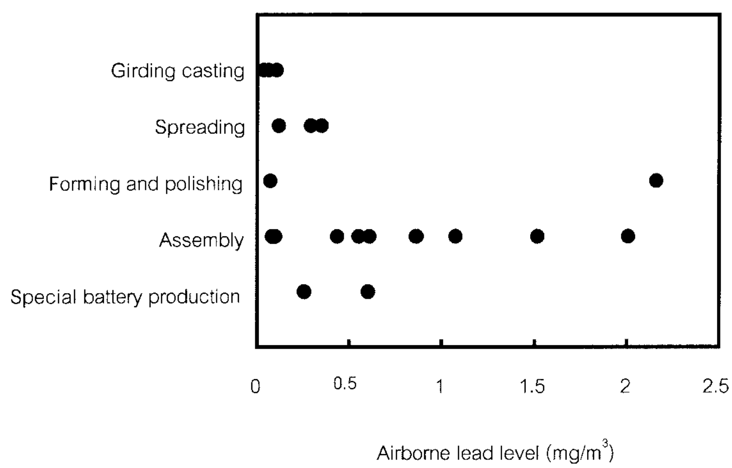

Fig. 1. Airborne lead level (personal sampling) by sections in 2002.

casting section and the spreading section.

In the assembly section, the floor was dirtied by lead dust. The working conditions in the special battery production section were like ones in the other sections.

Airborne lead level in the workplace

Table 2 shows airborne lead level (area sampling) by sections in 1998–2002. High airborne lead level was detected in all sections, especially in the forming and polishing sections in the year 2000. The airborne lead level in the forming and polishing sections was the highest and higher than the standard level by Ministry of Labor and Social Welfare of Thailand (0.2 mg/m^3). This Thai standard level is more than the standard levels of NIOSH (< 0.1 mg/m^3)[3] and OSHA (0.05 mg/m^3)[4]. In 2002 airborne lead level in all sections was lower than the standard level.

The results of personal sampling are shown in Fig. 1. Twenty-one subjects were examined for personal sampling in 2002. High lead exposure was obtained in the workers in forming and polishing sections and assembly section.

Blood lead level of workers

The geometric average of blood lead level by sections in 1998–2002 is shown in Table 3. The workers had high geometric average of blood lead level in the sections that were responsible for lead - acid battery production including spreading, forming and polishing, assembly and special battery production sections. The workers in research and development section also had high geometric average of blood lead level. The workers in office and general administration had the lowest geometric average of blood lead level.

We examined the distribution of the blood lead level of workers in each year. The results are shown in Table 3. Geometric average of blood lead level slightly increased from 17.9 to 22.3 μg/dl during 1998 and 2001, but decreased to 17.4 μg/dl in 2002. As shown in Table 4, the blood lead level of some workers (1–3%) exceeded the standard level by Ministry of Public Health of Thailand (less than 60 μg/dl) in 1998–2001. However, no workers had blood lead level 60 μg/dl and more in 2002.

We compared the average blood lead level by sex, age,

Table 3. Geometric average of blood lead level by sections in 1998–2002

Section	Geometric average of blood lead level (μg/dl)				
	1998	1999	2000	2001	2002
1. General administration	6.9	7.6	8.4	9.8	7.2
2. Accounting and finance	5.7	5.6	8.1	8.9	7.9
3. Research and development	32.1	33.0	38.7	25.8	18.1
4. Planning and production control	–	8.9	–	–	–
5. Analysis and quality control	18.1	17.8	21.8	20.1	18.2
6. Grid casting	16.2	19.7	17.9	22.9	15.8
7. Spreading	35.7	42.2	36.4	41.1	32.3
8. Forming and polishing	31.8	35.6	38.7	43.2	32.2
9. Assembly	32.3	33.9	34.3	39.3	32.4
10. Special battery production	25.6	31.2	31.4	33.2	27.5
11. Work of lead and container	19.1	17.9	22.3	27.8	23.8
12. Work of distilled water and acid	12.3	15.7	11.7	16.7	10.5
13. Maintenance	15.8	13.2	15.7	20.8	15.2
14. Marketing	12.8	6.1	11.6	10.9	8.1
15. Sales department	11.7	17.1	17.3	13.9	13.1
16. Warehousing and transportation	14.9	17.2	14.9	16.1	18.6
17. Planning and marketing development	8.1	16.7	20.3	19.8	8.2
18. Office	5.7	5.6	–	9.0	6.9
Average level	17.9	18.9	21.8	22.3	17.4

Table 4. Distribution of the blood lead levels of workers in 1998–2002

Blood Lead Level	Number (%)				
(μg/dl)	1998	1999	2000	2001	2002
< 5	24 (12.4)	9 (4.9)	2 (1.1)	1 (0.5)	7 (3.8)
5–40	142 (73.6)	137 (74.9)	140 (80.0)	144 (78.7)	161 (88.5)
41–60	23 (11.9)	35 (19.1)	32 (18.3)	33 (18.0)	14 (7.7)
≥ 60	4 (2.1)	2 (1.1)	1 (0.6)	5 (2.7)	–
Total	193	183	175	183	182

and duration of work (N=182). The blood lead levels in 2002 were used. Table 5 shows the results. The average blood lead level in male was 23.3 μg/dl and 12.6 μg/dl in female. There was sex difference in the average blood lead level. Workers whose duration of work was between 20–29 years had average blood lead level of 21.5 μg/dl. It was slightly higher than those whose duration of work was 19 years and less, but it was not significantly different (p<0.001).

Correlation between blood lead level and airborne lead level

Figure 2 shows the correlation between the airborne lead level (personal sampling) and the blood lead level of the workers in 2002. Subjects (N=21) were the workers who took the annual health examination and the personal sampling in 2002. The relationship between the airborne lead level

Table 5. Average blood lead level by sex, age and duration of work in 2002

Factors	Average blood lead level (SD) (μg/dl)	
Sex		
Female (N=28)	12.6 (9.9)	t-test = 4.58
Male (N=154)	23.3 (11.7)	p-value < 0.001
Age (year)		
27–44 (N=24)	20.1 (10.2)	Not significant
45–54 (N=103)	21.6 (11.8)	
55–64 (N=55)	22.3 (13.4)	
Duration of work (year)		
0–19 (N=17)	18.9 (11.5)	Not significant
20–29 (N=79)	21.5 (11.3)	
30–47 (N=86)	22.2 (12.9)	

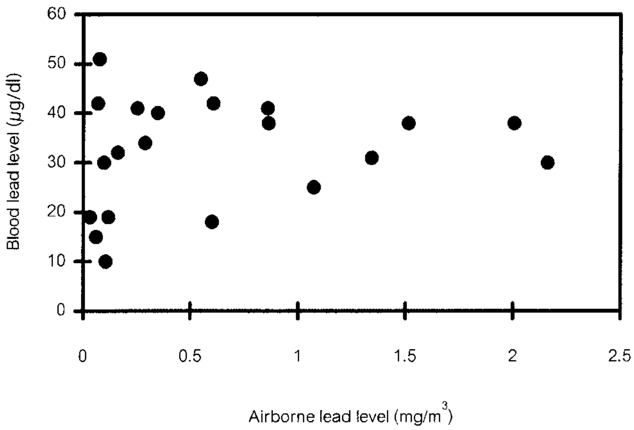

Fig. 2. Correlation between the airborne lead level (personal sampling) and the blood lead level of the workers.

and the blood lead level was not significant (r=0.161, P=0.486).

Discussion

In this study we reviewed manufacturing processes in 5 sections, grid casting, spreading, forming and polishing, assembly, and special battery production sections, where workers were directly exposed to lead. In these sections the airborne lead level was high. Especially in the forming and polishing sections, it exceeded the standard level every year. Thus, control measures against exposure to lead should quickly be taken in these sections.

As to working conditions, we found a problem that most workers did not use any masks, although some workers used a cotton mask to protect themselves from dust exposure from the dirty floor of the workplace. In the assembly section exhaust ventilation system worked, but its efficiency seemed low. Thus, working conditions should be improved.

Geometric average of blood lead level slightly increased from 17.9 to 22.3 μg/dl in 1998 - 2001. However, it decreased to 17.4 μg/dl in 2002. No one was found whose blood lead level was 60 μg/dl and more. The number of battery production has been decreased in 2002 (reduced from 162,516 batteries between October 2000–September 2001 to 144,500 batteries between October 2001–September 2002). Since 2000, the plant has strictly enforced that the workers clean up his workplace after finishing his work each day and take a bath before going home. Besides, all the handtools were cleaned. Personal protective equipment such as respirators and gloves were provided. Drinking, smoking and eating were not allowed while working. If workers have blood lead level more than 60 μg/dl, they will be moved to another workplace where the airborne lead level seems low. This system has worked since 1999. These factors resulted in decreased blood lead level in 2002. The blood lead level corresponded to one after providing technical work protection and intensive medical supervision of the exposed workers in a starter battery production plant[5].

In this study, average blood level was not associated with age as shown in the results of Liou *et al.*[6]. The correlation between blood lead level and airborne lead level was not significant. These results might come from the small sample population, exposures by routes other than inhalation such as contamination on cloths and hands, inappropriate personal protective equipment use[7,8]. The ingested lead might reduced the relationship of blood lead level to age and airborne lead level. Thus, safety behaviors of workers including personal hygiene should be emphasized[9].

We should have various control measures to decrease blood lead level of workers who exposed to lead. Training or health education, as pointed out as a fundamental tool in the prevention of occupational diseases[10], will be repeated at least annually for each worker. Motivation program will be effective to make job safety analysis spontaneously by oneself[11]. Respiratory protective equipment and protective clothing should be used to supplement the engineering measures and the work control, such as eating, drinking and smoking in different workplaces where workers are unexposed to lead. Furthermore, personal hygienic behavior and life habits such as alcohol consumption and smoking are important. An analysis should be performed each year to monitor the effectiveness of occupational hygiene in workplaces of a battery manufacturing plant.

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