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THE DISTRIBUTION OF BLOOD LEAD LEVELS AND JOB TITLES AMONG LEAD-ACID BATTERY WORKERS IN TAIWAN

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There were several reports about elevated blood lead levels in lead battery workers. However, their subjects came from only one or several plants. We visited all the 23 registered lead-acid battery plants in Taiwan and collected their health examination records in 1992, the blood lead analyses of which were completed in 3 medical college hospitals. In total, we have obtained 1726 records. The average blood lead concentration was 37.1 ug/dl, and 37% of blood lead levels were more than 40 ug/dl (action level). The overall participation rate for health examination among employees was 69.4%. The participation rates were different among both plant sizes and job titles. Assuming that there was no peculiar variation within the four working zones (plate manufacture jobs, assembly jobs, part-time exposure jobs, and office jobs) in each plant, and that blood lead levels of our samples were stable after deleting newly hired workers, we estimated that the blood lead distributions of 2486 employees in these plants were 63. 3%, 26.4%, 9.25% and 1.05% for below 40, 40-59, 60-79, and above 80 ug/dl respectively. We conclude that such an analysis should be performed each year to monitor the effectiveness of occupational hygiene in workplace of lead battery plants.

Key words: lead battery workers, blood lead

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Lead is a well-known toxic substance to human; however, it is a useful material in industry [1]. In many countries, medical surveillance for lead workers was set up by law to prevent occupational lead poisoning [2-4]. In Taiwan, The Labor Health Protection Act stipulates that lead workers have to receive an annual special health examination, including blood lead levels, hematological tests, and renal function tests. The act formed a system of surveillance to monitor occupational lead intoxication [5].

The purpose of this surveillance is to prevent occupational lead intoxication by a reporting system from blood lead examination laboratories around this island. These laboratories receive all the blood samples from annual regular health examinations of any lead factories under the regulation of The Act of Labor Health Protection[6]. Meanwhile, the system obtained a nationwide dataset. However, the participation rates were different among lead factories, and there were few reports to show what the correct participation rate of annual examination was. On the other hand, the reporting rates from these blood lead testing laboratories were also lacking in data. These limitations restricted uses of the nationwide dataset.

To better understand occupational lead exposure, there were several reports about elevated blood lead levels in lead workers [7-9]. However their subjects came from only one or a few plants. The

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participation rates were different in these reports. Comparisons of blood lead level distributions among the reports were not appropriate, and it is difficult to describe an overall distribution from those studies. Currently, there are few reports from a comprehensive survey on certain kind of lead factories. For example, the lead-acid battery manufactory is one of the most heavily contaminated lead working environments under the official information in Taiwan [10], but there was lack of data to show nationwide lead acid battery workers' distribution of blood lead concentrations.

The aim of this study is to find a measure that would obtain the overall distribution of blood lead levels of lead battery workers in Taiwan.

MATERIALS AND METHODS

Subjects

Our study subjects included all the 23 lead-acid battery plants that had registered in Taiwan. We visited all the plants, performed a comprehensive walk-through survey and completed a questionnaire for each plant in 1992. The data was collected, including manpower of the plant, work processes, contents and frequency of periodic health examinations in past 2 years. We also collected their health examination records and compared to these their current working power to calculate the participation rate of lead special annual health examination in 1991.

Blood lead measurement

Most blood lead analyses were performed by 3 laboratories in the Institute of Occupational Medicine and Industrial Hygiene, National Taiwan University (NTU), Kaohsiung Medical University Hospital (KMUH) and Chung-Sun Medical College Hospital (CSMCH). All blood lead concentrations were analyzed by Atomic absorption spectrometry (AAS) in these 3 laboratories. Six hundred and eighty samples were analyzed at NTU laboratory, 345 samples at KMUH, and 701 samples at CSMCH, respectively. We drew blood samples for 2 plants (almost small plants, employee numbers were less than 30) that had not yet performed lead special health examination when we visited. The blood samples were sent to our central laboratory in NTU, which has a consistent intra-laboratory quality control and has participated in the blood lead proficiency test supervised by the United States Center for Disease Control and Prevention (USCDC) since 1985.

In addition, for the purpose of quality control among these 3 laboratories, we rechecked the workers with blood lead level over 40 ug/dL, the samples from whom were analyzed by the other 2 laboratories. We obtained 52 blood samples and 40 of them had not changed their jobs in the past year. Nineteen of the 40 samples were tested by NTU and CMCH, and the other 21 samples by NTU and KMUH. The results from the 2 laboratories tested by paired t test were both non-significant, which meant the blood lead measured consistently among these 3 laboratories.

Data analysis

According to the plant size, we categorized these 23 plants into three groups; small-sized, medium-sized, and large-sized plants, based on a number of employees of less than 50, 50 to 200, and more than 200, respectively. For job titles, we grouped the workers in large-sized plants into 4 groups; lead-plate manufactory, assembly, maintenance work, and office workers. Among medium and small-sized plants, only 3 groups of job categories were used, because workers in jobs of maintenance, quality control, packing and office workers could not be clearly divided. Especially, in the small-sized plants, workers or employers themselves did these kinds of jobs together. ANOVA tests, including one-way, and two-way, were used to compare their blood lead concentrations among plants and job titles. Simple frequency or percentage of each 5 ug/dl of blood lead levels was used to describe the distribution. According to the blood lead distributions in each job title and plant size in 1991, and based on their participant rate of health examination in each category, we estimated the nationwide distribution of blood lead concentrations in overall lead battery workers in 1992. The method was like life-table calculation; depending on the numbers in each job title and plant size in 1991, we used percentage of workers in each 5 ug/dl interval of blood lead levels to form a table. Then the percentage timed the numbers of workers in each job title and plant size in 1992 to obtain the numbers of workers in each blood lead interval among job titles and plant sizes. Finally, all numbers in these tables were summarized by each blood lead interval to obtain the overall blood lead distribution of lead battery workers in 1992.

RESULTS

There were 3 lead plate manufacture plants, 6 assembly plants and 14 whole-process acid-battery plants in Taiwan. They hired a total of 2486 persons and two thirds of this population belonged to 4 large-sized plants. There were 6 medium-sized plants, and 13 small sized plants. Among the jobs, about a half or more of manpower dealt with assembly jobs. (Table 1)

In 1990, only 16 plants performed the lead worker special health examination. In 1991, 69.4% of these 2486 persons came from 20 factories received the health examination. The participation rates among lead battery workers and office persons (white collar) in 1991 were 73.4% and 29.8%, respectively. There were great differences among participation rate in different plant sizes (Table 2). Among large-sized plants, the average participation rate of the health examination was 82.5%, and the mean participation rates of medium-sized plants and small-sized plants were 68.6% and 65.6%, respectively. Most workers in large-sized plants who did not receive health examinations had night-shift duties on the date of health examination.

There were 1726 examined persons whose average blood lead level was 37.1 ug/dl. Sixty-three percent of blood lead levels were below 40 ug/dl, 27.3% were between 40-59 ug/dl, and 9.5% were between 60-79 ug/dl. Twelve persons (0.7%) had levels greater than 80 ug/dl (Table 3). The distribution figure (in Table 3) is a little skewed to the right.

Because blood lead concentration represents the exposure in the recent one to three months, we excluded the newly hired workers (working duration less than 45 days). Totally, there were 1691 persons in our statistical analysis. We grouped them with plant sizes and job titles (Table 4). Because the working zones were limited and few people worked only in the office in the plants of medium and small sizes, workers besides lead plate forming and assembly jobs were grouped as the group of others. According to the group means of blood lead levels, the plate manufacture workers in small plants had the most serious exposure (Table 4). Their average blood lead level was 55.4 ug/dl, and 87.8% of their blood lead levels were over 40 ug/dl. Using ANOVA to test blood lead levels of workers in different jobs was also significantly different. The ANOVA tests for same job title but in different plant sizes were significantly different. Finally, two-factor ANOVA (different sizes of plants

Table 1. Employee number categorized by working zone and plant size in lead-acid battery plants in Taiwan, 1992

Plant size* (Number)/ Job title	Large plant (4)	Medium plant (6)	Small plant (13)
Plate manufacture	336 (20.4%)	97 (18.4%)	114 (36.7%)
Assembly	895 (54.3%)	273 (51.9%)	129 (41.5%)
Maintenance job or others			
(in small and medium plants)	192 (11.6%)	156 (29.6%)	68 (21.9%)
Office	226 (13.7%)	-	-
Total	1649 (66.3%)	526 (21.2%)	311 (12.5%)

* Plant size was categorized by large as employee number more than 200, small as employee number less than 50, and medium size with 50 to 200 employees.

Table 2. Participation rate for health examination among lead battery workers in 1991

Participation rate(%)	Number of large-sized plant	Number of medium-sized plant	Number of small-sized plant
91 to 100	1		4
81 to 90	2	2	2
71 to 80	1	1	1
61 to 70		2	1
51 to 60		1	2
0			3

Table 3. Distribution of blood lead levels of the examined lead battery employees in Taiwan in 1991

N	Minimum	Maximum	Mean	S.D.
1726	3.3	101.0	37.1	16.7

*Blood Pb(ug/*dL*)*	Percent	*N*	Cumulative *N*	*%*	Cumulative *%*
0-5		3	3	0.17	0.17
6-10	******	50	53	2.90	3.07
11-15	***********	97	150	5.62	8.69
16-20	**************	121	271	7.01	15.70
21-25	*********************	189	460	10.95	26.65
26-30	*********************	186	646	10.78	37.43
31-35	**************************	232	878	13.44	50.87
36-40	**********************	201	1079	11.65	62.51
41-45	*****************	152	1231	8.81	71.32
46-50	***************	119	1350	6.89	78.22
51-55	************	106	1456	6.14	84.36
56-60	***********	94	1550	5.45	89.80
61-65	********	70	1620	4.06	93.86
66-70	*****	41	1661	2.38	96.23
71-75	****	33	1694	1.91	98.15
76-80	**	20	1714	1.16	99.30
81-85	*	8	1722	0.46	99.77
86-90		1	1723	0.06	99.83
91-95		2	1725	0.12	99.94
96-100		0	1725	0.00	99.94
>100		1	1726	0.06	100.00

and job titles) was still significant.

After our industrial walk-through in these 23 plants, we had the confidence to assume that there was no particular variation within the job titles (plate manufacture job, assembly job, maintenance work, office job) in each plant, and that blood lead levels of our samples were stable after deleting the newly hired workers. We used the blood lead distribution of each category in 1991 and adjusted each category with the participation rate to obtain an estimated overall distribution of 2486 employees in these plants in 1992. Thus, Table 5 with the distribution figure might be the most accurate estimation of blood lead distribution for the nationwide lead battery workers in Taiwan. Table 5 shows that 63.3%, 26.4%, 9.25% and 1.05% of workers had blood lead concentrations below 40, 40-59, 60-79, and over 80 ug/dl, respectively.

DISCUSSION

According to our walk-through, different size factories showed different industrial hygiene patterns including working processes, management styles and protective equipment, which in the large factories were essentially better than in smaller ones. In the large plants, workers were fixed in the working zones,

Table 4. Distribution of blood lead concentration among different job titles and size of plants in 1691 lead battery workers. Newly hired workers (less than 45 days) were not included

	Blood lead		Numbers of each blood lead levels, n(%)				
Job title	Total	Mean(SD)	0-20(ug/dL)	21-40(ug/dL)	41-60(ug/dL)	61-80(ug/dL)	>80(ug/dL)
Large plants							
Plate manufacture	276	41.2(15.3)	23(8.3%)	114(41.3%)	104(37.7%)	35(12.7%)	0
Assembly	580	37.5(13.7)	41(7.1%)	339(58.4%)	159(27.4%)	39(6.7%)	2(0.3%)
Maintenance worker	247	28.2(12.0)	72(29.1%)	136(55.1%)	37(15.0%)	2(0.8%)	0
Office person	66	13.8(8.20)	55(83.3%)	10(15.2%)	1(1.5%)	0	0
Total	1169	35.1(15.1)	191(16.3%)	599(51.2%)	301(25.7%)	76(6.5%)	2(0.2%)
Medium plants							
Plate manufacture	84	50.0(16.6)	2(2.3%)	25(29.8%)	29(34.5%)	27(32.1%)	1(1.2%)
Assembly	221	40.9(13.5)	6(2.7%)	120(54.3%)	77(34.8%)	16(7.2%)	2(0.9%)
Other	19	24.3(11.9)	10(52.6%)	7(36.8%)	2(10.5%)	0	0
Total	324	42.3(15.5)	18(5.6%)	152(46.9%)	108(33.3%)	43(13.3%)	3(0.9%)
Small plants							
Plate manufacture	74	55.4(14.9)	0	9(12.2%)	40(54.1%)	20(27.0%)	5(6.8%)
Assembly	97	47.8(18.7)	3(3.1%)	37(38.1%)	30(30.9%)	24(24.7%)	3(3.1%)
Other	27	35.0(16.6)	5(18.5%)	13(48.1%)	6(22.2%)	3(11.1%)	0
Total	198	48.9(18.2)	8(4.0%)	59(29.8%)	76(38.4%)	47(23.7%)	8(4.0%)

One way ANOVA tests for : same-sized plant in different job titles: P<0.001, same job titles in different sized plants: P<0.001
Two-way ANOVA (plant sizes and job titles); P<0.001

but employees commonly rotated to perform all kinds of jobs in the small factories. In addition, there were employees performing in fixed jobs on maintenance, quality control, research and development, safety health and environmental protection only in large-sized plants. On the other hand, in smaller plants, such jobs were done as part-time and employees should rotate to do works in the other working zones. These observations paralleled with the statistical analysis of the workers' blood lead concentrations.

Regarding the workers who did not participate the health examination, in large-sized plants, most were working on the night shift when the health examinations were performed. Since these workers were not permanently on night shift but rather were rotated, their missing of blood lead data could be likely randomized. Persons working in office (white collar) in large-sized plants could be professional personnel whose health examination would be not regulated by the Act of Labor Health Protection. Thus, they were excluded from the calculation of participation rates in the large-sized plants. However, in the small and medium-sized plants, few workers worked only in the office. As we categorized, they should be part of workers who still have to participate in the lead-worker special health examination, but they did not. Under this recognition difference, the participation rates were varying among the small and medium-sized plants. We suggest that labor inspection personnel must ensure this kind of workers (especially, in small plants) participate in the annual health examination.

In our study, we observed that the same working zone had a similar exposure, and similar lead exposure resulted in a similar blood lead distribution. Thus, we assumed that there was no peculiar variation within these titles in each plant, and concluded that job titles could be representations of their blood lead. Especially, under an expert review of job histories, the job title could be a reasonable surrogate of exposure assessments [11]. This assumption was more objective for estimation of blood lead dis-

Table 5. Estimated distribution of blood lead levels of the lead battery workers in Taiwan, 1992

Blood Pb (g/dl)	Percent	N	Cumulative N	%	Cumulative %
0-5	*	11	11	0.44	0.44
6-10	**********	124	135	4.99	5.43
11-15	****************	204	339	8.21	13.64
16-20	***********	137	476	5.51	19.15
21-25	********************	239	715	9.61	28.76
26-30	********************	245	960	9.86	38.62
31-35	****************************	332	1292	13.35	51.97
36-40	************************	282	1574	11.34	63.31
41-45	*******************	220	1794	8.85	72.16
46-50	***************	163	1957	6.56	78.72
51-55	************	138	2095	5.55	84.27
56-60	************	135	2230	5.43	89.70
61-65	********	94	2324	3.78	93.48
66-70	*****	67	2391	2.70	96.18
71-75	****	40	2431	1.61	97.79
76-80	**	29	2460	1.17	98.95
81-85	*	17	2477	0.68	99.63
86-90		3	2480	0.12	99.75
91-95		4	2484	0.16	99.91
96-100		0	2484	0.00	99.91
>100		2	2486	0.08	100.00

tributions when we collected blood lead data in the same or a similar kind of factory. According to our study, we believe that the blood lead surveillance ought to be reformed and enforced.

There are two kinds of medical surveillance. The sentinel event (case-based) surveillance could effectively find new cases of occupational health problems or detect any workplace with poor industrial hygiene. The laboratory reporting system of the " Adult Blood Lead Surveillance " by The American National Institute of Occupational Safety and Health (NIOSH) is an example [12], which usually obtains a trend of increase or decrease of cases for a particular year. However, the trend may not indicate an improvement or deterioration of actual working environments, because it does not consider the distribution of underlying population [13]. Therefore, a more detailed understanding of the whole population, including their participation rates for each exposure zone, as well as the sizes of different factories may provide a complete aspect or a global picture of the work environments and could be a basis for comparison year by year [14]. Thus, our study may be helpful as a supplementary surveillance strategy in the future. For example, as evident from the Tables of this study, there was potential danger for lead battery workers in Taiwan to become ill, and we should work hard to improve the industry hygiene of these lead battery plants. However, due to economic and technical factors, the problem will probably persist for a certain period. We suggest that such an analysis should be performed each year to monitor the effectiveness of occupational health examinations and hygiene in the workplace of all lead factories. We believe the method could be applied to comparison among different plants or different countries also.

Currently, there is a case-based surveillance system in Taiwan, which reports male lead workers with blood lead levels over 40 ug/dl, and female workers with blood lead over 30 ug/dl to the government [15]. However, a nationwide surveillance system for all lead workers is not well established today, and we did not have nationwide data from the workers with blood lead levels less than 40 in the male and 30 in the female populations. Thus, this study is the most recent national data including all workers in all lead-acid battery manufactories, though this data or surveillance was from1992.

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台灣鉛蓄電池製造工人的工作項目與血鉛值分佈

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關於鉛蓄電池製造工人的血鉛值已經有一些報告發表，可是這些報告的工人常是只來自一家或少數幾家鉛蓄電池製造廠。我們訪查了全台灣有註册登記的23家鉛蓄電池製造廠，並且收集他們於1992年的體檢報告，主要是因爲當年的血鉛值檢查皆由三家醫學院附設醫院完成，資料比較可靠。結果共有1726個有效體檢報告，顯示全國鉛蓄電池製造工人平均血鉛值爲37.1 (ug/dL)，其中37% 超過40 ug/dL (血鉛通報標準)。以訪查時(1993年4月)的全體鉛蓄電池製造工人爲分母，則體檢受檢率爲69.4%。假設在四種主要製程工作區（極板製造工作，組立工作，維護工作，辦公室工作）沒有特別的變異變化，則我們估計全國共有2486個鉛作業工人，且他們的血鉛值分佈可能爲63.3% 低於（含）40ug/dL，26.4% 介於40到59ug/dL，9.25% 介於60到79ug/dL，以及1.05% 大於（含）80ug/dL 以上。我們認爲如此全國資料應每年彙整分析，可供鉛蓄電池製造作業的職業衛生成效及改進參考。如此的分析方法，並可以應用到其他行業，每年分析其特殊體檢資料，作爲其職業衛生成效及改進參考。

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