The Journal of Toxicological Sciences,
Vol.23, Supplement II, 241—245, 1998

Proccedings of the 1st ASIATOX Conference, June 29-July 2, 1997, Yokohama, Japan

OCCUPATIONAL AND ENVIRONMENTAL LEAD POISIONING: CASE STUDY OF A BATTERY RECYCLING SMELTER IN TAIWAN

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ABSTRACT — The rapid industrialization in Taiwan has caused both prosperity and environmental pollution. The purpose of this study is to demonstrate a case of both occupational and environmental lead poisoning. A patient of lead poisoning initiated a survey of the battery recycling factory, which revealed that 31 of 64 workers suffered from lead poisoning. Children who attended a nearby kindergarten showed a significant increase of blood lead up to 15-25 μg/dl and a mild but significant decrease of IQ (intelligent quotient, by Binet-Simon scale) if compared with children of a nonexposed but socioeconomically comparable kindergarten. Outdoor workers of the nearby forging factory also showed a significant increase of blood lead if compared with indoor workers or workers of another nonexposed forging factory 20 Km away. Air sampling showed an average of more than 10 $\mu g/m^3$ in the kindergarten. Soil sampling and analysis also revealed 400 folds increase of lead content, which decreased if the sample was taken deep down to 15-30 cm or 350 meters away from the battery recycling smelter. Moreover, after children were moved away from the pollution source, follow-up examination performed 2.5 years later showed a significant decrease of blood lead and partial recovery of IQ among them.

INTRODUCTION

The toxicity of lead has been known for more than a thousand years, but occupational and environmental lead poisoning still occurs endemically, especially in developing countries. While there have been many reports about environmental pollution by lead-related industries, the victims were mostly confined to workers' families or residents, especially children, of nearby communities(1-6). To our knowledge, few reports exist about the lead contamination spreading to nearby factories and workers. In 1987, a lead battery recycling worker came to the medical clinic of the National Taiwan University Hospital (NTUH) with symptoms of anemia and bilateral wrist drop. He was diagnosed with lead poisoning when we found his blood lead was over 80 μg/dl. To determine the prevalence rates of occupational and environmental lead poisoning, we conducted a series of epi-demiological studies which were summarized in this paper(7-10).

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SUBJECTS AND METHODS

The factory began to operate in 1985. Used lead batteries were imported from overseas and transported by truck into the factory. After dissecting into separate plates, they were thrown into furnaces for re-melting and later refined to lead ingots. Sixty-four out of the 110 employees of the factory participated in this voluntary physical examination. Blood lead determination, CBC (complete blood count) and blood smear, liver function and a comprehensive neurological examination were performed. A diagnosis of lead poisoning was made if there was an increased lead burden (blood lead over 40 μg/dl or a positive lead immobilization test) and measurable impairment of at least one organ system associated with lead exposure and without any alternative medical explanation.

Children of a nearby kindergarten (50 meters away) and a non-exposed kindergarten (5 km away) were invited to participate in the study. Each child and his/her parents were asked to fill out a questionnaire including his/her birth date, parental education and occupational exposure to lead, residential environment (regarding nearby road traffic). Blood lead, hemoglobin, ZPP(zinc protoporphyrin), and IQ (intelligent quotient, by the Chinese 4 th revision of Binet-Simon Scale) of each child were determined. In addition, workers of a forging factory (exposed) next to the lead recycling factory and a reference forging factory (20 km away) were also recruited to be performed physical examination and blood lead measurement. These two factories had the same raw materials, manufacturing processes, and products, which contained no lead or its alloy. More than half of the workers of the exposed factory had worked in the reference factory, but they had left and set up their own company about 5 years previously.

All blood lead were analyzed by graphite furnace atomic absorption spectometry (AAS) with a Perkin-Elmer Zeeman 5100 PC and AS-60 autosampler. Our laboratory has a consistent intra-laboratory quality control and has participated in the blood lead proficiency test program of the United States CDC (Center for Disease Control and Prevention) since 1985. Air sampling was performed 3 times during 1988-9. Each time was performed at a different season for 6-10 days. We collected total particulates in air at 4 different sites, i.e., 50m, 100m, 950m, and 1050m away from the smelter chimney with Kimoto and Anderson high volume samplers. The glass fiber filters were replaced everyday and were analyzed for the lead content. Soil samples were taken from the surface, 1 cm, 1-14 cm, 15-30 cm in depth at 29 different sites and their contents of lead, copper, and zinc were measured by AAS after extraction with mixtures of nitric acid and hyperchlor-ic acid.

RESULTS AND DISCUSSION

We have examined 64 out of 110 workers, and found 31 (48%) workers fulfilled the criteria of lead poisoning. Among them, 22 suffered from polyneuropathy and 13 had anemia. Furnace workers, maintenance workers and field cleaners had an average blood lead exceeding 80 μg/dl. Since workers who came for examination had a shorter working duration and jobs of lower exposure such as office cleaning and salesman (Table 1), the 48% of lead poisoning might be an under- estimation of the true overall prevalence rate.

In total, 36 children from the exposed and 35 from the reference kindergartens voluntarily participated in the study. There was no significant difference between the two groups on sex ratio, age, hemoglobin, number of years in kindergarten, proportion of living beside a main street (Table 2). However, 22 out of 36 exposed children had a blood lead exceeding 15

Table 1. Comparison of age, job tasks, and duration of employment among battery recycling workers who came and did not come for the medical examination. (modified from Jang et al (10), expressed in mean ± 1 S.D.).

			Examined			non-	examined
Job categoriies	Blood lead (μg/dl)	no. workers	age (year)	durationn of employment (day)	no. worers	age (year)	duration of employment (day)
Furnace	87±14	19	37±10	349±328*	14	35±5	553±261
Maintenance	82±8	3	30±4	259±243*	2	37±1	410±218
Dissecting	69±16	10	35±8	450±225	14	36±9	324±306
Refining	64±16	6	31±4	559±166	3	29±2	679±311
Crane operator	64±11	6	44±4*	544±376	3	36±4	1007±838
Field cleaner	95±35	4	43±1*	698±229*	2	49±1	133±14
Office cleaner	48± 5	6	50±3	548±248	0	-	-
Office, guard	38± 4	5	52±13	960±861	8	43±20	465±336
Salesman etc.	8± 6	5	27±6	149±136	0	-	-

* p<.05.

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μg/dl in comparison with 0 out of 35 non-exposed (p<.001), and the IQ's of the former were also significantly lower than those of the later (Wilcoxon rank sum test, p<.05). Because there was no difference on paternal education and nutritional status as demonstrated by similar hemoglobin levels, we concluded that the IQ impairment among the exposed children were caused by increased absorption of lead. Moreover, the average air concentration of lead inside the exposed kindergarten were about 12.9±11.4 and 12.8±8.0 $\mu g/m^3$ at 50 m and 100 m distance from the smelter during sunshine days and usually decreased to 1/6 of the above figure during rainy days. The lead content in the surface soil was approximately inverse to the distance from the chimney of the smelter and decreased linearly along with the depth, while copper and zinc did not show such a trend (Table 3). It indicated that the lead in soil and air near the smelter might come from the chimney and fugitive sources. Thus, the exposed kindergarten was immediately advised to move at least 2 km away from the recycling smelter. Further follow up examination of these children 2.5 years after the exposed kindergarten moved away showed that there was no change of hemoglobins for both groups. The blood lead of the exposed dropped significantly with an average difference of 6.9±2.0 μg/dl compared with previous examination, while that of the reference was 1.7±1.3 μg/dl. The IQ of the exposed recovered with an average increase of 11.7±13.2 points, while that of the reference was 4.2±13.0. We conclude that the increased lead absorption and IQ impairment of the exposed children were caused by air and soil pollution of lead from the nearby lead recycling smelter.

A comparison of blood lead levels between the exposed and reference forging factory also showed a significant elevation of blood lead for the exposed

Table 2. Comparison of demographic data, blood lead, hemoglobin, and IQ (intelligent quotient) of children of the exposed (nearby lead recycling smelter) and reference kindergartens. (modified from Wang et al (8)).

Kindergarten	Exposed children		Reference children	
Total no.	36		35	
male/female	16/20		22/13	
Age(years)				
4-6/>6	19/17		24/11	
Living beside a main street				
yes/no	10/26		14/21	
Years of education of their parents	father	mother	father	mother
< 9 years	25	26	25	22
9-12 years	9	9	8	13
> 12 years	2	1	2	0
Hemogobin (gm/dl)				
< 12	7		5	
12-14	22		26	
> 14	7		4	
Blood lead (£gg/dl)*				
< 10	1		25	
10-15	13		10	
15-20	19		0	
> 20	3		0	
IQ*				
< 70	1		0	
70-89	12		4	
89-109	15		20	
> 110	4		11	

* p < .01 by Mantel extension for the test of trend.

workers (mean±S.D.: 20.4±9.4 vs 5.9±2.9 μg/dl). The difference remained consistent even after stratification by working indoors vs outdoors (Table 4). Blood lead levels were lower among exposed workers who were employed less than 2 months than those employed longer, but no such difference was observed in the reference group. A multiple regression analysis showed that blood lead was significantly associated with working at the exposed factory outdoors and indoors. Five months after improvements in pollution control and decrease in production volume at the nearby lead factory, 30 of the exposed workers were re-tested for blood lead. Outdoor workers of the exposed factory had an average decrease of 4.2±1.4 μg/dl, while that of indoor workers showed no difference (0.9±0.7 μg/dl). We conclude that the increased lead absorption

Table 3. Contents of lead (Pb), copper (Cu), Zinc (Zn) (in mean ±S.D μg/gm) in the soil near the lead recycling factory stratified by different depths of the soil and distance from the factory. Numbers in parentheses indicate the number of sample. (modified from Wang *et al* (8)).

Depth of the soil / Distance from the recycling factory	Surface Roadside Yes	No	1cm	1-15 cm	16-30 cm
< 350 m					
Pb	4187±3331	1914±1468	508±372	86±72	28±12
	(9)	(5)	(13)	(20)	(10)
Cu	3.1±2.1	1.3±1.0	0.9±0.4	0.6±0.2	0.5±0.1
	(9)	(5)	(7)	(6)	(5)
Zn	8.4±2.3	5.0±2.7	4.3±4.5	1.8±2.3	1.4±2.4
	(8)	(5)	(7)	(6)	(5)
350-1100 m					
Pb	193	±122	38±13	17±11	10±11
		(7)	(5)	(10)	(5)
Cu	1.9	±1.0	1.2±0.2	1.4±1.5	14±0.3
		(6)	(3)	(3)	(2)
Zn	9.9	±1.3	1.7±0.1	4.4±3.8	2. 2
		(5)	(2)	(3)	(1)

* p < .01 by Mantel extension for the test of trend.

Table 4. Comparison of demographic data and blood lead levels (μg/dl) of workers in the two iron forging factories by Wilcoxon Rank Sum test. (modified from Chao et al (9)).

	Exposed factory (next to the lead recycling smelter)			Reference factory (20 Km away)		
Total number		36			47	
Age(years)		33.0±9.6			35.1±11.5	
Duration of work (years)		3.0±1.7			6.7±5.4	
Blood lead(μg/dl)	No. of workers	median	Range	No. of workers	median	Range
working indoors	11	11	21-6	11	5	5-4
working outdoors	25	24	49-10	36	5.5	20-4
New employees or truck driver	5	8	14-3	4	6	9-5

* p < .01 by Mantel extension for the test of trend.

of the exposed workers were caused by the environmental pollution of lead recycling smelter next door.

REFERENCES

Baghurst P., Oldfield R., Wigg N, McMichael A., Robertson E. and Vimpani G. (1985): Some characteristics and correlates of blood lead in early childhood Preliminary results from the Port Pirie study. Environ. Res., **38**, 24-30.

Baker EL, Folland DS, Taylor TA, Frank M, Peterson W, Lovejoy G. (1997): Lead poisoning in children of lead workers: Home contamination with industrial dust. New Engl. J. Med., **296**, 260-261.

Chao KY, Wang JD. (1994): Increased lead absorption caused by working next to a lead recycling factoty. Am. J. Industr. Med., **26**, 229-235.

Cullen MR, Robin JM, Eskenazi B. (1983): Adult inorganic lead intoxication: presentation of 31 new cases and a review of recent advances in the literature. Medicine., **62**, 221-47.

Jang CS, Wang JD, Hwang YH, Chang YC. (1994): Lead poisoning in a battery recycling smelter. J Occup. Safety Health (R.O.C.)., **2**, 11-21.

Kaye WE, Novotny TE, Tucker M. (1987): New ceramics-related industry implicated in elevated blood lead levels in children. Arch. Environ. Health, **42**, 161-164.

Morse DL, Landrigan PJ, Rosenblum BF, Hubert JS, Housworth J. (1979): El Paso revisited: Epidemiologic follow-up of an environmental lead problems. J. Am. Med. Assoc., **242**, 739-741.

Soong WT, Jang CS, Wang JD. (1989): A study of lead exposure and intelligence in kindergarten students living in the vicinity of a lead smelter. Chinese Psychiatry, **3**(Suppl. 1), 91-96.

Vimpani G, McMichael A, Robertson E, Wigg N. (1985): The Port Pirie study: A prospective study of pregnancy outcome and early childhood growth and development in a lead exposed community- protocol and status report. Environ. Res., **38**, 19- 23.

Wang JD, Shy WY, Chen JS, Yang KH. (1989): Parental occupational lead exposure and lead concentration of newborn cord blood. Am J Industr. Med., **15**, 111-115.

Wang JD, Jang CS, Hwang YH, Chen ZS. (1992): Lead contamination around a kindergarten near a battery recycling plant. Bull. Environ. Contam. Toxicol., **49**, 23-30.