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Lead Contamination around a Kindergarten near a Battery Recycling Plant

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Lead poisoning has been noticed for more than a thousand years (World Health Organization 1977). Increased lead absorption and/or impaired neurobehavioral function among children who lived nearby lead smelters were reported in many different countries (Landigran and Baker 1975; Roels et al. 1980; Ewers et al. 1982; Carra 1984; Chenard et al. 1987; Benetou-Marantidou et al. 1988; Silvany-Neto et al. 1989). In November of 1987, a worker from a lead battery recycling smelter suffered from anemia and bilateral weakness of his extremities. He was diagnosed as lead poisoning at the National Taiwan University Hospital (NTUH). A subsequent epidemiological survey of the workers from this recycling smelter showed that 31 out of 64 who came for a medical examination suffered from lead poisoning. Since there was a kindergarten next to the factory, we performed this study to determine whether there was an increased lead absorption among children of the exposed kindergarten and its association with the extent of air and soil pollution in the surrounding area.

MATERIALS AND METHODS

Children of the exposed kindergarten and two nonexposed kindergartens of the same city, which were 2 km away from the recycling factory, were invited to participate in the study. Each child and his parents were asked to fill out a questionnaire regarding his birth date, parental education and occupational status (especially any occupational exposure to lead), whether they lived beside a main street with major traffic, and other background information. The child was drawn 5 c.c. blood for measurements of lead, zinc proporphyrin (ZPP), hemoglobin (Hb) and serum ferritin. Determinations of blood lead was performed by flameless atomic absorption spectrometry on an Instrumental Laboratory 12E, ZPP by Aviv ZP Hematofluorometer, serum ferritin by LKB Wallac 1282 Compugama universal gamma counter.

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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. 50 m, 100 m, 950 m, and 1050 m away from the smelter chimney with Kimoto and Anderson high volume samplers. The glass fiber filters were replaced everyday and were analyzed the lead content. Soil samples were taken from the surface, 1 cm, 1-14 cm, and 15-30 cm in depth at 29 different sites and their contents of lead, sodium, potassium, copper and zinc were measured by atomic
absorption spectrometry after extraction with mixtures of hydrochloric acid (Environmental Protection Bureau 1973).

Simple Chi-square tests, Wilcoxon rank sum tests (Snedecor and Cochran 1980), and multiple linear regressions were performed by a BMDP package on a microcomputer (Dixon 1981).

RESULTS AND DISCUSSION

In total, 36 children from the exposed kindergarten (A) and 83 from the two nonexposed kindergartens voluntarily participated in the study (Table 1). Although children from the B kindergarten were generally younger,, their parents had a significantly higher education than those of kindergartens A and C. There was no difference between the exposed and nonexposed groups on sex ratio, number of years in kindergarten, and proportion of living beside a main street. Only one child's father out of 119 had an occupational exposure to lead.

22 out of 36 children from the exposed kindergarten had a blood lead exceeding 15 ug/dl in comparison with 1 out of 83 nonexposed ($p<0.001$, Table 2). All the hemoglobins, serum ferritins were within normal limits, however, group C had a significantly higher Hb than the exposed. For those who were in the exposed kindergarten, male students and a whole day class were the major risk predictors of increased absorption of blood lead (Table 3).

The average air concentrations of lead were about 12.9 ± 11.4 and 12.8 ± 8.0 ug/m3 at 50 m and 100 m distance from the smelter during sunshine days and usually decreased to 1/6 - 1/10 of the above figures during rainy days. The air leads were all around 1.2 - 1.9 ug/m3 at 950 m and 1050 m distance regardless of weather (Table 4). Lead content in the surface soil was inversely related to the distance from the chimney of the lead smelter (Figure 1). The best model for regression analysis is as follows:

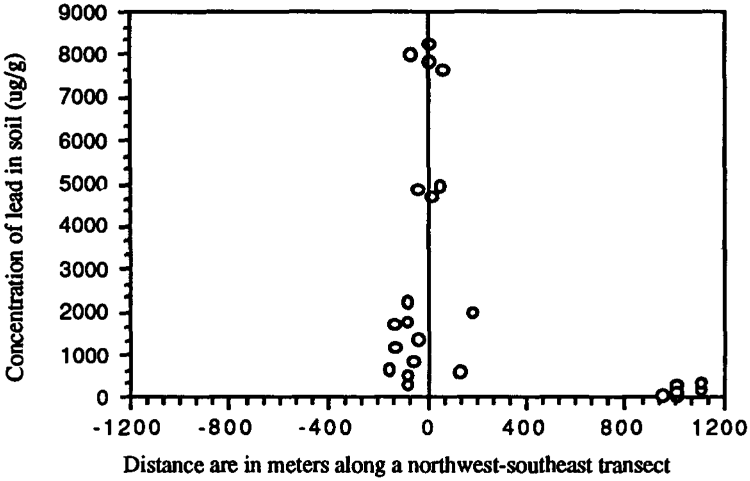

Figure 1. Lead content of the surface soil near a lead recycling smelter chimney

Table 1. Childrens' background information in the three kindergartens

Kinder-gartens	Exposed A		Nonexposed B		Nonexposed C	
Total no.	36		48		35	
male	16		23		22	
female	20		25		13	
Age						
< 4 yrs	0		11*		0	
4-6 yrs	19		26		24	
> 6 yrs	17		11		11	
Years of education of their parents	father	mother	father**	mother**	father	mother
< 9 yrs	25	26	14	15	25	22
10-12 yrs	9	9	17	25	8	13
> 12 yrs	2	1	17	8	2	0
No. of years in kindergarten						
< 1 yrs	7		27		19	
1-2.9 yrs	23		18		16	
>2.9 yrs	6		3		0	
Living beside a main street						
yes	10		8		14	
no	26		25		21	
undetermined	0		15		0	
Parents with occupational exposure	1		0		0	

* P< 0.01 if compared with A group
** P< 0.001 if compared with A group

Table 2. Frequency distribution of different levels of blood lead, zinc protoporphyrin (ZPP), hemoglobin (Hb) and serum ferritin

Kindergartens	Exposed (A)	Nonexposed (B)	(C)
Blood level (μg/dl)			
<10	1	36*	25**
10-15	13	11	10
15-20	19	0	0
>20	3	1	0
ZPP (m-mole/ mole heme)			
< 0.3	19	27*	14
0.3-0.6	12	21	21
> 0.6	5	0	0
Hb (mg/dl)			
< 12	7	2*	5
12-14	22	27	26
> 14	7	19	4
Ferritin (ng/ml)			
< 20	1	4	1*
20-50	17	17	13
50-90	12	20	15
> 90	2	7	6

* P<.05 if compared with group A by Wilcoxon rank sum test
** P<.01 if compared with guoup A by Wilcoxon rank sum test

Table 3. Blood lead level stratified by sex and length of stay in the exposed kindergarten

Length of stay	All day	Half day	P - value of Wilcoxon rank sum test ifcompared all with half day
Sex			
male	23.6±6.6 (n=4)	15.3±3.3 (n=12)	0.03
female	14.6±2.9 (n=8)	13.2±2.9 (n=12)	0.28
P - value of Wilcoxon rank sum test if compared male vs. female	6.03	0.07	

Table 4. Air concentration of lead in Wu-Lun stratified by the distance from the chimney of the recycling plant and the weather. Figures in parentheses indicated one standard deviations.

distance from the recycling plant	50m		100m		950m		1070m	
Weather	sunshine	raining	sunshine	raining	sunshine	raining	sunshine	raining
Lead(mcg/m3)	12.9 (11.4)	2.4 (3.1)	12.8 (8.0)	1.3 (1.5)	1.2 (0.9)	1.9 (1.0)	1.4 (0.7)	1.5 (1.0)

Table 5. Content of lead and other metals (in ug/gm) in the soil of Wu-Lun near the recycling plant stratified by different depths of the soil and distance from the factory.(n)

Depth of the soil	surface		1 cm	1-15 cm	16-30 cm
Distance from the recycling factory	roadside yes	roadside no			
< 350 m					
Lead (Pb)	4187±3331 (9)	1914±1468 (5)	508±372 (13)	86.4±72.4 (20)	27.7±12.2 (10)
Potassium (K)	11.5±4.8 (9)	6.8±3.3 (5)	8.7±2.7 (7)	6.9± 1.0 (6)	6.9±0.7 (5)
Sodium (Na)	30.3±9.8 (9)	12.2±8.0 (5)	4.3±3.8 (7)	3.1± 3.1 (6)	3.1±2.4 (5)
Copper (Cu)	3.1±2.1 (9)	1.3±1.0 (5)	0.9±0.4 (6)	0.6± 0.2 (6)	0.5±0.1 (5)
Zinc (Zn)	8.4±2.3 (8)	5.0±2.7 (5)	4.3±4.5 (7)	1.8± 2.3 (6)	1.4±2.4 (5)
350 - 1100 m					
Lead (Pb)	193±122 (7)		38.4±13.0 (5)	17.1±11.0 (10)	10.3±11.2 (5)
Potassium (K)	2.1±3.3 (6)		7.7±2.6 (3)	9.2± 0.4 (3)	10.6±3.2 (2)
Sodium (Na)	4.9±7.0 (6)		2.4±1.7 (3)	7.5± 1.9 (3)	6.2±4.1 (2)
Copper (Cu)	1.9±1.0 (6)		1.2±0.2 (3)	1.4± 1.5 (3)	1.4±0.3 (2)
Zinc (Zn)	9.9±1.3 (5)		1.7±0.1 (2)	4.4± 3.8 (3)	2.2±0 (1)

$$Y = 4208.8 - 4.1X$$

Y: soil content of lead in ug/g

X: distance away from the chimney of the lead smelter in meters

The lead content in the surface soil near the smelter was up to 4.,2 $\pm$ 3.3 mg/g at the roadside and decreased linearly along with the depth. Soil lead levels are high near the smelter but are approximate natural levels 1km away (Fig.1). It was down to 28.0 $\pm$ 12 ug/g if soil samples were taken from 15-30 cm in depth (Table 5). All other metals, including potassium, sodium, copper and zinc, did not show such a consistent trend. It indicated that the lead in soil near the smelter might come from both the chimney and fugitive sources.

Although we found a significant increase of blood lead among the exposed children, it did not necessarily follow that the source of lead came from the nearby recycling smelter. However, we could argue strongly for the above relationship because of following reasons: Firstly, the air lead was about 5-10 times higher during the sunshine days in the kindergarten A than those of 1 km away (Table 4) and the Taipei city (Hwang and Wang 1990). A child stayed in the exposed region would generally breathe more lead than the nonexposed. Boys who stayed half a day in the exposed kindergarten had a 2.1 ug/dl higher average of blood lead than girls. This phenomenon might be explained by a relatively higher activity of boys than girls. Since there was no difference on the proportion of children living beside a main street, lead dust coming from the traffic would probably contribute little on the difference of blood leads among 3 groups. So, absorption through inhalation of contaminated air from the smelter probably contributed some increase in the blood lead of the exposed children. Secondly, boys who stayed in the exposed kindergarten a whole day had an average increase of blood lead for 9 ug/dl than that of girls (Table 3). It indicated that the higher concentration of lead in the surface soil could possibly enter the boys' mouth after they played with the sand on the contamination ground, where girls did not usually go. In fact, the lead content on the surface of playground was about 2000 ug/g. The trend of increase of lead content in the soil sample along with the depth of the soil indicated its fugitive and air origin. No such trend on the other metals further supported the hypothesis that the lead source mainly came from the recycling smelter. Thirdly, since all three kindergartens were in the same city and children generally drank the same source of tap water, the likelihood of drinking a specially contaminated water from a source other than the smelter among the exposed children was low. Fourthly, all the indicators of nutrition in our study, including Hb and ferritin were within normal limits. This indicated that nutritional difference could not explain much about the difference of blood lead. Moreover, since none of 35 children of group C had a blood lead exceeding 15 ug/dl and the parental educational background of this group were the same as those of the exposed attributing to a peculiar source like pica would not be an appropriate explanation for the difference between kindergartens A and C.

Were the health of exposed children affected by the increased absorption of lead? Under the assistance of a child psychiatrist, we could not detect any overt clinical neurobehaviroal abnormality. However, we found that the average IQ (Intelligence Quotient, by the Chinese Fourth Revision of Binet-Simon Scale) of exposed children were 10 points lower than those of the kindergarten C, of which the parental education is statistically significant ($p<0.01$ by Wilcoxon rank sum test). A multivariate analysis of IQ by controlling the effect of father's education and other factors indicated that increased blood lead has a definite adverse effect on IQ of these children (Jang and Wang 1989).

In conclusion, the increase of blood lead among the exposed children was due to the contaminated air and fugitive soil coming from the lead recycling smelter. Because Taiwan is a small island and we do not usually have a clear separation between factories and communities, the same thing might happen in other parts of Taiwan. Therefore, we recommend that ambient air standard of lead should be set up and enforced in Taiwan to protect children in the community.

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