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A Comparison of Blood Lead Levels between Migrant and Native Lead Workers Before and After Implementation of a New Employment Permit System for Migrant Workers

Nam-Soo KIM[1] and Byung-Kook LEE[1]*

[1]Institute of Environmental & Occupational Medicine, College of Medicine, Soonchunhyang University, 646 Eupnae-ri, Shinchang-myun, Asan, Choongnam 336-745, Korea

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Abstract: We compared the blood lead and other lead biomarkers between migrant and native workers with a focus on the impact of the legal employment permit system that was effective from 2003, which required employers to provide mandatory annual health examinations for migrant workers on lead biomarkers in 1997 and 2005. The mean blood lead level of migrant workers was 59.5 ± 19.4 μg/dl, yielding 47% of lead poisoning cases, which was significantly higher than that of native workers (36.8 ± 14.5 μg/dl; 11% of lead poisoning cases) in 1997 before enactment of the act. The overall mean blood ZPP levels and ALAU of migrant workers were significantly higher than those of native workers. In 2005, after new migrant worker regulations were instituted, the mean value of above lead biomarkers workers was still significantly higher than that of native workers, but the magnitude of the differences was smaller compared with the difference in 1997. We confirmed that the 2003 regulations played an important role in improving the health of migrant workers in the lead industry in terms of their blood lead levels and other lead biomarkers.

Key words: Migrant workers, Blood lead, Blood ZPP, ALAU, New employment permit system

Introduction

Until 2003, Korea had no official provisions for allowing unskilled laborers temporary access to the labor market. Instead, only official trainee workers of the industrial trainee scheme and undocumented illegal migrant workers were allowed in Korean labor markets, the latter mainly in small or medium-scale manufacturing industries[1)].

In July 2003, the Korean government introduced a new employment permit system for migrant workers. Under the new scheme, unskilled migrant workers with proper qualifications for work visas began to get jobs in certain types of Korean labor markets and were eligible for benefits as legitimate workers. The Korean Occupational Safety and Health Act (OSHA) mandated that all migrant workers were entitled to have a regular health examination—the same entitlement as was granted Korean workers[2)]. Even though the working conditions in lead factories in the 1990s were improved compared with the working conditions before and during the 1980s, some small or medium-sized (<300) lead factories, including those involved in storage batteries and secondary smelting/litharge, faced challenges in complying with the government-mandated standards[3)]. Accordingly, these types of lead industries were regarded as 3-D industries (Dirty, Dangerous, and Difficult) and had difficulty obtaining enough skilled native workers, therefore, eventually hiring migrant workers from both the official trainee scheme and the undocumented illegal migrant workforce[4, 5)]. Consequently, no offi-

*To whom correspondence should be addressed.
E-mail: bklee@sch.ac.kr

cial health examination program was provided to these migrant workers before the enactment of the 2003 employment permit system.

Soonchunhyang Institute of Environmental and Occupational Medicine provided biological monitoring on a regular basis to the lead industry that included the measurement of blood lead, zinc protoporphyrin (ZPP), and hemoglobin, as well as the measurement of urine δ-aminolevulinic acid (ALAU). The institute occasionally extended this same biological monitoring service to migrant workers in the lead industry. In 2004, the institute began providing regular biological monitoring to all lead workers, regardless of their nationality.

We report here the results from the comparison of blood lead and other lead biomarkers between migrant and native workers with a focus on the impact of the legal employment permit system on lead biomarkers.

Subjects and Methods

Eighty-one migrant workers, who worked in seven lead industries during 1997, including two storage battery and five secondary smelting/litharge-making industries, were selected. Seventy migrant workers came from Southeast Asia (mainly Indonesia), and 11 migrant workers came from China. For comparison with these migrant workers, 92 native male lead workers were selected from the same lead factories during the same period that were comparable in terms of job categories and had job duration of less than 2 yr. All migrant workers were male, and they were only compared to male native workers.

For the analysis after enactment of the new employment system of 2003, 93 migrant workers and 124 native lead workers who worked in the same lead factories as above were studied in 2005. Eighty-four of the migrant workers were from Southeast Asia (mainly Indonesia), and nine were from China.

The study variables selected were lead, ZPP, and hemoglobin in the blood and δ-aminolevulinic acid in the urine (ALAU). Information on the age and job duration of the lead workers was also collected.

Blood lead levels were measured in duplicate using the standard addition method of the National Institute of Occupational Safety and Health (7105) at the Soonchunhyang University Institute of Industrial Medicine, a certified reference laboratory for lead measurement in Korea, with a Zeeman background-corrected atomic absorption spectrophotometer (model Z-8100; Hitachi, Tokyo, Japan)[6]. As an external quality assurance and control program, the Institute passed the German External Quality Assessment Scheme operated by Friedrick Alexander University, which is standard for institutions measuring chemicals at low concentrations. Commercial reference materials were obtained from Bio-Rad (Lyphochek® Whole Blood Metals Control) for the internal quality assurance and control program. The coefficients of variation were 2.9, 4.72, and 5.42% for the three blood lead samples (reference values: 7.94, 10.7, and 22.7 μg/dl), respectively. The method detection limit for blood lead was 0.30 μg/dl.

ZPP levels were measured at medical surveillance sites by a portable hematofluorometer (Aviv-206; Aviv, Lakewood, NJ, USA)[7]. Hemoglobin was assayed by the cyanmethemoglobin method (model Ac-T; Beckman Coulter, Fullerton, CA, USA), and ALAU was measured by the method of Tomokuni *et al*. using high-performance liquid chromatography (HPLC)[8].

This study was approved by the institutional review board of the Soonchunhyang University College of Medicine. Written consent was obtained from all native workers in 1997 and 2005 and from migrant workers in 2005.

The statistical analyses were performed using SAS 9.2 (SAS Institute, Inc., Cary, NC, USA). Descriptive analyses including mean value and standard deviation of study variables were carried out between migrant and native workers and further divided by type of lead industry, such as storage battery or secondary smelting/litharge-making industry.

Because age, job duration, blood ZPP, and ALAU were not normally distributed, the Mann–Whitney test was applied to compare the differences in classification variables. For blood lead and hemoglobin analysis, Student's *t*-tests were applied to compare the differences in classification variables. Then, analysis of covariance (ANCOVA) was performed to compare the differences of blood lead and hemoglobin among classification variables after adjusting for age due to significant age differences between migrant and native workers.

Results

Table 1 summarizes the air lead concentrations of the storage battery and secondary smelting/litharge-making industries in 1997 and 2005. The geometric means of air lead concentration in the two storage battery industries and the five secondary/litharge-making industries were 179.0 and 128.0 μg/m^3, respectively. In contrast, in 2005, the mean GMs of air lead concentration in both industries decreased significantly to 34.0 and 48.0 μg/m^3, respectively.

Table 2 summarizes data on the study variables for migrant and native lead workers classified by the type of lead industry (storage battery and secondary smelting/litharge-making industry) in 1997 and 2005. In

Table 1. Air lead concentration ($\mu g/m^3$) of lead industries by year and type of industry

Type of industry	1997			2005		
	No. of samples	GM ($\mu g/m^3$)	GSD	No. of samples	GM ($\mu g/m^3$)	GSD
Storage battery	52	128.0	3.8	34	34.0	2.1
Secondary smelting/Litharge	83	179.0	5.1	73	48.0	3.7

GM: geometric mean; GSD: geometric standard deviation.

Table 2. Data on study variables in native and migrant workers classified by year and type of lead industry

Year	Variables	Native workers			Migrant workers		
		Storage battery (n=67)	Secondary smelting/ Litharge (n=25)	Total (n=92)	Storage battery (n=34)	Secondary smelting/ Litharge (n=47)	Total (n=81)
		AM ± ASD	AM ± ASD	AM ± ASD	AM ± ASD	AM ± ASD	AM ± ASD
1997	Age, yr	29.1 ± 9.0	41.8 ± 15.0	32.6 ± 12.3	25.8 ± 1.23*	27.9 ± 4.4*	27.0 ± 3.6**
	Job duration, yr	1.54 ± 0.7	2.00 ± 1.5	1.66 ± 1.0	0.53 ± 0.51**	0.80 ± 0.54**	0.69 ± 0.53**
	Blood lead, μg/dl	33.7 ± 13.1	45.0 ± 14.9	36.8 ± 14.5	56.7 ± 17.4**	61.5 ± 20.7**	59.5 ± 19.4**
	ZPP, μg/dl	75.4 ± 56.7	106.5 ± 83.4	83.9 ± 66.0	146.4 ± 140.7*	175.9 ± 113.3**	163.5 ± 125.6**
	ALAU, mg/l	2.23 ± 1.63	4.68 ± 5.1	2.90 ± 3.1	4.41 ± 5.4	8.07 ± 12.8	6.53 ± 10.5**
	Hemoglobin, g/dl	14.4 ± 1.9	15.1 ± 1.2	14.6 ± 1.8	14.5 ± 1.0	14.5 ± 1.2	14.5 ± 1.1
		Storage battery (n=58)	Secondary smelting/ Litharge (n=66)	Total (n=124)	Storage battery (n=42)	Secondary smelting/ Litharge (n=51)	Total (n=93)
2005	Age, yr	28.7 ± 5.7	36.0 ± 9.3	32.6 ± 8.6	29.2 ± 3.8	29.0 ± 5.9**	29.1 ± 5.0*
	Job duration, yr	1.05 ± 0.2	1.80 ± 1.1	1.45 ± 0.9	1.33 ± 0.6**	0.98 ± 0.8**	1.14 ± 0.72
	Blood lead, μg/dl	27.8 ± 8.3	39.0 ± 13.0	33.8 ± 12.3	34.0 ± 8.4**	45.4 ± 13.6**	40.2 ± 12.8**
	ZPP, μg/dl	50.5 ± 54.2	74.1 ± 57.0	63.1 ± 56.7	59.3 ± 30.4**	96.9 ± 71.1	79.9 ± 59.3**
	ALAU, mg/l	1.65 ± 0.7	2.10 ± 1.11	1.89 ± 1.0	1.69 ± 0.6	3.31 ± 2.8**	2.58 ± 2.2**
	Hemoglobin, g/dl	14.7 ± 0.8	14.1 ± 1.7	14.4 ± 1.4	14.5 ± 0.9	14.7 ± 0.8*	14.6 ± 0.8

AM, Arithmetic mean; ASD, Arithmetic standard deviation;
ZPP, zinc protoporphyrin; ALAU, urine delta-aminolevulinic acid; Mann-Whitney test for age, job duration, ZPP and ALAU; student test for blood lead and hemoglobin.
*p<0.05; **p<0.01.

1997, when the official health examination for migrant workers was not available, the migrant workers were significantly younger than native workers in all industries, with a greater difference in the secondary smelting/litharge-making industry than in the battery-making industry. The job durations of migrant workers were shorter than those of native workers in all industries.

The overall mean blood lead level of migrant workers was 59.5 ± 19.4 μg/dl, which was significantly higher than that of native workers (36.8 ± 14.5 μg/dl). The mean blood lead levels of migrant workers in storage battery and secondary smelting/litharge-making industries were 56.7 ± 17.4 μg/dl and 61.5 ± 20.7 μg/dl, respectively, and those of native workers in the same lead industries were 33.7 ± 13.1 μg/dl and 45.0 ± 14.9 μg/dl, respectively.

The overall mean blood ZPP levels and ALAU of migrant workers were significantly higher than those of native workers. The greatest difference between migrant and native workers was observed in the secondary smelting/litharge-making industry.

On the other hand, no differences in overall hemoglobin levels were observed between migrant and native lead workers. Further classification of lead workers by lead industry type did not reveal any difference in hemoglobin levels between migrant and native workers.

However, in 2005, when migrant workers were protected under new regulations with annual lead health examinations, the overall means of blood lead and other lead related indices except hemoglobin decreased significantly compared with those recorded in 1997. The overall mean blood lead level of migrant workers was 40.2 ± 12.8 μg/dl, which was significantly higher than that of native workers (33.8 ± 12.3 μg/dl), but the magnitude of the difference in mean blood levels was lower compared to the difference in 1997. The mean blood lead levels of migrant workers in storage battery and secondary smelting/litharge-making industries were

Table 3. Percentage of blood lead ≤60 μg/dl, ≤80 μg/dl and blood ZPP ≤150 μg/dl of lead workers classified by year and type of industry

Criteria		Yr	Native workers			Migrant workers		
			Storage battery	Secondary smelting/ Litharge	Total	Storage battery	Secondary smelting/ Litharge	Total
Blood lead	≥60 μg/dl	1997	6.0	24.0	10.9	47.1	46.8	46.9
		2005	0.0	3.0	1.6	0.0	13.7	7.5
	≥80 μg/dl	1997	0.0	0.0	0.0	5.9	21.3	14.8
		2005	0.0	0.0	0.0	0.0	0.0	0.0
Blood ZPP	≥150 μg/dl	1997	10.4	28.0	15.2	41.1	53.2	48.1
		2005	2.4	4.5	4.0	2.3	23.5	14.0

34.0 ± 8.4 μg/dl and 45.4 ± 13.6 μg/dl, respectively, and those of native workers in same lead industries were 27.8 ± 8.3 μg/dl and 39.0 ± 13.0 μg/dl, respectively.

The overall mean blood ZPP levels and ALAU of migrant workers were significantly higher than those of native workers. However, the only significant difference was in mean ALAU, and not in mean blood ZPP levels, of migrant and native workers in the secondary smelting/litharge-making industry. In the storage battery industry, no differences of mean blood ZPP levels and ALAU were found between migrant and native workers.

Interestingly, the mean hemoglobin level of migrant workers in the secondary smelting/litharge-making industry was statistically higher than that of native workers in the same industry; this difference disappeared after adjustment for age by ANCOVA analysis.

Table 3 describes the percentage of lead workers whose blood lead was above 60 μg/dl and 80 μg/dl and the percentage of whose blood ZPP was above 150 μg/dl in native and domestic workers by year. In 1997, the percentage of lead workers with blood lead ≤60 and ≤80 μg/dl were 46.9 and 14.8% among migrant workers, which was significantly higher than that among native workers (10.9 and 0.0%, respectively). In contrast, in 2005, only 3 and 13.7% of native and migrant workers, respectively, in the secondary smelting/litharge-making industry had blood lead levels >60 μg/dl, and none of the lead workers had blood lead levels >80 μg/dl.

The percentage of lead workers whose blood ZPP was above 150 μg/dl was 15.2 and 48.1% in native and domestic lead workers in 1997, respectively, whereas those decreased significantly in 2005.

In a bivariate correlation analysis of the study variables, blood lead levels were associated with blood ZPP levels and ALAU but were not associated with blood hemoglobin (Table not shown).

Discussion

Once a major labor exporter, Korea has become a prime destination for migrant workers from developing countries due to a severe shortage of unskilled production workers in small and medium-sized industries[5]. Because of the nature and job characteristics of the storage battery and secondary smelting/litharge-making industries, only male workers were accepted to work in Korea's lead industry. In the 1990s, a shortage of manpower in small and medium-sized lead factories due to the so-called "3-D syndrome" and the relatively high pay in the construction sector caused native lead workers to be replaced by migrant workers[5, 9].

Compared to other non-skilled manufacturing jobs, the relatively higher wages of lead factories attracted migrant workers. In order to work in the lead industry, migrant workers had to adapt to a new culture, language, work methods, and psychological strains in addition to the hazardous lead environment[10]. Only one published paper, by Yang *et al*. (2008), has examined the lead exposure of migrant lead workers in secondary smelting lead industries during the 1990s[11]. This study found that 17 migrant lead workers had a high mean blood lead level (55.8 μg/dl) compared to that of the native workers (28.9 μg/dl) in the same industries. The lack of safety manuals in their own language on proper prevention of lead exposure was provided as the explanation for migrant workers' high blood lead levels. Our results also revealed that the mean blood lead level of migrant workers was significantly higher than that of native workers; however, the difference between migrant and native workers in secondary smelting/litharge-making industries found in the present study was not as great as that reported by Yang *et al*. (61.5/41.5 = 148% versus 55.8/28.9 = 198%, respectively). Yang *et al*. also confirmed that the higher blood lead levels in migrant workers resulted in higher blood ZPP levels and higher ALAU compared with native workers, even with shorter job duration. Our data support these findings with higher ZPP and ALAU (163.5 μg/dl and 6.53 mg/l, respectively) in migrant workers compared with native workers (83.9 μg/dl and 2.90 mg/l, respectively) (Table 2).

Before regulations for migrant workers were enacted in 2003, employers in the lead industry were not required to provide health check-ups that included blood lead measurements. Employers were only concerned with lead poisoning cases (blood lead level above 60 μg/dl) of native workers that required to report to the Government. The blood lead levels of migrant workers were often well above the diagnostic criteria of 60 μg/dl for removal from lead exposure[12]. In this study, 46.9% of migrant workers had a blood lead level >60 μg/dl, and furthermore, 14.8% had a blood lead level >80 μg/dl. The relatively higher percentage of high blood lead levels (≥60 μg/dl) compared with native lead workers suggested that their exposure environments were more hazardous and dangerous than those of native workers. However, although the possibility that migrant workers were forced to work under worse conditions than native workers cannot be ruled out, the nature of some storage battery operations, and particularly, the secondary smelting/litharge-making industries, could not be well distinguished from the favorable work operation of others. Even with the possible consideration of several other factors mentioned above, a major factor could be workers' awareness of their exposure level in terms of blood lead or blood ZPP through regular health examinations or biomonitoring, along with proper health education regarding the possible risk of lead exposure.

Acute lead poisoning cases have been reported several times in lead workers in Korea whose lead exposure duration was relatively short[14]. Because of possible high lead exposure in the lead industries under study, all lead workers were provided maintenance-free respirators to protect themselves from high lead exposure regardless of their nationality. But the lack of proper respiratory protection program for migrant workers and the lack of employer's responsibility for the protection of migrant lead workers from lead poisoning may have made the migrant workers ignore their health problems and focus only on their job security. In 1997, the working conditions of study industries were apparently hazardous with higher air lead concentrations which were at least 2.5 times higher than Korean standard of lead in air (50 $\mu g/m^3$) in lead using industries[15].

Since the 2003 employment permit system for migrant workers, every employer is required to provide four major insurance policies, including worker's compensation insurance, to the migrant workers. Employers are also required to provide regular health examinations, especially special health examinations for lead workers, under the Korean OHSA, without any discrimination in favor of native workers[2]. The 2003 employment permit system recommended that blood lead levels of migrant workers in the lead industry should be kept below 60 μg/dl to prevent the need to report lead poisoning cases to the government and to avoid workers' removal from the workplace to reduce their blood levels until their blood lead decreased to below 60 μg/dl.

Our study confirmed that the blood lead levels of migrant workers in 2005 were significantly decreased compared to those in 1997, and we also found that the magnitude of the difference in blood lead levels between migrant and native workers was significantly reduced. The reduction of blood lead levels in migrant workers also resulted in the improvement of hematopoietic function in terms of decreased blood ZPP levels and ALAU. In the storage battery industry, however, no difference in blood ZPP levels and ALAU between the 2005 migrant and native workers was observed.

Migrant workers were more vulnerable to lead exposure due to a longer working time and inferior working conditions compared with those for native workers[13]. Furthermore, most migrant workers resided in dormitories or similar housing conditions within the work site and thus experienced greater exposure to a lead environment than did native workers, whose exposure was only during working hours. In comparison to the past when there was no legal protection, remarkable improvement in the health conditions of migrant workers can be seen in terms of blood lead levels and other biomarkers[1]. In the 2005 sample, the overall mean hemoglobin levels of migrant workers did not differ from those of native workers. On the other hand, the higher mean hemoglobin level of migrant workers in comparison to native workers in the secondary smelting/litharge-making industry was statistically significant, although the difference disappeared in age-adjusted comparison. Of interest was the absence of any relationship between hemoglobin and blood lead levels, even in cases of relatively high blood lead levels. Based on an evaluation of the published data, the threshold blood lead level for a decrease in hemoglobin levels in occupationally exposed adults was estimated by the EPA to be 50 μg/dl (1986)[16]. Some papers reported no relationship between blood lead and hemoglobin levels in occupationally exposed adults whose blood lead levels were less than 50 μg/dl[17, 18]. However, others reported a significant relationship between blood lead and hemoglobin levels when blood lead levels were below 40 μg/dl[19, 20].

Hemoglobin reduction may be induced by chronic lead exposure. In this study, workers were new (i.e., mean job duration less than 2 yr). This may explain the absence of association between blood lead and hemoglobin levels. Another possible explanation is that most migrant workers were young and healthy compared with the native worker population.

We found that the new migrant worker regulations that included a workers' compensation insurance scheme and regular health examinations has played an important role in reducing employee lead exposure and improve working standards. However, other factors may need to be considered. Fortunately, the working conditions in this study improved significantly from 1997 to 2005, which decreased the workers' blood lead and related biomarkers.

However, in addition to this fundamental change, other factors may need to be considered. For example, new-comers (irrespective of native or non-native status, but migrant workers are typical new-comers) were forced to work under worse conditions than those of their experienced co-workers, partly due to less experience, less knowledge, and less ability to communicate. Such disadvantages for migrant workers may have been reduced in recent years. On the other hand, migrant workers were usually selected from the very healthy and educated groups in their mother countries. Even with better initial health status, it should be emphasized that the health status of migrant workers in terms of blood lead and other lead related biomarkers was a disadvantage of this job. Fortunately, the working conditions in this study improved significantly from 1997 to 2005.

In conclusion, we confirmed that the 2003 regulations played a role in improving the health of migrant workers in the lead industry in terms of their blood lead levels. It should be noted, however, that their blood lead levels were still high and need to be controlled. Compared to the recent blood lead of adult general population in Korea (2.61 μg/dl) obtained in Korean national health and nutrition survey (KNHANES 2005)[21], the mean blood lead concentrations of lead workers in this study were significantly high and not acceptable. Further improvement in working condition and proper surveillance system required.

Asian nations, including the Republic of Korea, have become important countries of destination for migrant workers from developing Southeast Asian countries. Proper protection of migrant workers in every field of industrial development is needed to create better health conditions for prosperous globalization. To achieve better benefits and equality between migrant workers and native workers, further detailed follow-up studies are needed.

References

1) Park YB (2008) Admission of foreign workers as trainees in Korea. ILO Asian Regional Program on Governance of Labor Migration Working Paper No. Regional Office for Asia and the Pacific, January 2008.
2) Ministry of Labor (2004) Act on employment of foreign workers. Ministry of Labor, the Government of Korea, Seoul.
3) Choi JW, Kim NS, Cho KS, Ham JO, Lee BK (2010) The change of air lead concentrations in litharge-making and smelting industries. J Korean Soc Occup Environ Hyg **20**, 10–18 (in Korean with English abstract).
4) Lee HK (1997) The employment of foreign workers in Korea. International Sociology **12**, 353–71.
5) Seol DH (2000) Past and present foreign workers in Korea 1987–2000. Asia Solidarity Quarterly **2**, 6–31.
6) National Institute for Occupational Safety and Health (1994) Lead by GGAAS: Method 7105. NIOSH Manual of Analytical Methods, 4th Ed., NIOSH, Cincinnati.
7) Blumberg WE, Eisinger J, Lamola AA, Zuckerman DM (1977) Zinc protoporphyrin level in blood determination by a portable hematofluorometer: a screening device for lead poisoning. J Lab Clin Med **89**, 712–23.
8) Tomokuni K, Ichiba M, Hirai Y (1992) Measurement of urinary aminolevulinic acid (ALA) by fluorometric HPLC and colorimetric methods. Ind Health **30**, 119–28.
9) Korea Labor Institute (2003) A survey of the employment situation of migrant workers. Korea Labor Institute, Seoul (in Korean).
10) Wu TN, Liou SH, Hsu CC, Chao SL, Liou SF, Ko KN, Yeh WY, Chang PY (1997) Epidemiologic study of occupational injuries among foreign and native workers in Taiwan. Am J Ind Med **31**, 623–30.
11) Yang JS, Kim IJ, Kim MG, Lee SW, Heo KH, Kang SK (2008) A pilot study on increased blood lead concentration of some foreign workers in lead refining industry. J Korean Soc Occup Environ Hyg **18**, 248–51 (in Korean with English abstract).
12) Ministry of Labor (2000) Diagnostic guideline for special health examination. Ministry of Labor, the Government of Korea, Seoul.
13) Lee SW, Kim KS, Kim TW (2008) The status and characteristics of industrial accidents for migrant workers in Korea compared with native workers. Korean J Occup Environ Med **20**, 351–61 (in Korean with English abstract).
14) Lee BK (2000) The role of biological monitoring in the health management of lead-exposed workers. Toxicol Lett **108**, 149–60.
15) Ministry of Labor (1991) Permissible level of hazardous materials and method of environmental measurement. Ministry of Labor, the Government of Korea, Seoul (in Korean).
16) United States Environmental Protection Agency (1986) Air quality criteria for lead. Vol **4**, US EPA, Washington, DC.
17) Solliway BM, Schaffer A, Pratt H, Yannai S (1996) Effects of exposure to lead on selected biochemical

and hematological variables. Pharmacol Toxicol **78**, 18–22.

18) Froom P, Kristal-Boneh E, Benbassat J, Ashkanazi R, Ribak J (1999) Lead exposure in battery-factory workers is not associated with anemia. J Occup Environ Med **41**, 120–6.
19) Karita K, Yano E, Dakeishi M, Iwata T, Murata K (2005) Benchmark dose of lead-induced anemia at the workplace. Risk Analysis **25**, 957–62.
20) Kim HS, Lee SS, Hwangbo Y, Ahn KD, Lee BK (2003) Cross-sectional study of blood lead effects on iron status in Korean lead workers. Nutrition **19**, 571–6.
21) Kim NS, Lee BK (2011) National estimates of blood lead, cadmium, and mercury levels in the Korean general adult population. Int Arch Occup Environ Health **84**, 53–63.