J. ENVIRON. TOXICOL.
Vol. 19, No. 4, 327~334 (2004)

Distribution of Inorganic Metals in Blood of Adults in Urban Area of Seoul, Korea

Ho-Hyun Kim, Young-Wook Lim[1], Ji-Yeon Yang[2], Moon-Ki Ho[2] and Dong-Chun Shin※

Dept. of Preventive Medicine, College of Medicine, Yonsei University, Seoul, Korea
[1]Dept. of Environmental Health, Seonam University, Namwon, Korea
[2]The Institute for Environmental Research, Yonsei University, Seoul, Korea

도심지역 성인의 혈중 중금속 농도 분포

김호현, 임영욱[1], 양지연[2], 호문기[2], 신동천※

연세대학교 의과대학 예방의학교실, [1]서남대학교 환경보건학과, [2]연세대학교 환경공해연구소

요 약

도심지역의 중금속 배출원은 매우 다양하며, 배출 중금속은 물질별 노출 수준, 노출기간에 따라 건강유해영향을 일으킬 수 있다. 따라서 직업적 노출이 없는 도심 지역의 일반인의 혈중 중금속의 모니터링은 독성학적 측면에서 중요하다. 본 연구는 서울 도심지역의 직업적 노출이 없는 성인 남녀 144명(20~75세)을 대상으로 중금속 (납, 크롬, 니켈, 카드뮴)의 혈액 내 축적된 정도를 평가하였다. 채취한 혈액의 분석은 GF-AAS를 사용하였다. 물질별 혈중 중금속 농도는 납 63.2 μg/L, 크롬 0.12 μg/L, 니켈 μg/L, 카드뮴 1.43 μg/L로 각각 조사되었다.

Key words : blood, lead, chromium, nikel, cadmium, urban environment

INTRODUCTION

Increasing environmental pollution has given rise to concern about the accumulation of heavy metals in humans. The main route of exposure to these metals is ingestion; however, in an urban environment, atmospheric particulates originating from automobile exhaust and industries may make a significant contribution. Both lead (Pb) and cadmium (Cd) accumulate in the human body with lengthy biological half-lives, causing the continuous increase in the target tissue concentration (WHO, 1995).

The toxic effects of lead on humans have been known for centuries. Although occupational exposure to lead occurs in many industries, the principal source of exposure for the general population is lead in foodstuffs. However, lead is contained in low-dose exposure (Elinder *et al.*, 1986). The Cd and Pb concentrations in the blood mainly reflect recent exposure, but are also influenced by the body burden, particularly after a long exposure (Berglund *et al.*, 1994). Toxicological studies in occupational and environmental medicine have shown adverse biological

※ To whom correspondence should be addressed.
Tel: +82-2-361-5361, E-mail: dshin5@yumc.yonsei.ac.kr

effects from Cr during long-term exposure. Trivalent Chromium compounds Cr(III) are less toxic than those of hexavalent chromium [Cr(VI)], but they have been shown to be carcinogenic in human and animal models. Cr is not rapidly eliminated, but accumulates in the tissues and in red blood cells. Sufficient nickel (Ni) refinery dust from pyrometallurgical sulfide nickel material refineries is believed to be a human carcinogen when inhaled. The evidence of carcinogenicity includes a consistency of findings across many countries (Clydach, Wales; Copper Cliff, Ontario; Port Colborne, Ontario; Kristiansand, Norway; and Huntington, WV) in several epidemiological studies, the specificity of the tumor site (lung and nose), the high relative risks particularly for nasal cancer, and a dose-response relationship according to the length of exposure (EPA. 1986). The objective of this study was to describe the metal distribution in the blood of adults who were not occupationally exposed in Seoul.

MATERIALS AND METHODS

1. Subject

During 2001, 144 blood samples were obtained from volunteers (66 male and 78 female who had lived more than 5 years in the Seoul) who had given informed consent. The participants in the study were aged between 20 and 75 years and had no occupational exposure to the metals (Table 1). The participants answered a detailed questionnaire on the sociodemographic variables such as gender, age, smoking habits, lifestyle, place of residence, and possible exposure through occupational and non-occupational contact as well as their present and former locations.

Table 1. Characteristics of the subjects in this study

		Subjects
Gender (persons) (%)	Total	144
	Male	66 (45.8%)
	Female	78 (54.2%)
Age (years old) (min~max)	Total	144 (20~75)
	Male	66 (20~75)
	Female	78 (20~69)
Age distribution (persons) (%)	20~29	31 (21%)
	30~39	32 (22%)
	40~49	46 (32%)
	50~59	21 (15%)
	above 60	14 (10%)
Smoking habit (persons) (%)	Smoker	32 (22.2%)
	Non-smoker	106 (73.6%)
	No response	6 (4.2%)

2. Collection samples and analytical method

Approximately 5cc of blood were collected using a 6-mL vacutainer tube with an anticoagulant and kept frozen at -20°C until the analysis. The metals (Pb, Cr, Ni, Cd) concentration in the blood were determined by atomic absorption spectrophotometry with a graphite furnace (GF-AAS, Varian GTA-96, Australia). The calibration curve used a standard addition method and hydrogen phosphate was used as matrix modifiers. An internal quality control was performed using the certified Standard Reference Materials of blood-lead (SRM: 955a-1 and 955a-2, NIST in USA). SRM Means were 43.3 μg/L, 117.9 μg/L compared to 50.1 ±0.9, 135.3.1±1.3 for 955a-1 and 955a-2, respectively. The detection limit were 10 μg/L for Pb, 0.01 μg/L for Cr, 0.1 μg/L for Ni and 0.5 μg/L for Cd.

3. Statistical method

The distribution of the blood metal (Pb, Cd, Cr, Ni) concentrations was fitted to a log-normal distribution and accordingly the results are expressed in terms of the geometric mean and standard deviation. The statistical calculation was performed using the SPSS software. P values < 0.05 were considered significant.

RESULTS AND DISCUSSION

Table 2 shows geometric means (GM), geometric standard deviation (GSD) and the range of the blood metal (Pb, Cr, Cd, Ni) concentrations according to gender. The geometric mean concentrations of B-Pb were 70.27 μg/L (range 47.3 ~ 142.1 μg/L) for men and 59.1 μg/L (range 40.6 ~ 87.3 μg/L) for women. The geometric mean concentrations of B-Cr were 0.13 μg/L (range ND ~ 0.61 μg/L) for men and 0.10 μg/L (range ND ~ 0.88 μg/L) for women. The geometric mean concentrations of B-Ni were 0.21 μg/L (range ND ~ 6.88 μg/L) for men and 0.27 μg/L (range ND ~ 9.39 μg/L) for women. The geometric mean concentrations of B-Cd were 1.21 μg/L (range ND ~ 16.56 μg/L) for men and 1.66 μg/L (range ND ~ 17.24 μg/L) for women (Fig. 1).

One study reported the lowest mean value of B-Pb (23.2 μg/L) in the general population of Japan, while Swedish population had mean B-Pb concentrations of 27 μg/L (range 5.6 ~ 150 μg/L) (Watanabe *et al.*, 1996; Maria *et al.*, 1999). The wide variation in the blood lead concentrations observed is due to numerous factors, such as age, gender, drinking and smoking habits, hobbies, season, the year of sampling, and the residential area (P. Apostoli *et al.*, 2002). One

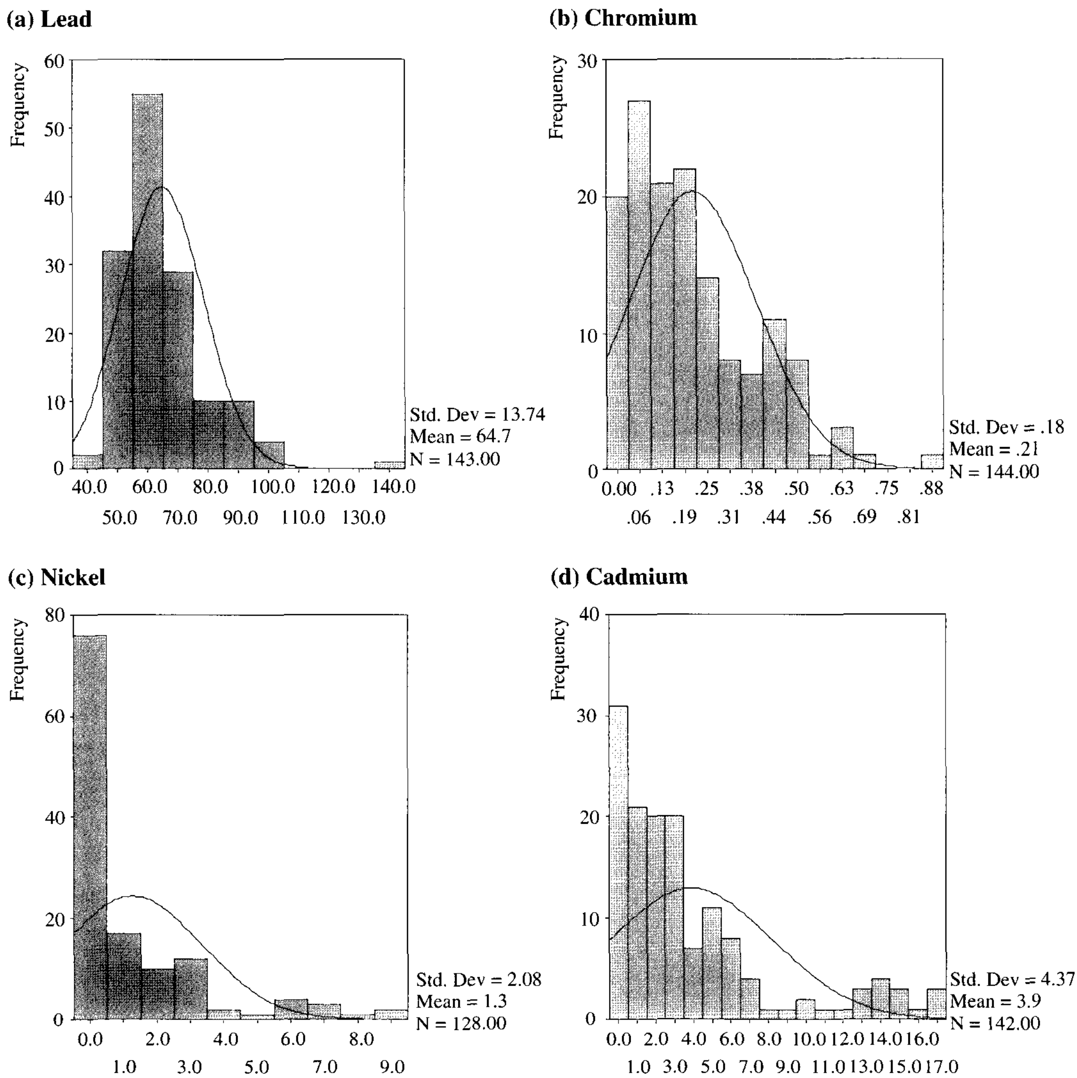

Fig. 1. Distribution of metals levels in blood.

Table 2. Concentrations of blood metals according to gender (unit : μg/L)

Blood -metals		Total (n=144)	Male (n=66)	Female (n=78)	WHO guideline[1)]
B-Pb	GM±GSD (Min~Max)	63.2±1.23 (40.6~142.1)	70.27±1.27 (47.3~142.1)	59.1±1.15 (40.6~87.3)	100
B-Cr	GM±GSD (Min~Max)	0.12±4.04 (ND~0.88)	0.13±3.51 (ND~0.61)	0.10±4.50 (ND~0.88)	1
B-Ni	GM±GSD (Min~Max)	0.25±6.82 (ND~9.39)	0.21±5.99 (ND~6.88)	0.27±7.53 (ND~9.39)	10
B-Cd	GM±GSD (Min~Max)	1.43±6.68 (ND~17.24)	1.21±7.06 (ND~16.56)	1.66±6.36 (ND~17.24)	5

[1)]WHO-Environmental Health criteria (2001)

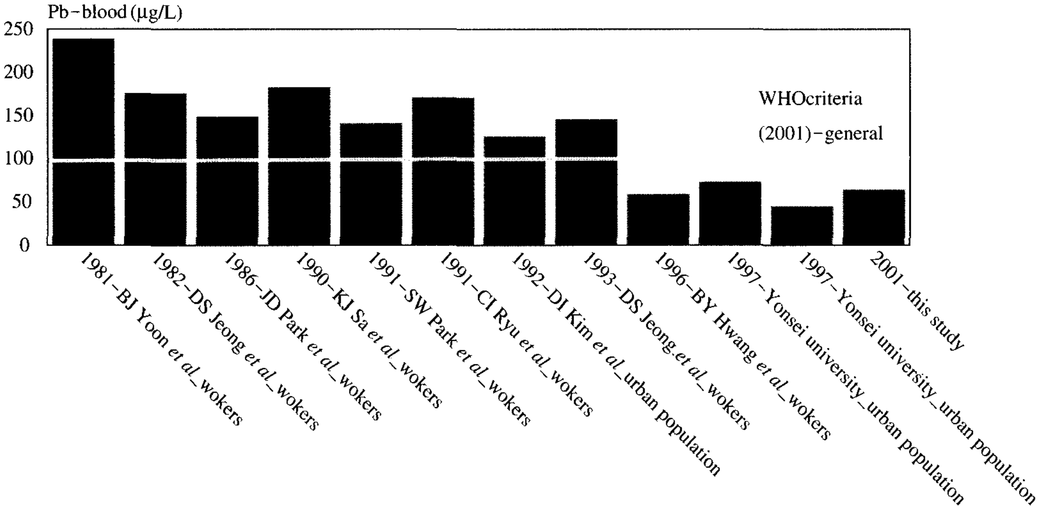

Fig. 2. Trend of blood-Pb levels for population in Korea.

study performed in Sweden showed a means B-Cd level ranging from 0.05 and 6.8 μg/L (median 0.36 μg/L) (Maria *et al.*, 1999). A comparison with another study (Qu *et al.*, 1993, Chen *et al.*, 1996, Zhang *et al.*, 1999b, C. Prohaska *et al.*, 2000, Patrick J *et al.*, 2001), where a similar analytical method was used for metal analysis, showed that the B-Pb and B-Cd levels in our study (63.2 μg/L B-Pb and 1.43 μg/L B-Cd) were lower and higher, respectively. Two papers investigating the B-Cr levels of the general population in Austria (Schaffer *et al.*, 1999, C. Prohaska *et al.*, 2000), showed mean values of 1.8 (0.3~2.5) and 1.6 μg/L, respectively. In South Korea it is assumed that the blood lead concentration has reduced since the 1990s as a result of unleaded fuel, and discharge gas regulations (Fig. 2).

The distribution in men, compared with that in women, has a broader range of values probably due to the differences between sexes in term of their smoking and drinking habits (Schuhmacher *et al.* 1992). Significantly higher B-Pb levels were observed in smokers than in non-smokers (Table 3).

The association between the smoking habit and the B-Pb level for subjects is already known indeed sm-

Table 3. Distribution of blood metals levels for smoking habit (unit : μg/L)

Blood -metals		Total (n=144)	Smoker (n=32)	Non-smoker (n=106)	p-value
B-Pb	GM±GSD (Min～Max)	63.23 (40.60～142.09)	72.23 (47.27～142.09)	60.79 (40.60～93.95)	<0.01
B-Cr	GM±GSD (Min～Max)	0.12 (ND～0.88)	0.12 (ND～0.88)	0.11 (ND～0.88)	>0.05
B-Ni	GM±GSD (Min～Max)	0.25 (ND～9.39)	0.19 (ND～6.88)	0.28 (ND～9.39)	>0.05
B-Cd	GM±GSD (Min～Max)	1.43 (ND～17.24)	1.57 (ND～16.56)	1.57 (ND～16.56)	>0.05

Table 4. Concentration of blood metals by gender in non-smokers (unit : μg/L)

Blood -metals		Non-smoker (n=106)	Male (n=35)	Female (n=71)	p-value
B-Pb	GM±GSD (Min～Max)	60.92 (40.60～93.95)	60.92 (40.60～93.95)	58.49 (40.60～77.71)	<0.01
B-Cr	GM±GSD (Min～Max)	0.12 (ND～0.88)	0.15 (ND～0.61)	0.10 (ND～0.88)	>0.05
B-Ni	GM±GSD (Min～Max)	0.26 (ND～9.39)	0.23 (ND～6.69)	0.30 (ND～9.39)	>0.05
B-Cd	GM±GSD (Min～Max)	1.40 (ND～17.24)	1.01 (ND～15.40)	1.66 (ND～17.24)	>0.05

oking is sometimes the principal factor involved in increasing blood-lead levels (Morisi *et al.*, 1992). This study found an association between smoking and the B-Pb levels among men, but this association was not significant among women (Table 4).

A similar effect linked to smoking among both men and among women has been reported (Liou *et al.*, 1996; Yang *et al.*, 1996). The differences observed between each study can be attributed to differences in the tobacco used in each country (Ariane Leroyer *et al.*, 2001).

An increase in the blood-metals levels with age among men and women has been observed by most authors (Berode *et al.*, 1991; Liou *et al.*, 1996; Takao *et al.*, 2000), although not all studies have observed significant increases in the blood-metals levels according to age (Kamal *et al.*, 1991; Yang *et al.*, 1996). Maria *et al.*(1999) provided evidence for an age-related increase in B-Pb and Cd after 70years of age. This study, found no significant association between the blood-metals levels and age (Fig. 3).

There are few documented in creases in the B-Pb levels for adults and in some case, there have either been no changes over time, or a decrease in the B-Pb levels (Watanabe *et al.*, 1985; Meyer *et al.*, 1992). Other studies from the Northern Hemisphere have found no significant difference in the B-Pb between seasons (Zarembski *et al.*, 1983; Delves *et al.*, 1984).

CONCLUSIONS

The GM levels of metals in the blood of the men were 65.88 μg/L, 1.01 μg/L, 0.23 μg/L and 0.15 μg/L, for Pb, Cr, Ni and Cd, respectively. The GM levels of metals in the blood of the women were 58.49 μg/L,

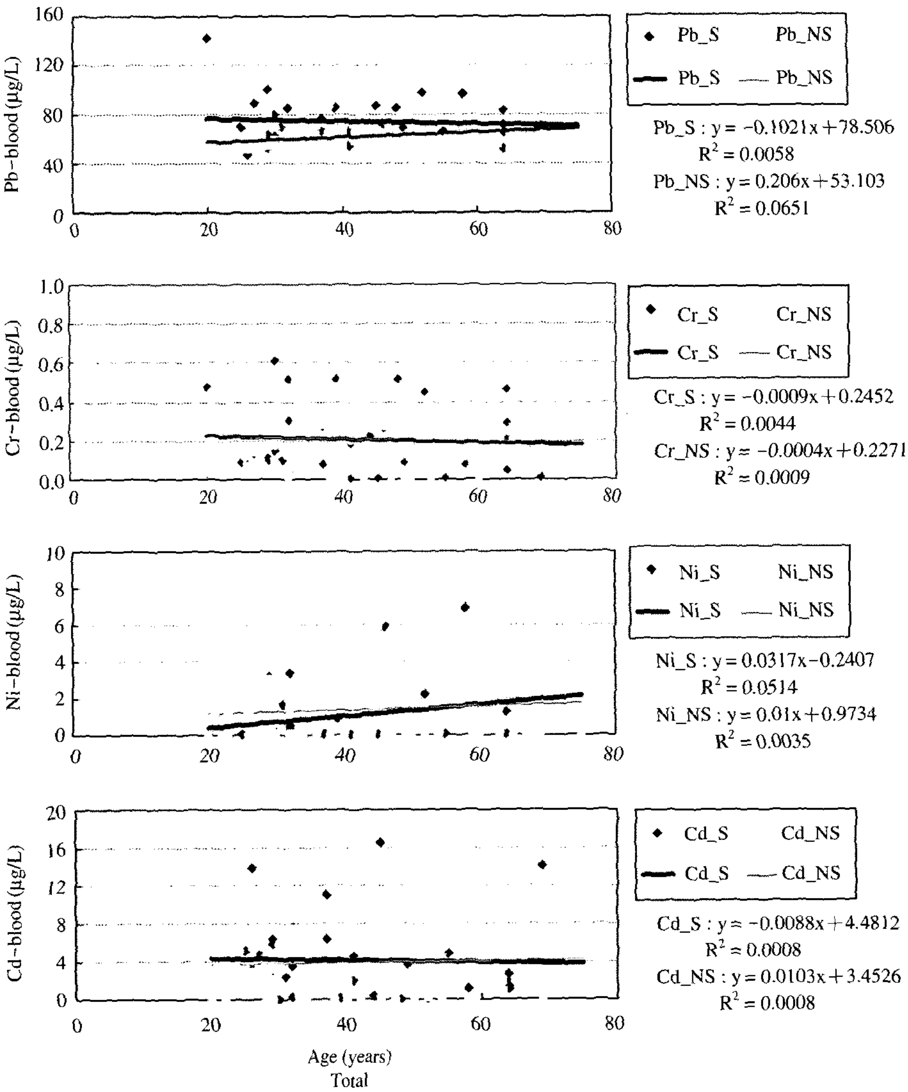

Fig. 3. Relationship between age and blood metals levels.

1.66 µg/L, 0.30 µg/L and 0.10 µg/L, for Pb, Cr, Ni and Cd, respectively. The B-Pb concentrations were significantly higher in smokers than non-smokers, whereas those of B-Cr, B-Ni, and B-Cd were unaffected by the smoking habit. In this study, the blood metal levels of the subjects were fairly low, but there was considerable inter-individual variation. Although these exposure levels have not been proven to cause serious adverse health effects, they may exert additional stress on the tissues and might contribute to premature aging (Grandjean, 1991). From this point of view, the existence of a dose-response relationship for metal exposure in the general environment is believed to be very important and suggests the urgent need for another study to evaluate the significance of this relationship.

REFERENCES

Ariane Leroyer, Denis Hemon, Catherine Nisse and Jerome

Bazerques, Jean-Louis Salomez, Jean-Marie Haguenoer. Environmental exposure to lead in a population of adults living in northern France: lead burden levels and their determinants. The science of the Total Environment. 2001; 267: 87-99.

Apostoli P, Baj A, Bavazzano P, Ganzi A, Neri G, Ronchi A, Soleo L, Lorenzo Di L, Spinelli P, Valente T and Minoia C. Blood lead reference values: the results of an Italian polycentric study. The science of the Total Environment 2002; 287: 1-11.

Berglund M, Akesson A, Nermell B and Vahter M. Intestinal absorption of dietary cadmium in women depends on body iron stores and fiber intake. Environ. Health Perspect. 1994; 102: 1058-1066.

Berode M, Wietlisbach V, Rickenbach M, Guillemin MP. Lifestyle and environmental factors as determinants of blood lead levels in a Swiss population. Environ Res. 1991; 555: 1-17.

C. Prohaska, K. Pomazal and I. Steffan. ETAAS method for the determination of Cd, Cr, Cu, Mn and Se in blood fractions and whole blood. Fresenius J Anal Chem. 2000; 368: 627-632.

Chen F-I, Tsun L-L and Khuein T-K. Blood content of lead and cadmium in adults of the city of Changsha (in Russian), People's Republic of China. Gig Sanit 1996; Mar-Apr (2): 39-40.

Devels HT, Sherlock JC and Quinn MJ. Temporal stability of blood lead concentrations in adults exposed only to environmental lead. Hum Toxicol 1984; 3: 279-288.

EPA. 1986. Health Assessment Document for Nickel and Nickel Compounds. Prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Research Triangle Park, NC. EPA/600/8-83/012FF.

Grandjean P. Effects on reserve capacity: Significance for exposure limits. Sci. Total Environ. 1991; 101: 25-32.

Hwang BY, Kim YB, Lee GS, Lee SS, Ahn KD, Lee BK and Kim JS. A study on lead exposure indices of male workers exposed to lead less than 1 year in storage battery industries. Korean J Prev Med. 1996; 29(4): 747-764

Jeong DS, Kim HS, Ahn KD and Lee BK. Prevalence rate of lead related subjective symptoms in lead workers. Korean J Prev Med. 1993; 26(2): 251-267.

Kamel AA, Eldamaty S and Faris R. Blood lead level of Cairo traffic policemen. Sci. Total Environ 1991; 105: 165-170.

Kim DI, Kim YK, Kim JM, Jeong GY, Kim JY, Jang HS, Lee YH and Choi AH. The levels of blood lead and zinc protoporphyrin for healthy urban population in Korea. Korean J Prev Med. 1992; 25(3): 287-302.

Liou SH, Wu TN, Chiang HC *et al.* Blood lead levels in Taiwanese adults; distribution and influencing factors. Sci. Total Environ. 1996; 180: 211-219.

Maria Baecklund, Nancy L. Pedersen, Lars Bjorkman and Marie Vahter. Variation in Blood Concentrations of Cadmium and Lead in the Elderly. Environmental Research Section A 80, 1999; 222-230.

Meyer J, Geuenich HH, Robra BP and Windorfer A. Determinants of lead concentration in the umbilical cord blood of 9189 newborns of a birth cohort in the government district in Brauschweig. Zentralbl Hyg Umweltmed 1992; 192: 522-533.

Morisi G, Menditto A, Patriarca M and Menotti A. Association of selected social, environmental and constitutional factors to blood lead levels in men aged 55-75 years. Sci. Total Environ. 1992; 126: 209-229.

Park JD. A study on the precision in determinations of lead and zinc in the whole blood. Korean J Prev Med. 1986; 19(1): 76-84.

Park SW and Kim DH. The relationship of low-level blood lead to plasma renin activity and blood pressure. Korean J Prev Med. 1991; 24(4): 516-530.

Patrick J. Parsons, Ciaran Geraghty and Mary Frances Verostek. An assessment of contemporary atomic spectroscopic techniques for the determination of lead in blood and urine matrices. Spectrochimica Acta Part B. 2001; 56: 1593-1604.

Qu J-B, Xin X-F, Li S-X and Ikeda M. Blood lead cadmium in a general poplution in Jinan City, China. Int Arch Occup Environ Health 1993; 65: S201-S204.

Sa KJ, Kang BS and Jeong JH. Blood lead concentration of taxi drivers in Taegu, Korea. Korean J Prev Med. 1990; 23(3): 255-261.

Schaffer, Andreas W. Pilger, Alexander Engelhardt, Christa Zweymueller, Karl Ruediger and Hugo W. Incresed Blood cobalt and Chromium After Total Hip Replacement. Journal of Toxicology-Clinical Toxicology. 1999; 37(7): 839-844.

Takao Watanabe, Zuo-Wen Zhang, Jiang-Bin Qu, Wei-Ping Gao, Zhen-Kui Jian, Shinichiro Shimbo, Haruo Nakatsuka, Naoko Matsuda-Inoguchi, Kae Higashikawa and Masayuki Ikeda. Background lead and cadmium exposure of adult women in Xian City and two farming villages in Shaanxi Province, China. 2000; 247: 1-13.

Watanabe T, Fujita H, Koizumi A, Chiba K, Miyasaka M and Ikeda M. Baseline level of blood lead coccentration among Japanese farmers. Arch Environ Health 1985; 40: 170-176.

Watanabe T, Nakatsuka H, Shimbo S, Iwami O, Imai Y, Moon CS, Zhang ZW, Iguchi H and Ikeda M. Reduced cadmium and lead burden in Japan in the past ten years. Int Arch Occup Environ Health 1996; 68(5): 305-314.

WHO. Inorganic Lead. Environmental Health Criteria 165. International Programme on Chemical Safety, World Health Organization, Geneva 1995.

Yoon BJ. A study on cadmium and lead concentration in blood of solderers among autoworkers. Koresn J Prev Med. 1981; 14(1): 111-116.

Zarembski PM, Griffiths PD, Griffiths PD, Walker J and Goodhall HB. Lead in neonates and mothers. Clin Chim Acta 1983; 134: 35-49.

Zhang Z-W, Moon C-S, Shimbo S *et al.* Further reduction in lead exposure of general women population in Japan in 1990s, comparison of the level with the levels in east and southest Asia. Int Arch Occup Environ Health, 1999b; in press.