# NON-OCCUPATIONAL DETERMINANTS OF CADMIUM AND LEAD IN BLOOD AND URINE AMONG A GENERAL POPULATION IN THAILAND

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**Abstract.** In this study the levels of cadmium and lead in blood and urine were measured by the method of graphite furnace atomic absorption spectrometry in 356 healthy, non-occupationally exposed individuals and the factors affecting the metal concentrations were investigated. The geometric means for cadmium in blood and urine were 0.98 μg/l (Cd-B) and 0.87 μg/gCr (Cd-U). The lead levels were 32.5 μg/l for blood (Pb-B) and 2.54 μg/gCr for urine (Pb-U). Men had significantly higher blood cadmium and lead levels than women whereas the urinary excretion rates of both metals were higher in women than men. Cigarette smoking was found to affect the levels of Cd-B, Cd-U, and Pb-B. Other factors like alcohol intake and place of residence also related to blood lead levels. Both blood and urine levels of cadmium and lead in this study group were within acceptable ranges for non-occupationally exposed populations and were decreased compared with the past. It is important to continue monitoring levels of these metals in order to prevent adverse health effects in the Thai population.

## INTRODUCTION

In many countries, there is increasing recognition of heavy metals as environmental hazards. Since epidemiological evidence suggests that low exposure to metals, such as cadmium and lead, over the long time peroid can cause adverse health effects. Among these effects are impairements of hematologic, central nervous, cardiovascular and renal systems (Goyer, 1995; Henretig, 1998; Nadig, 1998).

Numerous population groups exposed to environmental cadmium and lead have been studied to find reliable biological indicators for detecting the toxic effects of metals. Many studies (WHO, 1992a; Jung *et al*, 1993; Moon *et al*, 1998) suggested that blood concentration of cadmium was a useful indicator of recent cadmium exposure, whereas urinary cadmium reflected the cadmium body burden and the concentration in the kidney. In addition, the concentration of lead in blood has been used to estimate the degree of exposure and diagnose lead intoxication, while urine lead has become a widely used index of body burden of lead (WHO, 1992b; Hense *et al*, 1992; Zhang *et al*, 1997).

An epidemiological study in Italy (Minoia *et al*, 1990) was performed to determine metal concentrations in whole blood and urine of unexposed healthy subjects. The results showed the geometric means of blood and urine cadmium levels (0.60 and 0.86 μg/l, respectively) as well as lead levels (157.7 μg/l in whole blood and 17 μg/l in urine). Cikrt *et al* (1992) reported that blood cadmium and lead levels of general population in Czechoslovakia were 0.99 and 93.4 μg/l, respectively. Staessen *et al* (1984) found that the 24 hour urinary excretion of cadmium and lead increased with age and were significantly higher in men compared to women not occupationally exposed to both metals.

Previous studies (Pavittranon and Teeyapant, 1995; Taveepong *et al*, 1999) in Thai people mainly focused on the lead level in different groups in relation to non-occupational and occupational exposure. The results from these studies showed a decrease in blood lead concentration in the general population compared with occupationally exposed persons, similar to findings in many countries. Data on blood and urine cadmium concentrations in Thai people are limited. Recently, Zhang *et al* (1999) reported the geometric mean for the cadmium in blood (0.41 μg/l) and urine (1.40 μg/gCr) of non-occupationally exposed adult women.

This study was conducted to determine blood and urine levels of cadmium and lead as well as to investigate factors influencing these metal levels in the general population (non-occupationally exposed population).

## MATERIALS AND METHODS

### Study population and sample collection

In 1999-2000, 356 healthy subjects (187 males, 169 females) took part in the present study. The average age of subjects was 33.5 years (range 17-55). Occupational exposure to any toxic substances, including cadmium and lead, was ruled out in a medical interview. In addition, each subject was interviewed about demographic information, medical history, smoking habit, alcohol intake and other health-related habits.

Blood samples were taken from the cubital vein between 09.00 and 12.00 hours (with fasting) into heparinized tubes. Morning spot urine was collected also on the same day as physical examination. Both blood and urine samples were taken to avoid possible metal contamination and kept at -20ºC until analysed in the laboratory.

### Analysis of blood and urine samples for cadmium and lead

Metal analyses for cadmium and lead were conducted by graphite furnace atomic absorption spectrometry (GFAAS) with Zeeman background correction. Certified atomic absorption standards of cadmium and lead were obtained from Merk (E Merk, Darmstadt). Standards of low concentrations were freshly prepared by serial dilution with 20% (w/v) nitric acid. Seronorm trace elements whole blood control (Nycomed As, Oslo, Norway) was used for cadmium and lead blood controls. Bio-Rad lymphocheck urine control and Seronorm trace elements urine control were performed for quality control of urine metal determination. Diammonium hydrogen phosphate was used as matrix modifier. Cadmium and lead were measured at 228.8 nm and 283.3 nm, respectively, by standard addition method. Other analytical conditions and procedures were as previously described (Subramanian *et al*, 1983; Subramanian and Meranger, 1981). Both cadmium and lead concentrations in urine were expressed after correction for creatinine concentrations.

### Statistical analysis

Because cadmium and lead concentrations in blood and urine are typically skewed, analyes were performed on a natural logarithm basis; geometric mean and range were reported. Other data like age, body weight, blood pressure and blood chemistry were expressed as arithmetic means and the range was also given. Difference between means were analyzed by *t*-test and analysis of varience. To determine the independent effects on blood and urine of cadmium and lead levels multiple regression was performed, using a stepwise procedure terminating when all regression coefficients were significant at the 5% level.

## RESULTS

The main characteristics of subjects are summarized in the Table 1, including metal levels. All subjects were in good status and results for hematocrit, blood urea nitrogen and blood creatinine were in the normal range. Cadmium and lead concentrations in blood and urine were measured as described above. The results in terms of geometric mean (GM) and range have been reported. It was found that the GM of the two elements in blood were 0.98 μgCd/l and 32.5 μgPb/l, those in urine were 0.87 μg/gCr for cadmium and 2.54 μg/gCr for lead. All of the metals levels were in

Table 1
Clinical characteristics and metal levels of subjects.

| Parameters | Mean (range) |
|---|---|
| Age, years | 33.5 (17-55) |
| Body weight, kg | 61.4 (42.3-88.5) |
| Systolic blood pressure, mmHg | 122.6 (80-140) |
| Diastolic blood pressure, mmHg | 74.2 (55-100) |
| Hematocrit,% | 41.3 (26.4-54.2) |
| Blood urea nitrogen, mg/dl | 0.81 (0.35-1.26) |
| Blood creatinine, mg/dl | 12.4 (4.0-25.6) |
| Blood cadmium[a], μg/l | 0.98 (0.45-2.11) |
| Blood lead[a], μg/l | 32.5 (18.7-40.7) |
| Urine cadmium[a], μg/gCr | 0.87 (0.25-1.98) |
| Urine lead[a], μg/gCr | 2.54 (0.89-4.65) |

[a]Values are geometric mean and range in parenthesis.

Table 2
Cadmium and lead concentrations in blood and urine with different variables.

| Classifications | | No. | Blood*, μg/l | | Urine*, μg/gCr | |
|---|---|---|---|---|---|---|
| | | | Cadmium | Lead | Cadmium | Lead |
| Sex | male | 187 | 0.98 (0.57-2.11) | 31.3 (20.9-38.5) | 0.74 (0.25-1.72) | 2.15 (0.89-4.65) |
| | female | 169 | 0.84[a] (0.45-1.46) | 26.9[a] (18.7-32.4) | 0.91[a] (0.60-1.98) | 2.69[a] (1.87-3.57) |
| Age, years | 17-20 | 54 | 0.76 (0.61-1.44) | 30.7 (19.2-36.4) | 0.63 (0.49-1.66) | 2.46 (1.22-4.50) |
| | 21-30 | 108 | 0.88 (0.45-1.55) | 29.4 (18.9-32.6) | 0.85 (0.28-1.91) | 2.38 (1.19-4.65) |
| | 31-40 | 137 | 0.93 (0.49-2.11) | 32.8 (20.1-38.5) | 0.92 (0.25-1.98) | 2.65 (0.89-4.62) |
| | 41-55 | 57 | 0.99[b] (0.67-1.87) | 27.5 (18.7-34.5) | 0.76 (0.27-1.56) | 2.30 (0.96-4.31) |
| Smoking habit | non-smoker | 241 | 0.86 (0.45-1.96) | 27.6 (18.7-37.5) | 0.74 (0.58-1.98) | 2.72 (1.81-4.33) |
| | smoker | 115 | 0.98[c] (0.73-2.11) | 31.8[c] (19.9-38.5) | 0.95[c] (0.39-1.63) | 2.53 (0.89-4.60) |
| Alcohol intake | non-drinker | 193 | 0.89 (0.72-1.37) | 26.4 (18.7-38.5) | 0.91 (0.57-1.98) | 2.57 (1.86-4.65) |
| | drinker | 163 | 0.94 (0.45-2.11) | 30.8[d] (22.1-37.3) | 0.86 (0.25-1.61) | 2.48 (0.89-3.23) |
| Place of residence | Bangkok | 227 | 0.87 (0.53-2.11) | 32.6 (18.7-38.5) | 0.79 (0.35-1.97) | 2.51 (1.32-4.65) |
| | non-BKK** | 129 | 0.92 (0.45-1.79) | 28.3[e] (22.5-33.7) | 0.88 (0.27-1.73) | 2.33 (0.89-3.96) |

*Values are geometric mean and range in parenthesis. ** non-BKK = other province ( rural area )
[a,b]Significant differently from male and age group 17-20 years, respectively, $p < 0.01$
[c,d,e]Significant differently from non-smoker, non-drinker and Bangkok, respectively, $p < 0.05$

Table 3
Results of multiple regression of cadmium and lead levels and different variables.

| | Blood | | Urine | |
|---|---|---|---|---|
| | Cadmium | Lead | Cadmium | Lead |
| $R^2$ | 0.672 | 0.583 | 0.317 | 0.478 |
| Intercept | -0.351 | +0.644 | -0.064 | +0.835 |
| Regression coefficients | | | | |
| Sex | +0.726[a] | +0.416[a] | -0.435[a] | -0.527[a] |
| Age | +0.314[a] | NS | NS | NS |
| Smoking habit | +0.957[b] | NS | NS | NS |
| Alcohol intake | NS | NS | NS | NS |
| Place of residence | NS | NS | NS | NS |

Regression coefficients obtained as a result of stepwise analysis.
Code as follows; sex: 0 or 1 for male or female
:smoking habit and alcohol intake :0 or 1 for condition absent or present
:place of residence :0 or 1 for lived in non-Bangkok or Bangkok.
NS: Not significant and therefore not include in the regression equation.
$^a p < 0.05$, $^b p < 0.01$

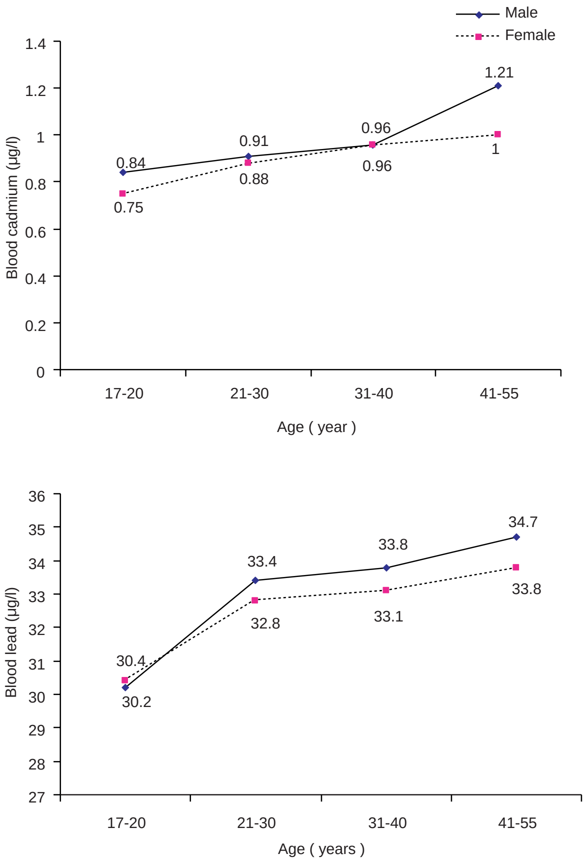


Fig 1–The association between blood cadmium, lead and age in men and women.

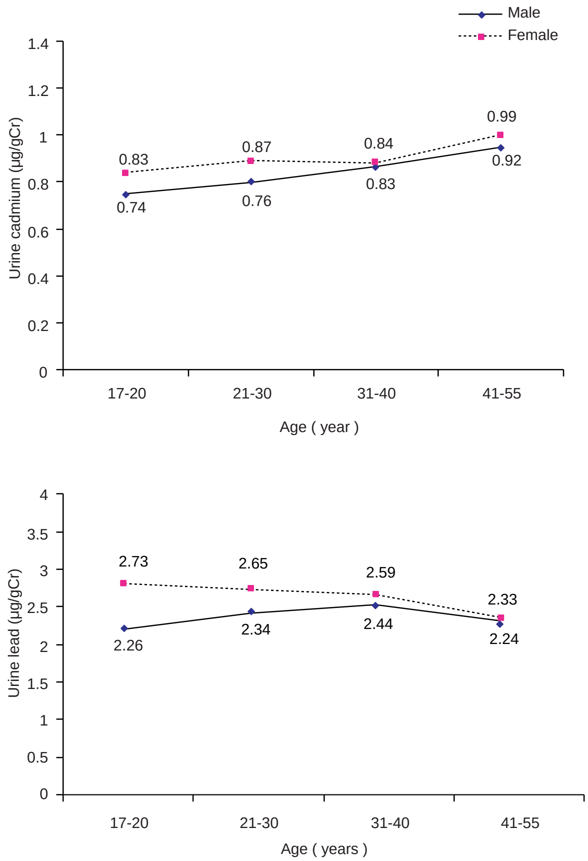


Fig 2–The association between urinary cadmium, lead excretion and age in men and women.

acceptable values for non-occupationally population groups (WHO, 1992a, 1992b).

The concentration of cadmium and lead in blood and urine showed significant differences (Table 2). Both blood cadmium and lead levels were higher in men than in women (0.98 *vs* 0.84 μgCd/l and 31.3 *vs* 26.9 μgPb/l; $p<0.05$). But urinary excretion of cadmium was found to be higher in women than in men (0.91 *vs* 0.74 μg/gCr; $p<0.05$) as were urinary lead levels (2.69 *vs* 2.15 μg/gCr; $p<0.05$).

Age, smoking habit, alcohol intake and place of residence have been reported to be determinants of the two metal levels. Since the ages of the subjects were distributed in a range of 17 to 55 years, the subjects were devided into four groups (17-20,21-30,31-40 and 41-55 years) to examine possible effects of aging. The subjects aged 41-55 years had significantly higher blood cadmium levels than the group of 17-20 years (0.99 and 0.76 μg/l,respectively; $p<0.05$). In addition, the factors of sex and age were analysed together and the results (Figs 1,2) showed no statistically significant differences in blood and urine of both metal concentrations between men and women ($p>0.05$).

Smoking status was a significant influence on blood and urine cadmium levels (0.98 *vs* 0.86 μg/l and 0.95 *vs* 0.74 μg/gCr; $p<0.05$) as were blood lead (31.8 *vs* 27.6 μg/l; $p<0.05$). Place of residence have been mentioned to be a possible factor on the metal levels thus it was devided into two areas; Bangkok and non-BKK. Subjects living in Bangkok had a higher blood lead level than those residing in non-Bangkok area (32.6 *vs* 28.3 μg/l; $p<0.05$).

Preliminary analysis had indicated that various factors may influence the levels of cadmium and lead in blood and urine. Stepwise multiple regression results are summarized in Table 3. The explanatory variables included sex, age, smoking habit, alcohol intake and place of residence. Multivariate analysis confirmed a significant positive relation between blood cadmium and sex ($p=0.036$), age ($p=0.043$) and smoking ($p=0.009$) whereas blood lead was associated only with sex ($p=0.039$) In addition, urinary excretion of cadmium and lead were found negatively correlated in men($p=0.028$ and $p=0.046$, respectively).

## DISCUSSION

It is well-known that the levels of cadmium and lead in blood and urine have been employed as indicators of non-occupational environmental exposure in the general population (Goyer, 1995; Henretig, 1998; Nadig, 1998). The cadmium and lead levels in blood and urine measured in the present study were in good agreement with those of larger studies carried out in many countries (Hense *et al*, 1992; Zhang *et al*, 1997; Minoia *et al*, 1990; Cikrt *et al*, 1992; Staessen *et al*, 19840). Rey *et al* (1997) reported mean blood cadmium levels in a non-smoker population of 1.03 μg/l and Jung *et al* (1993) found that the urinary cadmium of healthy non-exposed subjects was 0.96 μg/gCr. Watanabe *et al* (1996) reported GM of blood and urinary lead concentrations (23.2 μg/l and 1.98 μg/gCr) in a general population.

The major pathways of cadmium and lead exposure occur mainly via the dietary and the respiratory routes. In certain individuals additional factors may be important, *eg* age and cigarette consumption. Especially, in heavy smokers the absorption of cadmium from cigarette smoke may exceed that absorbed from the diet (WHO, 1992a, 1992b).

Sex, age, smoking habit, alcohol intake and residence place-dependent differences could be detected in the present report among the general population examined when the indicators of the exposure intensity were compared (Table 2).

In this study, men have been found to have higher blood cadmium and lead levels than women (0.98 *vs* 0.84 μgCd/l and 31.3 *vs* 26.9 μgPb/l; $p<0.05$). These results were similar to a previous report (Hense *et al*, 1992). However, Rey *et al* (1997) reported no difference between sex and blood cadmium (0.94

μg/l for non-smoker men and 1.12 μg/l for non-smoker women) and Willer's study (1992) found the concentration of blood cadmium in both sexes to be ~0.19 μg/l. Gianjean *et al* (1989) reported a median blood lead level of 130 and 90 μg/l at aged 40 years in men and women, respectively. In this study and others,it has been suggested that the relatively high blood cadmium and lead concentrations in adult men than women result from a high occupational and environmental exposure to both metals and from the effect of cigarette smoking (WHO, 1992a,1992b; Cikrt *et al*, 1992; Staessen *et al*, 1984; Rey *et al*, 1997; Watanabe *et al*, 1996).

The present study found greater excretion of urinary cadmium and lead in females than males (0.91 *vs* 0.74 μgCd/gCr and 2.69 *vs* 2.15 μgPb/gCr; $p<0.05$). We agree with the result of Kido *et al* (1992) that urinary cadmium concentration in females was significantly higher than in males. Studies (Staessen *et al*, 1991; Sator *et al*, 1992) showed the urinary cadmium and lead excretions were higher in men than women. We note that it was difficult to determine a biological explanation for this difference; perhaps its result from diurnal variation, degree of environmental exposure or food consumption.

Since cadmium and lead were a highly accumulative metals which were preferentially concentrated in the organ tissues and bone (Goyer,1995; Henretig, 1998; Nadig, 1998). Many researches (Cikrt *et al*, 1992; Staessen *et al*, 1984; Rey *et al*, 1997; Watanabe *et al*, 1996) reported the relationship between metal levels of blood and urine in the general population and age. Watanabe *et al* (1987) presented blood cadmium level was lower in the young adults and increased gradually to reach a plateau at the ages of 40 and 59 years while Hense *et al* (1992) found similarly increased trend of blood lead level with age. Study in Belgium by Staessen *et al* (1984) depicted that the urinary cadmium and lead excretion increased with advancing age and compatible with a low average exposure in study population. But in the present population, this association was found only in blood cadmium level. We observed that in the further study with a large number of each subgroup population, we should be found more detail of these relationship.

In several population-based studies (Hense *et al*, 1992; Watanabe *et al*, 1983), investigators assessed the roles of lifestyle factors, particularly smoking habit and alcohol. It has been reported that one cigarette contains 1 to 2 μg of cadmium (Nadig, 1998; WHO, 1992a; Chiba and Masironi, 1992). According to the study of Shaham *et al* (1996) exposure to cigarette smoke via active or passive smoking increased blood cadmium by an average of 0.01 μg%; they also found a direct relationship between blood cadmium level and the extent of smoking. This report showed blood cadmium in the smokers was higher than non-smokers group (0.98 *vs* 0.86 μg/l; $p<0.05$) as was the urine cadmium concentration (0.95 μg/gCr for smokers and 0.74 μg/gCr for non-smokers; $p<0.05$). This was similar to in the other population groups (Rey *et al*, 1997; Staessen *et al*, 1984).

Cigarettes also contain varying amount of lead and smoking 20 cigarettes/day resulted in the inhalation of approximately 1-5 μg of lead (WHO, 1992b; Chiba and Masironi, 1992). Similarly to published data in Germany (Hense *et al*, 1992), in the present population smokers had higher blood lead levels than non-smokers. No difference in urinary lead output was found between non-smokers and current smokers. In our study, only 15% of the smokers consumed more than one pack a day and this may explain the absence of any significant relation between urinary lead output and smoking habit.

Several studies (Hense *et al*, 1992; Cikrt *et al*, 1992; Weyermann and Brener,1997), have identified a positive association between the amount of alcohol consumed and blood or urine cadmium and lead concentrations. Our study showed a difference of blood lead level in non-drinkers and drinker (26.4 μg/l *vs* 30.8 μg/l; $p<0.05$),in accordance with other reports (*eg* Micciolo *et al*, 1994; Hense *et al*, 1992) that confirmed an association between alcohol consumption and blood lead concentration. Most assumed that this perhaps resulted from the lead present in alcoholic beverages and/or alcohol-related changes in lead metabolism.

In industrialized countries, release of cadmium and lead into the environment has increased considerably over many years. Previous large-scale epidemiologic studies (Hense *et al*, 1992; Kido *et al*, 1992), assessed whether environmental metal pollution led to an increased uptake of cadmium and lead. Sator *et al*(1992) showed that cadmium levels in blood and urine were significantly influenced by the place of residence, which probably reflected environmental exposure. Our results depicted no difference in blood and urine cadmium concentrations of people living in non-Bangkok (rural area) and Bangkok(urban area), except that the blood lead level of subjects inhabitant in Bangkok was higher than in non-Bangkok area (32.6 and 28.3 μg/l,respectively; $p<0.05$). Previous reports (WHO,1992a,1992b; Hense *et al*, 1992; Kido *et al*, 1992) indicated that blood lead values of non-occupationally exposed populations were highest among urban dwellers, especially those living in central cities, and became progressively lower as did the degree of urbanization.

In conclusion, blood and urine levels of cadmium and lead in the present study are in acceptable range and can be used as a reference values of non-occupationally exposed Thai population. Further study should emphasize toxicokinetic of both metals after short term and long term exposure with the concern of affecting factors (sex, age and cigarette smoking).

## REFERENCES

Chiba M, Masironi R. Toxic and trace elements in tobacco and tobacco smoke. *Bull WHO* 1992; 70: 269-75.

Cikrt M, Tichy M, Blaha K, *et al*.The study of exposure to cadmium in the general population. II. Morbidity studies. *Pol J Occupa Environ Health* 1992; 5: 345-56.

Gianjean P, Hollnage H, Hedegard L, Christensen JM, Lassen S.Blood lead-blood pressure relations: alcohol intake and hemoglobin as confounders. *Am J Epidemiol* 1989; 129: 732-9.

Goyer RA. Toxic effects of metals. In: Klassen CD,ed.Casarette and Doull's Toxicology. The basic science of poison, 5th ed. New York: McGrow Hill, 1995: 634-736.

Henretig FM. Lead. In: Goldfrank LR,ed. Goldfrank's Toxicologic Emergency, 6th ed. Connecticut: Applecton and Lange; 1998: 1278-309.

Hense HW, Filipiak B, Novak L, Stoeppher M. Non-occupational determinants of blood lead concentrations in a general population. *J Epidemiol* 1992; 21: 753-62.

Jung K, Pergande M, Graubaum HJ, Fels LM, Endl U, Stolte H. Urinary proteins and enzymes as early indicators of renal dysfunction in chronic exposure to cadmium. *Clin Chem* 1993; 39: 757-65.

Kido T, Nogawa K, Ohmichi M, *et al*. Significance of urinary cadmium concentration in a Japanese population environmentally exposed to cadmium. *Arch Environ Health* 1992; 47: 196-202.

Micciolo R, Canal L, Maranelli G, Apostoli P.Non-occupational lead exposure and hypertension in northern Italy. *Int J Epidemiol* 1994; 23: 312-20.

Minoia C,Sabbioni E,Apostoli P, *et al*. Trace element reference values in tissue from inhabitants of the Europe community I. A study of 46 elements in urine, blood and serum of Italian subjects. *Sci Total Environ* 1990; 95: 80-105.

Moon CS, Zhang ZW, Shimbo S. Evaluation of urinary cadmium and lead as markers of background exposure of middle-aged women in Korea. *Int Arch Occup Environ Health* 1998; 71: 251-6.

Nadig RJ. Cadmium and other metals and metalloids. Goldfrank's Toxicologic Emergency, 6th ed. Connecticut: Applecton and Lange; 1998: 1063-87.

Pavittranon S, Teeyapant P. A report on blood lead level in Thai population 1987-1992. *Bull Dept Med Serv* 1995; 37: 11-7.

Rey M, Turcotte F, Lapoinate C, Dewailly E. High blood cadmium levels are not associated with consumption of traditional food among the Inuit of Nunavik. *J Toxicol Environ Health* 1997; 51: 5-14.

Sator FA, Rondia DJ, Claeys FD, *et al*.Impact of environmental cadmium pollution on cadmium exposure and body burden. *Arch Environ Health*

1992; 47: 347-53.

Shaham J, Meltzer A, Ashkenazi R, Riban J. Biological monitoring of exposure to cadmium, a human carcinogen, as a result of active and passive smoking. *J Occup Environ Med* 1996: 38: 1220-8.

Staessen J, Amery A, Benard A, *et al*. Blood pressure, the prevalence of cardiovascular disease, and exposure to cadmium: a population study. *Am J Epidemiol* 1991; 134: 257-67.

Staessen J,Bulpitt CJ, Roles H,*et al*. Urinary cadmium and lead concentrations and their relation to blood pressure in a population with low exposure. *Br J Ind Med* 1984; 41: 241-8.

Subramanian KS, Meranger JC, Mackeen JE. Graphite furnace atomic absorption spectrometry with matrix modification for determination of cadmium and lead in human urine. *Anal Chem* 1983; 55: 1064-7.

Subramanian KS, Meranger JC. Rapid electrothermal atomic absorption spectrometric method for cadmium and lead in human whloe blood. *Clin Chem* 1981; 27: 1866-71.

Taveerapong S, Sripiron V, Sriburi H, Panjaburi B. Blood lead levels in normal people and workers in factories of the northern industrial estate. *Bull Chiang Mai Assoc Med Sci* 1999; 32: 3-9.

Watanabe T, Koizumi A, Fujita H, Ikeda M. Cadmium levels in the blood of inhabitants in nonpolluted areas in Japan with special reference to aging and smoking. *Environ Res* 1983; 31: 472-83.

Watanabe T, Abe H, Kido K,Ikeda M. Relationships of cadmium levels among blood, urine and diet in a general population. *Bull Environ Contam Toxicol* 1987; 38: 196-202.

Watanabe T, Nakatsuks H, Shimbo S. Reduced cadmium and lead burden in past 10 years in Japan. *Int Arch Occup Environ Health* 1996; 68: 305-14.

Weyermann M, Brener H. Alcohol consumption and smoking habits as determinants of blood lead levels in a national population sample from Germany. *Arch Environ Health* 1997; 52: 233-9.

WHO. International Programme on Chemical Safety. Environmental Health Criteria 134. Cadmium. Geneva: World Health Organization, 1992a.

WHO. International Programme on Chemical Safety. Environmental Health Criteria 85. Lead. Geneva: World Health Organization,1992b.

WillerS, Attewell R, Bensryd I, *et al*. Exposure to environmental tobacco smoke in the household and urinary cotinine excretion, heavy metals retention and lung function. *Arch Environ Health* 1992; 47: 357-63.

Zhang ZW, Moon CS, Watanabe T. Background exposure of urban populations to lead and cadmium; comparison between China and Japan. *Int Arch Occup Environ Health* 1997; 69: 273-81.

Zhang ZW, Shimbo S, Watanabe T, *et al*. Non-occupational lead and cadmium exposure of adult women in Bangkok, Thailand. *Sci Total Environ* 1999; 226: 65-74.