Non-occupational exposure of Malay women in Kuala Lumpur, Malaysia, to cadmium and lead

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Peripheral blood and 24-h total food duplicate samples were obtained from 49 adult Malay women in Kuala Lumpur, Malaysia, in July, 1995. Samples of boiled and uncooked (raw) rice were also collected from the subjects. The blood samples, homogenates of each food duplicates and rice samples (both cooked and raw) were digested by heating in the presence of mineral acids, and the digests were subjected to analysis for cadmium (Cd) and lead (Pb) with a system composed of a fully automated liquid sampler, a graphite furnace atomic absorption spectrometer and a data processor. The geometric mean metal concentrations in blood were 0.71 ng Cd per ml and 45.6 ng Pb per ml, and the dietary metal intakes were 7.31 µg Cd per day and 10.1 µg Pb per day. The metal intake via rice accounted for 53% and 13% of total dietary intake of cadmium and lead, respectively. When the absorption from the air and foods was compared, the cadmium burden came almost exclusively from foods, whereas the lead burden came both from air (44%) and foods (56%).

Keywords: *blood, cadmium, environmental pollution, food duplicate, lead, Malay women, rice.*

Introduction

Some heavy metals such as cadmium (Cd) and lead (Pb) are reliable indicators of long-term environmental pollution, because they have been extensively used in various industries, are persistent in the environment once discharged, and stay in the human body with long half-times of over a year (Vahter 1982, Vahter and Slorach 1990). In Malaysia, attention has already been focused on the years around 1980 in the investigation of the possible association of the human lead body burden and environmental lead pollution caused by, for example, automobile exhaust (Low and Lee 1979, Lim *et al.* 1983).

This study was initiated to investigate the cadmium and lead burden for Malay women in comparison with other populations in Asia. Attention was paid to the cadmium and lead content of rice, because rice, a staple energy-providing food in the daily life of the Malay people, is also a known leading source of the cadmium burden for the general Japanese population (Watanabe *et al.* 1984).

MATERIALS AND METHODS

Study population

The survey was conducted in the last third of July, 1995, in Kuala Lumpur, the capital city of Malaysia. Adult Malay women who cook foods for their family were invited to participate in the study. Altogether, 49 women volunteered. They were employees (office workers, laboratory assistants, nurses, etc.) of a university medical school and a large hospital with no known occupational exposure to heavy metals (including Cd and Pb) as confirmed through a medical interview. Their ages ranged from 18 to 47 years with an arithmetic mean of 33.2 years. A majority of them were 30–39-years-old (51%), 15 (31%) were below 29 and 9 (18%) were above 40.

Sample collection

Each participating woman was asked to (1) allow the drawing of a peripheral blood sample from the cubital vein (taken at 0900–1100 or 1500–1530), (2) collect a 24-h duplicate of total foods (Acheson *et al.* 1980) comprising three meals, snacks and any drinks, even fresh water, in the amounts taken by her over a 24-h period (Watanabe *et al.* 1985a, Ikeda *et al.* 1989, Shimbo et al. 1993, 1994), and (3) offer some 50 g each of boiled and uncooked (raw) rice samples from her kitchen. After separation and weighing of each food item in duplicate, the food duplicate was homogenized individually to prepare the sample for acid-digestion.

Analysis of blood, food duplicate and rice samples for cadmium and lead

A portion of each heparinized blood (1 ml), food duplicate (6 g) or rice (6 g) sample was heated using a block digester in the presence of mineral acids for complete wet-ashing as previously described (Watanabe *et al.* 1982), and the final digest was subjected to metal analysis.

A system used for cadmium and lead analysis consisted of a fully automated liquid sampler (Hitachi Model SSC-200), a graphite furnace atomic absorption spectrometer (utilizing Zeeman effect for background correction: Hitachi Model Z-8100) and a data processor, as previously described (Watanabe *et al.* 1983, 1985a, b, Ikeda *et al.* 1989). Cadmium in blood (Cd-B), food (Cd-F) and rice, and lead in blood (Pb-B), food (Pb-F) and rice were measured at 228.8 nm (7.5 mA) and 283.3 nm (7.5 mA), respectively. Other analytical conditions were as previously described in detail (Watanabe *et al.* 1983, 1985a). Ammonium nitrate was used as a matrix modifier in Pb-F analysis, and ammonium phosphate in other analyses.

Quality-control

Quality control of analysis for cadmium and lead was made in reference to the following certified reference materials: sargasso (NIES No. 9, Japan), tea leaves (NIHS No. 7, Japan), rice flour—unpolished [NIES No. 10-a (high level Cd), NIES No. 10-b (medium level Cd), NIES No. 10-c (low level Cd)] and human whole blood [Bio-Rad Lyphochek whole blood control (human), levels 1, 2 and 3]. The ratios of the observed values over the certified values were 93–117% for cadmium, and 92–115% for lead.

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Statistical analysis

It was previously demonstrated that cadmium and lead in blood and food duplicates distribute log-normally (Watanabe *et al.* 1983, 1985a, b, Ikeda *et al.* 1989). Accordingly, a log-normal distribution was assumed for metal concentrations or dietary metal intakes, so that the concentrations or amounts were expressed in terms of geometric mean (GM) and geometric standard deviation (GSD) together with the sample size (*n*). Arithmetic mean (AM) and arithmetic standard deviation (ASD) were also used when appropriate. Student's unpaired *t*-test and ANOVA were employed to detect possible significant differences between (or among) means.

Results

Cadmium levels in blood, food and rice samples

The results of the analysis of blood, food duplicate and rice (both boiled and raw) samples for cadmium and lead are summarized in Table 1. The results of blood and food duplicate analysis are also shown by age groups. The amounts of cadmium and lead were calculated by multiplication of the cadmium or lead concentration in a wet-ashed sample with the weight of the food duplicate.

The grand GM was 0.71 ng ml^{-1} for Cd-B, 45.6 ng ml^{-1} for Pb-B, 7.31 µg day^{-1} for Cd-F, and 10.1 µg day^{-1} for Pb-F. When the possible age-dependencies of Cd-B, Pb-B, Cd-F and Pb-F were examined, it was observed that Cd-B was uniform among the three age groups ($p > 0.05$ by ANOVA). ANOVA of Pb-B, Cd-F and Pb-F among the three age groups also did not show any significant differences ($p > 0.05$). Accordingly, the three age groups were combined in the further analysis.

GMs for cadmium and lead in rice samples were 9.10 and 3.06 ng g^{-1} in boiled rice, respectively, and 31.5 and 8.94 ng g^{-1} in raw rice. The ratio of the level of cadmium and lead in raw rice over that in boiled rice was about 3.

Cadmium and lead intake via rice

Table 2 summarizes the cadmium and lead intake via rice. The weighing of food duplicates showed that the participants took on average 1097 g food (three meals and snacks) per day. The summation of the weights of boiled rice and rice dishes (e.g. rice packed and steamed in a banana leaf) showed that the consumption of cooked rice was 461 g day^{-1} on average, which accounted for almost a half of the whole diet, suggesting that people depended heavily on rice. Multiplication of cadmium and lead contents in rice with the weight of rice consumed showed that the subjects took 3.85 µg Cd and 1.29 µg Pb from rice daily. Accordingly, the contribution of rice as a source of cadmium and lead in total foods was estimated to be 52.7% (= 3.85 µg/7.31 µg) in the case of Cd, and 12.8% (= 1.29 µg/10.1 µg) in the case of Pb.

Matrix	Unit (years)	Age	No.	Cadmium	Lead
Blood	(ng ml^{-1})	total	49	0.71 (2.02)	45.6 (1.35)
		18–29	15	0.50 (2.17)	46.2 (1.36)
		30–39	25	0.88 (1.84)	44.7 (1.36)
		40–47	9	0.69 (1.80)	47.5 (1.29)
Food duplicate	(µg day^{-1})	Total	49	7.31 (2.58)	10.1 (1.88)
		18–29	15	5.24 (2.27)	9.1 (2.05)
		30–39	25	9.35 (2.88)	11.2 (1.90)
		40–47	9	6.45 (1.71)	8.9 (1.37)
Rice, boiled	(ng g^{-1})	Total	49	9.10 (1.47)	3.06 (1.92)
Rice, raw	(ng g^{-1})	Total	49	31.5 (1.42)	8.94 (1.46)

Table 1. Cadmium and lead in blood and food duplicates by age group, and in rice samples collected from Malay women.

Values are GM in unit shown in the table (GSD). None of the differences among the three age groups were statistically significant $p > 0.05$) when assayed by ANOVA.

Intake	AM ± ASD or GM (GSD)
Consumption of all foods (g day^{-1})	1097 ± 341
Consumption of cooked rice (g day^{-1})	461 ± 185
Cadmium intake (µg day^{-1})[a]	3.85 (1.78)
Lead intake (µg day^{-1})[a]	1.29 (2.44)

Table 2. Cadmium and lead intake via cooked rice.

Values are AM ± ASD in cases of consumption of all foods and boiled rice, and GM (GSD) in cases of cadmium and lead intake via boiled rice, both for 49 subjects.

[a] Intake was calculated by multiplication of cadmium or lead contents in boiled rice with the amount of cooked rice consumed a day on an individual basis, followed by calculation of GM and GSD on a group basis.

Discussion

The present study made it clear that cadmium and lead levels in the blood of Malay women in Kuala Lumpur are 0.71 ng ml^{-1} for cadmium and 45.6 ng ml^{-1} for lead. Cadmium in blood rather than that in urine was chosen in this study to avoid the problems of intensive condensation of urine owing to the hot climate. These levels were associated with dietary intake of 7.31 µg Cd and 10.1 µg Pb per day. It was also shown that the contribution of rice as the source of both metals is large, and it is especially so in the case of cadmium which accounts for about a half of the total dietary intake (i.e. 3.85 µg Cd per day out of a total 7.31 µg Cd per day. The characteristics of food habits of these urban Malay women

Element and study area	Blood conc. (ng ml⁻¹)	GM or AM	Reference
Cadmium			
Malaysia	0.7(W)	GM	Present study results
Japan (1980s)	1.8(W), 1.8(M)	GM	Watanabe *et al.* 1983
Japan (1990s)	2.3(W), 2.0(M)	GM	Ikeda *et al.* 1994
Japan	1.9(W)	GM	Watanabe *et al.* 1995
Korea	1.3(W)	GM	Moon *et al.* 1995
China (Continent)	0.8(W), 1.0(M)	GM	Qu *et al.* 1993
China (Taiwan)	1.1(W)	GM	Ikeda *et al.* 1995
Lead			
Malaysia	46(W)	GM	Present study results
Japan (1980s)	32(W), 49(M)	GM	Watanabe *et al.* 1985b
Japan (1990s)	38(W)	GM	Watanabe *et al.* 1994a
Japan	23(W)	GM	Watanabe *et al.* 1995
Korea	44(W)	GM	Moon *et al.* 1995
China (Continent)	72(W), 92(M)	GM	Qu *et al.* 1993
China (Continent)	29–86(C)	GM	Song *et al.* 1993
China (Continent)	54(W)	GM	Watanabe *et al.* 1994b
China (Taiwan)	83	AM	Liou *et al.* 1994
China (Taiwan)	45(W)	GM	Ikeda *et al.* 1995

Table 3. Comparison of cadmium and lead concentrations in blood of occupationally non-exposed population in Asia.

Key: W, Women; M, men; C children (boys and girls in combination). GM, Geometric mean; AM, arithmetic mean.

Element and study area	Daily intake (μg day⁻¹)	GM or AM	Reference
Cadmium			
Malaysia	7(W)	GM•	Present study results
Japan (1980s)	37(W), 44(M)	GM•	Watanabe *et al* 1985a
Japan (1990s)	27(W), 25(M)	GM•	Ikeda *et al.* 1994
Japan	30(W)	GM•	Watanabe *et al.* 1995
Korea (1980s)	17–25(W)	GM•	Watanabe *et al.* 1987
Korea	21(W)	GM•	Moon *et al.* 1995
China (Continent)	30	AM?⁺	Yang *et al.* 1994
China (Continent)	14	AM⁺	Chen and Gao 1993
China (Continent)	7	GM•	Watanabe *et al.* 1994b
China (Taiwan)	10(W)	GM•	Ikeda *et al.* 1995
Lead			
Malaysia	10(W)	GM•	Present study results
Japan (1980s)	33(W), 48(M)	GM•	Ikeda *et al.* 1989
Japan (1990s)	11(W)	GM•	Watanabe *et al.* 1994b
Japan	6(W)	GM•	Watanabe *et al* 1995
Korea (1980s)	33–88(W)	GM•	Watanabe *et al.* 1987
Korea	20(W)	GM•	Moon *et al.* 1995
China (Continent)	29–86(C)	GM•	Song *et al.* 1993
China (Continent)	86	AM⁺	Chen and Gao 1993
China (Taiwan)	22(W)	GM•	Ikeda *et al.* 1995

Table 4. Comparison of dietary intake of cadmium and lead in occupationally non-exposed populations in Asia.

Key: •, By the total food duplicate method; ⁺, by other methods (e.g. market-based method); ?, as estimated.

W, women; M, men; C, children (boys and girls in combination). GM, Geometric mean; AM, arithmetic mean.

will be presented in a separate paper (Shimbo *et al.* 1995).

Tables 3 and 4 summarize Cd-B, Pb-B, Cd-F and Pb-F reported since 1990 in literature on rice-consuming Asian populations (Watanabe *et al.* 1983, 1985a, b, 1987, 1994a, b, 1995, Ikeda *et al.* 1989, 1994, 1995, Chen and Gao 1993, Qu *et al.* 1993, Song *et al.* 1993, Yang *et al.* 1994, Moon *et al.* 1995). Attention was placed on women (who are traditionally non-smokers in most Asian populations) because it is known that dietary metal intake and blood metal concentrations are different between the two sexes even when they live together (Watanabe *et al.* 1985a, Ikeda *et al.* 1989) and that smoking elevates blood metal concentrations (Watanabe *et al.* 1982). Among the authors in Table 3, Liou *et al.* (1994) presented their results in terms of AM which should be theoretically somewhat larger than the corresponding GM. Nevertheless, simple comparison shows that the Cd-B in the present study for Malaysia is the lowest among the seven study results, whereas the Pb-B of the present study results appears to be among the highest group, being comparable to the level in continental China. Both Cd-F and Pb-F in the present study appear to be among the lowest (Table 4) when possible differences between GM and AM (Chen and Gao 1993, Yang *et al.* 1994) are ignored.

In a recent nutritional study, Zawiah and Rosmiza (1995) recorded food consumption of 50 female university students for 7 days, and analysed the most frequently consumed foods and drinks for metal contents. From the data, they estimated the daily dietary lead intake to be 134 ± 77 μg (AM ± ASD) in a range of 0 to 333 μg. The major sources of lead were fish and seafood. Their estimate was much higher than the values reported for other Asian populations (Table 4). In a separate study, Siti Mizura *et al.* (1988) measured lead contents in 80 food items and 11 groups of Malaysian foods including two milled rice and five glutinous rice samples. The AM values of lead concentrations in the milled rice samples and the glutinous rice samples were 1.1 and 0.8 μg g^{-1}, respectively, which gives 0.6 μg g^{-1} (2.45) as GM (GSD). The lead contents reported by Siti Mizura *et al.* (1988) are almost 70 times higher than the levels observed in the present study (Table 1).

Theoretically, metals may be absorbed via both respiratory and dietary routes. Trials are made to estimate the amounts of cadmium and lead absorbed from inspired air and those from foods. Information on pollutant metal concentrations in ambient air of Kuala Lumpur is limited. Jamal and Zailina (1995) are the authors of the only report known to us which gives information on the cadmium and lead contents of the air. In March 1992, they collected suspended particulates in the atmospheric air at five sites in Klang Valley where the city of Kuala Lumpur is located, and measured the cadmium and lead trapped in the particulates. The AM lead concentrations were highest in Pudu in the city centre, Kuala Lumpur (462 ng m^{-3}), and lowest in the rural village of Sungai Merab (30 ng m^{-3}). The AM cadmium concentrations ranged from a high of 1.85 ng m^{-3} (in the campus of the National Agricultural University in a suburban area) to a low of 0.28 ng m^{-3} (in Sungia Merab). Cadmium in the air of Pudu in Kuala Lumpur was 1.39 ng m^{-3} which was the third highest among the five locations.

Metal and route	Conc. in air (ng m^{-3})	Intake (µg day^{-1})	Uptake (ng day^{-1})	Uptake ratio (R/D)[a]	Blood conc. (ng ml^{-1})
Cadmium					
Respiratory (R)	0.28–1.85[b]	0.016	8	0.015	0.70
dietary (D)	–	7.31	548		
Lead					
Respiratory (R)	30–462[b]	3.690	1845	2.46	65.21
dietary (D)	–	10.1	750		

Table 5. estimation of respiratory and dietary uptake of cadmium and lead by the study subjects.

A respiratory volume of 15 m^3 day^{-1} was assumed for calculation of respiratory intake (Ikeda 1992). For estimation of uptake, the ratios of 50% and 7.5% were *assumed for the* uptake in the lungs and in the digestive tract, respectively (Ikeda 1992).

[a] The ratio of the uptake via respiratory route over the uptake via dietary route.

[b] *Cited from Jamal and Zailina* (1995).

Based on the concentrations reported by Jamal and Zailina (1995) in combination with two assumptions that the respiratory volume is 15 m^3 day^{-1} and the absorption ratio in the lungs is 50% (Ikeda 1992), it is possible to estimate that the cadmium and lead intakes via the respiratory route are 0.016 µg Cd and 3.69 µg Pb per day. Assuming that the absorption ratio of both cadmium and lead in the gastrointestinal tract is 7.5% (Ikeda 1992), the daily dietary intake of 7.31 µg Cd and 10.1 µg Pb will result in the uptake of 548 ng Cd and 750 ng Pb. When the absorbed amounts via the respiratory route and via the dietary route are compared, cadmium absorption is almost exclusively from foods, whereas lead absorption from inspired air is significant (71% of the total burden) and is more than twice as large as that from foods (29%) (Table 5).

The geographic lead distribution reported by Jamal and Zailina (1995) appears to suggest that the contribution of automobile exhaust to lead in air should be large because traffic is most probably heaviest in Kuala Lumpur. According to Khiruddin (1995), a regulation was promulgated in 1985 which requires the reduction of tetraethyl lead content in automobile gasoline. Thus, tetraethyl lead was reduced from 0.84 mg l^{-1} gasoline in the past to 0.15 mg l^{-1} at present. Use of unleaded gasoline continues to penetrate the market, from 30% in 1993 to 64% in March 1995. Although the number of automobiles in the city of Kuala Lumpur is increasing, lead in the ambient air in the city (which apparently includes lead from all sources) decreased from 0.85 µg m^{-3} in 1988 to 0.11 µg m^{-3} in 1994, suggesting that the lead burden on the citizens will be reduced in the near future.

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