

# Cadmium-Exposed Population in Mae Sot District, Tak Province: 1. Prevalence of High Urinary Cadmium Levels in the Adults

Witaya Swaddiwudhipong MD, MSc\*,  
Pisit Limpatanachote MD\*\*, Pranee Mahasakpan BSc, MPH\*,  
Somyot Krintratun MD\*\*, Chantana Padungtod MD, DrPH\*\*\*

\* Department of Community and Social Medicine, Mae Sot General Hospital

\*\* Department of Internal Medicine, Mae Sot General Hospital

\*\*\* Bureau of Occupational and Environmental Diseases, Ministry of Public Health

---

**Background:** In Mae Sot District, Tak Province, Thailand, the paddy fields receiving irrigation from the two creeks and crops grown in the areas were found to contain markedly elevated cadmium levels during the surveys in 2001-2004.

**Objective:** The present report carried out a survey in 2004 to determine urinary cadmium, a good index of excessive cadmium exposure and body burden, among the exposed residents aged 15 years and older in these contaminated areas.

**Material and Method:** Morning urine samples were collected from the subjects and then kept frozen until cadmium analysis. Urinary cadmium was determined using the atomic absorption spectrometry and urinary creatinine was determined using a method of reaction with picric acid at alkaline pH and colorimetry.

**Results:** Of the 7,697 persons surveyed, only 45.6% had urinary cadmium levels < 2 µg/g creatinine. About 4.9% were between 5 and 10 µg/g creatinine and 2.3% had cadmium concentrations > 10. The urinary cadmium level was greater among women than men and increased with increasing age. Smokers were more likely to have high urinary cadmium than non-smokers. Persons who mainly consumed rice grown locally in the contaminated areas had higher urinary cadmium than those who did not.

**Conclusion:** Persons who had high urinary cadmium levels and might have cadmium-induced toxic effects should be screened for early detection of chronic cadmium toxicity. Smoking cessation programs should be one component of preventive action beneficial for the study population. The production of rice and other crops for human consumption should be prohibited to prevent further accumulation of cadmium in the body of the exposed population.

**Keywords:** Cadmium, Urinary cadmium, Smoking, Rice consumption

*J Med Assoc Thai* 2007; 90 (1): 143-8

**Full text. e-Journal:** <http://www.medassocthai.org/journal>

---

Human excessive exposure to cadmium produces a wide variety of toxic effects involving many organs and systems<sup>(1-4)</sup>. The kidney is considered the critical target organ for long-term cadmium-exposed people. An early sign of cadmium nephrotoxic effects is tubular dysfunction, demonstrated by increased

urinary excretion of low molecular weight proteins such as  $\beta_2$ -microglobulin, retinol binding protein,  $\alpha_1$  microglobulin, enzymes such as N-acetyl- $\beta$ -glucosaminidase, or calcium<sup>(1-4)</sup>. Renal tubular dysfunction may progress to glomerular dysfunction and end-stage renal disease<sup>(1-5)</sup>.

Urinary excretion of cadmium is a good indicator of excessive cadmium exposure and body burden<sup>(1-4)</sup>. In persons without excessive exposure to cadmium, urinary cadmium excretion is usually < 2 µg/

---

Correspondence to : Swaddiwudhipong W, Department of Community and Social Medicine Mae Sot General Hospital Tak 63110, Thailand. Phone: 055-531-229, Fax: 055-533-046, E-mail: swaddi@hotmail.com

g creatinine<sup>(2,6,7)</sup>. Among people exposed to cadmium occupationally or environmentally, the body burden increases with higher urinary cadmium levels<sup>(1-4)</sup>. A significantly increased prevalence of calciuria was found in subjects whose urinary cadmium excretion exceeded 2 µg/g creatinine<sup>(8)</sup>. The odds ratio for increased urinary  $\alpha_1$ -microglobulin was increased more than fivefold at urinary cadmium concentrations > 5 µg/g creatinine<sup>(9)</sup>. Excretion of urinary proteins increased significantly when urinary cadmium excretion was > 10 µg/g creatinine<sup>(10,11)</sup>. There is debate as to whether the threshold for preventing cadmium nephropathy is 5 or 10 µg/g creatinine<sup>(2,3)</sup>. The American Conference of Governmental Industrial Hygienists biological exposure index for urinary cadmium is 5 µg/g creatinine<sup>(3)</sup>.

The major route of cadmium exposure for the general population is via food. An increase in soil cadmium content generally results in an increase of plant uptake of cadmium although some soil and plant factors may influence cadmium accumulation by plants. Crops grown in cadmium-contaminated areas have been found to contain elevated cadmium content compared with normal levels<sup>(1)</sup>. Therefore, human cadmium exposure via food in contaminated areas can be many times above normal intakes and lead to cadmium toxicity.

In Mae Sot District, Tak Province, Thailand, the paddy fields receiving irrigation from the two creeks (Mae Tao and Mae Ku) were found to contain markedly elevated cadmium levels during the surveys in 2001-2004<sup>(12-15)</sup>. Both creeks passed through a zinc rich area where the zinc mine had been actively operated for more than 20 years. About 69.2% of the sediment samples of the creeks exceeded the maximum permissible level of 3.0 mg/kg (Table 1). Cadmium concentrations were low in the samples collected from the creeks before reaching the zinc area, became much higher when

passing through this area, and then reduced according to the distance. About 85.0% of the paddy soil samples receiving irrigation from both creeks contained cadmium content above the acceptable level. Rice grain and soybean grown in the areas were also detected to have elevated cadmium content compared with the normal values. The cadmium-contaminated areas were estimated to be about 13,200 rais (x 1,600 m<sup>2</sup>) of paddy fields affecting 12 villages with a total population of 12,075 in 2004<sup>(16)</sup>. Since the majority of residents consumed rice grown locally, they were at risk of chronic cadmium toxicity. Health risk assessment among these exposed people was launched in 2004. Urinary cadmium measurement was used for screening in the present study. This first report presented the prevalence of high urinary cadmium levels among the adult population in these contaminated areas.

#### Material and Method

The screening program for cadmium exposure among residents in these 12 contaminated villages was conducted between March and August 2004. Persons aged 15 years and older were the subjects of the present study. Health education about cadmium toxic effects and the benefits of the screening program through a group lecture and discussion were provided to the target persons in each village, at night, a few days before the day allotted for taking urine samples.

In each village, all persons aged 15 years and older were identified and interviewed by trained health workers. The questionnaire requested information about age, sex, address, smoking status, and areas where consumed rice was grown. Morning urine samples were collected from the subjects and then kept frozen (-20°C) until cadmium analysis within 2 weeks after collection. Urinary cadmium concentration was determined using the graphite furnace atomic absorption spectrometry

**Table 1.** Cadmium concentrations in sediments of the creeks, paddy soils, and crops in contaminated areas, Mae Sot District, Tak Province

	No. surveyed	Cadmium concentration range (mg/kg)	% exceeding the maximum permissible levels
Sediment	91	0.3-326	69.2*
Paddy soil	1,090	<0.1-284	85.0*
Rice grain	1,067	<0.1-7.7	83.0**
Soyabean	113	0.3-3.4	100.0**

\* > 3.0 mg/kg, recommended by the European Union

\*\* > 0.2 mg/kg, recommended by the Codex Committee on Food Additives and Contaminants

Sources: References 12-15

by the Bureau of Occupational and Environmental Diseases, Thailand Ministry of Public Health. This center is a national laboratory and has been certified for toxicological analyses in biological materials by the German External Quality Assessment Scheme. Urinary creatinine content was determined using a method of reaction with picric acid at alkaline pH and colorimetry (automated chemistry analyzer).

The distributions of urinary cadmium levels were expressed in percentages of the persons surveyed. The geometric mean and standard deviation were used to summarize cadmium content for each group of persons. The chi-square test was used for comparison of proportions and analysis of variance (or the Kruskal-Wallis test) for comparison between means. A p-value of less than 0.05 was considered statistically significant.

## Results

Seven thousand six hundred and ninety seven (79.6%) of the 9,668 persons aged 15 years and older living in the study area participated in the screening program. About 14.7% refused to be screened and claimed that they were healthy. The remainders were absent and could not be contacted at the time of the survey.

Of the 7,697 persons surveyed, only 45.6% had urinary cadmium levels < 2 µg/g creatinine. About 4.9% were between 5 and 10 µg/g creatinine and 2.3% had cadmium concentrations > 10 (Table 2). The proportion of persons who had urinary cadmium > 5 µg/g creatinine significantly increased with increasing age.

The geometric mean level of cadmium in urine similarly increased with age. The proportion of those containing urinary cadmium > 5 µg/g creatinine was significantly higher among women than men. The mean cadmium level for women was also greater than that for men.

About half (50.7%) of the persons surveyed were never smokers, 34.9% were current smokers, and the remaining 14.4% were former smokers. Current smokers significantly had the highest proportion of those experiencing urinary cadmium > 5 µg/g creatinine (Table 3). The geometric mean level of urinary cadmium was also highest in current smokers.

Most (88.0%) of the persons mainly consumed rice grown locally in the contaminated areas. About 11.1% purchased rice from Mae Sot markets that contained rice harvested from both contaminated and uncontaminated areas. The remainder consumed rice mainly grown in other districts. The highest proportion of persons who had urinary cadmium > 5 µg/g creatinine was observed among those who consumed locally grown rice (Table 4).

## Discussion

Increase in urinary cadmium excretion correlates with excessive cadmium exposure and body burden<sup>(1-4)</sup>. In the general population without excessive cadmium exposure, urinary excretion of cadmium is small and constant. The present results revealed that the studied population had much higher levels of urinary cadmium than those living in other districts of Tak Province<sup>(6,17)</sup>. Most of them consumed locally produced

**Table 2.** Distribution and mean of urinary cadmium in the adult population surveyed, by age and sex\*

	No. surveyed	Urinary cadmium (µg/g creatinine)				Mean ± SD**	p-value
		<2	2-4.9	5-10	>10		
Total	7,697	45.6	47.2	4.9	2.3	2.1 ± 2.9	
Age (years)							
15-24	983	66.8	31.9	0.8	0.2	1.4 ± 2.2	
25-34	1,296	56.2	39.7	3.1	0.8	1.6 ± 2.6	
35-44	1,983	44.1	49.4	4.6	1.9	2.1 ± 2.9	<0.01
45-54	1,518	40.8	49.9	6.0	3.2	2.3 ± 3.0	
≥ 55	1,917	32.9	55.6	7.6	4.0	2.9 ± 3.2	
Sex							
Male	3,667	49.6	44.7	3.7	2.0	1.9 ± 2.8	<0.01
Female	4,030	42.0	49.5	5.9	2.6	2.3 ± 3.0	

\* Expressed as a percentage of the number surveyed

\*\* Geometric mean ± standard deviation

**Table 3.** Distribution and mean of urinary cadmium in the adult population surveyed, by smoking status\*

Smoking status	No. surveyed	Urinary cadmium ( $\mu\text{g/g}$ creatinine)				Mean $\pm$ SD**	p-value
		<2	2-4.9	5-10	>10		
Never	3,902	51.7 (51.1)	42.8 (43.0)	3.7 (3.8)	1.8 (2.1)	1.8 $\pm$ 2.8	<0.01
Former	1,111	42.9 (43.1)	50.0 (50.0)	4.7 (4.6)	2.4 (2.3)	2.3 $\pm$ 3.1	
Current	2,684	37.8 (35.6)	52.5 (53.9)	6.6 (7.2)	3.1 (3.2)	2.5 $\pm$ 3.1	
Total	7,697	45.6	47.2	4.9	2.3	2.1 $\pm$ 2.9	

\* Expressed as a percentage of the number surveyed

Figures in parentheses were percentages adjusted for age and sex

\*\* Geometric mean  $\pm$  standard deviation

**Table 4.** Distribution and mean of urinary cadmium in the adult population surveyed, by area where consumed rice was grown\*

Rice-producing area	No. surveyed	Urinary cadmium ( $\mu\text{g/g}$ creatinine)				Mean $\pm$ SD**	p-value
		<2	2-4.9	5-10	>10		
Rice grown locally in contaminated areas	6,770	44.5	47.7	5.2	2.6	2.1 $\pm$ 3.0	<0.01
Rice purchased from Mae Sot markets+	858	52.6	44.1	3.0	0.3	1.8 $\pm$ 2.7	
Rice purchased from other districts	69	62.3	37.7	0.0	0.0	1.5 $\pm$ 2.4	
Total	7,697	45.6	47.2	4.9	2.3	2.1 $\pm$ 2.9	

\* Expressed as a percentage of the number surveyed

\*\* Geometric mean  $\pm$  standard deviation

+ Containing rice from both contaminated and uncontaminated areas

rice that was found to contain markedly elevated cadmium levels, and therefore might increase daily intake of cadmium from food. The present study showed that persons who mainly consumed locally grown rice had higher urinary cadmium than those who did not. These findings implicated that dietary cadmium was the major source of excessive exposure for the present study population.

The concentrations of cadmium in the body increased with increased age<sup>(10,18,19)</sup>. Women normally have higher cadmium levels than men, which can be explained by increased gastrointestinal absorption of cadmium due to low body iron stores in women<sup>(18,20-22)</sup>. Increases in urinary cadmium with age and being females were similarly found in the present survey. Since a significant proportion of the survey persons contained high urinary cadmium levels and might have cadmium-

induced toxic effects, they should be screened for early detection of chronic cadmium toxicity, primarily renal and bone effects.

Tobacco leaves, which naturally accumulate high cadmium concentrations, can contribute another important source of exposure for smokers<sup>(1-4)</sup>. Tobacco smoking was prevalent among the study population. The present survey indicated that smokers in the areas were significantly more likely than non-smokers to have high urinary cadmium leading to a higher risk of toxic effects. Smoking cessation programs should be one component of preventive action beneficial for the study population. In addition, cessation of smoking can reduce many cardiovascular and non-cardiovascular morbidities and mortalities related to smoking<sup>(23)</sup>.

Preventive and control measures for these exposed persons included (i) screening for early detec-

tion of chronic cadmium toxicity, mainly renal and bone effects, among those having high urinary cadmium, (ii) reducing cadmium exposure by massive health education to avoid consumption of contaminated food, particularly rice, grown in the areas, and (iii) anti-smoking programs for the smokers and other exposed persons.

Since consumption of the contaminated food grown in the areas is the main source of excessive cadmium exposure and improvement in the soil contamination is very difficult, the production of rice and other crops for human consumption should be prohibited. This measure can prevent further accumulation of cadmium in the body of the exposed population. The production of non-food crops in these areas is strongly recommended and supported by the government.

### References

1. World Health Organization. International Programme on Chemical Safety: Environmental Health Criteria 134. Cadmium. Geneva: World Health Organization; 1992.
2. Agency for Toxic Substances and Disease Registry. Toxicological profile for cadmium. Atlanta: US Department of Health and Human Services; 1999.
3. Goyer RA, Clarkson TW. Toxic effects of metals. In: Klassen CD, ed. Casarett & Doull's Toxicology: the basic science of poisons, 6<sup>th</sup> ed. New York: McGraw-Hill; 2001: 811-67.
4. Satarug S, Moore MR. Adverse health effects of chronic exposure to low-level cadmium in foodstuffs and cigarette smoke. *Environ Health Perspect* 2004; 112: 1099-103.
5. Hellstrom L, Elinder CG, Dahlberg B, Lundberg M, Jarup L, Persson B, et al. Cadmium exposure and end-stage renal disease. *Am J Kidney Dis* 2001; 38: 1001-8.
6. Kaojarern S, Wananukul W, Sirivarasai J. The study of blood and urine levels of cadmium and chromium in non-exposed people. Bangkok: Department of Medicine Ramathibodi Hospital, Mahidol University; 2000.
7. Sirivarasai J, Kaojarern S, Wananukul W, Srisomerang P. Non-occupational determinants of cadmium and lead in blood and urine among a general population in Thailand. *Southeast Asian J Trop Med Public Health* 2002; 33: 180-7.
8. Wu X, Jin T, Wang Z, Ye T, Kong Q, Nordberg G. Urinary calcium as a biomarker of renal dysfunction in a general population exposed to cadmium. *J Occup Environ Med* 2001; 43: 898-904.
9. Jarup L, Hellstrom L, Alfven T, Carlsson MD, Grubb A, Persson B, et al. Low level exposure to cadmium and early kidney damage: the OSCAR study. *Occup Environ Med* 2000; 57: 668-72.
10. Buchet JP, Roels H, Bernard A, Lauwerys R. Assessment of renal function of workers exposed to inorganic lead, cadmium or mercury vapor. *J Occup Med* 1980; 22: 741-50.
11. Ikeda M, Ezaki T, Tsukahara T, Moriguchi J, Furuki K, Fukui Y, et al. Threshold levels of urinary cadmium in relation to increases in urinary  $\beta_2$ -microglobulin among general Japanese populations. *Toxicol Lett* 2003; 137: 135-41.
12. Pollution Control Department. Cadmium contamination in Mae Tao Creek, Mae Sot District, Tak Province. Bangkok: Thailand Ministry of Natural Resources and Environment; 2004.
13. National Research for Environmental and Hazardous Waste Management, Chulalongkorn University. Distribution of cadmium and absorption by rice plants in areas nearby the zinc mine in Mae Sot District. Bangkok: Chulalongkorn University; 2005.
14. Simmons RW, Sukreeyapongse O, Noble AD, Chinabut N. Report of LDD-IWMI land zoning and risk assessment activities undertaken in Phatathai and Mae Tao Mai Subdistricts, Mae Sot, Tak Province, Thailand. Bangkok: International Water Management Institute; 2005.
15. Simmons RW, Pongsakul P, Saiyasitpanich D, Klinphoklap S. Elevated levels of cadmium and zinc in paddy soils and elevated levels of cadmium in rice grain downstream of a zinc mineralized area in Thailand: Implication for public health. *Environ Geochem Health* 2005; 27: 501-11.
16. Tak Provincial Office. Project development for solving the problems related to cadmium-contaminated areas in Mae Sot District, Tak Province. Tak: Tak Provincial Office; 2005.
17. Tak Provincial Health Office. A survey of urinary cadmium levels in adults in three districts in Tak Province. Tak: Tak Provincial Health Office; 2005.
18. Olsson IM, Bensryd I, Lundh T, Ottosson H, Skerfving S, Oskarsson A. Cadmium in blood and urine - impact of sex, age, dietary intake, iron status, and former smoking - association of renal effects. *Environ Health Perspect* 2002; 110: 1185-90.
19. Horiguchi H, Oguma E, Sasaki S, Miyamoto K, Ikeda Y, Machida M, et al. Dietary exposure to cadmium at close to the current provisional tolerable weekly intake does not affect renal function among female Japanese farmers. *Environ Res* 2004;

- 95: 20-31.
20. Flanagan PR, McLellan JS, Haist J, Cherian G, Chamberlain MJ, Valberg LS. Increased dietary cadmium absorption in mice and human subjects with iron deficiency. *Gastroenterology* 1978; 74: 841-6.
  21. Berglund M, Akesson A, Nermell B, Vahter M. Intestinal absorption of dietary cadmium in women depends on body iron stores and fiber intake. *Environ Health Perspect* 1994; 102: 1058-66.
  22. Satarug S, Ujjin P, Vanavanitkun Y, Baker JR, Moore MR. Influence of body iron store status and cigarette smoking on cadmium body burden of healthy Thai women and men. *Toxicol Lett* 2004; 148: 177-85.
  23. US Department of Health and Human Services. The health consequences of smoking: a report of the Surgeon General. Atlanta: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2004.

## การได้รับสารแคดเมียมในประชากรอำเภอแม่สอด จังหวัดตาก: 1. ระดับแคดเมียมในปัสสาวะของประชากรอายุ $\geq 15$ ปี

วิทยา สวัสดิวุฒิพงศ์, พิสิฐ ลิมปธนโชติ, ปราณีย์ มหาศักดิ์พันธ์, สมยศ กรินทราทัศน์, ฉันทนา ผดุงทศ

**บทนำ:** จากการศึกษาของกระทรวงเกษตรและสหกรณ์ ในช่วงปี พ.ศ. 2544 - พ.ศ. 2547 พบมีการปนเปื้อนของสารแคดเมียมในดินและพืชผลการเกษตร ในเขต 3 ตำบลของอำเภอแม่สอด จังหวัดตาก

**วัตถุประสงค์:** รายงานนี้ได้นำเสนอผลการสำรวจระดับแคดเมียมในปัสสาวะของประชากรที่อายุ  $\geq 15$  ปี ที่อาศัยอยู่ในพื้นที่ปนเปื้อนดังกล่าว

**วัสดุและวิธีการ:** ได้เก็บตัวอย่างปัสสาวะในตอนเช้า ของประชากรที่อายุ  $\geq 15$  ปี เพื่อตรวจหาระดับแคดเมียมโดยใช้การตรวจ atomic absorption spectrometry และตรวจหาระดับครีเอตินีนด้วยวิธีการทำปฏิกิริยากับ picric acid at alkaline pH และใช้ colorimetry

**ผลการศึกษา:** ได้เก็บปัสสาวะเพื่อตรวจหาระดับแคดเมียมรวม 7,697 ราย พบว่ามีเพียงร้อยละ 45.6 ที่มีระดับแคดเมียมน้อยกว่า 2 ไมโครกรัม/กรัมครีเอตินีน ร้อยละ 4.9 มีระดับอยู่ระหว่าง 5-10 ไมโครกรัม / กรัมครีเอตินีน และร้อยละ 2.3 มีระดับมากกว่า 10 ไมโครกรัม/กรัมครีเอตินีน ระดับแคดเมียมจะพบสูงขึ้นในเพศหญิง และตามอายุที่เพิ่มขึ้น ประชากรที่สูบบุหรี่จะมีระดับแคดเมียมสูงกว่าประชากรที่ไม่สูบบุหรี่ และประชากรที่บริโภคข้าวที่ปลูกในพื้นที่ที่ปนเปื้อนสารนี้ จะมีระดับแคดเมียมสูงกว่าประชากรที่ไม่ได้บริโภคข้าวที่ปลูกในพื้นที่

**สรุป:** ประชากรที่มีระดับแคดเมียมสูงกว่าปกติควรได้รับการตรวจคัดกรองเพื่อค้นหาภาวะพิษของสารแคดเมียม การรณรงค์เพื่อลดการสูบบุหรี่ และการงดบริโภคข้าวและพืชผลอื่น ๆ ที่ปลูกในพื้นที่ซึ่งมีส่วนช่วยลดการได้รับสารแคดเมียมเข้าสู่ร่างกายในประชากรเหล่านี้