

## **Health Risk Management for Cadmium Contamination in Thailand : *Are Challenges Overcome ?***

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### **Abstract**

This report addresses the challenges encountered and, to a certain extent, overcome, while health risk assessment and management were being conducted in Mae Sot, Thailand following cadmium contamination to rice, the main diet of Thais.

In November 2003, Department of Agriculture (DOA), Ministry of Agriculture (MOA) sent a summary report of a 6-year study revealing serious contamination of cadmium to soil and rice grown in the vicinity of a large zinc mine to Department of Pollution Control (DPC). The report concluded that level of rice contamination warranted immediate attention to prevent cadmium poisoning among the exposed population. A team of DPC experts initiated a risk assessment plan and Department of Disease Control (DDC) was among the 6 central governmental offices contacted to join this effort.

Department of Disease Control (DDC) staffs and Mae Sot Hospital team initiated a rapid survey to assess exposure situation among the 100,000 residents in the affected municipality. Using GIS data, health staffs mapped contaminated rice fields with consumers. By the end of 2004, affected population was classified according to their exposure statuses. Toxicologists from Chiang Mai University Medical School and Japanese cadmium experts from Kanazawa Medical University started a research project to assess the effect of cadmium on kidneys, the major target organ of cadmium. It is expected that a 10-year surveillance is needed to reduce health risks among 800 people, who had high urinary cadmium level ( $> 5 \mu\text{g/g}$  creatinine) and were at risk of having cadmium-induced renal failure, to acceptable level.

Challenges encountered during health risk management included; unclear source of contamination, between natural and man-made origins, rendering it difficult to claim accountability from the sole zinc mine, discontinuation of rice growing on contaminated land against local cultural beliefs, compensation for rice growing without alternative crops cultivation solution, and human rights issues for Karen population in the affected area. All these issues prompt public staffs to search for alternative ways to manage health risks more economically, socially and culturally acceptable.

### Thailand context

Located on the Thai-Myanmar border, Mae Sot district in Tak province is hidden in mountainous area. With the abundant supplies of water from Moei River and smaller canalization, local residents of Mae Sot have depended on rice, soybean and garlic cultivations for at least 3 generations. Rice grown in the area has yielded national award-winning products for many consecutive years.

Around 1977, zinc mining activities of 3 companies were started after the Department of Mineral Resources, Ministry of Industry<sup>1</sup> classified this area as the richest source of zinc minerals in Thailand. However, at present, only one company has remained in the area and its gross income and profit is shown in table 1.

Table 1 : Gross income and profit of the only zinc mining company in Mae Sot, Tak, 1999 – 2004 (Social Research Institute, Chiang Mai University, Thailand 2006)

Year	Gross Income in Millions Bahts (US\$ : 1 US\$ = 40 Bahts)	Net Profit in Millions Bahts (US\$ : 1 US\$ = 40 Bahts)
1999	4,462 (110,550,000)	145 (3,625,000)
2000	5,315 (132,875,000)	211 (5,275,000)
2001	5,222 (130,550,000)	335 (8,375,000)
2002	4,406 (110,150,000)	-29 (-725,000)
2003	4,932 (123,300,000)	284 (7,100,000)
2004	5,715 (142,875,000)	217 (5,425,000)

With regard to pollution control in Thailand, the Office of Environmental Policy and Planning, Ministry of Natural Resource and Environment (MNRE) is mandated to review and approve the environmental impact assessment (EIA) of 22 hazardous industries. This activity can be considered as primary prevention of industrial pollution. Meanwhile, once pollution is suspected, the Department of Pollution Control (DPC) is called for investigation and control activity. Generally, the DPC staffs conduct their work independently and Ministry of Public Health (MOPH) is consulted for diagnosis and treatment of the diseases or clinical symptoms presented. In addition, after a certain period of time, follow up of environmental contamination and adverse health effects are both discontinued.

### Collaboration between Thai MOA and IWMI

The discovery of cadmium contamination to rice and soil in Thailand began in 1998 (1,2). Dr. Robert W. Simmons, a senior researcher at International Water Management Institute (IWMI) and his team decided to conduct a study in Mae Sot district, Tak province, Thailand. Based on their experiences from water and soil contamination studies in China and other Asian countries, they foresaw that rice growing in the vicinity of zinc mine could lead to cadmium, which co-exists naturally with zinc, contamination to rice and would inevitably cause adverse health effect, particularly itai-itai disease, or chronic cadmium poisoning, among the exposed population.

IWMI jointly quantified soil and rice cadmium contamination in Mae Sot district with Dr.Pichit Pongsakul, a soil and plant expert at Department of Agriculture, Ministry of Agriculture, Thailand. From 1998 – 2000, the first phase of the study was done in the most potentially polluted area where water was naturally supplied by Mae Tao Creek in which sediment was suspected of having high contamination of cadmium.

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<sup>1</sup> Since October 2002, this department has branched into Department of Mineral Resources, Ministry of Natural Resources and Environment and Department of Primary Industries and Mine, Ministry of Industry.

It was concluded that source of cadmium contamination was soil containing high level of cadmium, which evidences were not sufficient to confirm that whether cadmium was from natural zinc mineralized area or contamination by zinc mining activities, flooded or eroded into natural and man-made water supplies which was, then, irrigated into rice paddy fields. Cadmium was eventually transferred from soil into rice, the only plant known to absorb cadmium completely.

Results showed that cadmium levels in 154 soil samples ranged from 3.4 – 284 mg Cd/kg soil which was 1.13 – 94 times European Economic Community (EEC) Maximum Permissible (MP) soil cadmium concentration of 3.0 mg Cd/kg soil and 1,800 times the Thai standard of 0.15 mgCd/kg soil. Moreover, rice samples from 90 fields were found to be contaminated with cadmium ranging from 0.1 to 4.4 mg/kg rice while the mean background Thai rice Cd concentrations as reported by Pongsakul and Attajarusit (1999) was  $0.043 \pm 0.019$  mg/kg rice.

With this amount of cadmium presented in rice and based on Thai daily rice consumption, it was estimated that local residents would have been exposed to cadmium 14 – 30 times higher than the Joint FAO/WHO Expert Committee on Food Additives (JECFA) Provisional Tolerable Weekly Intake (PTWI) of 7  $\mu$ g Cd / kg body weight (BW) per week.

The second phase of the study, from 2001 – 2003, was expanded to cover the downstream part of Mae Tao Creek. Cadmium level in soil samples was found to be 72 times European Union (EU) standard and 80 % of rice samples were contaminated with cadmium at the level higher than Food and Agriculture Organization (FAO) and Japanese standards. This concentration of cadmium could lead to 2.8 – 11 times higher than the aforementioned PTWI set by JECFA.

### **Risk Assessment**

Due to the Department's roles and functions, Department of Pollution Control (DPC), MNRE was the first governmental office invited to attend MOA/IWMI research result dissemination meeting in October 2003. DPC staffs, then, initiated a plan to investigate the extent and severity of cadmium contamination in Mae Sot. However, contradicted to the general practice, Department of Disease Control (DDC) was asked to join the effort at that early stage.

From January to April 2004, using GIS mapping based on cadmium concentration gradient in soil and rice provided by MOA/IWMI research team, DPC staffs collected environmental samples from Mae Tao Creek, surface water, underground water, well water and soil. Rice and fish were also sampled. Concurrently, MOPH staffs located the exposed population and biological samples were collected for cadmium measurements.

### *Environmental samplings*

Table 2 summarized standards used for all environmental samplings conducted under the auspice of a special technical task force led by DPC (3).

- The Department of Underground Water found that all underground and surface water samples contained cadmium less than 0.001 mg/L which was considered safe for drinking according to international standard of < 0.01 mg/L.
- The Department of Water Resources reported that all samples throughout the creek length contained cadmium between 0.00281 – 0.001 mg/L which was also considered safe for consumers (<0.05 mg/L at water hardness >100 mg/L).
- The Department of Fisheries found that all fish samples had cadmium concentration within safe limit for consumption of < 2 mg/Kg.
- The Department of Mineral Resources found that 88 % of sediment samples from Mae Tao Creek contained high concentration of cadmium. The highest level was 93 times the lowest contamination concentration (326 mg Cd /Kg soil).
- DPC reported that 86 % of soil samples were contaminated ranging from 61 – 207 mg Cd /Kg soil.

- Rice samples from household storage were found to contain cadmium from trace to 5 mg Cd/Kg rice with the average of 1.33 mg Cd/Kg rice. In other words, 91 % of rice samples exceeded Codex Committee on Food Additives and Contaminants (CCFAC) of 0.2 mg Cd/Kg rice.

Table 2 : Standards of cadmium concentration used by Department of Pollution Control for environmental samplings in Mae Sot area (January – April 2004)

Type of samples	Low contamination	Medium contamination	High contamination
Underground and surface water	$\leq 0.01$ mg/L	0.01 - < 0.1 mg/L	$\geq 0.1$ mg/L
Water from Mae Tao Creek	$\leq 0.05$ mg/L	0.05 - < 0.5 mg/L	$\geq 0.5$ mg/L
Sediment in Mae Tao Creek	$\leq 3.5$ mg Cd /Kg soil	3.5 - < 35 mg Cd / Kg soil	$\geq 35$ mg Cd / Kg soil
Soil from rice paddy fields	$\leq 3$ mg Cd / Kg soil	3 - < 30 mg Cd / Kg soil	$\geq 30$ mg Cd / Kg soil
Rice grown on contaminated soil	$\leq 0.2$ mg Cd / Kg rice	0.2 - < 1 mg Cd / Kg rice	$\geq 1$ mg Cd / Kg rice

The environmental samplings revealed similar results to MOA/IWMI research except the conclusion on pollution source. DPC reported a significant difference of cadmium concentration in sediments sampled along Mae Tao Creek (Table 3). From this report, it was evident that cadmium contamination in natural water supply could be attributed to zinc mining activity.

Table 3 : Cadmium concentration found in sediments of Mae Tao Creek as reported by Department of Pollution Control (April 2004)

Location along Mae Tao Creek	Cd concentration in sediments (mg Cd/Kg soil)
Tham Sue village (creek origin)	0.5
Zinc mining area	82 – 326
Small dam near Zinc mining area	80 – 104
Towards the end of creek	44 – 63

#### *Population survey*

Mae Sot hospital staffs, supported by health staffs from Tak Provincial Health Office and Bureau of Occupational and Environmental Disease, Department of Disease Control, classified approximately 100,000 residents in Mae Sot district into exposed and non-exposed group based on the duration of living in the area and rice consumption habit (4). Among the exposed, 7,697 residents aged 15 years and older were asked to donate urine samples for cadmium concentration measurement.

Using World Health Organization (WHO) standard of 2  $\mu\text{g/g}$  creatinine for environmental exposure, 5  $\mu\text{g/g}$  creatinine for occupational exposure and > 10  $\mu\text{g/g}$  creatinine for possible renal damage caused by cadmium, it was found that 45.6 % of surveyed population had urinary cadmium levels < 2  $\mu\text{g/g}$  creatinine while 4.9 % had cadmium between 5 and 10  $\mu\text{g/g}$  creatinine and 2.3 % had cadmium concentration > 10  $\mu\text{g/g}$  creatinine.

When classified by the origin of rice that the exposed population habitually consumed, it was shown in table 4 that those who ate rice grown in contaminated area had significantly higher level of urine cadmium concentration compared to those eating rice purchased from markets or other districts.

Table 4 : Mean urinary cadmium of adult population surveyed classified by origin of rice consumed\* (2004)

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	
Rice purchased from Mae Sot markets	858	52.6	44.1	3.0	0.3	1.8 $\pm$ 2.7	< 0.01
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

Table 5 showed urinary cadmium concentration classified by age and gender. Older population appeared to have, significantly and in a dose-response manner, higher urinary cadmium levels compared to younger population and females had significantly higher level of urinary cadmium than males.

Table 5 : Mean urinary cadmium of exposed adult population classified by age and gender\* (2004)

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

\* Expressed as a percentage of the number surveyed

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

Smoking is known to increase body burden of cadmium. When classified exposed population by smoking status, current smokers had significantly higher concentration of urinary cadmium ( $1.8 \pm 2.8 \mu\text{g/g}$  creatinine) compared to former ( $2.3 \pm 3.1 \mu\text{g/g}$  creatinine) and non-smokers ( $2.5 \pm 3.1 \mu\text{g/g}$  creatinine).

#### *Clinical assessment*

The aforementioned epidemiological survey in 2004 could be concluded that consumption of contaminated rice was associated with elevated urinary cadmium levels. The next step was to assess the renal and bone effects caused by cadmium.

Mae Sot Hospital registered 800 exposed population having urinary cadmium  $> 5 \mu\text{g/g}$  creatinine as “high risk group” and provided follow up by an internist every 3 months at a special clinic. This high risk group was also further investigated as followed;

- Bone density measurement of both wrists (data is being analyzed)
- Renal function test (BUN, creatinine) revealed that 5% (n=40) of the high risk group could have early stage renal failure.

In 2005, toxicologists from Chiang Mai University Medical School and Kanazawa Medical University, Japan, jointly measured selected renal markers related to cadmium-induced renal failure namely urinary protein, urinary  $\beta$ 2-microglobulin and Urinary *N*-acetyl- $\beta$ -glucosaminidase (NAG)(5).

It was found that the proportion of the high risk group having  $\beta$ 2-microglobulin  $\geq 1,000 \mu\text{g/g}$  creatinine, Japanese cut-off level for people living in cadmium-polluted area, was 22.5% and 17.2% among males and females respectively. The proportion of the high risk group having NAG  $\geq 10 \text{ U/g}$  creatinine, the upper limit of that measurement, was 7.7% and 28.7% in men and women respectively. Lastly, positive rate for urinary protein, measured by urinary strip, was 39.8% and 28.7% in men and women respectively.

These results showed that the exposed population with renal tubular disturbance could potentially exist in Mae Sot and that the positive rates found were as high as those found among residents of polluted areas in Kakehashi River Basin, Japan. It was anticipated that a 10-year surveillance would be needed to reduce health risks among 800 high risk people, who had high urinary cadmium level ( $> 5 \mu\text{g/g}$  creatinine) and were at risk of having cadmium-induced renal failure, to acceptable level.

#### *Conclusions*

The results of environmental samplings, population survey and clinical assessment led to the conclusion that selected areas of Mae Sot district were highly contaminated with cadmium and that this level of contamination has already posed excessive risk of having cadmium-induced renal failure among the local residents who habitually consumed contaminated rice.

#### **Risk management**

To reduce risk posed by cadmium contamination among Mae Sot residents, a two-pronged approach was needed. The so-called “main” part was environmental and behavioral modification to reduce cadmium intake while the supportive part was long term health surveillance to detect, as early as possible, renal damage caused by cadmium.

#### *Bright start in 2004*

In 2004, after data on environmental samplings from DPC and preliminary results of population survey from Mae Sot Hospital were available, an initial risk management plan was set up under auspice of special committee led by DPC. Based on the cadmium level found in soil, DPC suggested discontinuation of rice cultivation in the area. This solution was fully supported

by health staffs, who, further added that contaminated rice consumption should also be stopped. However, if this option was to be adopted, alternative crops cultivation, or even alternative occupation, should have been suggested or provided for the local residents who had depended on rice and other edible crops cultivation through out their lives.

Instead of offering alternative crop cultivation, the MOA suggested cadmium absorption by a plant which was known as cadmium accumulator. At the same time, to encourage local residents to stop rice growing, local administration gave financial compensation to the residents based on the amount of rice stored from 2003 cultivation and the number of rice paddy fields owned.

#### *Difficult 2005*

In 2005, rice cultivation was halted while MOA was still searching for alternative crops cultivation solution. Residents began to protest that compensation was unjustly allocated particularly among the Karen population, a minority tribe living along Thai-Myanmar border including Mae Sot area. This dissatisfaction eventually bloomed into human rights debates and the Office of the National Human Rights Commission of Thailand stepped in to investigate and settle this issue.

Rumor was spreading that all exposed population would eventually suffer and die from renal damage and that hospital was not prepared for this increasing demand. Mae Sot Hospital was, then, pushed to seek for additional financial resources to expand the existing renal dialysis unit and to set up laboratory for cadmium and renal markers measurement needed for long term health surveillance.

On the other hand, the sole zinc mining company in the area was suspected as polluter and accountability was asked for. However, the unclear source of contamination, between natural and man-made origins, rendering it difficult to claim accountability from the zinc mine. The company itself has hired several research teams from academic institutions to study in the area and none of the studies had revealed positive correlation between cadmium in the environment and mining activities.

Meanwhile, faced with these difficulties, Ministry of Interior (MOI) has worked closely with key advocacy groups, particularly the Mae Sot Civil Society, to alleviate the problems. Several town meetings were organized by the Civil Society group to improve local residents' understanding of the situation. Emphasis was also placed on the collaboration between governmental offices and local residents to successfully reduce cadmium exposure.

#### *Difficulty continued for 2006*

MOA suggested sugar cane, decorative palm and rubber plantation to replace rice cultivation. However, up to present, these plants are still in experimental phase.

A social survey among 312 household leaders from 6 villages located in contaminated area in March 2006 (6) showed that residents who had better access to information could adjust and cope more positively with cadmium contamination compared to those neglected or having limited access. It was also noted that social and spiritual health was interrupted after discontinuation of rice cultivation. Mae Sot residents had a cultural calendar closely tied with rice cultivation cycle and it had been difficult for them to stop these activities and, to a certain extent, to change their agricultural habits.

A 3-year Mae Tao Creek area Development Plan was proposed to the cabinet, by MOI, early in September 2006. If approved, a 195 millions Bahts (4.8 millions US\$) -budget would be allocated for 14 projects classified under 4 strategies as followed.

- Strategy 1 : Soil rehabilitation
  - cadmium absorption by cadmium accumulating plant
- Strategy 2 : Pollution prevention and control

- environmental monitoring
- Strategy 3 : Economic development for security, health and quality of life
  - Alternative occupation promotion such as mushroom plantation
  - Fund for occupation changes
  - Fund for chronic renal failure patients
  - Hospital laboratory capacity building
  - Long term health surveillance
  - Alternative crops cultivation for ethanol production such as sugar cane and others
  - Animal health risk assessment
  - Detection of cadmium concentration in animal feedings
  - Decorative palm plantation promotion
- Strategy 4 : Capacity building for risk management
  - Funding for Mae Sot Civil Society activities
  - Mae Tao Creek Development Center
  - GIS of contaminated area

### **Conclusions**

Although multidisciplinary approach was used for environmental health risk management, public, in particular public health, staffs needed to search for alternative ways to manage health risks more participatory, economically, socially and culturally acceptable.

### **Acknowledgement**

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