Health Risk among Asbestos Cement Sheet Manufacturing Workers in Thailand

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Objective: *To assess asbestos exposure and calculate the relative risks of lung cancer among asbestos cement roof sheet workers and to predict the incidence rate of lung cancer caused by asbestos in Thailand.*
Material and Method: *A cross-sectional study was conducted in four asbestos cement roof factories. Both area and personal air samples were collected and analyzed employing NIOSH method # 7400 and counting rule A for all processess and activities. The time weight average exposures were calculated for each studied task using average area concentrations of the mill and personal concentrations. Then, cumulative exposures were estimated based on the past nation-wide air sampling concentrations and those from the present study. The relative risk (RR) of lung cancer among asbestos cement sheet workers was calculated and the number of asbestos related lung cancer case was estimated.*
Results: *The roof fitting polishers had the highest exposure to airborne asbestos fiber (0.73 fiber/ml). The highest average area concentration was at the conveyor to the de-bagger areas (0.02 fiber/ml). The estimated cumulative exposure for the workers performed studied-tasks ranged in between 90.13-115.65 fiber-years/ml while the relative risk of lung cancer calculated using US. EPA's model were 5.37-5.96. Based on the obtained RR, lung cancer among AC sheet in Thailand would be 2 case/year.*
Conclusion: *In case that AC sheet will not be prohibited from being manufactured, even though only chrysotile is allowed, the surveillance system should be further developed and more seriously implemented. The better control measures for all processes must be implemented. Furthermore, due to the environmental persistence of asbestos fiber, its life cycle analysis should be conducted in order to control environmental exposure of general population.*

Keywords: *Asbestos exposure, Asbestos cement roof sheet, Risk assessment*

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It has been long recognized that asbestos is harmful to human health. It can cause lung cancer, mesothelioma, and asbestosis. In the past, when there was no substitute for asbestos available, for the sake of good industrial hygiene practice, the appropriate exposure control measures were employed and the occupational exposure limits were enforced. Currently, asbestos has been banned in several countries, not only because it is carcinogen, but also because the substitutes have been researched and proven to be safer than chrysotile[1-3].

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Asbestos cement roof sheet has been classified as non-friable asbestos containing material (ACM) which does not generally release fiber unless damaged. It has been the first choice for people from medium and low income populations. Thus, AC sheets are still produced and used in Thailand and many other countries[4-7] especially in Asia and Africa due to its low cost and its several good properties, *e.g.* durability, strength, and ability to absorb heat from the sun.

All types of asbestos have been imported to Thailand since 1938. Approximately 120,000,000 tons per year have been imported in the last 20 years and about 90% of this was used in asbestos cement manufacturing[8]. Nevertheless, there were no asbestos related diseases or deaths reported in either the surveillance schemes or the Workmen's compensation fund. Until 1991 the Bureau of Occupational and Environmental Health[9] conducted a survey and reported finding 9 pleural thickenings from 106 diagnosed workers in asbestos used factories and in 1993 found 5 pleural thickenings out of 140 diagnosed workers. However, no asbestosis or other asbestos related diseases were found.

According to the experience of other countries whose asbestos consumption was high in the past *e.g.* USA, and Japan, many cases were found. The reasons for the absence or rarity of asbestos cases in Thailand could be the lack of a good surveillance system and Thai general medical doctors' lack of knowledge and awareness of occupational diseases. It could not be that asbestos does not harm Thais. It would be beneficial to public health personnel and policy makers if the number of asbestos cases could be estimated from our own data, so that a strategic plan on asbestos related issue and cases could be made. The aim of this study was to assess the level of asbestos exposure and use available data to calculate the relative risks of lung cancer among asbestos-cement roof sheet workers and to predict the mortality rate of lung cancer caused by asbestos exposure in Thailand.

Material and Method

A cross-sectional study was conducted in four asbestos cement roof factories during the year of 2002. The air samples were collected and analyzed using the NIOSH Method #7400[10] (issued 2, 1994), and counting rule A. Open face sampling was performed in both area and personal samples at an approximate flow rate of 2 lpm. The highest risk workers, as judged from observation during a walkthrough survey, were selected for air sampling. In the wet process areas such as mixing and forming roll area, a single sample for a full period was applied. In dusty areas or during processes such as the polishing of roof fittings, consecutive samples for the full period or consecutive samples for partial periods were taken.

A wedge of approximate 25% of the filter area was cut with a curve blade surgical steel knife #10 using a rocking motion to prevent tearing, and prepared for fiber counting with a phase contrast microscope using the acetone vaporizer, acetone and triacetin. The edge of the cover slip was glued to the slide using nail polish, and then the sample was labeled with a permanent ink pen.

Table 1. Asbestos concentration in 1987-1988[15] and 2000-2001[16] in asbestos cement roof tile

Year 1987-1988, 7 plants	Fiber conc. (fiber/ml)	
Area sampling	0.00-12.00	
Personal sampling	0.00-1.11	
Year 2000-2001, 3 plants	**Fiber conc. (fiber/ml)**	**No. of samples**
Raw materials preparation	1.15 (0.53-1.65)	3
Loading asbestos to production line	0.08 (0.02-0.19)	4
Loading & transfer asbestos bags	1.14 (0.01-2.2)	6

Although the process of AC sheet manufacturing has not changed much over the past 30 years, control measures have been developed and implemented. Such changes do affect the exposure of the workers therefore; the concentrations in Table 1 and those obtained in this study will be used as the workers' cumulative exposure. The activities studied were the unloading and transfer of asbestos bags from the containers to the warehouse, loading asbestos bags to the de-bagger, mixing and roll forming, separating cement sheets from the mold, polishing the roof fitting molds using sand-paper, loading products on to trucks, and testing asbestos and products in a laboratory.

Cumulative exposure for each task was calculated based on the assumption that the workers had worked in the cement factory for 30 years, from 1975 until 2005 as it usually takes 20-40 years from the first exposure to asbestos fibers and the onset of lung cancer. For the first fifteen year from 1975 to 1989 the exposure concentration level was 6.0 fiber/ml, the mid point of the maximum area concentration obtained from the survey of the Ministry of Public Health[10] during 1987 to 1988. There were not any control measurements or good practice in place. Those of the next ten years were the average of the Ministry of Labor[11] in 2000 - 2001 concentrations as assigned by tasks. For the last five year of workers' exposure, the results of this study were used in the calculation.

The US. EPA lung cancer model[12] was used for the calculation of the relative risk, *i.e.*

$$RR = CR\,(1 + K_L * CE_{10}) \ldots\ldots\ldots\ldots(1)$$

Where CR = Background lung cancer risk of the exposed population differs from that of the comparison population = 4.26

K_L = Lung cancer potency factor = 0.0029

CE_{10} = Cumulative exposure as measured by PCM (fiber-years/ml), omitting the last 10 years exposure.

Both CR and K_L were obtained from the EPA's estimation[12] by fitting the model to data from Finkelstein's 1984 study[13]. These constants were selected because the study was an analogous mortality study conducted among the asbestos *cement manufacturing plant* workers where *mixed asbestos* was used and the cumulative exposure of the workers ranged in between 75-105 fiber-years/ml, which all of these conditions were similar to our case.

Results

Airborne asbestos concentrations collected as personal and area samples presented in Table 2 and 3 respectively. Among the cement sheet manufacturing workers there were those whose duties were unloading asbestos bags from the container, fork-lift truck driving, placing asbestos bags on the conveyor to the de-baggers, polishing roof fittings, and checking & loading cement sheets onto the truck, as well as the testing product and asbestos in the laboratory. Only one out of these six duties had exposure level which exceeded the Threshold Limit Value (TLV) of 0.1 fiber/ml, and this was the polishing of roof fittings (0.73 fiber/ml). The second highest concentration of personal samples occurred among those placing asbestos bags on the conveyor to the de-bagger, 0.042 (0.003, 0.082) fiber/ml; the next was among checkers and those loading cement sheets onto the truck, 0.027 (0.001-0.82) fiber/ml. The lower end of the exposure were those of the fork-lift driver, 0.004 (0.000-0.017) fiber/ml; and workers unloading asbestos bags from the container, 0.008 (0.000-0.015) fiber/ml.

The average concentrations of area samples in the four factories were 0.017, 0.001, 0.006 and 0.001 fiber/ml respectively. None of the area samples had a concentration level which exceeded the TLV. The highest concentration was at the fitting packing area

Table 2. Airborne asbestos concentration, personal samples, in asbestos cement roof tile manufacturing

Areas/Duties	Type of samples	Fiber conc. (fiber/ml) Avg (min, max)	No. of Sample
Unload asbestos bags from container	P	0.008 (0.000, 0.015)	3
Fork-lift driver*	P	0.004 (0.000, 0.017)	4
Placing asbestos bags on conveyor to the de-baggers	P	0.042 (0.003, 0.082)	4
Polishing roof fittings	P	0.729 (-, -)	1
Checkers & Loading cement sheet to the truck	P	0.027 (0.001, 0.082)	4
Lab. staff	P	0.012 (0.002, 0.025)	3
Average (SD)		0.078 (0.19)	19

Table 3. Airborne asbestos concentration, area samples, in asbestos cement roof tile manufacturing

Areas/Duties	Type of samples	Fiber conc. (fiber/ml) Avg (min, max)	No. of Sample
Asbestos warehouse*	A	0.006 (0.000, 0.027)	8
Asbestos warehouse	A	0.000 (0.000, 0.001)	3
Conveyor to de-baggers	A	0.021 (0.000, 0.058)	4
Mixing and Forming roll areas	A	0.009 (0.003, 0.019)	3
Separate sheets from molds	A	0.002 (0.000, 0.006)	4
Fittings packing area	A	0.027 (-, -)	1
Products Warehouse	A	0.007 (0.000, 0.019)	4
Laboratory	A	0.002 (0.000, 0.004)	4
Average(SD)		0.007 (0.012)	31

A = area sampling, P = personal sampling

* During loading asbestos bag from container to warehouse

Table 4. Cumulative dose and relative risk among the asbestos cement roof tile manufacturing workers

Duties	CE_{10} (fiber-years/ml)	RR	95%CI of RR
Unload asbestos bags from container	101.44	5.51	4.25-6.78
Fork-lift driver	90.13	5.37	4.24-6.50
Placing asbestos bags on conveyor to the de-baggers	106.67	5.58	4.25-6.91
Polishing roof fittings	115.65	5.69	4.27-7.13
Checkers & loading cement sheet to the truck	90.42	5.38	4.25-6.50
Laboratory staff	90.16	5.37	4.25-6.50

(0.027 fiber/ml) and the next highest was at the conveyor carrying bags to the de-bagger, 0.021 (0.000, 0.058) fiber/ml.

The estimated cumulative exposure (CE) and relative risk (RR) of all studied tasks, based on the given situations, are presented in Table 4. The cumulative exposures were 90.13-115.65 fiber-years/ml and the RRs were 5.37-5.69. The highest cumulative exposure was among the roof fittings polishers, 145.65 fiber-years/ml; the RR for this group was 5.69.

Discussion

Overall airborne asbestos concentrations in this study tend to be lower than those conducted in the same kind of factory in the past. The factors contributed to the result could be the better dust control measures in the present as discussed below. Furthermore, the different of the air sampling and analysis techniques and the small number of samples were taken in each factory could cause the large variation of the result. These limitations could affect the uncertainty of the relative risk predicted.

The maximum area sample concentration was reduced from 12 fiber/ml to 0.058 fiber/ml. The personal sample concentrations taken from similar duties (asbestos bag opener vs. placing asbestos bags on the conveyor) was reduced from 1.11 fiber/ml to 0.082 fiber/ml. The reasons for this could be that the engineering controls such as the bag opening machine (the "de-bagger"), the bag lifting machine, and the enclosed mixing process were in use in 1997 as were vacuum cleaners, and stop using hook with asbestos bags were employed. Such control measures were implemented and have been improved more and more due to the pressure from both National and International pressure group. Similar action may influence other countries as well. About the same time s this study was being undertaken, Ansari FA, et al, 2007[14] was conducting workplace monitoring in an AC sheet factory in India using similar method of sampling and analysis. The fiber concentrations from the Indian factory were found to be about the same as those of the Thai factories (0.057-0.079 fiber/ml).

According to our observations, the highest level of asbestos exposure among AC sheet workers was when workers were unloading asbestos bags from the container, especially manually lifting, and polishing roof fittings. For the first task, it was because workers were exposed to freed asbestos fiber from the many damaged bags which was spilled in the containers. However, the exposure level during unloading was only 0.015 fiber/ml. This could be due to the fibers being packed tightly in the bags; they were stuck together in large crumbs and hardly dispersed. It was when workers carried out the bags and placed them on the pallet outside the container, the fibers could have been dispersed. This task was performed in an open air area. While polishing roof fittings, workers had the highest exposure to asbestos. This was to be expected, because such activity liberated many fibers from the sheets, dispersing them directly in to the workers' breathing zone. That polishing liberates a lot of fibers could be confirmed by the fiber concentration in the roof fitting packing area, where the workers brushed the edges of the sheets with a metal brush or sand paper. The fiber concentration was quite high, even though it was located far from the roof fitting polishing area and only performed for a comparatively short duration.

The conveyor leading to the de-bagger areas provided the second highest level among the personal samples. When a worker dropped the asbestos bags onto the conveyor, the repaired spots sometimes cracked; causing fiber to spill on the floor or the conveyor and be dispersed into the air when disturbed by the next bags impact on the conveyor. This could cause high exposure to the workers in these areas.

In regards to mortality studies[12] in asbestos cement factories using mixed asbestos, Finkelstein

(1984), Laquet et al (1980) and Hughes et al (1987) had shown cumulative exposure level of 75-105, 100-199 and 99.4 fiber-years/ml respectively and SMR's of 12.1, 1.1 and 1.8 respectively. The cumulative exposures among the AC sheet workers in Thailand based on the given situation were 90.13-115.65 fiber-years/ml, but no cases were reported. The predicted RRs were 5.37-5.69. The estimated incidence rate of lung cancer in Thailand is 25.9 per 100,000[15], The number of workers exposed to asbestos in AC sheet industry is approximately 1500. Thus lung cancer among AC sheet workers in Thailand is only 2 cases per year. The combined numbers of workers from other industries involving asbestos, such as workers who manufacture friction products, construction workers, and automobile repair workers, etc is approximately 100,000. That would translate to 133 occupational lung cancer cases related to asbestos per year.

Tossavainen[16] used the following formula to estimate the number of Mesotelioma cases based on asbestos consumption: Y = 6.82 x amount of consumption (25-30 years ago) + 0.43; where Y is number of cases/million/year, and the amount of consumption is the number of Kg/capita/year. Thailand's rate is 2.0 Kg/capita/year and has a population of 60 million. Based on this formula mesotelioma cases in Thailand then, could be 844 persons/year. The ratio of asbestos-related lung cancers to mesotelioma deaths range from one to two[17], thus, lung cancer cases would be approximately 500 cases per year. About 3% of lung cancer cases then, can be attributed to asbestos, and among these about 3 out of four cases are from the general population.

In conclusion, unless AC sheet manufacturing is not prohibited, and only chrysotile use remains permissible, a surveillance system should be further developed and more seriously implemented. This would ensure that workers' exposure is monitored, and asbestos related cases can be documented and effectively investigated. Improved control measures for all processes including the packaging of asbestos bags shipped to the manufacturing plant (must be unit loaded), better housekeeping (vacuum cleaning only in all areas of the production line), better storage (all stored products must be wrapped or covered with plastic sheet) and better, or safer, loading of products onto the truck (no manual lifting) are needed. In addition, asbestos exposure through out the life cycle of the AC sheet, *e.g.* its use in roofing, and its affects on those living in houses using it, its demolition, and its ultimate disposal, must be studied and controlled, not only its initial processing in manufacturing plants. Nevertheless, the present preferred control measure is the use of safe asbestos substitute materials.

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ความเสี่ยงต่อสุขภาพของคนงานผลิตกระเบื้องมุงหลังคา

วันทนี พันธุ์ประสิทธิ์, ดุสิต สุจิรารัตน์, เฉลิมชัย ชัยกิตติภรณ์

วัตถุประสงค์: *เพื่อประเมินการสัมผัสแอสเบสและคำนวณความเสี่ยงสัมพัทธ์ในการเกิดมะเร็งปอดในกลุ่มคนงานผลิตกระเบื้องมุงหลังคาแอสเบสตอส และทำนายอัตราการเกิดโรคมะเร็งปอดเนื่องจากแอสเบสตอสในประเทศไทย*
วัสดุและวิธีการ: *เป็นการศึกษาแบบตัดขวางในโรงงานผลิตกระเบื้องมุงหลังคาแอสเบสตอสสี่แห่ง โดยเก็บตัวอย่างอากาศทั้งแบบพื้นที่และแบบตัวบุคคล ด้วยวิธีของ NIOSH หมายเลข 7400 และนับเส้นใยด้วยกฎ เอ ในทุกกระบวนการผลิตและกิจกรรม ค่าเฉลี่ยการสัมผัสเส้นใยตลอดเวลาทำงานคำนวณจากค่าเฉลี่ยความเข้มข้นของเส้นใยในพื้นที่และความเข้มข้นของเส้นใยจากตัวอย่างบุคคล จากนั้น คำนวณการสัมผัสสารสะสมจากข้อมูลการเก็บตัวอย่างทั่วทั้งประเทศและข้อมูลจากการศึกษานี้ แล้วคำนวณหาค่าความเสี่ยงสัมผัส (RR) ของการเกิดมะเร็งปอดในกลุ่มคนงานโรงงานผลิตกระเบื้องมุงหลังคาแอสเบสตอส พร้อมทั้งประมาณจำนวนผู้ป่วยมะเร็งปอดเนื่องจากแอสเบสตอส*
ผลการศึกษา: *คนงานที่ทำหน้าที่ขัดครอบกระเบื้องเป็นผู้ที่สัมผัสเส้นใยแอสเบสตอสสูงสุด (0.73 เส้นใย/ลบ.ซม.) และความเข้มข้นเส้นใยในบริเวณสายพานลำเลียงถุงแอสเบสตอสไปยังเครื่องเปิดถุง (0.02 เส้นใย/ลบ.ซม.) ปริมาณการสัมผัสสะสมของคนงานมีค่าระหว่าง 90.13–115.65 เส้นใย-ปี/ลบ.ซม. ขณะที่ความเสี่ยงสัมพัทธ์ของมะเร็งปอดเนื่องจากแอสเบสตอสคำนวณโดยใช้โมเดลของ US. EPA มีค่าระหว่าง 5.37–5.96 และคำนวณหาจำนวนผู้ป่วยมะเร็งปอดเนื่องจากแอสเบสตอสด้วยค่าดังกล่าวได้ 2 ราย/ปี*
สรุป: *ดังนั้นในกรณีที่ไม่สามารถห้ามการผลิตกระเบื้องมุงหลังคาแอสเบสตอส แม้ว่าจะอนุญาตให้ใช้ได้เฉพาะแอสเบสตอสชนิดไครโซไทล์ ควรให้มีการพัฒนาระบบเฝ้าระวังและนำไปสู่การปฏิบัติอย่างจริงจัง รวมทั้งให้มีมาตรการควบคุมที่ดีกว่าสำหรับทุกกระบวนการผลิต และเนื่องจากแอสเบสตอสทนทานในสภาพแวดล้อมได้ดี จึงควรให้มีการศึกษาวัฏจักรชีวิตของกระเบื้องมุงหลังคาแอสเบสตอส เพื่อป้องกันการสัมผัสของประชาชนทั่วไป*