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Cancer incidence of Taiwanese shipbreaking workers who have been potentially exposed to asbestos

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ABSTRACT

Background: Shipbreaking remains one of the most dangerous jobs worldwide. Shipbreaking workers are exposed to many hazardous chemicals, especially asbestos. Unfortunately, long-term follow-up studies of cancer incidence patterns in shipbreaking workers are lacking. This study examines whether there is an increased risk of cancer among male shipbreaking workers over a 24-year follow-up period.
Methods: 4155 male shipbreaking worker's information was retrospectively collected from Kaohsiung's Shipbreaking Workers Union database from 1985. The study cohort was linked to the Taiwan Cancer Registry from 1985 to 2008 for new cancer cases. The expected number of cancers for shipbreaking workers was calculated by using the age (5-year intervals) and calendar time-specific annual rates of cancer incidence with reference to the general population of Taiwan from 1985 to 2008. Standardized incidence ratios (SIRs) were calculated as relative risk estimates. The hazard ratio (HR) for cancer was calculated for the shipbreaking workers with Total Exposure Potential Scores for asbestos.
Results: After consideration of a 5-year latency period, an elevated incidence of overall cancer (N=368; SIR=1.13 (1.01–1.25)), oral cavity cancer (N=83; SIR=1.99 (1.58–2.46)), and trachea, bronchus, and lung cancers (N=53; SIR=1.36 (1.02–1.78)) was found among male shipbreaking employees. Moreover, mesothelioma cases were found in those who had the occupation of flame cutter. The high asbestos exposure group was associated with an increased SIR of developing overall cancer and oral cancer, whether we considered a 5-year or 10-year latency period.
Conclusion: Asbestos-related diseases, including lung cancer and mesothelioma, were seen in excess in these shipbreaking workers and some cases appeared to have a dose-dependent relationship. Preventative measures among male shipbreaking workers should be researched further.

1. Introduction

The global shipping industry relies upon the developing world to dispose of retired deep-sea vessels through the process of shipbreaking. The ship-recycling market hit a 13-year high in 2009 and has attracted many international organizations concerned with environmental and occupational health effects in shipbreaking industry countries (Japan, 2012; Sarraf, 2010). South Asian countries (such as Bangladesh, Pakistan, India and China) are the leaders of the shipbreaking industry (Japan, 2012; Sarraf, 2010). A small percentage of ships are dismantled in facilities located in Europe and USA. These facilities mainly use dry docks or work alongside the piers. The International Labor Organization issued draft guidelines for shipbreaking industries to follow focusing on improvements for occupational safety and creation of healthy working conditions for employees (ILO, 2004). However, many shipbreaking yards located in developing countries do not operate according to laws and do not address work-related environmental hazards. These situations can potentially lead to large quantities of toxic materials escaping into the environment and cause serious health problems for workers, the local population, and wildlife.

Abbreviations: SIRs, age and calendar standardized incidence ratios; PVC, poly-vinyl chloride; ICD-O3, International Classification of Diseases for Oncology issued

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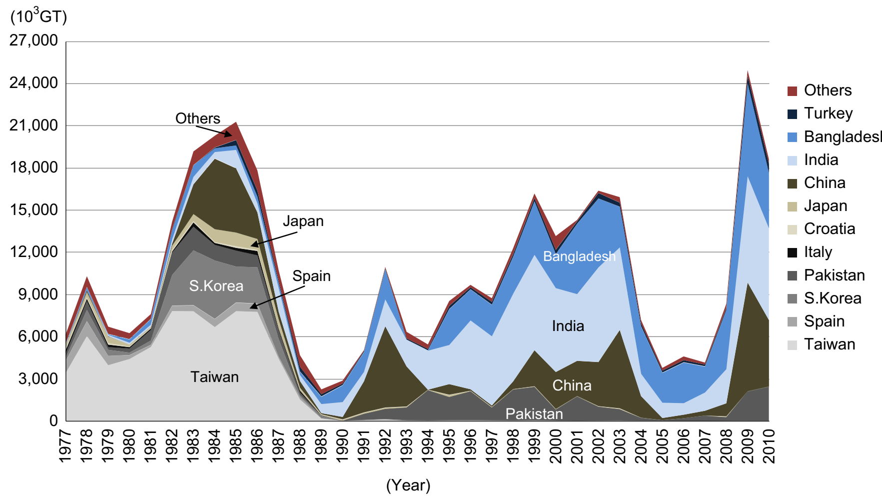

Fig. 1. Trends of GT of ships by major demolition countries in the world from 1977 to 2010.

The occupational environment has been fruitful for studying the etiology of human cancers. Many recognized human carcinogens can be found in the occupational environment. Many vessels that were built in the 1960s–1970s contained many tons of asbestos. The amount of asbestos in a naval vessel exceeded the expected amount in typical merchant ships (Sarraf, 2010). Every year, out of about 1000 ocean-going ships sold for recycling, 80% end up on the beaches of South Asia. There they are disassembled by thousands of poorly trained and poorly equipped workers who use blowtorches to demolish and dismantle the ships (Heidegger and Reuter, 2013). Exposure to asbestos remains a significant long-term problem in the shipbreaking industry. Asbestos can cause a range of diseases, such as lung cancer, mesothelioma, larynx cancer, ovarian cancer and asbestosis (Straif et al., 2009; WHO, 2006). Long-term health effects of cancer among shipbreaking workers have not been adequately documented. In addition to asbestos, shipbreaking workers are exposed daily to other environmental health hazards and toxins such as metals in paint, polychlorinated biphenyls, and metal fumes. Shipbreaking workers also risk falling off the ship and being crushed by falling plates (Mattorano et al., 2001; Rousmaniere and Raj, 2007; Tewari et al., 2001). Chronic illnesses and cancers with long latency periods caused by exposure to toxins are more difficult to track because workers are often not registered and may migrate within or outside their country.

Taiwan was the world's largest shipbreaking nation with approximately 65% of the obsolete ships in the world being crushed there. These vessels accounted for more than 67 million gross tonnage (GT) and were scrapped from 1977 to 1988 in Taiwan (Fig. 1), Taiwan's shipbreaking teams were able to dismantle a 30,000-ton tanker in as little as 6 weeks (Kojima, 2008). These past experiences in Taiwan provided a unique opportunity to study the long-term effects of the shipbreaking workers on the development of cancer.

In the present research, a cohort study was conducted to link male shipbreaking workers with the Taiwan Cancer Registry (TCR). This was done in order to test the hypothesis that shipbreaking workers have experienced an increased risk of neoplasm, particularly for asbestos-related cancers, after a 24-year follow up.

2. Methods

2.1. Study population

A 24-year retrospective study design was adopted for this study. The study's subjects were members of the 1985 Kaohsiung Shipbreaking Workers Union who participated in the state-run Labor Insurance Program. These workers were registered in the Union in order to be covered by insurance. A total of 70% of workers employed in the shipbreaking industry were members of the Union during this period. The Union kept employment records for each worker, including birth date, gender, job title, and employment period. The whole cohort, between 1975 and 1989, comprised 4962 workers. This number included 4157 men and 805 women. Female workers were excluded from this study because of their relatively small sample size and low cancer incidence numbers ($n=69$). The researchers also excluded two male shipbreaking workers who were diagnosed with cancer before employment. A total of 4155 male shipbreaking workers were used in this study. In order to qualify, these participants must have been employed for over a year and the date of their first employment in the shipbreaking industry must have begun in 1975. The Institutional Review Board of National Health Research Institutes, Miaoli County, Taiwan, approved this study.

2.2. Data sources for outcomes

Information on new cases of cancer was obtained from the Taiwan Cancer Registry (TCR), which was established in 1979 to monitor the incidence and the mortality rates of cancer in Taiwan (Bureau of Health Promotion, 2013). All hospitals with more than 50-beds and that provided outpatient and hospitalized cancer care were required to report all newly diagnosed malignant neoplasms to the registry. Under the current system, the TCR captures 97% of cancer cases in Taiwan (Bureau of Health Promotion, 2013). The percentage of Death Certificate Only Cases (DCO%) and the percentage of Morphologically Verified Cases (MV%) help indicate if the cancer registry is of good quality. High data quality represented by a DCO% would be 0% and MV% would be 100% (Bray and Parkin, 2009). The DCO% of the cancer cases in the TCR decreased from 8.78% in 1998 to 0.85% in 2010 (Bureau of Health Promotion, 2013). The MV% ranged from 87.5% in 2002 to 91.11% in 2010 (Bureau of Health Promotion, 2013). These indices show that the quality of the TCR is comparable to other well-established cancer registries in the world (Bray and Parkin, 2009; Shin, 2008). TCR has been frequently used as a quality measure or benchmark in cancer epidemiological studies (Chen et al., 2002; Lee et al., 2010; Tsai et al., 2013). The cancer found in participant records was coded based on the *International Classification of Diseases for Oncology, Third Edition (ICD-O3)*.

In the present study, the deterministic record linkage strategy was used to pick Personal Identification Numbers (PINs) for the study subjects as their unique identifiers. Records that share the same value identified the same person. Using each worker's PIN, researchers were able to link 377 newly diagnosed cancer cases from shipbreaking workers in the last 24 years (1 January 1985 to 31 December 2008) to the TNCR. To account for any latency period reflected in occupation exposure that could have been etiologically responsible for the cancer incidence, this analysis only included cancer incidence that occurred 5 and 10 years after the first day of employment (Silva, 1999).

2.3. Exposure scores for asbestos

The majority of the workforce in the shipbreaking industry consists of flame cutters, odd-jobbers, lifters, supervisors, knockers, sorters, drivers, and administrators. Flame cutters are reported to have the most severe exposure to hazardous substances because many of them perform their tasks in confined spaces or within close proximity to asbestos-related emissions (Krstev et al., 2007). After cutting, flame cutters collect and pack the pieces of the ship that they cut. They pass these pieces to the odd-jobbers who then continue with their respective tasks of

Table 1
The correlation coefficient between intensity of asbestos exposure ($n=7$) and asbestos sampling areas of the Kaohsiung harbor of Taiwan in 1987 ($n=91$).

Job categories	Intensity of asbestos exposure ($n=7$)		Environmental sampling in 1987 ($n=91$)											
			Asbestos (f/c.c)			Chrysotile (f/c.c)			Amosite (f/c.c)			Crocidolite (f/c.c)		
	mean	s.d.	mean	s.d.	R[a]	mean	s.d.	R[a]	mean	s.d.	R[a]	mean	s.d.	R[a]
Flame cutters	9.6	1.1	0.196	0.202	0.878[b]	0.044	0.058	0.672	0.029	0.028	0.708[c]	0.032	0.036	0.708[c]
Odd-jobbers	7.1	1.9	0.208	0.097		0.029	0.029		0.016	0.022		0.018	0.019	
Lifters	5.7	2.8	0.138	0.156		0.037	0.030		0.033	0.038		0.039	0.041	
Sorters	6.0	2.4	0.060	–		0.000	–		0.006	–		0.018	–	
Knockers	4.6	2.1	0.050	0.014		0.005	0.007		0.010	0.005		0.018	0.003	
Supervisors	5.6	2.4	0.020	–		0.000	–		0.005	–		0.008	–	
Drivers	2.6	1.5	0.020	–		0.000	–		0.005	–		0.008	–	
Administrators	2.1	2.2	0.020	–		0.000	–		0.005	–		0.008	–	

[a] Spearman's correlation coefficient between exposure intensity and environmental sampling.
[b] Correlation is significant at the 0.01 level (2-tailed).
[c] Correlation is significant at the 0.1 level (2-tailed).

transporting the packed pieces, clearing the cabin, and dismantling the asbestos materials and glass-fibers. The lifters use lifting equipment to separate and sort steel pieces.

A panel of seven experts was asked to assess exposure subjectively. The panel consisted of two occupational hygienists, four occupational physicians, and a risk assessment expert. The occupational hygienists previously worked in government agencies and had experience in the field of asbestos exposure assessment in the shipbreaking workplace. Occupational physicians are epidemiologists who also have had experience with the treatment of patients with a history of asbestos exposure. The experts responded to a survey with a 0-to-10 point rating scale (0: mild to 10: serious). The purpose was to score the intensity of asbestos exposure according to the eight job titles. The average amount of intensity of asbestos exposure within the eight job titles was flame cutters (scores=9.6), odd-jobbers (7.1), lifters (5.7), supervisors (5.6), knockers (4.6), sorters (6.0), drivers (2.6), and administrators (2.1) (Table 1). Moreover, this study assessed whether the intensity of asbestos exposure within the eight job titles reflected the real amount of asbestos to which workers in the shipbreaking workplace were being exposed. The information that was collected from the asbestos sampling throughout the 91 areas of Kaohsiung harbor in 1987 was applied and categorized into the eight job titles. This information is based on the data obtained from the thesis written by Dr. Yi-Chang Lin at National Taiwan University. The results showed that greater amounts of asbestos in the shipbreaking workplace were positively correlated with greater exposure intensities ($R=0.878$, $p<0.001$), particularly for Amosite and Crocidolite (Table 1). The researchers also used intraclass correlation coefficient (ICC) between the raters in experts for ranking eight job titles for the intensity of asbestos exposure ($n=7$; ICC=0.890). ICC was also used for the correlation between environmental asbestos levels and the intensity of asbestos exposure. The agreement between the experts (ICC) varied between 0.606 and 0.890. The occupational physicians showed a better agreement than hygienists. In comparison to actual exposure, the ranked intensity of asbestos exposure in the occupational physicians was better than the risk assessment experts and hygienists (Supplement 1–3).

The study calculated the Exposure Potential Scores for asbestos based on the formula listed below (1). The Total Exposure Potential Scores for asbestos were calculated for the eight job titles according to years of employment for each shipbreaking worker (2). Within the Total Exposure Potential Scores for asbestos subjects were categorized into high (≥ 45.46), medium (32.86–45.45), and low (<32.86) asbestos exposure groups.

$$EP_k = EI\left(\frac{T_k}{T_{max}}\right) \quad (1)$$

where

EP: exposure potential
EI: exposure intensity
T_k: the GT of ships broken in kth year
T_{max}: the GT of ships broken in 1982 (the maximum number of GT of ships broken over the years)

$$TEP_i = \sum_{k=1}^{n} EP_k \quad (2)$$

where

TEP_i: the total Exposure Potential Scores for asbestos of ith job title
k: the kth year on shipbreaking job

2.4. Statistical analysis

The categories of cancer that had less than 2 cancer cases were not shown in tables. Due to the Taiwan's Personal Information Protection Act that was established on October 1, 2012 there are new restrictions that require researchers to use symbols to express cancer cases that are less than 2 in a subgroup analysis. Those workers who survived between the time period of when their employment began to December 31, 2008 contributed to the person-years time. Those known to have deceased before the cutoff date contributed the person-year time between their work start date and their date of death or when they were diagnosed with cancer. The expected number of cancers for shipbreaking workers was calculated by the person-year approach, using the age (5-year intervals) and calendar time-specific annual rates of cancer incidence with reference to the general population of Taiwan from 1985 to 2008. SIRs were calculated as relative risk estimates. The 95% confidence interval (CI) for SIRs was estimated using Byar's approximation proposed by Breslow and Day (1987). The SIRs were calculated by each job group category (flame cutters, lifter, odd-jobbers, supervisors, and others) and by each of the asbestos exposure groups (high, medium, and low). The Cox proportional hazards model was performed to estimate the hazard ratio (HR) and the adjusted hazard ratio (AHR) for various types of cancers among shipbreaking workers with total Exposure Potential Scores for asbestos. The analysis was performed using SAS software (version 9.3; SAS Institute).

3. Results

By the end of the follow-up period (December 31, 2008) there were 368 cancer cases among the employees with at least 5 years of work experience and 347 cancer cases among employees with at least 10 years of work experience. More than half of the cohort subjects were less than 40 years old at the time of their first employment. The major job titles included flame cutters ($n=2825$), lifters ($n=867$), odd-jobbers ($n=238$), supervisors ($n=52$) and others ($n=173$). According to the categories of potential exposed scores for asbestos, workers were divided into high ($n=1143$), medium ($n=1407$), and low ($n=1605$) asbestos exposure groups (Table 2).

A statistically significant increase in SIRs was noted for overall cancer ($N=368$; SIR=1.13 (1.01–1.25)), oral cavity cancer ($N=83$; SIR=1.99 (1.58–2.46)), and trachea, bronchus, and lung cancers ($N=53$; SIR=1.36 (1.02–1.78)) after consideration of a 5-year latency period (Table 3). Moreover, the shipbreaking workers had a statistically significant decrease in SIRs for rectal cancer ($N=10$; SIR=0.51 (0.25–0.94)). Conversely, the SIRs for overall cancer and trachea, bronchus, and lung cancers increased the most, but were not statistically significant statistically after consideration of a 10-year latency period. No statistically significant increase in HR was noted for various cancers with duration of employment after consideration of either 5-year or 10-year latency period (Table 3).

Table 2
Demographic characteristics of the male shipbreaking workers, 1985–2008.

Demographic characteristics	Subjects		Person-years	
	n	(%)	*sum*	(%)
Total subjects	**4155**	**(100)**	**103037.6**	**(100)**
Non-cancer group	3778	(90.9)	95583.4	(92.8)
Cancer group	377	(9.1)	7454.3	(7.2)
Cancer group (5-year latent period)	368	(8.9)	7429.9	(7.2)
Cancer group (10-year latent period)	347	(8.4)	7284.0	(7.1)
Year of first employment				
1975–1979	1313	(31.6)	34926.2	(33.9)
1980–1989	2842	(68.4)	68111.4	(66.1)
Age of first employment (years)				
≤ 25	1286	(31.0)	33146.3	(32.2)
26-40	2162	(52.0)	54240.4	(52.6)
≥ 41	707	(17.0)	15650.9	(15.2)
Age at exit employment (years)				
≤40	2799	(67.4)	71192.3	(69.1)
41–55	1067	(25.7)	25826.2	(25.1)
≥ 56	289	(7.0)	6019.1	(5.8)
Duration of employment (years)				
<5	727	(17.50)	15702.6	(15.2)
5–7	1263	(30.40)	29809.2	(28.9)
7–9	881	(21.20)	22777.8	(22.1)
>9	1284	(30.90)	34748.0	(33.7)
Job title				
Flame cutters	2825	(68.0)	71251.7	(69.2)
Lifter	867	(20.9)	21236.0	(20.6)
Odd-jobbers	238	(5.7)	5078.2	(4.9)
Supervisors	52	(1.3)	1279.3	(1.2)
Others	173	(4.2)	4192.5	(4.1)
Asbestos exposure groups				
Low (<32.86)	1143	(27.5)	25867.1	(25.1)
Medium (32.86–45.45)	1407	(33.9)	34573.7	(33.6)
High (≥45.46)	1605	(38.6)	42596.9	(41.3)

In Table 4, the flame cutters had a statistically significant increase in the risk of overall cancer (N=236; SIR=1.24 (1.08–1.41)) and oral cavity (N=50; SIR=1.77 (1.31–2.33)) after consideration of a 5-year latency period. This information included mesotheliomas cases. For lifters and odd-jobbers, researchers observed a statistically significant increase in SIRs for oral cavity cancer. After consideration of a 10-year latency period the results were similar to the above mentioned.

In Table 5, overall and cause-specific cancer SIRs according to three asbestos exposure groups is presented. Whether the researchers considered 5-year or 10-year latency periods the high asbestos exposure group was associated with an increased SIRs of developing overall cancer and oral cancer. Moreover, mesothelioma cases only are found in the high asbestos exposure group. A statistically non-significant increase in SIRs for trachea, bronchus, and lung cancer was noted for the high asbestos exposure group. The low asbestos exposure group had a statistically significant decrease in stomach and rectal cancer. A statistically significant increase in SIRs for oral cavity cancer was noted in all three asbestos exposure groups.

Table 6 shows the Cox Proportional Hazards Model used to observe the HR and adjusted HR for all causes and cause-specific cancer among shipbreaking workers with total Exposure Potential Scores for asbestos. No statistically significant increase in HR was found for various cancers with total Exposure Potential Scores for asbestos even after adjusting for age of first employment, residence area, and premium ratable wage.

4. Discussion

In this 24-year follow-up study, increased risks of certain neoplasms and other particularly noteworthy asbestos-related cancers among shipbreaking workers were observed. The major

Table 3
Standardized incidence ratios (SIRs) and hazard ratio (HR) with 95% confidence intervals (CI) for various cancers, according to duration of employment.

Cancer site (ICD-O-3)	Total (5-year latent period)		Total (10-year latent period)		Duration of employment (5-year latent period)	Duration of employment (10-year latent period)
	N	*SIRs (95% CI)*[a]	*N*	*SIRs (95% CI)*[a]	*HR (95% CI)*	*HR (95% CI)*
All cancer	**368**	**1.13 (1.01–1.25)**	347	1.06 (0.95–1.18)	0.962 (0.902–1.026)	0.973 (0.910–1.040)
Oral cavity (C00, C01, C02, C03, C04, C05, C06, C09, C10, C12, C13, C14)	**83**	**1.99 (1.58–2.46)**	**80**	**1.92 (1.52–2.39)**	0.949 (0.826–1.090)	0.941 (0.816–1.084)
Nasopharynx (C11)	21	1.36 (0.84–2.08)	18	1.17 (0.69–1.84)	0.851 (0.657–1.103)	0.963 (0.727–1.276)
Esophagus (C15)	16	1.26 (0.72–2.04)	16	1.26 (0.72–2.04)	1.076 (0.782–1.479)	1.076 (0.782–1.479)
Stomach (C16)	19	0.95 (0.57–1.48)	19	0.95 (0.57–1.48)	0.924 (0.707–1.206)	0.924 (0.707–1.206)
Colon (C18)	13	0.59 (0.31–1.00)	**10**	**0.45 (0.22–0.83)**	0.890 (0.643–1.233)	0.974 (0.667–1.423)
Rectum (C19, C20, C21)	**10**	**0.51 (0.25–0.94)**	**10**	**0.51 (0.25–0.94)**	1.005 (0.641–1.576)	1.005 (0.641–1.576)
Liver and intrahepatic bile ducts (C22)	72	1.05 (0.82–1.33)	64	0.94 (0.72–1.20)	0.996 (0.861–1.151)	0.995 (0.851–1.163)
Larynx (C32)	3	0.61 (0.12–1.77)	3	0.61 (0.12–1.77)	0.994 (0.519–1.903)	0.994 (0.519–1.903)
Trachea, bronchus, and lung (C33, C34)	**53**	**1.36 (1.02–1.78)**	51	1.31 (0.97–1.72)	1.011 (0.854–1.197)	1.046 (0.879–1.245)
Mesotheliomas (C35)	#	10.7 (0.14–59.6)	#	10.7 (0.14–59.6)	–	–
Thymus, heart and mediastium (C37, C38, C39, C383, C384, C388)	3	2.34 (0.47–6.89)	3	2.34 (0.47–6.85)	1.085 (0.556–2.118)	1.085 (0.556–2.118)
Skin (C44)	13	1.49 (0.79–2.56)	12	1.38 (0.71–2.41)	0.896 (0.611–1.314)	0.813 (0.538–1.228)
Prostate gland (C61)	9	0.70 (0.32–1.32)	9	0.70 (0.32–1.32)	0.791 (0.519–1.205)	0.791 (0.519–1.205)
Bladder (C67)	12	1.11 (0.57–1.94)	12	1.11 (0.57–1.94)	1.113 (0.758–1.634)	1.113 (0.758–1.634)
Kidney (C64)	3	0.77 (0.16–2.26)	3	0.77 (0.16–2.26)	0.409 (0.110–1.517)	0.409 (0.110–1.517)
Other urinary organs (C65, C66, C68)	4	1.01 (0.27–2.58)	4	1.01 (0.27–2.58)	1.727 (0.569–5.242)	1.727 (0.569–5.242)
Brain (C71)	3	0.98 (0.20–2.86)	#	0.65 (0.07–2.35)	1.771 (0.656–4.780)	–
Thyroid gland (C73)	3	1.04 (0.21–3.05)	3	1.04 (0.21–3.05)	0.840 (0.438–1.611)	0.840 (0.438–1.611)
Unknown primary (C80)	7	1.37 (0.55–2.83)	7	1.37 (0.55–2.83)	0.786 (0.487–1.270)	0.786 (0.487–1.270)
Leukemia (C42, C77)	7	0.60 (0.24–1.23)	7	0.60 (0.24–1.23)	0.962 (0.620–1.492)	0.962 (0.620–1.492)

Bold italic, statistically significant; [#]The number of cancer cases less than 2.

[a] The expected number of cases amongst the total sample of 4155 workers was calculated based upon the age and calendar year-specific incidence rates of the general population.

Table 4
Standardized incidence ratios (SIRs) for various cancers among shipbreaking workers with different job titles, 1985–2008[a].

Cancer site (ICD-O-3)	Flame cutters		Lifters		Odd-jobbers		Supervisors		Others	
	N	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*
	5–year latent period									
All cancer	**236**	**1.24 (1.08–1.41)**	76	1.02 (0.81–1.28)	26	0.75 (0.49–1.11)	8	1.25 (0.54–2.47)	22	1.05 (0.66–1.59)
Oral cavity (C00, C01, C02, C03, C04, C05, C06, C09, C10, C12, C13, C14)	**50**	**1.77 (1.31–2.33)**	**21**	**2.38 (1.47–3.64)**	**6**	**2.76 (1.01–6.01)**	#	3.64 (0.41–13.1)	4	2.03 (0.55–5.20)
Nasopharynx (C11)	17	1.65 (0.96–2.64)	#	0.61 (0.07–2.20)		–		–	#	2.69 (0.3–9.72)
Esophagus (C15)	13	1.65 (0.88–2.83)	3	1.07 (0.21–3.12)		–		–		–
Stomach (C16)	15	1.41 (0.79–2.33)	3	0.65 (0.13–1.89)	#	0.35 (0.00–1.94)		–		–
Colon (C18)	6	0.48 (0.18–1.05)	4	0.78 (0.21–1.99)	#	0.38 (0.00–2.11)	#	2.12 (0.03–11.8)	#	0.65 (0.01–3.63)
Rectum (C19, C20, C21)	9	0.82 (0.37–1.55)	#	0.22 (0.00–1.23)		–		–		–
Liver and intrahepatic bile ducts (C22)	52	1.26 (0.94–1.65)	8	0.51 (0.22–1.01)	7	1.17 (0.47–2.4)	#	0.82 (0.01–4.54)	4	0.96 (0.26–2.45)
Larynx (C32)	#	0.71 (0.08–2.56)	#	0.88 (0.01–4.92)		–		–		–
Trachea, bronchus, and lung (C33, C34)	29	1.45 (0.97–2.08)	12	1.30 (0.67–2.27)	5	0.86 (0.28–2.01)	#	2.11 (0.24–7.62)	5	1.67 (0.54–3.90)
Mesotheliomas (C35)	#	18.74 (0.25–104.2)								
Thymus, heart and mediastium (C37, C38, C39, C383, C384, C388)	#	2.45 (0.28–8.85)		–		–		–	#	13.4 (0.17–74.4)
Skin (C44)	7	1.45 (0.58–2.98)	3	1.49 (0.30–4.36)	3	2.83 (0.57–8.27)		–		–
Prostate gland (C61)	6	1.06 (0.39–2.31)	#	0.31 (0.00–1.75)		–	#	2.61 (0.03–14.51)	#	0.86 (0.01–4.76)
Bladder (C67)	5	0.86 (0.28–2.00)	3	1.19 (0.24–3.48)	#	1.40 (0.16–5.04)		–	#	2.56 (0.29–9.24)
Kidney (C64)	#	0.87 (0.10–3.15)	#	1.15 (0.02–6.42)		–		–		–
Other urinary organs (C65, C66, C68)	#	0.46 (0.01–2.55)	3	3.21 (0.64–9.37)		–		–		–
Brain (C71)	#	1.03 (0.12–3.72)	#	1.50 (0.02–8.32)		–		–		–
Thyroid gland (C73)	3	1.57 (0.32–4.59)		–		–		–		–
Unknown primary (C80)	4	1.40 (0.38–3.58)	#	1.70 (0.19–6.13)		–	#	9.21 (0.12–51.26)		–
Leukemia (C42, C77)	4	0.58 (0.16–1.48)	#	0.38 (0.00–2.12)	#	0.82 (0.01–4.57)		–	#	1.37 (0.02–7.64)
	10–year latent period									
All cancer	**226**	**1.19 (1.04–1.35)**	70	0.94 (0.74–1.19)	24	0.70 (0.45–1.04)	7	1.10 (0.44–2.26)	20	0.95 (0.58–1.47)
Oral cavity (C00, C01, C02, C03, C04, C05, C06, C09, C10, C12, C13, C14)	**48**	**1.70 (1.25–2.25)**	**20**	**2.27 (1.39–3.51)**	**6**	**2.76 (1.01–6.01)**	#	3.64 (0.41–13.13)	4	2.03 (0.55–5.20)
Nasopharynx (C11)	14	1.36 (0.74–2.28)	#	0.61 (0.07–2.20)		–		–	#	2.70 (0.30–9.72)
Esophagus (C15)	13	1.65 (0.88–2.83)	3	1.07 (0.21–3.12)		–		–		–
Stomach (C16)	15	1.41 (0.79–2.33)	3	0.65 (0.13–1.89)	#	0.35 (0.00––1.94)		–		–
Colon (C18)	**5**	**0.40 (0.13–0.94)**	3	0.58 (0.12–1.71)		–	#	2.12 (0.03–11.82)	#	0.65 (0.01–3.63)
Rectum (C19, C20, C21)	9	0.82 (0.37–1.55)	#	0.22 (0.00–1.23)		–		–		–
Liver and intrahepatic bile ducts (C22)	48	1.16 (0.86–1.54)	7	**0.45 (0.18–0.93)**	6	1.00 (0.36–2.17)		–	3	0.72 (0.14–2.10)
Larynx (C32)	#	0.71 (0.08–2.56)	#	0.88 (0.01–4.92)		–		–		–
Trachea, bronchus, and lung (C33, C34)	29	1.45 (0.97–2.08)	11	1.19 (0.59–2.13)	5	0.86 (0.28–2.01)	#	2.11 (0.24–7.62)	4	1.34 (0.36–3.42)
Mesotheliomas (C35)	#	18.74 (0.25–104.3)								
Thymus, heart and mediastium (C37, C38, C39, C383, C384, C388)	#	2.45 (0.28–8.85)		–		–		–	#	13.4 (0.17–74.4)
Skin (C44)	7	1.45 (0.58–2.98)	#	0.99 (0.11–3.59)	3	2.83 (0.57–8.27)		–		
Prostate gland (C61)	6	1.06 (0.39–2.31)	#	0.31 (0.00–1.75)		–	#	2.61 (0.03–14.51)	#	0.86 (0.01–4.76)
Bladder (C67)	5	0.86 (0.28–2.00)	3	1.19 (0.24–3.48)	#	1.40 (0.16–5.04)		–	#	2.56 (0.29–9.24)
Kidney (C64)	#	0.87 (0.10–3.15)	#	1.15 (0.02–6.42)		–		–		–
Other urinary organs (C65, C66, C68)	#	0.46 (0.01–2.55)	3	3.21 (0.64–9.37)		–		–		–
Brain (C71)	#	1.03 (0.12–3.72)		–		–		–		–
Thyroid gland (C73)	3	1.57 (0.32–4.59)		–		–		–		–
Unknown primary (C80)	4	1.40 (0.38–3.58)	#	1.70 (0.19–6.13)		–	#	9.21 (0.12–51.26)		–
Leukemia (C42, C77)	4	0.58 (0.16–1.48)	#	0.38 (0.00–2.12)	#	0.82 (0.01–4.57)		–	1	1.37 (0.02–7.64)

Bold italic, statistically significant; #The number of cancer cases less than 2.

[a] The expected number of cases amongst the total sample of 4155 workers was calculated based upon the age and calendar year-specific incidence rates of the general population.

Table 5
Standardized incidence ratios (SIRs) for various cancers among shipbreaking workers with asbestos exposure groups, 1985–2008[a].

Cancer site (ICD-O-3)	**5-year latent period**						**10-year latent period**					
	Low asbestos exposure group		**Medium asbestos exposure group**		**High asbestos exposure group**		**Low asbestos exposure group**		**Medium asbestos exposure group**		**High asbestos exposure group**	
	N	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*	*N*	*SIRs (95% CI)*
All cancer	97	0.97 (0.78–1.18)	120	1.12 (0.93–1.34)	**151**	**1.26 (1.07–1.48)**	86	0.86 (0.69–1.06)	116	1.09 (0.90–1.30)	**145**	**1.21 (1.02–1.43)**
Oral cavity (C00, C01, C02, C03, C04, C05, C06, C09, C10, C12, C13, C14)	**24**	**2.19 (1.40–3.25)**	**26**	**1.86 (1.22–2.73)**	**33**	**1.96 (1.35–2.75)**	**23**	**2.09 (1.33–3.14)**	**26**	**1.86 (1.22–2.73)**	**31**	**1.84 (1.25–2.61)**
Nasopharynx (C11)	6	1.45 (0.53–3.16)	5	0.97 (0.31–2.26)	10	1.63 (0.78–2.99)	4	0.97 (0.26–2.48)	4	0.78 (0.21–1.98)	10	1.63 (0.78–2.99)
Esophagus (C15)	3	0.82 (0.16–2.38)	5	1.20 (0.39–2.80)	8	1.65 (0.71–3.24)	3	0.82 (0.16–2.38)	5	1.20 (0.39–2.80)	8	1.65 (0.71–3.24)
Stomach (C16)	**#**	**0.15 (0.00–0.83)**	11	1.70 (0.85–3.04)	7	1.02 (0.41–2.11)	**#**	**0.15 (0.00–0.83)**	11	1.70 (0.85–3.04)	7	1.02 (0.41–2.11)
Colon (C18)	5	0.71 (0.23–1.65)	4	0.56 (0.15–1.42)	4	0.50 (0.14–1.29)	3	0.43 (0.09–1.24)	4	0.56 (0.15–1.42)	3	0.38 (0.08–1.11)
Rectum (C19, C20, C21)	**#**	**0.16 (0.00–0.91)**	3	0.48 (0.10–1.39)	6	0.85 (0.31–1.85)	**#**	**0.16 (0.00–0.91)**	3	0.48 (0.10–1.39)	6	0.85 (0.31–1.85)
Liver and intrahepatic bile ducts (C22)	18	0.90 (0.53–1.42)	21	0.94 (0.58–1.44)	33	1.27 (0.87–1.78)	15	0.75 (0.42–1.24)	19	0.85 (0.51–1.33)	30	1.15 (0.78–1.65)
Larynx (C32)	#	0.65 (0.01–3.60)	#	0.63 (0.01–3.48)	#	0.56 (0.01–3.10)	#	0.65 (0.01–3.60)	#	0.63 (0.01–3.48)	#	0.56 (0.01–3.10)
Trachea, bronchus, and lung (C33, C34)	15	1.12 (0.63–1.85)	18	1.44 (0.85–2.27)	20	1.52 (0.93–2.35)	13	0.97 (0.52–1.66)	18	1.44 (0.85–2.27)	20	1.52 (0.93–2.35)
Mesotheliomas (C35)					#	29.1 (0.38–161)					#	29.1 (0.38–161)
Thymus, heart and mediastium (C37, C38, C39, C383, C384, C388)	#	2.54 (0.03–14.2)		–	#	4.07 (0.46–14.7)	#	2.54 (0.03–14.2)		–	#	4.07 (0.46–14.7)
Skin (C44)	4	1.44 (0.39–3.68)	4	1.41 (0.38–3.61)	5	1.63 (0.52–3.79)	4	1.44 (0.39–3.68)	3	1.06 (0.21–3.09)	5	1.63 (0.52–3.79)
Prostate gland (C61)	#	0.41 (0.05–1.47)	4	0.97 (0.26–2.48)	3	0.77 (0.16–2.26)	#	0.41 (0.05–1.47)	4	0.97 (0.26–2.48)	3	0.77 (0.16–2.26)
Bladder (C67)	5	1.41 (0.46–3.30)	3	0.86 (0.17–2.51)	4	1.06 (0.29–2.72)	5	1.41 (0.46–3.30)	3	0.86 (0.17–2.51)	4	1.06 (0.29–2.72)
Kidney (C64)	#	0.85 (0.01–4.71)	#	0.79 (0.01–4.40)	#	0.70 (0.01–3.89)	#	0.85 (0.01–4.71)	#	0.79 (0.01–4.40)	#	0.70 (0.01–3.89)
Other urinary organs (C65, C66, C68)		–	3	2.35 (0.47–6.86)	#	0.71 (0.01–3.93)		–	3	2.35 (0.47–6.86)	#	0.71 (0.01–3.93)
Brain (C71)	#	1.12 (0.01–6.26)		–	#	1.73 (0.19–6.24)		–		–	#	1.73 (0.19–6.24)
Thyroid gland (C73)		–	#	2.09 (0.23–7.53)	#	0.89 (0.01–4.97)		–	#	2.09 (0.23–7.53)	#	0.89 (0.01–4.97)
Unknown primary (C80)	3	1.85 (0.37–5.40)	3	1.81 (0.36–5.28)	#	0.55 (0.01–3.06)	3	1.85 (0.37–5.40)	3	1.81 (0.36–5.28)	#	0.55 (0.01–3.06)
Leukemia (C42, C77)	3	0.83 (0.17–2.44)	#	0.26 (0.00–1.45)	3	0.70 (0.14–2.05)	3	0.83 (0.17–2.44)	#	0.26 (0.00–1.45)	3	0.70 (0.14–2.05)

Bold italic, statistically significant; #The number of cancer cases less than 2.

[a] The expected number of cases amongst the total sample of 4155 workers was calculated based upon the age and calendar year-specific incidence rates of the general population.

Table 6
The hazard ratio (HR) for various types of cancers among shipbreaking workers with total Exposure Potential Scores for asbestos.

Cancer site (ICD-O-3)	5-year latent period			10-year latent period		
	HR (95% CI)	Adjusted HR (95% CI)[a]	Adjusted HR (95% CI)[b]	HR (95% CI)	Adjusted HR (95% CI)[a]	Adjusted HR (95% CI)[b]
All cancer	0.992 (0.985–0.998)	0.998 (0.991–1.005)	0.996 (0.988–1.004)	0.993 (0.986–1.000)	0.998 (0.991–1.006)	0.996 (0.989–1.004)
Oral cavity (C00, C01, C02, C03, C04, C05, C06, C09, C10, C12, C13, C14)	0.987 (0.973–1.001)	0.987 (0.973–1.002)	0.985 (0.970–1.001)	0.986 (0.972–1.000)	0.986 (0.971–1.000)	0.984 (0.969–1.000)
Nasopharynx (C11)	0.998 (0.971–1.025)	0.996 (0.969–1.025)	0.987 (0.955–1.019)	1.006 (0.977–1.037)	1.003 (0.973–1.034)	0.990 (0.957–1.024)
Esophagus (C15)	1.015 (0.982–1.049)	1.014 (0.980–1.049)	1.024 (0.987–1.062)	1.015 (0.982–1.049)	1.014 (0.980–1.049)	1.024 (0.987–1.062)
Stomach (C16)	0.999 (0.971–1.028)	1.013 (0.982–1.045)	1.002 (0.968–1.037)	0.999 (0.971–1.028)	1.013 (0.982–1.045)	1.002 (0.968–1.037)
Colon (C18)	0.971 (0.936–1.006)	0.985 (0.948–1.022)	0.981 (0.936–1.029)	0.974 (0.935–1.014)	0.989 (0.947–1.032)	0.983 (0.935–1.033)
Rectum (C19, C20, C21)	1.022 (0.976–1.070)	1.045 (0.996–1.097)	1.057 (0.999–1.117)	1.022 (0.976–1.070)	1.045 (0.996–1.097)	1.057 (0.999–1.117)
Liver and intrahepatic bile ducts (C22)	1.003 (0.988–1.018)	1.008 (0.993–1.024)	1.004 (0.986–1.022)	1.004 (0.988–1.020)	1.007 (0.991–1.024)	1.004 (0.986–1.022)
Larynx (C32)	0.999 (0.930–1.072)	1.002 (0.932–1.078)	1.009 (0.937–1.087)	0.999 (0.930–1.072)	1.002 (0.932–1.078)	1.009 (0.937–1.087)
Trachea, bronchus, and lung (C33, C34)	0.985 (0.968–1.002)	1.000 (0.982–1.019)	1.009 (0.987–1.030)	0.988 (0.971–1.006)	1.003 (0.984–1.022)	1.009 (0.987–1.030)
Thymus, heart and mediastium (C37, C38, C39, C383, C384, C388)	1.024 (0.954–1.099)	1.021 (0.950–1.098)	1.011 (0.936–1.092)	1.024 (0.954–1.099)	1.021 (0.950–1.098)	1.011 (0.936–1.092)
Skin (C44)	0.984 (0.949–1.020)	0.992 (0.951–1.035)	0.993 (0.952–1.036)	0.984 (0.948–1.022)	0.992 (0.951–1.035)	0.993 (0.952–1.036)
Prostate gland (C61)	0.982 (0.942–1.025)	1.004 (0.958–1.052)	0.998 (0.948–1.049)	0.982 (0.942–1.025)	1.004 (0.958–1.052)	0.998 (0.948–1.049)
Bladder (C67)	0.968 (0.933–1.005)	0.966 (0.924–1.009)	0.957 (0.910–1.006)	0.968 (0.933–1.005)	0.966 (0.924–1.009)	0.957 (0.910–1.006)
Kidney (C64)	0.964 (0.893–1.040)	0.967 (0.893–1.047)	0.956 (0.869–1.052)	0.964 (0.893–1.040)	0.967 (0.893–1.047)	0.956 (0.869–1.052)
Other urinary organs (C65, C66, C68)	0.959 (0.898–1.024)	0.983 (0.914–1.057)	0.960 (0.890–1.036)	0.959 (0.898–1.024)	0.983 (0.914–1.057)	0.960 (0.890–1.036)
Brain (C71)	1.035 (0.957–1.119)	1.030 (0.951–1.115)	–	–	–	–
Thyroid gland (C73)	1.001 (0.933–1.074)	0.998 (0.929–1.072)	1.003 (0.932–1.081)	1.001 (0.933–1.074)	0.998 (0.929–1.072)	1.003 (0.932–1.081)
Unknown primary (C80)	0.964 (0.917–1.013)	0.971 (0.922–1.022)	0.973 (0.923–1.026)	0.964 (0.917–1.013)	0.971 (0.922–1.022)	0.973 (0.923–1.026)
Leukemia (C42, C77)	0.994 (0.949–1.042)	1.003 (0.955–1.053)	1.013 (0.961–1.068)	0.994 (0.949–1.042)	1.003 (0.955–1.053)	1.013 (0.961–1.068)

[a] Adjusted for age of first employment and residence area.
[b] Adjusted for age of first employment, residence area and premium ratable wage.

finding of this study was an elevated incidence of overall cancer and trachea, bronchus, and lung cancers among male shipbreaking employees. Moreover, mesothelioma cases were found in both flame cutters and the high asbestos exposure group. Elevated overall cancer and trachea, bronchus, and lung cancers were consistent with the findings of the researcher's previous mortality study (Wu et al., 2013). A mixture of chemicals including asbestos, polycyclic aromatic hydrocarbons (PAHs), lead chromate, chromium, and cadmium are commonly seen in shipbreaking workplaces (Hossain et al., 2006; ILO, 2004). These chemicals are well recognized as being risk factors for lung cancer (Gregory, 1997; Mowe et al., 1984; Straif et al., 2009; WHO, 2006). The hazard is further enhanced by poor safety systems, hazardous working conditions, and that employees use their bare hands for dismantling the ships. Additionally, shipbreaking workers, similar to shipyard workers, were exposed to asbestos and to a mixture of toxic chemicals contained in a ship. A previous study reported that shipyard workers were at a higher risk of mortality from lung cancer by a magnitude of 26% (Krstev et al., 2007). Similar findings in shipyard workers were also reported in Finnish (18%) and Norwegian (69%) studies (Melkild et al., 1989; Tola et al., 1988).

The high asbestos exposure groups in shipbreaking industries have a higher risk of overall cancer and a slight increase in SIRs for trachea, bronchus, and lung cancers although they were not found to be statistically significant. The results also found mesothelioma cases in the high asbestos exposure groups of surviving shipbreaking workers. Asbestos-containing materials are commonly used for thermal system insulation and as surfacing materials (wall panels/bulkheads) in vessels. When World War II era ships were evaluated it was found that up to 88% of the weight of the ship was from thermal insulation products used on pipes and machinery that contained asbestos. Amosite was found to be the dominant navy insulation fiber that amounted to approximately 86% of all the asbestos fiber in the insulation systems of an average ship (Rushworth, 2005). Based on the Inventory of Hazardous Materials datasets that evaluated 14 merchants and 13 navy vessels, there were 509 t per million Gross Tonnage of asbestos found in the merchant vessels and 1722 t per million Light displacement tons in the navy vessels (Sarraf, 2010). This is likely a major contributor to the large amount lung cancer and mesothelioma (Gustavsson et al., 2000; WHO, 2006). Thus, asbestos exposure within shipbreaking workers can explain the increase in these cancer cases.

Different job titles were found to be associated with risks of different cancers. The researchers found that those who had the occupation of flame cutter were associated with the highest risks of developing overall cancer and had a slight increase in incidence of developing trachea, bronchus, and lung cancer. Flame cutters are the most skilled and best paid workers in the shipbreaking industry, but they also have the greatest likelihood of being exposed to certain toxic wastes such as PCBs, PAHs, asbestos, heavy metal dust, etc. Previous studies have noted that welding fumes may be associated with a higher incidence of lung cancer (SIR=2.5) (Danielsen et al., 1993). A meta-analysis provides a combined relative risk of 1.30 (95% CI 1.14–1.48) of lung cancer for the shipyard welders (Moulin, 1997).

During the machining processes for cutting, grinding, burning and chipping of paint, shipbreaking workers have a significant exposure to asbestos fibers, wood dust, man-made mineral fibers, PAHs, formaldehyde, and chromium. These factors are mentioned in past studies of oral cancer excess (Chiang et al., 2011; Merletti et al., 1991; Paget-Bailly et al., 2012). However, this research does not exclude the likelihood that betel quid chewing, cigarette smoking, and alcohol consumption that could also be responsible for an increased risk of incidence of oral cancer noted in the present study (Ko et al., 1995). Information on betel quid chewing, cigarette smoking, and alcohol consumption was not available for this study and it is not possible to directly assess their influence on the outcome.

A decreased risk of colon and rectal cancer was observed for the shipbreaking workers' cohort. Past occupational cohort studies indicated that socioeconomic status and education were positively associated with colon and rectal cancer (Colditz et al., 1997; Macfarlane and Lowenfels, 1994; Tavani et al., 1999). In Taiwan, employees in the shipbreaking industry tend to have a lower education, be from a social class that tends to have a higher proportion of physical activity in their occupations, and have a lower intake of meats and eggs. These factors are reasonable explanations of the decreased risk in colon and rectal cancer.

To the best of the authors' knowledge, this study is the first investigation of new cancer cases in cohorts of shipbreaking workers who have stopped working for a period of 24-years. Workers from the shipbreaking industry are usually not tightly organized and tend to have a high turnover rate. Over the past decade, there have been only a few investigations of the health effects of shipbreaking workers (Liu et al., 2003; Wu et al., 2013). This study is based on a large cohort with a satisfactory response rate and a long follow-up period. A nearly complete follow-up rate greatly reduces the potential of selection bias. Additionally, our study used the same dataset (i.e., TNCR) to retrieve the cancer incidence information for both the shipbreaking workers and the reference population of Taiwan. This ensures good comparability in the results and a lesser likelihood of information bias. Moreover, latency periods that reflected occupation exposures that were etiologically responsible for the cancer incidence were considered. Only cancer incidence that occurred 5 or10 years after first employment was counted in this analysis.

A major limitation of this study is the lack of personal sampling data. This made it difficult to analyze dose-response relationships. Shipbreaking industries in Taiwan have become gradually more regulated since 1983 and in 1993 they became completely prohibited. Thus, detailed information on multiple exposures to shipbreaking workers was unattainable. The researchers tried very hard to find survey data in the workplace of shipbreaking industry from 1960 to 1993 in Taiwan. Only one workplace survey by Dr. Yi-Chang Lin in 1987 was carried out that collected asbestos samples from 91 areas at Kaohsiung harbor. However, 91 environmental asbestos samples were mainly collected from highly exposed areas that reflected the flame cutter, odd-jobber, and lifter's workplace. On the contrary, it exhibited unclear recognition of asbestos concentrations among other subgroups as sorters, supervisors, drivers, and administrators (Table 1). Due to this situation, the researchers decided to use potential exposure scores for asbestos that considered working years to represent the long-term exposure levels. Secondly, certain competing causes of death (e.g., accidental deaths) reduced the likelihood of cancer incidence among shipbreaking workers (Liu et al., 2003; Wu et al., 2013). The real cancer incidence may be underestimated among male shipbreaking employees in this study. Thirdly, the healthy worker effect may reduce the occurrence of cancer and underestimate the effect of occupational exposure (Kirkeleit et al., 2013). Fourth, due to the unavailability of lifestyle data there was a lack of information on smoking, alcohol, and diet, etc. In comparison to previous Taiwan studies, the prevalence of smoking in the male general population (55–60%, 1976–1996) was slightly higher than male workers (48%, 1984–1997) (Bartrip, 2004; Tsai et al., 2005). These studies showed that tobacco use might not fully explain the cancer excess noted in this study. Fifth, previous studies demonstrated that there is a latency period of an average of 49.4 years for the development of mesothelioma (Bianchi et al., 1997), the 24-year follow-up may not have been long enough to observe mesothelioma. Moreover, potential under-estimation and possible misdiagnosis of mesothelioma have been reported according to a review study in Taiwan (Lee et al., 2010). Despite the above limitations presented, this study still found new mesothelioma cases in surviving shipbreaking workers. Finally, the effect of migration could result in workers that were diagnosed with cancer to migrate to other countries and not receive treatment in Taiwan. This will cause the cancer records within Taiwan to be reduced and underestimate results. Moreover, the researchers did not have information about whether the workers changed jobs during their exposure period. According to previous visits and reports about shipbreaking industries, flame cutters have the most severe exposure to hazardous substances and higher wage than others. If other shipbreaking workers changed jobs for higher wages rather than being flame cutters, it could cause a reduced amount of exposure in the assessment and underestimate the results.

In conclusion, the shipbreaking industry is still active in Asian countries including Bangladesh, Pakistan, India and China. The scraping process includes many toxic substances, leading to a potential for environmental damage as well as for human health effects. Despite the possible healthy worker effects, this long-term follow-up study demonstrated that shipbreaking workers experienced an increased risk of overall cancer, oral cancer, lung cancer, and mesothelioma. It is important for ship-owning and shipbreaking countries to enforce the regulations in place and make these jobs safe and clean for both the workers and for the environment.

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Appendix A. Supplementary information

Supporting information associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envres.2014.04.026.

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