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Assessment of the Future Mesothelioma Disease Burden from Past Exposure to Asbestos in Ship Recycling Yards in India

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Highlights of the study:

- No previous study has estimated the cancer risks associated with the past asbestos exposure of workers engaged in ship recycling in India.
- Before the implementation of legislation promoting sound recycling of ships, it is likely that airborne asbestos fibre concentrations in the yards in India could regularly have exceeded 100 fibres/ml.
- It is likely that there will be nearly 4500 mesothelioma deaths by the year 2027 as a consequence of improper handling of asbestos containing materials in ship recycling yards in India. These deaths have mostly gone unrecorded.
- More deaths are projected to occur amongst bystander workers in the yards than amongst those working with asbestos-containing materials.
- Recommendations are made for the safe management of asbestos containing materials in Indian ship recycling yards.

Abstract: The recycling of end-of-life vessels is a complex activity that generates an enormous amount of hazardous waste, including asbestos-containing materials (ACM). Efforts by the Government of India to comply with national and international regulations and improved standard operating procedures are expected to lower the exposure risk of the workforce to hazardous substances, including asbestos. The current workers are likely to face lesser risks than did those exposed in the past. The present study assesses the health risks from past exposure of asbestos for those workers engaged in handling and removing ACM in ship recycling yards before environmentally sound recycling of obsolete ships was introduced in the early 2000s. Estimates were made of the number of workers exposed, and the intensity of exposure and these data were used to estimate the likely number of mesothelioma deaths in the future. It was estimated that nearly 15% of the total workforce engaged in ship recycling will suffer from mesothelioma which translates to about 4,513 mesothelioma deaths among the total of 31,000 workers estimated to be ever employed in the yards from 1994 till 2002. Recommendations are made for a practical approach to the safe handling of ACMs in Indian ship recycling yards.

Abstract 199 words

Keywords: Asbestos exposure, Mesothelioma, Ship Recycling

(1) Introduction

Recycling of obsolete ships is an important economic activity for countries such as China, India, Pakistan, Turkey and Bangladesh (Welaya *et al*., 2012; Hiremath *et al*., 2015; Singh *et al*., 2017). However, over the past two or three decades, concern has been raised over the way this work was undertaken. The recycling of end-of-life ships has been a long-standing source of coastal pollution and a potential health hazard for the workers engaged in the ship dismantling operations, including from asbestos (Orloff and Falk, 2003; Demaria, 2010). India has the world's largest ship recycling operation – the Alang-Sosiya ship recycling yards, situated on the west coast of the State of Gujarat. This yard is responsible for 47% of all the ships recycled in the world and employs nearly 60,000 people (Deshpande *et al*., 2012). It started operations in 1982 and has expanded to more than 100 times its original size (Reddy and Manoharan, 2014). More than 350 ships are currently recycled every year in Alang-Sosiya (Deshpande *et al*., 2013).

In the past few years, there has been an effort to improve the infrastructure and implement a high standard of operating procedures in the Indian ship recycling yards. Many of the yards are now following the provisions of the Hong Kong Convention (HKC) and European Union Regulations (Hiremath and Vivek, 2018) for environmentally sound recycling of the end-of-life ships. Nearly half of the recycling yards in Alang-Sosiya are now HKC certified, demonstrating they are well equipped for undertaking green ship recycling activity and well informed about managing hazardous materials. However, during the past three decades, the conditions in ship recycling yards have undoubtedly been poor. In 1998, Greenpeace sent investigators to the Alang yards where they witnessed appalling working conditions and extensive environmental pollution; workers routinely had to remove asbestos-containing material (ACM) with their bare hands (Joshi *et al*., 2006). The conditions may continue to be poor in countries such as Pakistan and Bangladesh where the yards lack specific regulations and protocols for the management of asbestos and other hazardous wastes (Demaria, 2010; Pasha *et al*., 2012; Rabbi and Rahman, 2017; Rahman, 2017).

There is no information about the asbestos-related cancer risk for the workers in ship recycling yards in India. However, many authors have reported the occurrence of asbestos-related diseases among workers engaged in the ship-breaking and ship-repair activities elsewhere around the world (Puntoni *et al*., 2001; Krstev *et al*., 2007; Wu *et al*., 2015). Courtice *et al*. (2011) conducted a pilot study in Bangladesh among a group of internal migrant ship breakers to examine the prevalence of asbestos-related diseases, including asbestosis. This study reported that among 104 male ship breakers, the prevalence of asbestos-related disease was 12%, of which asbestosis accounted for 6%.

The present study aims to assess the risk of mesothelioma deaths from exposure to asbestos while recycling end-of-life vessels in India in the period prior to the introduction of improved working conditions around 2000. The paper also provides recommendations for the safe handling of ACMs at the recycling yards.

Process of ship recycling

The full extent of the hazard associated with removal of ACMs at the ship recycling yards was not appreciated in the past, and there were no defined procedures for ACM removal operations. Adequate preventive measures were not implemented in the Indian yards until the beginning of 2000. A typical ship recycling yard in India is presented in Figure 1. The steps involved in recycling an obsolete ship and the corresponding steps that generate asbestos fibers were identified and are presented in Figure 2.

The necessary procedures used for recycling end-of-life ships in Alang-Sosiya ship recycling yards are described here. First, the ship was beached by its propulsion power during high tide. The initial operations were performed in the primary cutting zone (wet inter-tidal region), and the remaining operations were conducted in the secondary cutting zone (harder dry area). After the sections of an obsolete vessel were manually cut away with the help of gas-torches in the inter-tidal region, the blocks were then dragged using winches to the dry area (Frey, 2015). The secondary cutting zone was then used for further cutting, sorting, and loading onto transportation vehicles as the ship recycling operation progressed. Demaria (2010) reported that ship recycling in India was a labour-intensive process. Typically, it required nearly three to six months for an average ship (15,000 tonnes) to be dismantled with a variable number of workers involved at different stages; from 150 to 300 workers ranging in age from 19-

45 years (IMF, 2006). According to Hiremath et al. (2015), the removal and disposal of the ACM typically took around one to two months. Asbestos fibers were generated from the demolition of various parts and equipment during the recycling in both the primary and secondary zones.

Amosite, chrysotile, and crocidolite asbestos were extensively used in shipbuilding operations since the 1880s (Harries, 1971a). Pipes and machinery insulated with molded sections containing amosite asbestos ranging from 15% to 90% were covered with a protective layer of chrysotile asbestos cloth (Harries, 1971b). Various ACMs inside the ship are inaccessible at the beginning of the ship recycling operation, and many workers came across the so-called "hidden" ACMs during the secondary cutting operations. These insulation materials were torn off the equipment and machinery using conventional drilling and cutting operations in the time before the implementation of the Hong Kong Convention for environmentally sound recycling of ships in India. A large amount of asbestos dust was typically released during the removal of ACMs from the ships, especially during the vigorous tearing-down process (Harries, 1968). The use of personal respiratory protection devices was not mandatory in Indian yards before 2000, which may have caused a high degree of exposure to the workers.

Reportedly, asbestos fibres were released primarily during the *removal of the propeller shafting, diesel engine, turbine engine/steam turbine, boiler, exhaust gas economiser, incinerator, auxiliary machinery, heat exchanger/heaters, valve, pipe, duct, tank, electric equipment, ceiling, floor and wall in accommodation area, galleys and messes, fire insulation, inert gas system, air conditioning system, and miscellaneous activities* (Du et al., 2018). Additionally, fibers were released from the removal of asbestos sheets used for acoustic insulation in the accommodation area of the ships. The general methods for removing the asbestos-containing materials from the pipe insulation were drilling, hammering, and scrapping. The ACM debris was collected in bags for disposal, which may also have contributed to the release of fibers in the surrounding environment. According to Harries (1968), there were many other minor processes involving the fitting and removal of ACMs which generated high dust concentration, such as the removal of friable asbestos board, cleaning pipes and glands previously lagged (material providing heat insulation for a water tank, pipes, etc.) with asbestos using wire brushes. The cleaning and bagging of the loose asbestos waste also generate an enormous quantity of asbestos dust in the ship recycling yards.

One of the milestones in ship recycling in India took place in 2003. Based on the HPC (High Power Committee) report submitted in 1999-2000, the Honourable Supreme Court of India passed an interim order while hearing the case no 657/95 accepting the recommendations of HPC. The Supreme Court Monitoring Committee (SCMC) was formed to monitor the orders of the court. It affected the ship recycling industries at Alang-Sosiya. Following this ruling, there was a dramatic decrease in the number of ships recycled at Alang-Sosiya and the ship recycling owners were compelled to provide protective equipment for their workers. Also, the adoption of HKC for the safe and environmentally sound recycling of ships (2009) has helped in minimizing exposure to asbestos fibers. The provisions of HKC required that third-party licensed contractors must wear half-face air-purifying respirator (APR) equipped with HEPA filters to reduce exposure risk.

Number of workers engaged in ship recycling in India

Alang-Sosiya is located in Taloja Tehsil of Bhavnagar District in Gujarat and stretches over about 10 km of coastline. The yard is divided into 167 plots that have been leased to private entrepreneurs for ship recycling. In 2015 these yards could recycle about 450 ships per year, producing around 4.5 million tonnes of steel for reuse. The ship recycling activity started in 1982 with the recycling of five ships, and it has grown considerably; over 5,000 ships have been dismantled since the yard opened. Figure 3 shows the number of ships dismantled in Alang per year from 1982 to 2010 (Demaria, 2010).

Most of the laborers in the ship recycling industry were uneducated rural migrants, who were provided with necessary skills training in the workplace through experienced workers or labor contractors (Demaria, 2010). Recruitment of laborers at Alang-Sosiya was unregulated, which was a vital characteristic of the informality of this industry. The number of workers engaged in ship recycling was estimated based on the number of ships recycled from 1982 to 2002. There were an estimated 30,100 workers employed in the yards during this period.

(2) **Methodology**

The asbestos fibre exposure was estimated using the method developed by Cherrie *et al*. (2018), which relies on descriptive information about the circumstances of the work that was obtained from the published literature. The assessment is based on the tasks undertaken and includes parameters for asbestos emission potential, activity emission potential, the effectiveness of any local control measures, passive emission, the fractional time the asbestos source was active, and the efficiency of any respiratory protection worn. The exposure estimates were calculated for three major groups of activities; namely, removal of the boiler and engine rooms (delagging of insulation materials), removal of the acoustic doors (accommodation area of the vessel) and other ACM encountered during ship dismantling in the primary as well as secondary cutting zone. The exposure estimates were calculated for both the 'near-field, - the volume around the worker whose exposure is being investigated, and 'far-field' area, which comprises the remainder of the work environment. We assume the near-field estimates are relevant to workers directly involved with work on ACMs and far-field levels are relevant to the exposure of bystanders. It is important to note that the exposure modelling is dependent on the intrinsic emission potential, which in turn is dependent on the proportion of amphibole asbestos in the materials being removed from the ship. As reported by Mikelis (2008) the average age of vessels worldwide that were dismantled during 1990's was 26-27 years. Hence, most of the ships that were recycled during 1990s' would have been built during 1970's, and we consider there was high possibility of finding amphibole asbestos in such vessels.

Also, as reported by Franke and Paustenbach (2011), the forms of asbestos that were typically used commercially over the past 100 years were: (1) Chrysotile (white asbestos) which was the predominantly used from the 1930s, (2) amosite (an amphibole) was extensively used in shipbuilding from 1940 to 1970 (Balzer and Cooper, 1968) and (3) Crocidolite was used in some specialized gaskets, packing, pipe, commercial siding, and filters such as those used in gas masks. Other forms of asbestos, such as fibrous anthophyllite and tremolite, were present in trace amounts in various products.

Rushworth (2005) reported that amosite was predominantly used as an insulation material in vessel built in 1960s and 1970s (nearly 86% of the ACMs found in naval ships reportedly contained amosite). In the present study, the intrinsic emission for all the work activities has been estimated by assuming that an end-of-life vessel contained chrysotile and amosite asbestos. The intrinsic emission of 3.5 fibres/mL was used in the study, which is the average of chrysotile and amosite in the Cherrie et al. model).

The year 1994 was chosen as an indicator year for the study because virtually all the workforce engaged in ship recycling activity were expected to be potentially exposed to the airborne asbestos during that period. Post-2002, with the introduction of legal restrictions on the operators of the ship recycling yards, it is likely that exposure to asbestos has been reduced. Therefore, in this study risk analysis was undertaken for the period during 1994 and 2002. Since there is no information about the gender, date of birth, date of first employment in the shipyards or the date of last employment in the yards for workers deployed in ship dismantling operations, these parameters were estimated based on a series of assumptions. First, it was assumed there was uniform distribution of the age of the workers, with a lower age limit of 19 years and an upper age limit of 45 years. Further, the average duration of employment for each worker was calculated as the difference between the indicator year (1994) and the year when legal restrictions were in place, *i.e.*, 2002.

The exposure estimates have been used to calculate the mesothelioma risk estimates by adopting the model developed by Berman and Crump (2008b). This model estimates the probability of incidence of mesothelioma for each of the workers group. The workers were further divided into near-field and far-field exposure by the work they performed, and the number of workers required conducting various tasks at the recycling yard. Mesothelioma risk for both the near-field and far-field has been estimated separately. It was assumed that 30% of the total workforce was directly involved in the dismantling of ACMs (near-field) and 70% of the workforce were indirectly exposed to the asbestos fibres (far-field). Furthermore, it was assumed the type of asbestos fibres constituting the ACMs in the ship recycling was the mixture of amosite or crocidolite and chrysotile (Harries *et al*., 1971).

Mesothelioma mortality risk was estimated by using the Berman and Crump equations:

Mesothelioma risk = 0	**If $0 = t < 10$**
Mesothelioma risk = $K_M \times E \times (t-10)^3$	**If $10 \leq t < 10+D$**
Mesothelioma risk =$K_M \times E \times [(t-10)^3 - (t - 10 - D)^3]$	**If $10 + D \leq t$**

Where $K_M = 0.73 \times 10^{-8}$, E = average exposure intensity, t = time since first exposure and D = duration of exposure (Berman & Crump, 2008a; Berman & Crump, 2008b)

All members of the workforce were assumed to be alive in 2002. Subsequent survival was estimated using the life expectancy data of India (extracted from World Bank data). Each worker contributed one person-year-at-risk (PYAR) to each year until they reached the average life expectancy based on their age in 1994. Total risk in each of the years for the group of 30,100 workers was calculated as the sum of the individual risks multiplied by PYAR for each worker. For the calculation of mesothelioma risk, time since first exposure was also calculated for each year, based on year of first employment in the yard.

(3) **Results**

The estimated average exposure level for the three work activities assessed was 103 fibres/ml (to the workers during the demolition of engine rooms and boiler rooms), 320 fibres/ml (during the demolition of accommodation area such as doors) and 42 fibres/ml (during the demolition of other ACM inside the ships). The corresponding far-field exposure levels, which are relevant to bystander exposure, were 23 fibres/ml to those working near the engine and boiler rooms; 140 fibres/ml near the demolition of accommodation area and 1.1 fibres/ml near work with other miscellaneous ACMs inside the ship. Mesothelioma risks to workers in intervals of five years are presented in Figure 4, which shows the estimated number of deaths from mesothelioma for the three work activities assessed and for the bystanders (i.e. based on the total far-field estimates). The number of total deaths estimated to happen in 2017 is 1841, and over the whole period there are estimated to be 4,515 deaths from mesothelioma; nearly 15% of the total workers employed in 1994. The year when maximum deaths are predicted to occur is 2027, with a rapid increase in the predicted death toll between 2012 to 2017.

It is noteworthy that the younger employee population is at higher risk than older employees because they are more likely to develop the disease by the time they reach their maximum life expectancy. A uniform age distribution of the worker population was assumed in the study but it is plausible that a more significant proportion of the workers were younger because the work was physically demanding, and in this case the death burden might have been underestimated using our assumptions. In addition, it is recognized that risk calculations were based on the 1994 -2002 period while the ship recycling operations in Alang actually began in 1982. This may also have resulted in an underestimate to the mesothelioma burden in this workforce.

It is also noteworthy that the number of predicted deaths amongst bystanders (far-field exposure) exceeds the number of deaths from those directly working with ACMs (near-field exposure); 3021 (14% of the total by-standers population) and 1494 (nearly 16% of the total near-field population) mesothelioma deaths were estimated respectively. This indicates the extent of vulnerability of employees who were deployed to work in the vicinity of boiler rooms, engine rooms etc.

(4) Discussion

Most people engaged in ship recycling activities in Alang-Sosiya were migrant workers who were employed on a contract basis. There was no medical supervision and no health check-ups after their employment ended. Due to the inherent long latency for mesothelioma, it is difficult to identify the incidence of mesothelioma amongst the ship workers after they stopped work in the yards and had moved from the area. In addition, the relatively short life expectancy of the population plays an essential role in the expression of mesothelioma risk. By the time the workers were likely to develop the disease they would be at high risk of death from other competing diseases. For example, the life expectancy of India before 1980 was less than 50 years and as a result, fewer deaths were predicted in the earlier years of our study. However, as the life expectancy has improved in recent years to more than 65 year, more deaths from mesothelioma are expected in the future. One of the limitations of this study could be that the smoking habits of the workers and other mortality risk factors have not been considered. Although smoking is not expected to contribute to the development of mesothelioma (Noonan, 2017), it would affect mortality from competing causes, which we have assumed were comparable to the general population in India. If the workers smoked more than the general population then this could have resulted in an overestimation of mesothelioma risk in our study. However, we have not estimated the lung cancer risk from the asbestos work, and this would have significantly increased the risk amongst workers who smoked tobacco. All factors considered, it is most likely that the estimates in this study are conservative, and the estimated asbestos-related deaths are probably understated.

Exposure estimates in the Indian ship recycling industry from this study are supported by historical studies undertaken by Harries (1968; 1971a and 1971b) in the UK ship repair sector. The estimates of asbestos exposure for specific activities such as work in engine rooms, boiler rooms and demolition of accommodation areas in this study is closely aligned with the findings of Harries. For example, Harries (1971b) reported the concentration of asbestos during the removal of the pipe lagging in a boiler and engine room to be 83 and 52 fibres/ml, respectively. This aligns with the estimated asbestos exposure in this study for removal of pipe insulation in a boiler room of 103 fibres/ml. Similarly, asbestos exposure estimates for demolition of an accommodation area (an activity with high asbestos concentration) exceeded 200 fibres/ml (Harries, 1971b). Harries also reported that asbestos exposure to relatively high concentration (50 fibres/ml) from samples in passages close to ACM work. The asbestos concentration suggests that bystanders at ship recycling yards are likely to be at high risk. Similar results were obtained in the present study with respect to the estimated asbestos exposure for the far-field workforce. The findings indicate that asbestos exposure estimates in Indian ship recycling yards were comparable with historical concentrations of respirable fibres in the ship building and repair yards of the UK.

Wu *et al.* (2014 and 2015) reported that shipbreaking workers experienced an increased risk of mesothelioma and other cancers due to potential exposure to asbestos fibres. However, their exposure estimates (mean levels mostly less than 0.2 fibres/ml) and the number of mesothelioma cases (less than two cases amongst 4,155 male workers) linked to Taiwanese shipbreaking yards were orders of magnitude lower than our estimates. The authors reported that potential under-estimation of mesothelioma cases in Taiwanese ship recycling yards may be due to three reasons: (1) possible misdiagnosis of the disease, which is supported by the studies conducted by Lee *et al.* (2010); (2) migration of workers with cancer to other countries and so they did not receive treatment in Taiwan and (3) the very long latency period, with an average of 49.4 years may mean disease is still to manifest (Bianchi *et al.*, 1997; Wu et al., 2013). The lower exposure estimates in Taiwanese shipbreaking may reflect the relatively well controlled conditions that applied before the industry migrating to India and other low cost countries.

The objective of this study was to estimate the mesothelioma deaths amongst workers exposed to asbestos in dismantling activities in ship recycling. There is a marked lack of data and information on the number of deaths from mesothelioma and other asbestos-related diseases in India (Kazan-Allen, 2005; Murlidhar and Kanhere, 2005; Delgermaa et al. 2011). As reported by Burki (2010), the Government of India has an indigent, almost non-existent, system for recording asbestos-related deaths and disease. Only 25 population-based cancer registries are active, covering just 7.45% of the Indian population. The numbers of mesothelioma deaths recorded in these registries are meager (0.05-0.1 among men per 100,000 populations and 0.05-0.08 among women per 100,000 population) as reported by Bianchi and Bianchi (2014).

Estimates from the present study shows that, it is likely that the mesothelioma death rate is nearly 15% in this group of highly exposed workers. The number of deaths recorded in Indian population-based cancer registries appears to be too low. Burki (2010) noted that in India, amongst all 300 medical schools, only one has a training program in occupational health. There is a strong possibility that the asbestos-related diseases are being misdiagnosed as other lung tumours in India and other South Asian countries (Courtice et al., 2011; Jadhav and Gawde, 2019). It is therefore unsurprising that more than 1800 mesothelioma deaths (2017) were predicted in this study amongst the former Alang-Sosiya workers; most of these deaths have gone unnoticed. It indicates limited occupational health knowledge of physicians and the lack of regional research on both asbestos-related disease and occupational disease in the ship recycling industry. Clearly, there is a need for new initiatives to identify all cases of mesothelioma occurring in the country.

While India is trying to phase out the use of asbestos, the demand for asbestos in the Indian market continues to be around 200,000 to 300,000 tonnes per year (Indian Bureau of Mines 2017) and reportedly, 10 million workers are occupationally exposed to the unsafe levels of asbestos and other hazardous dusts in India (Allred et al., 2003). Many researchers across the globe have reported that the occurrence of mesothelioma and asbestos-related diseases from occupational exposure to asbestos (Anderson et al.,2005; Pesch et al., 2010; Mensi et al., 2011; Micallef et al., 2019). There could be an alarming situation especially in countries with large population such as India. Beckett (2007) speculated "…that a single batch of asbestos mined in the 1930s could have resulted in plaques and asbestosis in Canadian miners in the 1960s, lung cancer and mesothelioma in US shipyard workers in the 1970s, and in the future, result in lung disease in Indian and Pakistani ship-breakers in the 2010s, and mesothelioma in the 2030s in Indians and Pakistanis exposed currently as children to improperly discarded asbestos waste." Given the appalling loss of life from ACMs throughout the world, the efforts to ban asbestos use and carefully manage asbestos removal activities are essential for addressing this severe problem in India and across the world.

There is an urgent need for reliable risk management and mitigation policies and practices in India to ensure that asbestos-related health hazards are adequately controlled. Most importantly, such policies and practices need to be based on scientific evidence-based studies that adequately distinguish hazardous situations from those that are not (Berman and Crump, 2008a). Many yards at Alang-Sosiya are now engaging third-party licensed contractors to undertake the work in a safe way, but many of the yards are still not certified by HKC. It is likely that poor working conditions continue to prevail in these yards resulting in unacceptable asbestos exposure to the workers.

The most effective control of airborne asbestos fibres concentrations in ship recycling yards is to seal off the source of contamination and use exhaust ventilation combined with high efficiency full-face respiratory protection for workers handling ACM. However, introducing exhaust ventilation inside a vessel is often not a feasible solution. In such cases, the entire area where ACM is present should be enclosed and the removal operation should be conducted with the help of a licensed contractor. Also, after the removal operation, the bagging and packing of the ACM debris should be carefully supervised to avoid further exposure.

Stricter monitoring of the health and safety of the workers and specialized training programmes to make workers aware of safe handling of asbestos-containing materials are recommended. The poor record of diagnosing asbestos-related diseases in India is a severe hurdle in assessing the health risks associated with asbestos exposure, and it is further recommended that current and former workers should have access to proper medical support if they become ill. Scientific evidence-based studies coupled with the requisite analyses are essential to developing evident-based policies, which can help create effective and appropriate work policies, a sound health monitoring regime and a comprehensive program for mesothelioma the workforce in ship recycling and other similar industries.

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Figures

Figure 1: Typical ship recycling yard at Alang-Sosiya

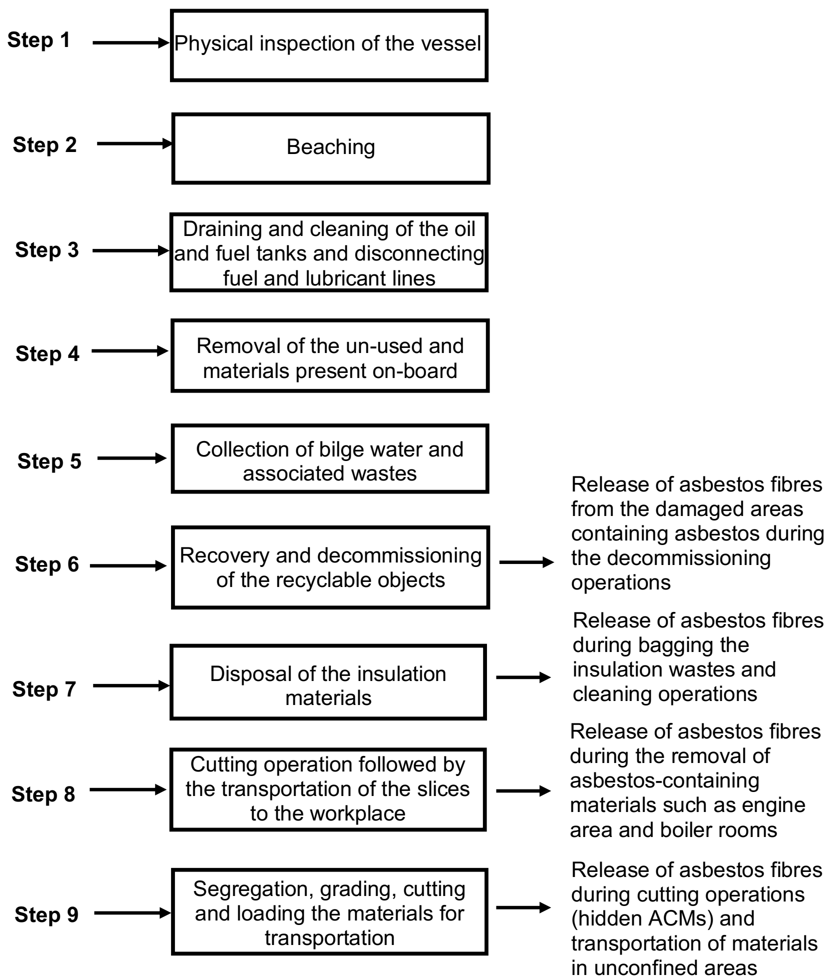

Figure 2: Typical steps of ship recycling at Alang-Sosiya ship recycling yard in India and corresponding release of asbestos fibres at each of the steps. Activities such as recovery of recyclables, disposal of insulation material, cutting, handling and transportation of ACWs generates asbestos fibres in a ship recycling yard.

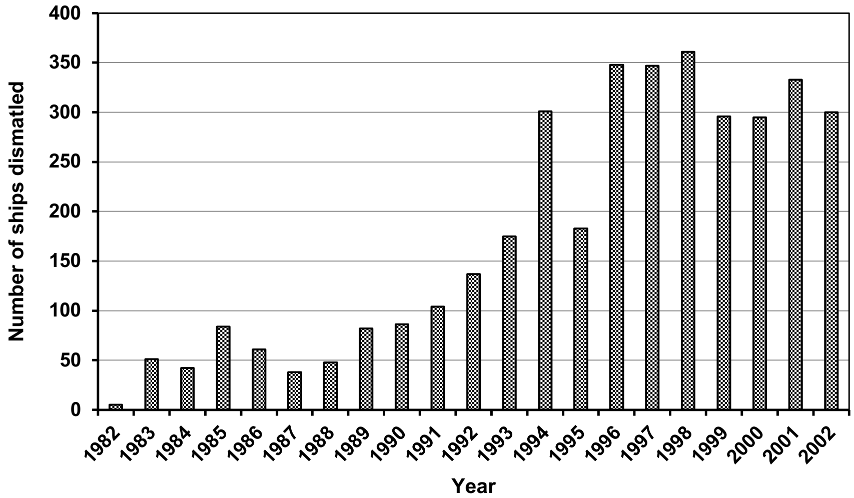

Figure 3: Number of ships dismantled per year from 1982 to 2010 (Demaria, 2010)

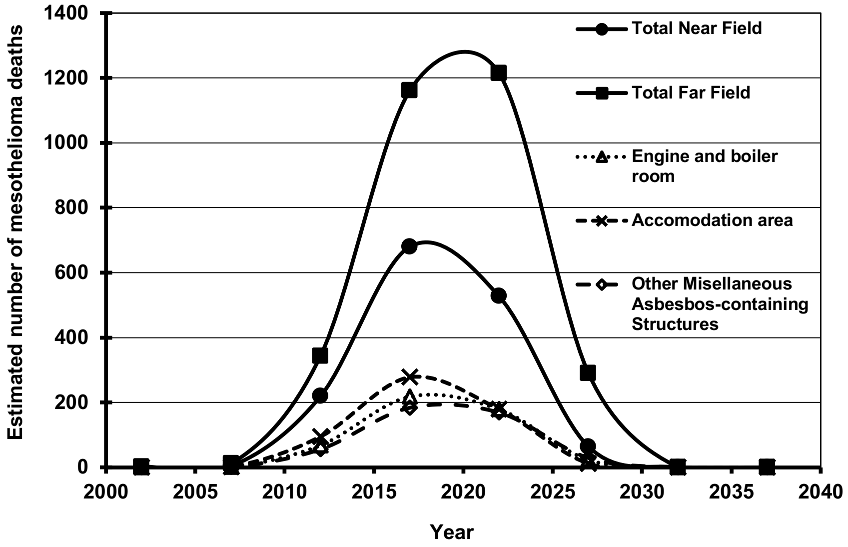

Figure 4: Mesothelioma risk assessment to the near filed population and bystanders working at ship recycling yard

Additional Online Material

Asbestos emission from Ship Recycling Activity:

Particulars	Near-field				Far-field			
	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Spec
Substance	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	
Task description	Drilling/ Hammering	Scrapping	Bagging	0.00	Hammering	Scrapping	Bagging	0.0
Intrinsic emission (fibres/mL)	3.50	3.50	3.50	0.00	3.5	3.5	3.50	0.0
Handling (fibres/mL)	3.00	30.00	3.00	0.00	3.00	30	3.00	0.0
Local controls (fibres/mL)	1.00	1.00	1.00	0.00	1.00	1	1.00	0.0
Active emission (fibres/mL)	10.50	105.00	10.5	0.00	10.50	105	10.50	0.0
Passive emission (fibres/mL)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Total emission (fibres/mL)	10.5	105	10.5	0.00	10.50	105	10.50	0.0
Time source active (fibres/mL)	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.0
General ventilation (fibres/mL)	1.40	1.40	1.4	0.00	0.40	0.40	0.40	0.0
PPE (fibres/mL)	1.00	1.00	1.00	0.00	1.00	1.00	1.00	0.0
% Time on task	0.25	0.50	0.25	0.00	0.25	0.50	0.25	0.0
Fractional exposure (fibres/mL)	3.68	73.50	3.68	0.00	0.53	21.00	1.05	0.0
Total emissions from removal of pipe and machinery insulation from boiler rooms and engine rooms							**103.43 fibres/m**	

Particulars	Near-field				Far-field			
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Task 7**	**Special**
Substance	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed		
Task description	Drilling	Breaking & ripping	Manual Scrapping	Bagging	Drilling	Breaking and ripping out	Manual Scrapping	Bagging
Intrinsic emission (fibres/mL)	3.50	3.5	3.50	3.50	3.50	3.50	3.50	3.50
Handling (fibres/mL)	3.00	30	100.00	3.00	3.00	30.00	100.00	3.00
Local controls (fibres/mL)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Active emission (fibres/mL)	10.50	105.00	350	10.50	10.50	105.00	350.00	10.50
Passive emission (fibres/mL)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total emission (fibres/mL)	10.50	105.00	350	10.50	10.50	105.00	350	10.50
Time source active (fibres/mL)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
General ventilation (fibres/mL)	1.50	1.50	1.50	1.50	1.20	1.20	1.20	1.20
PPE (fibres/mL)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
% Time on task	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Fractional exposure (fibres/mL)	3.94	39.38	131.25	3.94	1.58	31.50	105.00	3.15
Total emissions from removal of asbestos in accommodation area of EOL ships							**319.73** fibres/mL	

Particulars	Near-field				Far-field			
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**	**Task 7**	**Special**
Substance	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed		
Task description	Drilling	Breaking & ripping out	Scrapping	Bagging	Hammering	Scrapping	Bagging	Bagging
Intrinsic emission (fibres/mL)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Handling (fibres/mL)	3	30	30	3	3	30	3	3
Local controls (fibres/mL)	1	1	1	1	1	1	1	1
Active emission (fibres/mL)	1.8	18	18	1.8	1.8	18	1.8	1.8
Passive emission (fibres/mL)	0	0	0		0	0	0	0
Total emission (fibres/mL)	1.8	18	18	1.8	1.8	18	1.8	1.8
Time source active (fibres/mL)	1	1	1	1	1	1	1	1
General ventilation (fibres/mL)	4.1	4.1	4.1	4.1	0.2	0.2	0.2	0.2
PPE (fibres/mL)	1	1	1	1	1	1	1	1
% Time on task	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Fractional exposure (fibres/mL)	1.85	18.45	18.45	1.85	0.05	0.90	0.09	0.09
Total emissions from removal of miscellaneous ACMs							**41.72 fibres/mL**	