Asbestos-Related Disease in Bangladeshi Ship Breakers: A Pilot Study

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A pilot study tested the feasibility of conducting occupational health research in Bangladesh while examining prevalence of asbestos-related diseases including asbestosis, work-related respiratory symptoms, and attitudes to occupational health and safety among a group of internal migrant ship breakers. Data was collected on clinical and work history, respiratory symptoms, and occupational health and safety practices in Bengali. A B-reader read all postero-anterior chest x-rays. In the 104 male ship breakers studied, prevalence of asbestos-related disease was 12 %, of which asbestosis accounted for 6%. Knowledge of asbestos and occupational health and safety measures were almost nonexistent. The prevalence of asbestos-related diseases is low compared to studies in shipbuilders and repairers, but a risk underestimate could have resulted from challenges identified during study design and implementation including: industry noncooperation and a culture of corruption; technological and language barriers; and a regional lack of physician knowledge and research on occupational diseases. *Key words:* asbestos, asbestos-related disease, ship breaking, policy, Bangladesh

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INTRODUCTION

Ship breaking is the dismantling and recycling of large obsolete vessels. Of the 75,000 vessels worldwide, approximately 700 are dismantled annually, many on the beaches of Bangladesh, India, and Pakistan, due, in part, to the less-stringent environmental and labor laws in those countries. By 2006, Bangladesh's ship-breaking industry was the largest in the world, with a capacity for the largest ships (52% of all vessels greater than 200,000 dwt) due to a long intertidal zone with high tidal range.[1,2]

Approximately 70 to 200 ships are dismantled annually in Chittagong, Bangladesh, directly employing 25,000 persons and indirectly employing another 150,000 in industries such as steel rerolling and reselling salvaged materials.[3,4] Almost 70% of the ship breakers are internal migrant workers from northern areas of Bangladesh, due largely to scarce and irregular employment opportunities there.

Workers are at risk of asphyxiation, being crushed by steel plates, explosions, and electrocution. According to the International Labour Organization (ILO), worldwide, one ship breaker dies every week and thousands are injured annually.[5] Ships may also contain hazardous materials such as heavy metals, polychlorinated biphenyls (PCBs), and asbestos. While the health effects of ship-borne exposures have been examined in other working groups (i.e., shipbuilders and repairers), the long-term consequences of occupational diseases such as cancer and asbestos-related diseases in the ship breaker population are unknown.[6]

The pilot study described here focused on asbestos-related diseases. An average 40,000 ton vessel built before mid-1970 could contain 6,000 to 8,000 kg of asbestos; we estimate half of the ships dismantled in Bangladesh could contain asbestos. Ship breaking, including the removal of insulation, is a manual process with the potential for confined space entry, but workers lack personal protective equipment (PPE), control measures to reduce workplace exposures, and adequate safety training or information about the potential health risks posed by asbestos or other toxic materials. Though unable to observe practices employed for removing asbestos dust in the work place firsthand, there is evidence that asbestos is pulled out of ships in large bundles, dried, broken down, and bagged for resale, creating a risk for asbestos dust to become resuspended.[7] For Bangladeshi ship breakers and those indirectly employed in the asbestos resale industry, risks for asbestos-related diseases are compounded by working and living conditions. Virtually none of the recognized safeguards for the handling of asbestos such as ventilation systems, respiratory protective equipment, protective clothing, showering, or air monitoring, are in place and even regular hygiene is inadequate. Accommodations may comprise ships' components containing asbestos materials and expo-

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sure to fibers brought in by contaminated shipyard materials, including clothing, could affect members of the nearby communities. Mesothelioma has been shown elsewhere to result from household exposure.[8]

Asbestos-related Diseases

Asbestos is known to cause lung cancer and mesothelioma, a cancer of the pleura, and lead to nonmalignant asbestos-related diseases including asbestosis, a form of pneumoconiosis, or scarring of the lung tissue.[9] Asbestosis diagnosis requires a history of working with asbestos. In Bangladesh, access to health care is not available to everyone and work history has not been consistently collected in hospitals; hospital staff, unfamiliar with asbestosis, could misdiagnose it as another form of pneumoconiosis or respiratory illness such as tuberculosis.[10]

A 16% prevalence of asbestosis in Indian ship breakers was reported in a 2006 European Commission report and there were no asbestos-related disease prevalence studies from Bangladesh; such studies are difficult to conduct without systematic public health or death registries.[11] In studies of shipbuilding and repair, which are analogous to ship breaking, prevalence of asbestos-related diseases ranged from 0.3% to 31.7% for parenchymal abnormalities alone, 1.5% to 27% for pleural abnormalities alone, and 2.2% to 47% for those exhibiting both parenchymal and pleural abnormalities.[12–19]

The ILO reports more than 100,000 workers die from asbestos-related diseases every year and this is likely to peak around 2020 with between 0.5 to 1 million deaths.[20] Most of the peak will be seen in less- and mid-economically developed countries such as China, India, and Bangladesh, where asbestos use is still growing and where there are limited policies restricting the mineral.[21,22]

Rationale

Despite the fact that there is asbestos on the ship-breaking yards and a high potential for exposure, there is almost no literature on health outcomes related to ship breaking in Bangladesh. There are no effective asbestos exposure hazard reduction practices or PPE use, and beyond the ship-breaking yards, those involved with asbestos resale or people living in communities surrounding the yards may be exposed depending on disposal practice. Exposure on the yards will continue for many years and any current asbestos-related diseases will continue to rise as a result of past and current exposures due to the latency of several years seen between initial exposure and onset of disease.[9]

METHODS

The research protocol was approved by the University of British Columbia and the Bangladesh Medical Research Council ethical review boards, including the boards' requirements for low-literacy subjects.

This study was performed in villages in a northwest district of Bangladesh. Initial contact was made by an assistant to the civil surgeon, the district's highest health official, who described the study to villagers with no mention of incentives (to minimize potential bias) and collected contact information for individuals who expressed an interest in participating in a future study. The target study size ($n = 100$), determined by time and budget constraints, was to be randomly selected from this pool of previously contacted ship breakers, and included male ship breakers of any age who had worked on the ship-breaking yards for at least one year, and whose first year of work had taken place at least 10 years prior to ensure a sufficient number of years since first presumed exposure.

All documents were initially created in English, translated into Bangla by researchers at a local university, and then translated back by a UBC researcher fluent in English and Bangla for quality control purposes. This method has been validated and used for the World Health Organization (WHO) Quality of Life surveys.[23–25] The questionnaire was reviewed by a Bangladeshi respiratory physician and pilot tested before use.

The subjects were interviewed in Bangla by a physician fluent in English and Bangla, and information was collected on work history, clinical history, and knowledge, attitudes, and work practices regarding asbestos. The physician conducted physical examinations and posteroanterior chest x-rays were taken by a hospital technician using a 250 kVp x-ray unit type TuR DR154® (Transformatoren und Röntgenwerk, VEB Hermann Matern, Dresden, GDR). A B-reader, certified by the National Institute for Occupational Safety and Health (NIOSH), scored all radiographs using the ILO Guidelines for Classification of Radiographs of Pneumoconioses.[9,26]

Asbestos exposure was assumed for all subjects. Pleural abnormalities or other radiographic abnormalities were recorded and patients were grouped into three categories for asbestosis:

1. Probable asbestosis: ILO profusion score ≥ 1/1 with irregular opacities
2. Possible asbestosis: ILO profusion score of 0/1 or 1/0 with irregular opacities, or profusion score ≥ 1/1 with round opacities
3. Negative for asbestosis: ILO profusion score of 0/0 for irregular opacities and < 1/1 with round opacities

Respiratory symptoms from the American Thoracic Society (ATS) questionnaire were determined to be work-related if the subject was positive for the symptom and reported: improvement on days off and/or; improvement on long breaks from work and/or; work-related situations or environments that made the symp-

TABLE 1 Characteristics of Proxy Exposure Data (*n* = 104 Males)

	Beach-based (*n*)	Ship-based (*n*)	Total (*n*)	Total %
Job Type: Beach-based workers	98		98	94
Loader	52		52	50
Cable puller	21		21	20
Loader/Cable puller	20		20	19
Oil group	4		4	4
Manager	1		1	1
Job Type: Ship-based workers		6	6	6
Cutter		3	3	3
Fitter		3	3	3
Duration of employment in years				
< 3	26	0	26	25
3–7	28	2	30	29
8–14	25	0	25	24
> 14	19	4	23	22
Years since first employment				
10–14	35	0	35	33
15–19	29	2	31	30
> 19	34	4	38	37
Former dusty job				
No	66	5	71	68
Yes	32	1	33	32

tom worse. If the symptom started before starting work in the industry, the subject was considered not to have a work-related problem.[27]

Prevalence of asbestos-related disease and work-related respiratory symptoms was examined for association with explanatory variables: job type; duration of employment; years since first employment on the ship-breaking yards; and "former dusty job" (other than ship breaking). This last variable was subcategorized into jobs with potential for silica exposure.

Employment served as a proxy measure for exposure in duration of exposure and years since first exposure (YSFE). Job type distinguished between those who had theoretically spent more or less time with asbestos; and there are six main job types:

1. *Fitters* remove furnishings and mechanical parts from within the ships, including insulation.
2. *Cutters* cut the ship apart with oxy-acetylene gas torches; they are the most experienced and best paid.
3. *Cable pullers* drag metal cables several hundred meters down the beach and attach them to steel plates to be winched onto higher beach.
4. *Hammer group* members hammer out protrusions from steel sheets and break down cast metal parts.
5. *Loaders* are involved in heavy manual lifting and are the largest and most inexperienced group.
6. *Oil group* members empty the fuel tanks and separate oil for resale from the residual sludge of no commercial value.

Fitters and cutters work mainly within the ship or in its vicinity and were therefore assumed likely to experience higher exposure to asbestos, while the other four jobs are based mainly on the open beach.[28]

All data were coded and entered into Stata version 10 (StataCorp LP College Station, TX). Logistic regression was used to determine odds ratios and 95% confidence intervals for all asbestos-related diseases and asbestosis alone, and any respiratory symptoms and those determined to be work-related, all adjusted for age and smoking. Respiratory symptoms were additionally controlled for "former dusty job" (other than ship breaking), except when this variable was being examined as a predictor. Fisher's exact tests were performed for bivariate analyses and a one-way analysis of variance was used to examine the relationship between smoking pack-years and outcome variables.

RESULTS

Asbestos-related Diseases and Other Respiratory Disorders

The participation rate was 88% (104/118 invited subjects). The participants had a mean age of 40 years (range 25 to 70 years), and mean education of 2.5 years (range of 0 to 12 years); 63% had no formal education. Mean pack-years were 6.4 years (range of < 1 to 60 years) for current smokers and 0.4 years (range of < 1 to 11 years) for former smokers.

Table 1 displays proportions of beach-based (94%) and ship-based (6%) workers by exposure categories. Mean duration of employment was 7.3 years (range 1–25, standard deviation 5.5 years), and was divided into quartiles roughly equal in size. Mean years since first employment (YSFE) was 17.3 years (range 10–30, standard deviation 5.2 years), and was divided into three classes based on prior understanding of asbestos-

TABLE 2 Radiographic Outcome for Each Case (*n* = 13)

Profusion Core	Shape* (Secondary Diagnosis)	Pleural Plaque	Costophrenic Angle Obliteration
Parenchymal abnormalities—Probable asbestosis			
1/1	*t* (*t*)†		
Parenchymal abnormalities—Possible asbestosis			
1/1	*r* (*u*)		
1/1	*r* (*r*)		
0/1	*t* (*t*)†		
0/1	*t* (*t*)		
0/1	*u* (*u*)†		
Pleural abnormalities			
		L diaphragm + calcification	
		L diaphragm	
		L diaphragm	
		R diaphragm	
		L chest wall	
			Left side

**s,t,u* = irregular; *p,q,r* = round opacities
†Exhibited crepitation

related disease pathology and development: 10 to 14 years, indicating possible high exposure and early onset of disease; 15 to 19 years; and greater than 19 years. Because all subjects were potentially exposed, the comparison groups in analyses were those in the lowest exposure categories.

Anteroposterior chest radiographs were considered "good" in 12%, "acceptable" in 74%, "poor" in 14%, and none were unreadable. There were five possible and one probable cases of asbestosis, and these were grouped together as six cases for further analyses and a prevalence of 6%; all were diagnosed from "acceptable" films. Six cases of pleural abnormalities were found: five pleural plaques and one costophrenic angle obliteration with no further evidence of diffuse pleural thickening. Four of the five plaques were located on the diaphragm with one being calcified, and one plaque was found in-profile on the chest wall. None of the pleural abnormalities were found in subjects with parenchymal abnormalities and all were in beach-based workers, three of whom had a former dusty job. (See Table 2 for radiographic results.)

Table 3 shows the relationship between selected risk factors and all asbestos-related diseases, and asbestosis alone. All were found in beach-based workers. Asbestosis was diagnosed in five loaders and one cable puller, all with less than eight years duration of exposure, and with no former dusty job. The six pleural abnormalities were found in two loaders, two cable pullers and two oil men. The odds ratios did not show clear patterns. The risk of developing asbestosis for those with three to seven years duration of employment was six times that of the reference group, which was also the case when looking at all asbestos-related disease. Those with 15 to 19 YSFE had a higher risk of developing asbestosis compared to the reference group but those with more than 19 YSFE had one-third of the risk. The risk for all asbestos-related disease together increased with YSFE. Odds ratios were stable going from crude to adjusted estimates, but no estimates were statistically significant.

Respiratory Symptoms

Respiratory symptoms were determined based on the ATS questions, looking separately at "any" and those defined as "work-related." Due to the low prevalence of work-related symptoms, "cough and phlegm" were grouped together, and the rest of the symptoms, wheeze and breathlessness, were grouped together as "shortness of breath," for further analysis.

Prevalence of any respiratory symptom was 37%, of which 95% was in beach-based workers. Table 4 shows the relationship between selected risk factors and any respiratory symptoms. For all variables except former dusty job, risk factors indicated a "protective" effect with respect to the reference group.

Work-related Respiratory Symptoms

The prevalence of work-related cough and phlegm was 13%, and work-related shortness of breath was 8%; all cases were in beach-based workers. Table 5 shows the relationship between selected risk factors and these two outcome groups. A "protective" trend was seen for work-related cough and phlegm as YSFE increased and there was no discernable trend for duration of employment. A "protective" trend was seen for work-related shortness of breath as both duration of employment and YSFE increased. However, more than double the risk was seen with former dusty job. Respiratory symptom presence

TABLE 3 Odds Ratios and 95%CIs for Asbestosis Cases by Exposure Variables, Adjusted for Age and Smoking (*n* = 104)

Exposure Variables (*n* for Each Category)	Asbestosis (6 Cases)		All asbestos-related Disease (12 Cases)	
	Odds Ratio	95%CI	Odds Ratio	95%CI
Job type				
Beach-based (98)	1		1	
Ship-based (6)	0		0	
Duration of employment in years				
< 3 (26)	1		1	
3–7 (30)	5.6	(0.9–35.1)	5.8	(0.95–35.1)
8–14 (25)	0		6.2	(0.84–46)
> 14 (23)	0		0	
Years since first employment				
10–14 (35)	1		1	
15–19 (31)	1.5	(0.21–10.4)	0.92	(0.17–5.1)
> 19 (38)	0.36	(0.03–4.4)	1.8	(0.27–11.4)
Former dusty job				
No (71)	1		1	
Yes (33)	0		0.46	(0.1–2.1)

was examined along with asbestosis because shortness of breath is known to be a symptom of asbestosis.[29] Out of six asbestosis cases, two experienced shortness of breath of which one was work-related, and three experienced cough and phlegm of which two were work-related. Results were not statistically significant.

Knowledge, Attitudes, and Practice

Sixty-nine percent used a form of PPE. Equipment used included shoulder protectors while loading heavy metal sheets (49%), gloves (38%), rubber boots (12%), sandals (7%), hard hats (6%), cloth to cover face (6%), special (mechanic type) clothing (3%), and baseball caps (2%). PPE was reported to be supplied by foremen or found abandoned in the ships. Reasons for not using PPE included discomfort (24%), not appropriate for their job (16%), unavailable (15%), not understanding how to use (7%), not necessary because work is safe/God would protect them (6%), PPE is unsafe if used incorrectly (2%), and did not have a reason (30%). No subjects who used PPE had ever received training or education about prevention of spread of substances such as asbestos. Fifty-eight percent had been injured severely enough to take time off at least once.

Eighty-seven percent of subjects did not know what was meant by "asbestos," and 41% did not recognize photographs of asbestos-containing objects found on ships. One problem encountered was some photo content perceptions were far from actuality; some people mistook inanimate objects (ducting) for human anatomy, raising concerns of validity. Fifty-nine percent recognized the photos and stated the items were either removed and thrown into the sea or stored in a shed until "special parties" came to purchase it. Some considered the materials in the photos as trash, while others stated the materials were costly and valuable. Names used for these items included, "Shung shungitula" or "Khaizani," which means "itchy-itchy cotton," but these terms were used interchangeably for asbestos or fiberglass insulation.

DISCUSSION

Asbestos-related Diseases and Other Respiratory Disorders

The 6% asbestosis prevalence estimate is lower than the prevalence reported in the only other published estimate of 16% in Indian ship breakers and falls in the lower end of the asbestosis prevalence range seen in past studies of shipbuilders and repairers of 0.3% to 31.7%.[11–19] Because the pleura is more sensitive to asbestos than the lung parenchyma, the earliest effects of asbestos exposure can show there first and these radiographic abnormalities serve as markers of asbestos exposure; however, more pleural abnormalities would be expected than parenchymal, and some subjects expected to display both. Equal numbers of both abnormalities were found, and the six pleural abnormalities were not in the same subjects as asbestosis cases, suggesting the possibility that the workers in this study were less than moderately exposed.

There were no asbestos-related diseases in the small number of ship-based workers where a greater risk of developing disease was expected due to the presumed higher exposure. This likely reflects the under-representation of ship-based workers (only 6% in this study), but possibly also overemphasized assumptions about difference in exposures experi-

TABLE 4 Odds Ratios and 95%CIs for All Cases Experiencing Respiratory Symptoms, by Proxy Exposure Variables, Adjusted for Age, Smoking, and Former Dusty Job* (*n* = 104)

Exposure Variables (*n* for Each Category)	Cases	Odds Ratio	95%CI
Job type			
Beach-based (98)	36	1	
Ship-based (6)	2	0.53	(0.05–5.4)
Duration of employment in years			
< 3 (26)	13	1	
3–7 (30)	10	0.54	(0.17–1.7)
8–14 (25)	8	0.58	(0.17–1.9)
> 14 (23)	7	0.84	(0.2–3.5)
Years since first employment			
10–14 (35)	13	1	
15–19 (31)	11	0.44	(0.13–1.5)
> 19 (38)	14	0.6	(0.18–2)
Former dusty job			
No (71)	25	1	
Yes (33)	13	1.2	(0.45–3)

*Point estimates adjusted for age and smoking are shown separately for former dusty job

enced by beach- and ship-based workers. Without an exposure assessment to verify these assumptions, there was no way of knowing if loaders belonged to a more highly exposed group. Also, ship-based workers are generally selected from a pool of Chittagong locals who may experience relatively less poverty and better basic health than the migrant workers from Northern Bangladesh.

There was no exposure-response relation as might have been expected with "years since first exposure" (YSFE) or with duration of exposure when looking at asbestosis alone, but the relationship was a little clearer when looking at all 12 cases of asbestos-related disease together. This stronger exposure-response trend could demonstrate the increased sensitivity of the pleura to early effects of asbestos. Two of the six asbestosis cases belonged to the shortest YSFE class, between 10 and 14 years, and five had worked for less than eight years; typically asbestosis cases are not seen with such a short latency or duration of exposure unless exposures were very high.[30] Environmental exposures could vary depending on the number of ships dismantled, their asbestos content, and stage in the process. Individual exposure could vary with tasks and location of work. These findings highlight the need for a more detailed analysis of worker attrition due to illness and job-exposure relationships in the yards.

B-reader variability is affected by x-ray quality, and the readers' own training, experience, and individual interpretation. The ILO recommends at least two readers, but due to limited resources, only one B-reader assessed the x-rays in this study, leading to possible bias in this important outcome. The asbestosis case definition included "round" opacities if a profusion score was ≥ 1/1; normally only "irregular" opacities are included, but in one of two situations, the secondary categorization of the "round" opacity was "irregular," so they were both included as possible cases, and in this regard, the prevalence estimate could have been an overestimated and is another limitation of this study.

There were no significant indicators for developing work-related respiratory symptoms, though a "protective" trend was seen for work-related cough and phlegm with YSFE and for work-related shortness of breath with duration and YSFE. While not significant, more than double the risk of experiencing work-related shortness of breath was indicated for those with former dusty job. Shortness of breath, a common symp-

TABLE 5 Odds Ratios and 95%CIs for Work-related Cough and Phlegm and Shortness of Breath Cases by Proxy Exposure Variables, Adjusted for Age, Smoking, and Former Dusty Job* (*n* = 104)

Exposure Variables (*n* for each category)	Cough and Phlegm	Odds Ratio	95% CI	Shortness of Breath	Odds Ratio	95% CI
Job type						
Beach-based (98)	14	1		8	1	
Ship-based (6)	0			0		
Duration of employment in years						
< 3 (26)	4	1		5	1	
3–7 (30)	4	0.95	(0.2–4.5)	2	0.51	(0.09–3)
8–14 (25)	5	1.57	(0.34–7.2)	1	0.35	(0.03–3.4)
> 14 (23)	1	0.37	(0.3–4.1)	0		
Years since first employment						
10–14 (35)	6	1		4	1	
15–19 (31)	4	0.78	(0.18–3.3)	2	0.23	(0.03–2.1)
> 19 (38)	4	0.62	(0.13–3)	2	0.19	(0.02–1.4)
Former dusty job						
No (71)	9	1		4	1	
Yes (33)	5	1.2	(0.34–3.9)	4	2.4	(0.52–10.7)

*Point estimates adjusted for age and smoking are shown separately for former dusty job

tom in asbestosis, was found in only two of six asbestosis cases, which may indicate an early stage of disease with stronger symptoms yet to develop.

A 2008 paper of workers on Chittagong ship-breaking yards reports twice the prevalence of self-reported respiratory problems (80.56%), but does not state whether ATS questions were used.[1] A 2003 dissertation on general health of Bangladeshi ship breakers reports a 52% prevalence of self-reported respiratory tract illness, which is closer to the 37% prevalence for any respiratory symptom reported here. Standardized ATS questions were not used, which could account for some of the differences observed.[31] A cross-sectional study on the general prevalence of respiratory disorders in Bangladesh interviewed 5,642 people using the ATS questionnaire and found a prevalence of wheeze in 6.2% of adults 15 to 44 years old and 11.8% in adults over 45 years old[32]; our study also found a greater prevalence of wheeze in subjects over 45 years with 3% compared to no wheeze in the younger group. The lower prevalence of wheeze in ship breakers compared to the general Bangladeshi population is likely due to the nonrepresentative, small sample, and possibly a healthy worker effect.

Background Bangladesh mortality demographics have a high under age five mortality and high burden of disease for those who survive beyond their fifth birthday; the workforce is more likely to survive in an unhealthy worker environment compared to workforces where the healthy worker effect has been previously described. In addition to their extremely physically demanding work, they must have enough stamina to travel to a distant workplace and live in cramped, unhygienic conditions. These healthy worker and "healthy migrant" effects have been described by others.[33,34]

Knowledge, Attitudes, and Practice

The responses regarding use of PPE indicate an almost complete lack of understanding what appropriate PPE is, how to access it, and the rights an individual has to protect himself at work. A standard survey of PPE usage by western standards would likely conclude that PPE is almost completely unused by ship breakers, but in fact, 69% of ship breakers reported using PPE. Nobody interviewed had ever used a respirator or understood what it was and only two could correctly identify a photograph of a dust mask. Shoulder protectors, which were cited as the most frequently used form of PPE, consisted of foam padding, folded cloth, rubber sandals, or other discarded materials. While some of this equipment may provide comfort to the workers and prevent minor injuries, 58% still reported being injured enough to take time off work at least once. This is not only an indication of the lack of PPE use, but the lack of information and training available about general occupational safety measures. For those who cited using a standard PPE such as a hardhat, without training, incorrect usage could make it ineffective. (Two workers stated protection from rain as the reason for using a hardhat.) Reasons for not using PPE are additional indications of the lack of occupational health and safety training where importance of this equipment would normally be explained.

RESEARCH ENVIRONMENT AND LESSONS LEARNED

Initially, this study was intended to be an exposure assessment of asbestos on the ship-breaking yards and downwind in the surrounding communities. Researchers at the University of Chittagong, a local NGO "Young Power in Social Action" (YPSA), local health officials, and community representatives were consulted. An implicit research question regarded the fate of the asbestos after it left the ship-breaking yards: Where did it go and what were the demographics of those handling it? Understanding the life-course of the asbestos could have revealed large numbers of exposed women and children that had not yet been identified.

In 2008, just as this study was to begin, the government showed surprising foresight by regulating ship breaking by environmental law and requiring ships to be decontaminated before dismantling. In light of this recent bad publicity, local government authorities (including health) and community representatives in the vicinity of the ship-breaking yards became suspicious of our motives and reacted negatively toward the study. No longer welcome in the ship-breaking yards or the surrounding communities, the focus was changed to a health study located in the home villages of the migrant ship breakers.

This pilot study was designed to test feasibility and methodology, while gathering information which would allow confirmation of asbestos exposure history in the absence of an exposure assessment, and provide information with which to present to policy makers and other stakeholders. Data could be compared to disease documented in historical studies of shipbuilders and repairers in the absence of ship-breaker studies, and be used as a basis for future studies. In doing so, partnerships could be strengthened with local health institutes, nongovernmental organizations, and higher government authorities to assist us with future studies in the region, while learning about the challenges and obstacles in conducting such research in preparation for a full-size study.

The research environment posed a number of challenges. These can be grouped into: a reluctance of industry and local government authorities to cooperate and a culture of corruption; technological, cultural, and language barriers; and a regional lack of physician knowledge and research on occupational diseases related to asbestos and/or ship breakers.

The culture of corruption was evident in the influence yard owners possessed over local politicians and villagers when barred from performing exposure assessments even in the communities outside of the yards where asbestos could have traveled downwind. This influence was also evident in the absence of occupational health and safety standards, training, or information programs, including the potential health risks posed by asbestos or other toxic materials. Despite being recognized as a legitimate industry in the new 2006 Bangladesh Labour Law Act, which included standards on working conditions, hours, leave, and compensation, rights to protect workers have not been complied with or enforced.[35] A lack of resources could account for some of these issues, but corruption plays a large part; in 2008 Bangladesh was rated the tenth most corrupt country in the world, and previously had been ranked the most corrupt country for five consecutive years, 2001–2005.[36] In March 2008, in response to a writ filed by the Bangladesh Environmental Lawyers Association (BELA), the Bangladeshi High Court ordered eight directives including closure of any ship-breaking yards without environmental clearance and banning the beaching of any ships that had not been cleared of hazardous materials at source or outside the territory. They also directed the Department of Environment to frame rules on ship breaking according to the Basel Convention (1989), the Environment Conservation Act, (1995) and the Environment Conservation Rules, (1997). The order to close the yards was stayed after an appeal from the ship-breaking yard owners association, whose members are mostly comprised of ship-breaking yard owners.

Without the cooperation of yard owners, shifting the study to Northern Bangladesh resulted in an overrepresentation of loaders and cable pullers, the most labor-intensive and poorest paid jobs reserved for the migrant worker population; ship-based jobs are mainly reserved for local workers from Chittagong. It was also difficult to obtain a representative sample among the group of migrant workers. Although a list of 223 eligible subjects to select from was compiled prior to the study, 105 had either returned to the ship-breaking yards, or had sought other employment and were unavailable at the time of recruitment. This led to accepting any ship breaker who was available as long as his name was on the list, rather than selecting from it randomly. To truly understand risks for ship-based workers compared to beach-based, a more representative group was needed including the likely higher exposed.

Technological challenges were encountered especially in the context of x-ray quality. The most common problem was poor technique including: improper positioning of the scapulae, over/underexposure, focus, foreign artifacts (including a shirt left on), and others. Scapulae images were able to be ignored and would not have significantly affected the diagnoses but the other factors could have affected the B-reader's ability to read the films.[37]

Recalling information proved to be a challenge. Subjects often had trouble recalling their own age as much as ± five years. This phenomenon has been described before; in a study on Bangladeshi children, random error, age heaping (the tendency to over-report ages ending in zero or five), and preferences for particular ages were found.[38] We developed a series of questions to estimate age based on whether or not they remembered certain prominent historical events, how long ago since they were married, had their first child, and other memory triggers. This could have affected the study during the analysis by grouping cases into the wrong age groups and misreporting trends, but the bias was most likely nondifferential.

Information collected during the interviews was prone to inaccuracies because of the language barrier, and a culture unaccustomed to participating in surveys and questionnaires. Validated, standardized questions from the American Thoracic Society (ATS) included in the questionnaire were modified for cultural appropriateness through back-translations, pilot testing, and input from local researchers. The concept of anonymity in survey research can be hard for people in less economically developed countries to grasp and adverse effects of suspiciousness could include cautious responses that are not completely accurate.[34] For example, information about safety on the yards or tasks involving potential exposure to asbestos might have been left out for fear of retribution from yard owners. Photograph recognition was a challenge for some subjects, which could have affected our understanding of how much asbestos-containing material was encountered, without the ability to verify with exposure measurements. Inaccuracies in responses were evident when subjects were discovered copying responses other villagers had given. There was almost certainly interaction among villagers who had been interviewed and those about to be interviewed. Subjects would sometimes provide a correct answer for the "wrong" question, such as one that had not yet been asked.

The limited occupational health knowledge of physicians and the lack of regional research on both asbestos-related disease and occupational disease in ship breakers, made the study challenging by not having points of reference for unique findings such as a possible "extreme" healthy worker effect, and also for building the foundation for future occupational health studies. The Institute for Chest and Diseases Hospital in Dhaka is familiar with asthma, bronchiolitis, chronic obstructive pulmonary disorder, and tuberculosis, but little is known about asbestos-related diseases and there is a strong possibility these diseases are being misdiagnosed as other lung disorders. In the whole South Asian region, physicians are poorly trained in the

recognition and diagnosis of occupational diseases, especially pneumoconioses; of India's 300 or so medical schools, only one has a training program in occupational health.[39] In Bangladesh, the National Institute of Preventive and Social Medicine (NIPSOM), a branch of the University of Dhaka, is the only public health institute; it offers master of public health courses including one on occupational and environmental health.

CONCLUSION AND RECOMMENDATIONS

The prevalence of asbestosis was 6% which, despite our "sensitive" case definition, was lower than anticipated given our hypothesis of high asbestos exposure levels. Knowledge of asbestos by workers was almost nonexistent with a complete lack of education on occupational health and safety measures. While the estimates were lower than expected, we cannot conclude that the prevalence of asbestosis among ship breakers in Bangladesh was low.

Subsequent studies on prevalence of asbestos-related disorders should have a larger number of subjects for increased statistical power; take place in both Northern and Southern Bangladesh so a wider spectrum of job types can be captured; airborne asbestos fiber concentration measurements should be taken; validation of responses by re-interviewing a random selection would be useful;[40] a weeklong training program should be arranged for the x-ray technicians in Dhaka at a local health institute such as the Institute for Chest Diseases and Hospital; and other industries in Bangladesh including those downstream from ship breaking should be investigated for exposure to asbestos.

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