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Asbestotic radiological abnormalities among United States merchant marine seamen

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Abstract

There has been limited information concerning the prevalence of radiologically evident parenchymal and pleural fibrosis consistent with prior exposure to asbestos among merchant marine seamen, despite the wide use of asbestos in ship construction until the late 1970s and subsequent exposure of seamen to the asbestos that had been installed. A total of 3324 chest radiographs (1985–7) of long term United States seamen were reviewed. One third (34·8%) had parenchymal or pleural abnormalities, or both (ILO classification); pleural changes were predominant. Abnormalities increased with longer duration from onset of shipboard exposure (as defined by first year at sea). The prevalence of asbestotic changes was greater among seamen who had served in the engine department (391/420;42·5%) compared with seamen in other departments, including deck (301/820; 36·6%), steward (278/981; 28·4%), or with service in multiple departments (167/541; 30·9%). Since many vessels, particularly those built before 1978, contain asbestos materials, appropriate engineering controls (including complete removal, if possible) are required as well as appropriate medical surveillance for those who served aboard such ships.

The striking reports of asbestos associated disease in shipyards in 1968[1,2] were consistent with wide use of asbestos in vessels.[3] Much less was known about hazards that might exist as a result of subsequent exposure of seamen to the asbestos that had been installed.

There were, nevertheless, some indications that this could be a problem. Merewether, in the annual report of the Chief Inspector of Factories for 1956 had noted that the removal of old heat insulating lagging was hazardous and that adequate ventilation aboard ship was "rarely possible."[4] This was emphasised at the ILO International Symposium on Health Risks in Shipbuilding and Ship Repairing in 1971, where urgent repair in the engine rooms of ships at sea was regarded as a "most hazardous procedure."[5]

In American ships asbestos materials had largely been used in bulkhead systems in living spaces, insulation of hot water and steam piping, and boilers and tanks in machinery spaces. Asbestos insulation was also used in and around machinery spaces, using block insulation and asbestos cement. The latter had also been used for steam, hot water piping, and tanks. United States Maritime Commission studies noted that "Long after the vessel has been put to sea, flaking and cracking due to ship motions and vibrations are suspected of releasing asbestos into the surrounding space," and "In the course of a voyage it is not unusual for crewmen to repair pipes, pipe flanges, or valve leaks and this generally means a teardown situation. We must assume then that machinery and piping asbestos insulation . . . affect not only the shipyard worker, but the crew as well under a variety of conditions."[6]

It was estimated that all vessels delivered before 1975 had extensive asbestos insulating material aboard, and that most vessels delivered between 1975 and 1978 might have some asbestos in the form of insulating cement on machinery casings, although the total amount of asbestos bearing materials had been greatly reduced. No quantitative data were published concerning the levels of exposure to asbestos fibre associated with these different conditions.

Asbestos associated disease had been reported among seamen. The first report in 1918 on radiological abnormalities after exposure to asbestos included a marine fireman.[7] Subsequently, instances of parenchymal fibrosis,[8] pleural plaques,[9] pseudotumours,[10,11] lung cancer,[12,13] and mesothelioma[14-22] were published.

Nevertheless, no substantial information on how important the problem might be in population terms was available until Jones and his colleagues added

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substantially to our awareness of the problem in 1984.[23] They found pleural plaques in asymptomatic marine engineers given annual chest *x* ray examinations in their Union Diagnostic Clinic in New Orleans; asbestotic pleural abnormalities were present in 27% for the longest membership category (more than 35 years) and they were aware of instances of mesothelioma in this group of men.

Present study

Random instances of parenchymal and pleural fibrosis consistent with the effects of exposure to asbestos had been seen in merchant seamen in our hospital in the late 1970s and early 1980s. The individuals had been members of a major maritime union and inquiry was made of the union regarding the possibility of an appropriate large scale survey, particularly of their long term seafarer members, to ascertain how common asbestos associated disease might be among them. At the time, unfortunately, such a study could not be initiated. The situation changed in 1985, however, when an experienced legal specialist in maritime occupational health compensation problems began to explore the question, using union membership lists of about 10 000 active and retired merchant marine seamen. To determine whether large scale detailed asbestos health examinations of these workers would be warranted, it was considered desirable to first obtain information on the prevalence of *x* ray changes consistent with the effect of exposure to asbestos (parenchymal or pleural fibrosis, or both). It was appreciated that disease could be present in the absence of radiological abnormality, but it was equally understood that the prevalence of such changes could provide useful information on the overall question of asbestos associated disease among merchant marine seamen and could help guide the development of more detailed epidemiological or clinical studies.

All individuals on the membership lists were invited to come for chest *x* ray examination; approximately half did so. We were asked to review and evaluate the films. When the radiographs were submitted for evaluation, name, date of birth, social security number, first year at sea, last year at sea, department category aboard ship (engine, steward, deck), and date of *x* ray examination were provided. All had served aboard United States flag vessels, the majority having sailed on many different ships over the years, both ocean going and on the Great Lakes.

Interpretation of the films was undertaken, using the 1980 ILO classification. In addition to study of parenchymal and pleural fibrosis, attention was directed to the detection of other important abnormalities (cancer, mesothelioma, or tuberculosis, for example) and if detected or suspected notification of the merchant marine seamen and his/her physician was arranged.

Materials and methods

Altogether 3488 *x* ray films were reviewed without information on age, job category, year of onset of merchant marine service, or total number of years at sea, at hand. The films were interpreted according to the International Classification of Radiographs of Pneumoconioses by an experienced B reader.[24]

A total of 102 films of poor technical quality were classified as being "unreadable." Chest *x* ray films of 62 women had been included; because of their small number these films were excluded from the analysis.

Statistical analysis of abnormalities on chest *x* ray films was then performed (GL); prevalence rates of radiological abnormalities by job category and years from onset of merchant marine service were of particular interest.

The three major job categories were comprised of similar numbers of subjects; 920 had been categorised as "engine," 823 as "deck," and 981 as "steward." In addition 541 had worked in more than one of the foregoing departmental categories. This group was considered as potentially having been exposed to multiple sources (table 1).

Duration from onset of exposure to asbestos aboard ship was compared for the different job categories. The mean value (and standard deviation) for "years at sea" (duration of potential exposure aboard ship) was similar for the three major job classifications (27·8, 28·1, and 28·2 years). This long mean duration of exposure indicates that most seafarers examined had been at sea for more than 20 years (table 2).

Table 1 Job classification of 3324 United States merchant marine seaman

	No	*%*
Total chest x ray films	3488	
Film quality inadequate	102	2·9
Female	62	1·8
Departments:		
Engine	920	27·7
Deck	823	24·8
Steward	981	29·5
Multiple	541	16·3
Not known	59	1·8
Total	3324	

Table 2 Duration of potential asbestos exposure in 3324 United States merchant marine seamen

		Years at sea	
Department	*No*	*Mean (y)*	*SD*
Deck	823 (24·8%)	27·8	11·8
Engine	920 (27·7%)	28·1	10·8
Steward	981 (29·5%)	28·2	9·8
Multiple	541 (16·3%)	25·9	11·4
Not known	59 (1·8%)	29·3	8·6
Total	3324	27·7	11·0

Onset of exposure had occurred before 1939 in almost 11% of those whose chest x ray films were reviewed; however, most (49·5%) had started their employment in the decade 1940–9; only 8·1% had joined the merchant marine in 1970 or later (tables 3 and 4).

Table 3 Years of onset of potential asbestos exposure in 3324 United States merchant marine seamen

	Onset of merchant marine service	
First year at sea	*No*	*%*
≤1939	359	10·8
1940–9	1646	49·5
1950–9	488	14·7
1960–9	423	12·7
≥1970	268	8·1
Not known	140	4·2
Total	3324	

Table 4 Duration of merchant marine service in 3324 United States merchant marine seamen

		Last year at sea				
No	*First year at sea*	*1940–9*	*1950–9*	*1960–9*	*≥1970*	*Not known*
359	≤1939	2	4	123	226	4
1646	1940–9	5	17	417	1188	19
488	1950–9	—	3	36	445	4
423	1960–9	—	—	18	400	5
268	≥1970	—	—	—	265	3
140	Not known	—	—	—	—	50
3324						85

Results

In 2167 (65·2%) of the total of 3324 films reviewed no abnormalities consistent with pneumoconioses, as categorised in the ILO classification, were found (table 5).

Small irregular opacities in the lung parenchyma, with profusion 1/0 or higher as the only abnormality, were found in 329 cases (9·9%). In another 227 (6·8%) small parenchymal opacities and pleural abnormalities (pleural thickening, pleural plaques, with or without calcification) were present. In 601 cases (18·1%) pleural abnormalities were the only radiological changes (table 5). Altogether, parenchymal or pleural abnormalities, or both, consistent with the effect of exposure to asbestos were detected in 1157 (34·8%) of 3324 merchant marine seamen (tables 5 and 6).

The highest prevalence of radiological abnormalities was found among those classified as having been exposed in the engine department (42·5%) whereas the lowest prevalence (28·4%) was found for the steward category (table 7). This gradient is consistent with available information on intensity of exposure to asbestos aboard ship; the highest exposures occurred in the engine room where most asbestos insulation material was in place and where repair was most frequently required.

Table 5 Radiological findings in 3324 United States merchant marine seamen

	No	*%*
Parenchyma (≥1/0)	329	9·9
Pleural changes only	601	18·1
Parenchymal and pleural changes	227	6·8
Total parenchymal changes	556	16·7
Total pleural changes	828	24·9
Total abnormalities	1157	34·8
Absence of radiologically detectable abnormalities consistent with pneumoconioses*	2167	65·2

*Including changes limited to small opacities 0/1 or to costophrenic angle blunting (not categorised as abnormal).

Table 6 Radiological findings in 3324 United States merchant marine seamen 1985–7

	x Ray abnormalities	
	No	*%*
Parenchyma only:		
1/0 and higher	329	9·9
0/1*	346	10·4
Pleura only:†		
Circumscribed only	324	9·7
Diffuse only	37	1·1
Circumscribed and diffuse only	14	0·4
Other:		
Diaphragm only	64	1·9
Costophrenic angle only*	45	1·4
Multiple abnormalities:		
Parenchyma (1/0 and higher) and pleura	227	6·8
Pleural fibrosis with two or more sites	162	4·9

*For information only.
†Parenchymal opacities 0/1 may be present.

Table 7 Job classification category and radiological findings in 3324 United States merchant marine seamen

		x Ray abnormality			
Department	*No of seamen*	*None*	*%*	*Abnormal**	*%*
Deck	823	522	63·4	301	36·6
Engine	920	529	57·5	391	42·5
Steward	981	702	71·6	279	28·4
Multiple	541	374	69·1	167	30·9
Not known	59	40	67·8	19	32·2
Total	3324	2167	65·2	1157	34·8

*Changes limited to small opacities 0/1 or CP angle blunting not categorised as abnormal.

The relation between duration from onset of exposure and prevalence of parenchymal and pleural abnormalities was also investigated for each of the job categories (tables 8–12).

The prevalence of small opacities did not significantly increase after the duration from onset of exposure had reached 10–19 years; the overall prevalence of parenchymal abnormalities was 9·9%. Pleural abnormalities showed an appreciably dif-

Table 8 Years from onset of exposure and radiological abnormalities consistent with effects of asbestos

		All departments combined							
		Parenchymal changes only		*Pleural changes only*		*Parenchymal and pleural changes*		*Total abnormal*	
Years from onset	*No of seamen*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
0–9	147	6	4·1	8	5·4	1	0·7	15	10·2
10–9	298	32	10·7	24	8·1	14	4·7	70	23·5
20–9	374	36	9·6	63	16·8	24	6·4	123	32·9
30–9	777	83	10·7	148	19·0	59	7·6	290	37·3
≥40	1588	157	9·9	336	21·2	119	7·5	612	38·5
Unknown	140	15	10·7	22	15·7	10	7·1	47	33·6
Total	3324	329	9·9	601	18·1	227	6·8	1157	34·8

Table 9 Years from onset of exposure and radiological abnormalities consistent with effects of asbestos

		Engine department							
		Parenchymal changes only		*Pleural changes only*		*Parenchymal and pleural changes*		*Total abnormal*	
Years from onset	*No of seamen*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
0–9	42	2	4·8	3	7·1	0	—	5	11·9
10–9	77	7	9·1	6	7·8	5	6·5	18	23·4
20–9	116	13	11·2	23	19·8	8	6·9	44	37·9
30–9	238	28	11·8	59	24·8	27	11·3	114	47·9
≥40	411	31	7·5	113	27·5	49	11·9	193	47·0
Unknown	36	4	11·1	8	22·2	5	13·9	17	47·2
Total	920	85	9·2	212	23·0	94	10·2	391	42·5

Table 10 Years from onset of exposure and radiological abnormalities consistent with effects of asbestos

		Deck department							
		Parenchymal changes only		*Pleural changes only*		*Parenchymal and pleural changes*		*Total abnormal*	
Years from onset	*No of seamen*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
0–9	30	0	—	2	6·6	0	—	2	6·6
10–19	95	10	10·5	7	7·4	5	5·3	22	23·2
20–29	96	10	10·4	18	18·8	10	10·4	38	40·0
30–39	165	22	13·3	38	23·0	8	4·8	68	41·2
≥40	412	54	13·1	81	19·7	29	7·0	164	39·8
Unknown	25	1	4·0	4	6·0	2	8·0	7	28·0
Total	823	97	11·8	150	18·2	54	6·4	301	36·6

Table 11 Years from onset of exposure and radiological abnormalities consistent with effects of asbestos

		Steward department							
		Parenchymal changes only		*Pleural changes only*		*Parenchymal and pleural changes*		*Total abnormal*	
Years from onset	*No of seamen*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
0–9	31	2	6·5	3	9·7	1	3·2	6	19·4
10–19	56	7	12·5	4	7·1	2	3·6	13	23
20–29	100	5	5·0	11	11	6	6·0	22	22
30–39	246	23	9·3	35	14·2	12	4·9	70	28·5
≥40	517	48	9·3	90	17·4	24	4·6	162	31·3
Unknown	31	1	3·2	5	16·1	0	—	6	19·4
Total	981	86	8·8	148	15·1	45	4·6	279	28·4

Table 12 Years from onset of exposure and radiological abnormalities consistent with effects of asbestos

		Multiple departments							
		Parenchymal changes only		Pleural changes only		Parenchymal and pleural changes		Total abnormal	
Years from onset	No of seamen	No	%	No	%	No	%	No	%
0–9	42	2	4·8	0	—	0	—	2	4·8
10–19	69	8	11·6	7	10·1	2	2·9	17	24·6
20–29	60	8	13·3	9	15	0	—	17	28·3
30–39	121	10	8·3	14	11·6	12	9·9	36	29·8
≥40	229	23	10·0	48	21·0	16	7·0	87	38·0
Unknown	20	5	25·0	3	15·0	0	—	8	40·0
Total	541	56	10·4	81	15·0	30	5·5	167	30·9

ferent trend: their prevalence consistently increased with duration from onset of exposure; it reached the highest level, 21·2%, in those with more than 40 years from onset of exposure.

Since pleural abnormalities had a prevalence almost twofold higher than that of parenchymal abnormalities, their effect on the prevalence of all radiological abnormalities (parenchymal and pleural) resulted in a consistent increase with duration from onset of exposure. The prevalence rate for all radiological asbestos related abnormalities (pleural or parenchymal or both) reached its highest level (38·5%) in those with more than 40 years from onset of exposure.

Thus radiological abnormalities on chest *x* ray films of merchant marine seamen were found with higher prevalence for job classifications with higher exposure to asbestos (engine room); the prevalence rates also increased with duration from onset of exposure. The relation with duration of exposure was stronger for pleural changes than for parenchymal abnormalities.

Discussion

Exposure to asbestos of merchant marine seamen was of concern because of the large amounts of asbestos materials known to have been used in the past in ship building. Asbestos induced adverse effects in shipyard workers, including interstitial pulmonary fibrosis, pleural fibrosis, mesothelioma, and an increased incidence of lung cancer, are now well known and have been reported from most ship building areas in the world. Insulation with asbestos containing products was particularly extensive in engine rooms. It is appreciated that, with time, unavoidable deterioration of asbestos insulation products may occur in all types of buildings, including schools. That this would result in airborne asbestos contamination in the relatively confined spaces of ships was to be expected but the effects of the resulting exposure on merchant marine seamen had not been evaluated in a comprehensive manner.

Review of a large number of chest *x* ray films of merchant marine seamen with long duration from onset of work on ship was undertaken to assess the risk of developing asbestos induced parenchymal interstitial fibrosis or pleural fibrosis, or both, as a result of exposure to asbestos on board ship. The results indicate an overall prevalence of radiological abnormalities of over 34%. Pleural abnormalities were found with a higher prevalence than parenchymal changes. The prevalence of radiological abnormalities was highest in those with departmental classification "engine." There was a consistent increase of total asbestos related abnormalities with years from onset of exposure to asbestos; this trend was present for pleural abnormalities, although it was not consistently present for parenchymal abnormalities alone and did not result in a steady increase in the prevalence of interstitial pulmonary fibrosis.

Among the 3324 chest *x* ray films of merchant marine seamen, 13 cases of lung cancer were detected; all but two of these patients had started employment before 1949 (5·5 lung cancer cases per 1000) (table 13).

Data are available indicating that merchant marine seamen in the United Kingdom have significant adverse mortality experience, including an approximate doubling of total deaths (all causes), total cancer deaths, and deaths from lung cancer (for categories "deck, engine room hands, bargemen, light tenders, and boatmen; deck, engineering and radio officers, and pilots, ship; and foremen, ships, lighters, and other vessels).[25] This experience was not specific for shipboard exposure to asbestos, although it may be relevant to such a hazard; the effects of exposure to asbestos on mortality patterns of merchant marine seamen remain to be established by appropriate epidemiological mortality studies.

Table 13 Other significant lung disease among 3324 United States merchant marine seamen, 1985–7

Lung cancer	13
Tuberculosis: active/suspect	3
Metastatic cancer	1
Multiple myeloma	1
Coin lesion cholesterol granuloma	1

The identification of a risk of exposure to asbestos as a result of this study and other similar investigations[26] makes it imperative that exposure to asbestos on ships be eliminated or greatly reduced through adequate engineering controls, including removal of all asbestos in place. Such measures would prevent additional exposure of currently employed seamen and avoid exposure of new generations of merchant marine seamen. It would be advantageous that those exposed in the past be offered appropriate medical care and surveillance.

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