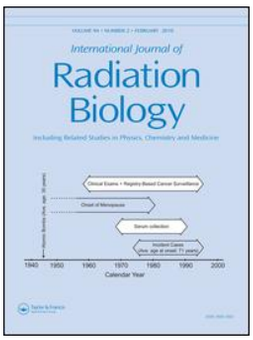

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ORIGINAL ARTICLE

Asbestos exposure and mesothelioma mortality among atomic veterans

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ABSTRACT

Background: The United States (U.S.) conducted 230 above-ground atmospheric nuclear weapons tests between 1945 and 1962 involving over 250,000 military personnel. This is the first quantitative assessment of asbestos-related mesothelioma, including cancers of the pleura and peritoneum, among military personnel who participated in above-ground nuclear weapons testing.

Methods: Approximately 114,000 atomic veterans were selected for an epidemiological study because they were in one of eight series of weapons tests that were associated with somewhat higher personnel exposures than the other tests and because they have been previously studied. We were able to categorize specific jobs into potential for asbestos exposure based on a detailed database of the military activities of the atomic veterans. Standardized mortality ratios (SMR) were calculated by service, rank (officer/enlisted) and ratings (occupation code and work location aboard ship) after 65 years of follow-up.

Results: Mesothelioma deaths were significantly increased overall (SMR 1.56; 95% CI 1.32–1.82; $n = 153$). This increase was seen only among those serving in the PPG (SMR 1.97; 95% CI 1.65–2.34; $n = 134$), enlisted men (SMR 1.81; 95% CI 1.53–2.13; $n = 145$), and the 70,309 navy personnel (SMR 2.15; 95% CI 1.80–2.56; $n = 130$). No increased mortality rates were seen among the other services: army (SMR 0.45), air force (SMR 0.85), or marines (SMR 0.75). Job categories with the highest potential for asbestos exposure (machinist's mates, boiler technicians, water tender, pipe fitters, and fireman) had an of SMR 6.47. Job categories with lower potential (SMR =1.35) or no potential (SMR =1.28) for asbestos exposure had non-significantly elevated mesothelioma mortality.

Conclusions: The large excess of mesothelioma deaths seen among atomic veterans was explained by asbestos exposure among enlisted naval personnel. The sources of exposure were determined to be on navy ships in areas (or with materials) with known asbestos content. No excess of mesothelioma was observed in other services or among naval personnel with minimal exposure to asbestos in this low-dose radiation exposed cohort.

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Atomic veterans; nuclear weapons tests; asbestos; mesothelioma; Pacific Proving Grounds

Background

Military veterans who participated in atmospheric nuclear weapons testing conducted by the United States between 1945 and 1963 are being studied for late-occurring health effects. More than 250,000 veterans participated in these tests. The cohort being investigated consists of ~114,000 individuals who were present in one or more of eight test series: CASTLE, CROSSROADS, GREENHOUSE, REDWING, and HARDTACK I conducted at the Bikini and Enewetak Atolls and Johnston Island in the Pacific Proving Grounds (PPG); UPSHOT-KNOTHOLE and PLUMBBOB conducted at the Nevada Test Site (NTS); and TRINITY, the first nuclear test, conducted in New Mexico. We refer to our analysis of this collection of tests as the Eight Series Study which is a subset of the Million Person Study (NCRP 2018; Boice 2019).

Prior to 1980, all navy ships used asbestos extensively for boilers, steam pipe insulation, hull insulation, floors, gaskets, cables, fireproofing, and many other applications. Although most interior areas contained some asbestos material, areas especially susceptible to exposure were engineering spaces where when making repairs, the asbestos insulation had to be removed to allow access and replaced when a job was completed. Over time the asbestos insulation would deteriorate and become brittle making exposure even more likely. Since 1980 the navy has taken far-reaching steps to remove and reduce the use of asbestos and to find other types of material as a substitute.

The purpose of this study was to evaluate an observed excess of mesothelioma in the entire cohort of 114,270 nuclear weapons test participants compared with the US general population. The excess was seen only among Navy personnel. We applied basic methods previously described in Till et al. (2014) to identify specific jobs with high potential for asbestos exposure, and accordingly, the personnel who

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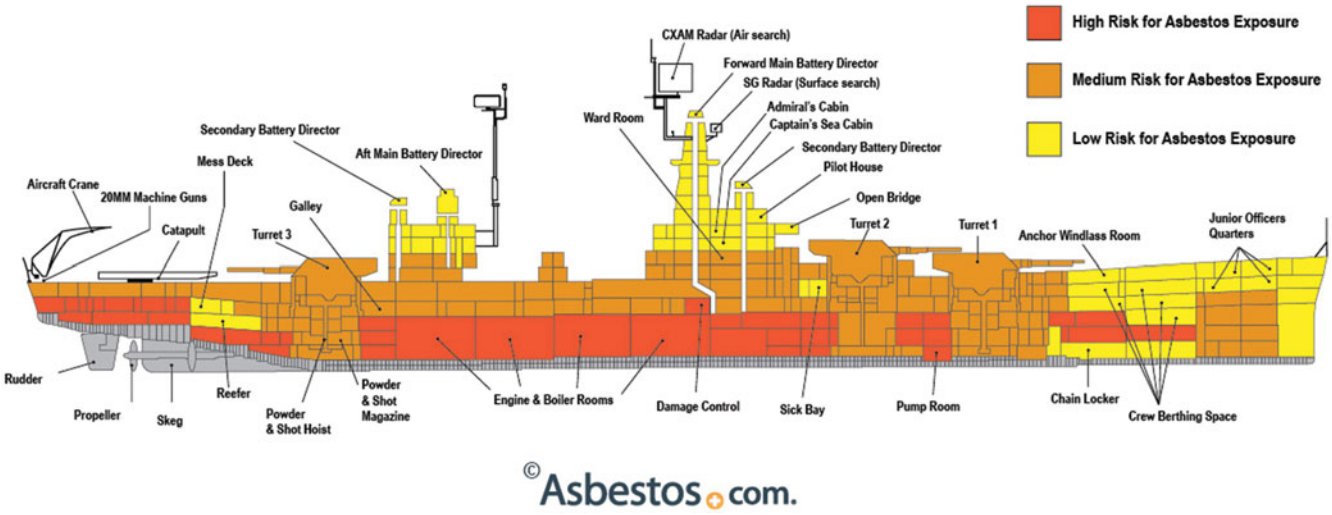

Figure 1. Diagram of naval vessel showing levels of risk for asbestos exposure (figure used with permission and acknowledgement of asbestos.com).

served in areas aboard ship where asbestos exposure would be likely. These efforts were concomitant with those used to estimate cumulative radiation exposure associated with the weapons testing.

Methods

Identification of exposed populations

Determination of which personnel aboard ship were most likely to be exposed to asbestos was achieved by identifying the individuals' job aboard ship and the locations on the ship where asbestos is located. The U.S. Navy employs a system of job descriptions among enlisted personnel that describes specifically what the person does while on duty. These specialties are known as ratings[1]. For example, boiler technicians spent most of their time below deck in the boiler room; boatswain's mates would generally be topside focusing on the material condition of the ship above decks; machinist's mates would generally be in the engineering spaces focusing on the propulsion system; and electrician's mates could be at almost any location aboard ship working on electrical components. Officers are more difficult to assign a specific location because they move from one leadership position to another over time, but as a general rule, they would not encounter the same level of asbestos exposure as enlisted personnel.

In addition to ratings for navy personnel that describe an individual's technical specialty, there are also pay grades known as rates. The most junior enlisted rates are seaman or fireman recruit (E-1), seaman or fireman apprentice (E-2), and seaman or fireman (E-3). The characterization of seaman or fireman describes the sailor's preference to 'strike' for a rating more related to either topside duties (e.g. boatswain's mate) or engineering duties (e.g. engineman). Among these junior rates, the 'fireman' designation would, therefore, be expected to be more highly exposed than the seaman and was assigned to a number of different duties aboard ship, including maintenance work where they may even provide the bulk of the manpower. Therefore, as we evaluated those most likely to be exposed, we considered the E-1 through E-3 fireman rates to be in the high-risk exposure category.

Figure 1 is a ship drawing illustrating where the highest levels of exposure to asbestos would be anticipated to occur. There were many types and sizes of navy ships involved in testing at the PPG and this figure is for illustrative purposes only, but the same fundamental compartments such as the engine room and boiler room, existed on essentially all of the ships stationed at the PPG. There are three grades of potential exposure risk—high, medium, and low. As indicated in the figure, the lower levels of the ship both fore and aft as well as the boiler and engine rooms present the highest exposure risk. Medium and low exposure would occur on decks above the lower levels and risk decreases within spaces as they ascend farther above the waterline.

If our conclusions about who would be most exposed were correct, we would expect to see the most junior rates (E-1 through E-3) and petty officers (E-4 through E-6) associated with the engine room, boiler room, and other engineering ratings as most likely to contract mesothelioma.

To support the Eight Series Study, a database was developed to manage the review of existing information for the atomic veterans, including details of their participation and duties (i.e. ratings) in the different test series at the NTS and the PPG (Till et al. 2014). Resulting exposures and doses were incorporated, along with information about the exposure location, activity, and source. The database facilitates review of existing information for the entire cohort, or for only the cases and controls in a specific unit, and it was used to develop the percentage of mesothelioma cases associated with different ratings.

The study population was selected from databases within the Department of Defense (DoD) Nuclear Test Review (NTPR) program. Military personnel who participated in one of eight test series (CASTLE, CROSSROADS, GREENHOUSE, REDWING, HARDTACK I, UPSHOT-KNOTHOLE, PLUMBBOB, and TRINITY) at any point were selected for inclusion in the study. These test series were selected because of the availability of high-quality personnel radiation dosimetry records and epidemiologic data from previous investigations (for all

Table 1. Standardized mortality analyses (SMR)[a] of mesothelioma[b] among nuclear weapons test participants by population characteristics.

Population characteristic	No. of atomic veterans	No. mesothelioma deaths[b]	SMR[a]	95% CI
All	114,270	153	1.56*	1.32–1.82
Rank				
Enlisted	96,071	145	1.81*	1.53–2.13
Officer	18,199	8	0.44*	0.19–0.87
Theatre				
Nevada Test Site	28,589	14	0.57*	0.31–0.95
Pacific Proving Ground	79,313	134	1.97*	1.65–2.34
Both	6368	5	0.89	0.29–2.07
Service				
Navy	70,309	130	2.15*	1.80–2.56
Officers	6494	4	0.61	0.16–1.56
Enlisted	63,815	126	2.34*	1.95–2.79
All other services[c]	43,961	23	0.61*	0.38–0.91
Army	26,091	10	0.45*	0.22–0.83
Air Force	12,848	10	0.85	0.41–1.56
Marines	5003	3	0.75	0.15–2.19

[a]The standardized mortality ratio is the observed number of deaths divided by the expected number of deaths computed on the basis of rates in the general population for males of similar age, race, and calendar years of life.
[b]Taken as cancers of the pleura and peritoneum (ICD5: 201; ICD6: 162.2; ICD7: 158,162.2; ICD8: 158.9,163.0; ICD9: 158.8,158.9,163) and mesothelioma (ICD10: C45).
[c]Nineteen atomic veterans were not in these four branches.
* $P < 0.05$.

series except TRINITY) (Johnson et al. 1996; Thaul et al. 2000; Watanabe et al. 1995). Available information included name, military service number, date of birth, sex, pay grade, rank or rating, unit membership, and dates during participation, and permanent unit.

Vital status determination

Ascertainment of vital status (alive or dead) and cause of death was determined by accessing various mortality databases, including the US Department of Veterans Affairs (VA) BIRLS (Beneficiary Identification Record Location Subsystem), the National Death Index, the Social Security Administration (Death Master File and Service for Epidemiologic Researchers), and death certificates requested and provided by the VA and state departments of health. See Mumma et al. (2018) for a detailed description of vital status and cause of death ascertainment. Deaths from mesothelioma, including cancers of the pleura and peritoneum, were coded according to the International Classification of Disease (ICD) revision being used at the time of death. Only the underlying cause of death was used in the analyses. Because an ICD code specific to malignant mesothelioma did not appear until ICD revision 10 in 1999 (C45), we identified probable deaths from mesothelioma, for example, cancers of the pleura and peritoneum, prior to ICD 10 using the following codes: ICD5: 201; ICD6: 162.2; ICD7: 158,162.2; ICD8: 158.9,163.0; ICD9: 158.8,158.9,163.

Statistical analyses

Standardized mortality ratios (SMRs) were computed comparing the numbers of deaths observed from mesothelioma and other causes among the workers with the numbers expected based on mortality rates in the general US population. US population mortality rates by age, calendar year, and sex were applied to the corresponding person-years of follow-up to obtain the expected number of deaths from mesothelioma had the study population experienced the same force of mortality as that of the U.S. population as a whole. The end of follow-up was taken as the date of death, the 95th birthday, or 31 December 2010, whichever came first. Observed and expected numbers of deaths were examined by test area (NTS, PPG, both areas), service (navy, army, air force, marines, and rank (enlisted, officer). Statistical variability was evaluated by the 95% exact Poisson confidence interval (CI) of the SMR assuming that the observed number of deaths followed a Poisson distribution.

Results

The SMR analyses revealed significant excess in mesothelioma deaths, overall (SMR 1.56; 95% CI 1.32–1.82; $n = 153$) and among certain subgroups (Table 1). Statistically significant elevations were seen among enlisted men (SMR 1.81; $n = 145$), navy personnel (SMR 2.15; $n = 130$), and those who served in the PPG (SMR 1.97; $n = 134$). Statistically significant deficits were seen among officers (SMR 0.44; $n = 8$), army personnel (SMR 0.45; $n = 10$) and those who served at the NTS (SMR 0.57; $n = 14$).

The SMR analyses showed a clear concentration of mesothelioma deaths among navy personnel and no increased mortality rates were seen among the other services: army (SMR 0.45), air force (SMR 0.85), or marines (SMR 0.75). In fact, the naval personnel had a significant excess of mesothelioma deaths (SMR 1.53), whereas the other three services combined had a significant deficit of mesothelioma deaths (SMR 0.61; 95% CI 0.38, 0.91; n-23). Thus the database developed to support the Eight Series Study was also used to evaluate the number and percentage of mesothelioma deaths for each naval rating and to determine whether or not the data support our conclusion that certain naval

Table 2. Standardized mortality ratio of mesothelioma by selected ratings and potential for asbestos exposure among 63,815 enlisted naval personnel (sailors).

Asbestos potential and rating	No. of sailors[a]	Observed	Expected	SMR	95% CI
High Potential					
Boiler technician	1002	8	0.72	11.1	4.78–21.9
Pipe fitter	283	3	0.23	13.0	2.62–38.1
Machinist's mate	3809	29	3.2	9.18	6.15–13.2
Water tender	845	2	0.65	3.06	0.34–11.1
Fireman	7302	30	6.2	4.85	3.27–6.92
Total	12,880	69	10.7	6.47	5.03–8.19
Low/Medium Potential					
Boatswain's mate	2938	2	2.40	0.83	0.09–3.01
Hull technician	2	0	<.01	n/a	n/a
Seaman	21,144	25	17.7	1.42	0.92–2.09
Total	23,936	27	19.9	1.35	0.89–1.97
Any Potential (Low to High)	36,639	96	30.5	3.15	2.55–3.85
No to minimal potential	27,176	30	23.4	1.28	0.87–1.83

[a]Six hundred and eighty-two naval personnel have more than one rating.

ratings would have a greater risk of asbestos exposure and of developing mesothelioma due to the areas they worked aboard ship.

If asbestos exposures aboard naval ships were sufficient to cause excess mesothelioma deaths, then it might be expected that deaths due to asbestosis also would be increased. A subsequent SMR analyses confirmed this to be the case. For all atomic veterans, 65 deaths from asbestosis occurred reflecting a doubling of risk (SMR 2.13; 95% CI 1.64-2.71). The increased mortality was concentrated entirely among navy personnel (SMR 3.22; 95% CI 2.45-4.14; $n = 60$) and all other services had SMRs less than 1. Furthermore, Navy enlisted sailors with job categories with the highest potential for asbestos exposure had very high rates of asbestosis (SMR 10.0; 95% CI 6.90-14.2; $n = 32$), whereas those with no/minimal potential had no significant excess (SMR 1.78, 95% CI 0.95-3.05, $n = 13$).

Within naval personnel, we looked at the difference in the number of mesothelioma deaths between officers and enlisted. Officers had a nearly fourfold lower SMR from mesothelioma than enlisted personnel. To further investigate the deaths due to mesothelioma among different ratings within the U.S. Navy, we calculated SMRs within the ratings by the potential for asbestos exposure. Boiler technician, pipe fitter, machinist's mate, water tender, and fireman have the highest potential for exposure based on where they worked on the ship and job duties. Boatswain's mate, hull technician, and seaman have lower potential.

Table 2 shows the number and SMR for mesothelioma deaths by ratings based on the potential for exposure to asbestos among the 63,815 enlisted naval personnel. Boiler technician, pipe fitter, and machinist's mate all have SMRs exceeding 9. Likewise, fireman has an SMR of nearly 5. Ratings with low to medium potential have a slightly elevated non-significant SMR. Naval personnel with minimal potential for asbestos exposure have an SMR of 1.28 (95 CI 0.87–1.83).

Discussion

A key objective of this analysis was to determine if the methodology developed to determine radiation doses to navy military personnel who were exposed during atmospheric testing of nuclear weapons could be applied to investigate mortality from mesothelioma among the same group. The process of estimating radiation dose was based on knowing an individual's general location aboard ship using the navy's system of rates and ratings for enlisted personnel and rank for officers. The results of the statistical analysis revealed that mesothelioma deaths occurred at higher rates and at locations aboard ship where asbestos exposure would have been greater with respect to other parts of the ship. Therefore, the method of using the navy job classification system of enlisted rates and ratings and rank for officers provides a viable method for evaluating asbestos exposure among navy personnel.

A secondary benefit to the study is the confirmation of the methodology to estimate radiation dose described in Till et al. (2014). In that study, higher radiation exposures were found to be in locations where personnel were stationed near contaminated seawater used for condenser cooling and at other locations around the ship such as berthing quarters below decks that were near the hull.

Although sailors who died from mesothelioma were not included in the subset of veterans whose radiation exposure was reconstructed in great detail (Till et al. 2014), their whole-body radiation doses could be accurately estimated from military records (Beck et al. 2017). Absorbed doses to the lung were low (mean 6.21 mGy with a maximum of 972 mGy) and the doses for the high-risk asbestos-mesothelioma rating groups did not differ meaningfully from the doses to the members of the other naval cohort rating groups nor the doses to members of the entire Navy cohort.

Conclusions

Over half of the mesothelioma deaths among 63,815 enlisted navy personnel were for sailors with jobs as machinist's mate, pipe fitters, boiler technicians, water tender, and fireman, even though these jobs were held by only 20% of the naval enlisted population. These jobs all had high potential for exposure to asbestos products, which would explain the significant increase in risk of death from mesothelioma in the navy (SMR 2.15) compared with the significant deficit seen among other services (SMR 0.61) which had low potential for asbestos exposure. Sailors who did not work in these job categories with high potential for asbestos exposure, were not found to be at excess risk for mesothelioma mortality compared to the general US population.

Our evaluation and analyses of the comprehensive data sets available for military personnel support the conclusion that the high mortality from mesothelioma among sailors in the U.S. Navy during the atmospheric nuclear testing at the PPG was related to a high potential for exposure to asbestos. In contrast, the military personnel serving in other services had a low potential exposure to asbestos as evidenced by their significant low mortality rate from mesothelioma. Certain naval ratings were at a greater risk for exposure to asbestos than others. There is also strong evidence that officers have a lower risk of exposure than enlisted personnel,

and accordingly a lower risk of death from mesothelioma. This analysis demonstrates the importance of considering an individual's job or duty on a ship and its relationship to risk of exposure to asbestos. Similar relationships were established between ratings, rates, and officers aboard ships in our estimation of radiation dose to the atomic veteran cohort (Till et al. 2014; Caldwell et al. 2016; Beck et al. 2017). In the absence of detailed knowledge on the potential exposure to a powerful carcinogen, such as asbestos, in a low-dose radiation study, misleading conclusions might be drawn. Thus, this investigation rules in asbestos as the cause of the mesothelioma excess, and accordingly rules out low-dose radiation.

Notes

1. The system of ratings and their abbreviations used by the U.S. Navy evolved over more than 200 years. The rating defines the job specialty of enlisted personnel and characterizes where aboard ship (or ashore) they work and what they do. Some ratings no longer exist, and new ratings have been introduced due to changes in technology with time.

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Disclosure statement

The authors declare no conflict of interest.

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References

Beck HB, Till JE, Grogan HA, Aanenson JW, Mohler HJ, Mohler SS, Voillequé PG. 2017. Red bone marrow and male breast doses for a cohort of atomic veterans. Radiat Res. 187:221–228.

Boice JD. 2019. The Million Person Study, whence it came and why. Int J Radiat Biol (Submitted for this special issue).

Caldwell GG, Zack M, Mumma M, Falk H, Heath CW, Till JE, Chen H, Boice JD. Jr. 2016. Mortality among military participants at the 1957 PLUMBBOB nuclear weapons test series and from leukaemia among participants at the SMOKY test. J Radiol Prot. 36: 474–489.

Johnson JC, Thaul S, Page WF, Crawford H. 1996. Mortality of veteran participants in the CROSSROADS nuclear test. Washington (DC): National Academies Press.

Mumma MT, Cohen SS, Sirko JL, Ellis ED, Boice JD. 2018. Obtaining vital status and cause of death on a million persons. Int J Radiat Biol. 1–21. DOI: 10.1080/09553002.2018.1539884. [Epub ahead of print]

National Council on Radiation Protection and Measurements (NCRP). 2018. Deriving organ doses and their uncertainty for epidemiologic studies (With a focus on the one million U.S. workers and veterans study of low-dose radiation health effects. NCRP Report 178. Bethesda (MD): NCRP.

Thaul S, Page WF, Crawford H, O'Maonaigh H. 2000. The five series study: mortality of military participants in U.S. nuclear weapons tests. Washington (DC): National Academies Press.

Till JE, Beck HB, Aanenson JW, Grogan HA, Mohler HJ, Mohler SS, Voillequé PG. 2014. Military participants at the U.S. atmospheric nuclear weapons testing—methodology for estimating dose and uncertainty. Radiat Res. 181:471–484.

Watanabe KK, Kang HK, Dalager NA. 1995. Cancer mortality risk among military participants of a 1958 atmospheric nuclear weapons test. Am J Public Health. 85:523–527.