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Airborne asbestos exposures associated with gasket and packing replacement: A simulation study and meta-analysis

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ABSTRACT

Exposures to airborne asbestos during the removal and installation of internal gaskets and packing associated with a valve overhaul were characterized and compared to published data according to different variables (e.g., product, equipment, task, tool, setting, duration). Personal breathing zone and area samples were collected during twelve events simulating gasket and packing replacement, clean-up and clothing handling. These samples were analyzed using PCM and TEM methods and PCM-equivalent (PCME) airborne asbestos concentrations were calculated. A meta-analysis was performed to compare these data with airborne asbestos concentrations measured in other studies involving gaskets and packing. Short-term mechanic and assistant airborne asbestos concentrations during valve work averaged 0.013 f/cc and 0.008 f/cc (PCME), respectively. Area samples averaged 0.008 f/cc, 0.005 f/cc, and 0.003 f/cc (PCME) for center, bystander, and remote background, respectively. Assuming a tradesman conservatively performs 1–3 gasket and/or packing replacements daily, an average 8-h TWA was estimated to be 0.002–0.010 f/cc (PCME). Combining these results in a meta-analysis of the published exposure data showed that the majority of airborne asbestos exposures during work with gaskets and packing fall within a consistent and low range. Significant differences in airborne concentrations were observed between power versus manual tools and removal versus installation tasks. Airborne asbestos concentrations resulting from gasket and packing work during a valve overhaul are consistent with historical exposure data on replacement of asbestos-containing gasket and packing materials involving multiple variables and, in nearly all plausible scenarios, result in average airborne asbestos concentrations below contemporaneous occupational exposure limits for asbestos.

1. Introduction

Asbestos-containing gaskets and packing materials were used in industrial and maritime settings, such as refineries, chemical plants, naval ships, and energy plants (Cheng and McDermott, 1991; Lindell, 1973; Spence and Rocchi, 1996). Naval specifications required that asbestos containing gaskets be used on many ships (United States Navy, 1924, 1953). In the past, the asbestos content of gaskets typically ranged from 40% to 90%, with binders and fillers making up the rest of the material (Madl et al., 2007). In most cases, chrysotile asbestos was the only asbestos fiber used in these materials, although crocidolite asbestos was sometimes used within very specialized acidic or corrosive environments.

Relatively few studies in the 1970s and 1980s evaluated exposures related to gasket and packing work, especially when compared to the many evaluations of asbestos insulation, due to a perception that asbestos exposures during gasket and packing work would be negligible or relatively small (Lindell, 1973; Selikoff, 1970). Studies, both published and unpublished, which evaluated airborne asbestos exposures due to replacement of gaskets and packing were generally conducted at worksites or simulated in a controlled environment. Later studies tried to limit confounding background asbestos levels (e.g., the extensive use of asbestos insulation on pipes and machinery) by simulating work activities involving gaskets and packing in controlled environments (e.g., laboratory test facilities). The first comprehensive

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study which characterized potential worker exposures to airborne asbestos during the removal and installation of asbestos-containing gaskets was conducted by the U.S. Navy in 1978 (Liukonen et al., 1978). This worksite study was performed in a shipyard setting and, although unclear how background airborne concentrations resulting from other asbestos-containing materials being used at the shipyard may have influenced the results, the vast majority of airborne asbestos exposures were below contemporaneous occupational exposure limits (Liukonen et al., 1978).

A review published by Madl et al. (2007) was the first to summarize all of the published data, as well as selected unpublished data, on airborne asbestos concentrations associated with the handling of asbestos-containing gaskets and packing materials (Madl et al., 2007). In that study, eight simulation studies (or series of simulation studies) and four worksite studies of industrial and maritime settings, which involved collection of more than 300 air samples, were analyzed (Boelter et al., 2002; Cheng and McDermott, 1991; Fowler, 2000; Liukonen et al., 1978; Longo et al., 2002; Mangold et al., 2006; McKinnery and Moore, 1992; Millette and Mount, 1993; Spence and Rocchi, 1996; Spencer, 1998a,b; Yeung et al., 1999). The replacement of gaskets and packing using hand-held tools showed, with few exceptions, short-term average exposures less than the current 30-min OSHA Excursion Limit (EL) of 1.0 f/cc and all of the long-term average exposures were less than the current 8-h TWA PEL of 0.1 f/cc. It was concluded that the use of hand tools and hand-operated power tools to remove or install gaskets or packing should not, under conditions normally encountered, have produced airborne concentrations in excess of contemporaneous regulatory levels (Madl et al., 2007).

While several published studies have evaluated asbestos exposures to workers removing and installing gaskets and packing, none have characterized exposures to a worker performing valve repair work limited to the replacement of internal gaskets and packing materials (e.g., as would be performed during a valve overhaul). Therefore, it was of interest to evaluate airborne asbestos concentrations generated during replacement of gaskets and packing internal to the valve and how these concentrations might contribute to asbestos exposures experienced by a worker or bystander. The primary objective of this work was to: (1) characterize exposures to airborne asbestos during the removal and installation of asbestos-containing packing and gaskets contained within vintage valves, (2) measure short- and long-term exposures during packing and gasket replacement and characterize the fiber type, size distribution (e.g., >5 and >20 μm length), and morphology of airborne asbestos fibers generated during these work activities, (3) compare short-term and long-term measurements to the occupational exposure limits (OELs) set forth by the Occupational Safety and Health Administration (OSHA), 30-min EL and 8-h Time Weighted Average (TWA) Permissible Exposure Limit (PEL), (4) conduct a statistical comparison of the airborne asbestos concentrations measured in this study to the body of available data from similar studies in the published literature, and (5) use the combined dataset (i.e., data from this simulation study and the published literature) to perform additional statistical comparisons according to different variables (e.g., product type, tool, task, or equipment) and explore any other trends that may be discerned when considering the full body of data available to date.

2. Methods

2.1. Valve simulation study

2.1.1. Equipment, test site and study conditions

Ten vintage Edward valves manufactured prior to the 1980s, an era in which some packing and gaskets contained asbestos, were selected for this study. Two 1-in. (2.54 cm) valves and eight 3-in. (7.62 cm) valves were used; all of the valves were globe valves with the exception of one gate valve. Each valve was blasted with abrasive material prior to testing to remove possible external debris or contamination. The service life of each valve was unknown; however, it was understood by the investigators that the valves were historically used on maritime vessels. It was not determined until after the testing through bulk sample analysis whether each valve housed asbestos-containing packing and gasket material.

Complete valve overhauls were performed inside an enclosed room by two retired mechanics with 50 combined years of training and experience in the U.S. Navy, servicing and repairing equipment. Further description of the study room is described in the Supplementary Information (SI). Prior to conducting the study, permission from a medical institutional review board (IRB) was requested and obtained (Copernicus Group IRB, Research Triangle Park, NC, USA).

2.1.2. Exposure scenarios

Airborne asbestos concentrations were measured during activities conducted during twelve sampling events. Ten of these events characterized exposures during valve overhaul work which included the removal and installation of asbestos-containing packing and/or gaskets contained within ten vintage valves (Event 1, 3–11), one characterized exposures associated with post-valve overhaul clean-up work (Event 2), and one characterized exposures during the handling of coveralls worn during the study (Event 12).

The packing replacement process was similar for all ten valves (Event 1, 3–11). On nine of the ten valves (Event 1, 3–4, 6–11), the gasket was also removed, and on three of those occasions (Event 3, 4, and 6), a new gasket was fabricated. In general, the mechanics took approximately 15–40 min to replace the packing material and approximately 10–30 min to replace the gasket, thus resulting in a total duration of approximately 30–60 min for a complete valve overhaul. The process of packing and gasket removal and installation and cleanup are described in further detail in the SI.

Clothes handling (i.e., shaking and folding of coveralls worn during valve overhaul work) was also studied. In total, six coveralls worn by the worker and the assistant (one pair each per day) were collected and sealed separately in plastic-lined bags. At the conclusion of the study, coveralls worn by the mechanic and assistant and collected each day of the testing (new coveralls were worn each day) were shaken, folded, and turned inside out for approximately 1–3 min by a volunteer, simulating the handling of these potentially contaminated work clothes (Event 12).

2.1.3. Sampling and analytical methods

Airborne asbestos fibers were collected onto mixed cellulose ester membranes as described elsewhere, as well as further described in the SI (Madl et al., 2009). During an entire valve job, personal samples from the mechanic's and assistant's lapel, bystander and remote area samples, and ambient samples for airborne asbestos were collected. Consecutive 30-min and long-term samples were collected on the right and left lapels of both the mechanic and the assistant. After each event, once the work activities had ceased, the room was ventilated for 30 min and background samples were taken prior to the start of the next testing event. All air samples were collected and analyzed for asbestos by phase contrast microscopy (PCM) and transmission electron microscopy (TEM) according to NIOSH Methods 7400 and 7402 which defines fibers >5 μm in length and ⩾0.25 μm in diameter and having at least a 3:1 aspect ratio (National Institute for Occupational Safety and Health (NIOSH), 1994). Using the ISO methodology 10312 (1995), asbestos fibers were classified according to fiber size and morphology as described in the SI.