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Literature Review of Industrial Hygiene Exposure to Asbestos
Take-Home from Bystander to work by others with Encapsulated Materials?
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Introduction to Encapsulated Materials

Asbestos-reinforced/filled encapsulated materials have historically been considered as safe uses of asbestos. In 1970 in the US, Irving Selikoff opined that "it is fortunate that the greatest part of this (all use of asbestos in society) has been in products in which the asbestos is "*locked in"* [original author emphasis] that is, it is bound with cement or plastics or other binder so that there is no release, *certainly no significant release*, of asbestos fibers in either working areas or general air".[1]

This historical view of the safety of such materials was international. In two papers detailing the UK Asbestos Regulations in 1969, a leading authority indicated that "these materials give rise to no dust and are perfectly safe to handle." and "it is obvious that no hazard exists in normal usage, unless such usage involves a high degree of abrasion" and "it is not suggested that there is any health hazard associated with the occasional drilling or cutting".[2][3] Indeed, Selikoff and others at an international conference in 1969, dismissed friction material in brakes as a source of any concern.[4]

In 1972, Nicholson indicated that "Asbestos-cement products are a good example of "locked-in" products which probably do not constitute a significant source of asbestos to the environment under normal conditions of use."[5] This opinion that "locked-in" asbestos within firmly-bonded materials such as A/C produced lower exposure was repeated by NIOSH in its recommendations to OSHA for the first permanent asbestos standard in 1972.[6]

In recognition of this lack of exposure risk, in 1972 OSHA specifically exempted such encapsulated materials from all labeling requirements.[7] This broad exemption for such encapsulated asbestos-containing materials continues in the US regulations in force today.[8]

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[1] Selikoff, I. Partnership for Prevention. Industrial Medicine. Vol 39, No. 4, April 1970.
[2] Holmes, S. Safe Use of Asbestos Plastic. Composites. March 1972. Vol 3, Issue 2. p 60-61.
[3] Holmes, S. The Measurement of Asbestos Dust. Staub Reinhaltung der Luft. English translation for USEPA. 33(1973)2.
[4] Shapiro, H.A., Editor. Pneumoconiosis. Proceedings of the International Conference, Johannesburg 1969. Oxford University Press. Published 1970. Ernst Walther, PhD. Dust Problems in the Use of Asbestos Products. Discussion: Page 51, Comment of Irving J. Selikoff. "Brake linings do not constitute a hazard."
[5] Nicholson, W.J. and Pundsack, F. L. Asbestos in the Environment. In the proceedings of: Biological Effects of Asbestos. IARC conference, Lyon, France, October, 1972. Page 127.
[6] NIOSH Recommended Asbestos Standard. US Dept. HEW, USPHS, CDC, NIOSH.1972
[7] OSHA Standard for Exposure to Asbestos Dust. Fed. Register, Vol. 37, No. 110, June 7, 1972.
[8] OSHA Occupational Exposure to Asbestos. Federal Register, 59:40964-41162. 1910.1001; 1915.1001; 1926.58, August 10, 1994. (6) The provisions for labels required by paragraph (j)(2) of this section or for material safety data sheets required by paragraph (j)(5) of this section do not apply where: (i) Asbestos fibers have been modified by a bonding agent, coating, binder, or other material provided that the manufacturer can demonstrate that during any reasonably foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of fibers of asbestos in excess of the TWA permissible exposure level and/or excursion limit will be released or (ii) Asbestos is present in a product in concentrations less than 1.0%.

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More than a decade later in 1984, it was recognized that the degree of encapsulation of asbestos fibers can vary, but the fibers within asbestos-cement pipe are relatively tightly bound within their cement matrix, so they present less potential exposure.[9] I am unaware of any research conducted since this publication in 1984 that would demonstrate otherwise.

A voluminous body of scientific literature now exists regarding asbestos-reinforced/filled resins. Industrial hygiene scientific studies are available that have determined the extent of exposure to asbestos, if any, from encapsulated asbestos-reinforced/filled plastic, resinous and cement materials.

A significant number of studies have been commissioned regarding worker exposure to vinyl asbestos flooring material, which is perhaps the most common example of asbestos-reinforced and filled plastics. This work in whole demonstrates the absence of any significant exposure from this historical use of asbestos in buildings. Studies of other asbestos-reinforced and asbestos-filled plastic resins, such as of Bakelite and mastics, have been conducted and demonstrate that these materials produce airborne concentrations that are very low. Studies of friction materials, such as brakes and clutches, have shown similar low results.

As a result of these studies, sufficient exposure data in US government-sponsored studies and other industrial hygiene measurements are present in the scientific literature to provide foundation values for the estimation of direct exposures to workers and indirect bystander exposures. Each of the major groups of encapsulated materials is reviewed in more detail below.

Encapsulated Materials - Vinyl Asbestos Floor Tile

The levels of asbestos exposure associated with the installation, maintenance, and removal of asbestos-reinforced/filled vinyl resin floor tile have been rigorously studied by OSHA, EPA, and the scientific community.

An article by Murphy in 1971 suggested the installation of floor tile was a source of asbestos exposure.[10] This study did not represent any normal building floor installation activity, but did document the potential exposure associated with an extreme sanding task that equated to an 8-hr TWA of only 0.05f/cc. Levine referenced Murphy along with others in 1978 in a widely distributed document on asbestos; it was the conclusion of this document with many authors that “because asbestos fibers are firmly embedded in the tiles, installation per se is unlikely to be a source of important asbestos exposure”.[11]

[9] Asbestiform Fibers: Nonoccupational Health Risks. Committee on Nonoccupational Health Risks of Asbestiform Fibers, Board on Toxicology and Environmental Health Hazards, National Research Council. ISBN: 0-309-55757-7. (1984). Page 55.

[10] Murphy, R. L. et al. Floor Tile Installation as a Source of Asbestos Exposure. American Review Of Respiratory Disease 1971. Case report with a work process simulation that produced levels of up to 1.3 fibers per cc while sanding vinyl asbestos with a belt sander for 20 minutes; a task not representative of any normal building maintenance activity.

[11] Asbestos: An Information Resource. Levine , R. J., Editor. US Department of Health Education and Welfare, Public Health Service. National Institutes of Health. Prepared by Stanford Research Institute International for the National Cancer Institute. DHEW Publication #79-1681. May 1978.

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A series of four studies was commissioned by the Resilient Floor Covering Institute and conducted by Stanford Research Institute International in 1979.[12] One of these studies addressed the installation of vinyl asbestos tile.[13] Analysis by TEM indicated that installation produced exposures from 0.0046 f/cc to 0.0092 f/cc and a second installation produced exposures of 0.008 f/cc to 0.027 f/cc, with an average of 0.01 f/cc. [14] Another study obtained similar results of <0.01 f/cc.[15] The results of these studies were relied upon by OSHA and EPA in mid-1980's asbestos rulemaking and the widely-referenced exposure associated with the installation of vinyl floor tile were <0.01f/cc and geometric mean of 0.01f/cc.[1617]

Additional studies focused directly on the installation of vinyl-asbestos floor tile including a study by Lundgren published in 1991. Electron microscopy analysis (that does distinguish between asbestos and other fibers) used in this study indicated worker exposure of 0.0018 f/cc.[18]

A later study published in 2003 by Williams confirmed that no measurable airborne asbestos resulted from the breaking of floor tile under severe conditions. Therefore, certainly no exposure would be expected from the normal "score and snap" breaking method that was traditionally utilized in the installation of vinyl asbestos floor tile.[19]

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[12] Walcott, R. And Warrick, J. Comparison Testing Monitoring For Airborne Asbestos Fibers -- Sheet Vinyl Floor Covering, Wet Versus Dry Scraping -1, Vinyl Asbestos Floor Tile-2, Monitoring For Airborne Asbestos Fibers - Sheet Vinyl Floor Tile – 3, Sheet Vinyl Floor Covering – 4. SRI Intl for the RFCI, 1979.

[13] SRI International. Richard Walcott And James Warrick. Comparison Testing Monitoring For Airborne Asbestos Fibers: Vinyl Asbestos Floor Tile. December 1979. Final Report. The principal objective of this study was to monitor for airborne asbestos fibers, if any, during conditions of preparation, installation, and removal of vinyl asbestos tile when processes deviate from RFCI recommended procedures and to determine their concentrations. Contrary to recommended processes, the existing flooring of GAF vinyl asbestos tile VAT that had been installed over Azrock vinyl asbestos tile VAT over hard board, was removed by prying the tile loose from the hard board with a large flat bladed scraper. The floor was then scraped to remove dry adhesive and eliminate uneven seams. During this operation there was sweeping of debris with a hand broom, which is contrary to recommended tile removal procedure. Significant deviation from recommended procedures was noted. Page 10, page 13. Sweeping of debris with a broom. Also Crow bar instead of a wall scraper for the ripping up operation. Breaking the tile before placing it in the disposal bagging. Individual sample results before removing the VAT with no controls were 0.38 f/cc 0.1151 f/cc, average 0.2476 f/cc. The higher result was from the worker that bagged loose tile including breaking the tile, using the crowbar instead of the wall scraper, and using a hand broom for sweep up. The results from breaking the tile, if any, cannot be separated from the other data. These results are for the complete removal. Preparation tasks including wax stripping and dry mopping produced no exposure.

[14] SRI Int'l. Richard Walcott and James Warrick. Comparison Testing Monitoring For Airborne Asbestos Fibers: Vinyl Asbestos Floor Tile. Dec 1979. Final Report. Table 9, p27; Table 8, p25.

[15] Dunigan, J. and Lebel, J. Measurement Of Chrysotile Fiber Emission Asbestos -- Vinyl Tile Laying and Sanding Ops. Pabillon Marie-Victoria, Univ de Sherbrooke, Québec Canada, 1982. <0.01f/cc installation.

[16] Anderson, P.H., et al. Analysis of Fiber Release from Certain Asbestos Products. Prepared for US Environmental Protection Agency. Contract # 68-01-5960. GCA Corp. December 1982.

[17] Asbestos Task Order For Construction Alternatives. Contract # J-9-F-4-0024. Prepared for US DOL OSHA. Prepared by CONSAD Research Corp. & Clayton Env Consultants, Inc. May 1984.

[18] Lundgren, D.A. et al. Asbestos Fiber Concentrations Resulting From the Installation, Maintenance and Removal Of Vinyl Asbestos Floor Tile. Part. Syst. Charact. 1991. Tile Installation. Personal 0.092 f/cc PCM. 0.0018f/cc SEM. Static 0.130 f/cc PCM. 0.0013 SEM. Floor Tile Removal. Cold removal 0.139f/ccPCM, 0.0056f/ccSEM. Hot removal 0.049f/ccPCM, 0.0005f/ccSEM. Static sampling, hot/cold removal 0.041f/ccPCM, 0.0004f/cc SEM.

[19] Williams, MG, et al. Asbestos Release during Removal of RFC Materials by Rec'd Work Practices of the Resilient Floor Covering Institute. AOEH. 2003. The results of the ATEM analyses of air samples collected inside a mini-enclosure while tiles were broken by striking a single blow with an automobile body hammer were: Both 12x12 and 9x9 tiles were tested. In each case the tiles were allowed to lie and were not further disturbed. The asbestos released, measured by ATEM, was at or less than the detection limit (<0.0058 str/cc). This probably was due in part to the binding of the matrix and the fact that no disturbance of the

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Such findings of no measurable airborne asbestos were again confirmed in a paper published in 2005 by Lange.[20]

Of the floor maintenance studies over decades, OSHA indicated the most significant study was the 1992 study conducted for the EPA by Wickman, et al.[21] This study indicated a very low average worker exposure of 0.0009 f/cc as an 8-hour TWA for fibers >5u in length. Others also showed very low levels, [2223] or did not reveal the presence of *any* asbestos fibers.[24] Other major studies also demonstrate the absence of any significant exposure from this use of asbestos.[2526]

There are no studies available for the power-sawing of vinyl asbestos floor tile as this would be an inappropriate manner in which to cut this product. However, OSHA noted NIOSH studies found that the handling, chipping, grinding, pulverizing of factory production quantities of asbestos-reinforced plastic material scrap can produce exposures of 0.02-0.3 fibers/cc. [27282930] Due to the significant variances between the plastic production-scrap and pipe-sawing processes and variations in the materials as well, these measurements are not considered appropriate surrogate exposure assessment data representative of end user tasks, but do present additional data points regarding the expectation of the low order of magnitude of asbestos exposure associated with rigid asbestos-reinforced or filled plastic resin materials.

Other floor tile studies have been conducted as well. This work in whole demonstrates the absence of any significant exposure from this historical use of asbestos in buildings.[313233343536373839]

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pieces occurred after breaking. The fact that the simple breaking of tiles in the mini-enclosure did not produce enough airborne fibers to be detected by ATEM supports the idea that a major portion of the asbestos emissions were caused by abrasion between tile/mastic fragments and/or by the scrapers.

[20] Lange, J. H. 2005. Asbestos-containing Floor Tile and Mastic Abatement: Is there Enough Exposure to Cause Asbestos-related Disease? Indoor Built Environ 2005 14;1:83–88.

[21] Exposure of Custodial Employees To Airborne Asbestos. EPA Project No. J1007468-2001-0. Arthur R. Wlckman, et al. Missouri Dept of Health. Bureau of Environ Epidem, for US EPA Office of Pesticides and Toxic Substances. EPA rep: David Treece. Unpublished by EPA. 1992.

[22] J. Donald Millar. Testimony of the NIOSH on the Occupational Safety and Health Administration's Proposed Rule on Occupational Exposure to Asbestos. January 24, 1991.

[23] Wong. S. Director of EHS. Los Angeles Unif School Dist. Internal report. Analysis by TEM.

[24] Lundgren, D.A. et al. Asbestos Fiber Concentrations Resulting From the Installation, Maintenance and Removal Of Vinyl Asbestos Floor Tile. Part. Syst. Charact. 8 (1991) 233-236.

[25] Walcott, R. And Warrick, J. Comparison Testing Monitoring For Airborne Asbestos Fibers -- Sheet Vinyl Floor Covering, Wet Versus Dry Scraping -1, Floor Tile-2, Monitoring For Airborne Asbestos Fibers - Sheet Vinyl Floor Tile – 3, Floor Covering – 4. SRI Intl for the Resilient Floor Covering Institute, 1979.

[26] Asbestos Task Order For Construction Alternatives. Contract # J-9-F-4-0024. Prepared for US DOL OSHA. Prepared by CONSAD Research Corp. & Clayton Env Consultants, Inc. May 1984.

[27] OSHA Preamble to Final Rules, Occupational Exposure to Asbestos, Friday, June 20, 1986. 29 CFR Parts 1910, 1926. Asbestos Reinforced Plastics. Table 17 - Worker Exposures During the Manufacture of Asbestos Reinforced Plastics.

[28] Belanger, PL, et al. NIOSH Health Hazard Eval. 78-73-612, Kentile Floors, Inc., Chicago, IL.

[29] Belanger,PL, etal. NIOSH Health Hazard Eval. 78-73-633, Kentile Floors, Inc., Brooklyn, NY.

[30] Ramos, H. NIOSH Health Hazard Eval. HHE-73-133-136, Armstrong Cork Co., Jackson, MS.

[31] A.F. MeyerAssoc. Study in Maryland school.WRC-TV; NBCnews affiliate. Wash,DC.Oct 89.

[32] 29 CFR Parts 1910, 1915, and 1926. Department Of Labor Occupational Safety and Health Administration. Occupational Exposure To Asbestos, Final Rule. 08/10/1994.

[33] J. Donald Millar. Testimony of NIOSH on the Occupational Safety and Health Administration's Proposed Rule on Occ Exposure to Asbestos. January 24, 1991.

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Encapsulated Materials - Asbestos-Reinforced/Filled Phenolic Resins, such as Bakelite
Asbestos-reinforced/filled plastic resin materials include the historical use of asbestos as a reinforcement and/or filler in various applications of formaldehyde phenol compounds generically referred to as Phenolic Resin. One such material is frequently generically referred to as Bakelite. Studies of other asbestos-reinforced and asbestos-filled plastic resins, such as of Bakelite and mastics, have been conducted and demonstrate that these materials produce airborne concentrations that are very low.[40]

It should be noted that Bakelite is a registered tradename, but much like the generically used trademarked term Kleenex, such generic references to this material may or may not pertain to the use of actual brand name material. The handling of factory production quantities of Bakelite-like asbestos-reinforced plastic materials can produce exposures of 0.033-0.042 fibers/cc.[41]

OSHA found that exposures during the manufacturing of these asbestos-reinforced plastics may be from 0.04-0.047 fibers/cc.[42] The secondary processing of phenolic asbestos-reinforced plastics such as Bakelite including activities such as the sawing, sanding, drilling, and cleanup of the dust has been studied, with the band saw or cutting phase producing average worker exposures of 0.13 f/cc and a maximum of 0.21 f/cc.[43]

Sawing Plastic-Encapsulated Asbestos-Reinforced/Filled Resin Pipe
Spielman conducted a study of the sawing of plastic-encapsulated asbestos-reinforced/filled resin pipe in 1977. The study indicated an eight-hour time-weighted average exposure of 0.254 f/cc for 21 saw cuts and six sanding procedures with a total task duration of 37.25 minutes in the eight-hour period.

It is important to note that the sanding task contributed far more to the exposure than the sawing task and therefore any estimate of sawing based on these results without

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[34] Kominsky, J.R. Et Al. Airborne Asbestos Concentrations During Buffing of Resilient Floor Tile. Conducted by Environmental Quality Management, Inc. and New Jersey Dept of Health for the US Environmental Protection Agency. Report EPA/600/R-93/159. Final Report 12/1992.
[35] Edwards, A. Kominsky, J.R. and Freyberg, R.W. Airborne Asbestos Concentrations During Spray-Buffing of Resilient Floor Tile. Applied Occ and Environmental Hygiene. February 1994.
[36] Kominsky, J.R. Et Al. Airborne Asbestos Concentrations During Buffing, Burnishing, And Stripping Of Resilient Floor Tile. Conducted By Environmental Quality Management, Inc. for the US Environmental Protection Agency. EPA No. EPA/600/R-95/121. Final Report Date Oct1997.
[37] Kominsky, J.R. Et Al. Evaluation of the Implementation of Operations and Maintenance Programs in New Jersey Schools. Conducted by Environmental Quality Management, Inc. For the US Environmental Protection Agency. EPA No. EPA/600/R-97/063. Report Date Aug1995.
[38] Kominsky, J.R. Et Al. Asbestos Exposures During Routine Floor Tile Maintenance. Part One: Spray-Buffing And Wet- Stripping. Applied Occ And Environmental Hygiene. February 1998.
[39] Kominsky, J.R. Et Al. Asbestos Exposures During Routine Floor Tile Maintenance. Part Two: Ultra High Speed Buffing And Wet-Stripping. Applied Occ And Env Hygiene. February 1998.
[40] Paustenbach, D. Occupational Exposure to Airborne Asbestos from Coatings, Mastic, and Adhesives. Journal of Exposure Analysis and Environmental Epidemiology. 2004.
[41] Almaguer, D. NIOSH Health Hazard Evaluation, Kautt & Bux Mfg. HETA 83-275-1394.1983.
[42] OSHA Preamble to Final Rules, Occupational Exposure to Asbestos, Friday, June 20, 1986. 29 CFR Parts 1910, 1926. Asbestos Reinforced Plastics. Table 17 - Worker Exposures During the Manufacture of Asbestos Reinforced Plastics.
[43] Mowat, F. Occupational Exposure to Airborne Asbestos from Phenolic Molding Material (Bakelite) During Sanding, Drilling, And Related Activities. Journal Of Occupational and Environmental Hygiene. 2005.

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adjusting downward for the lack of sanding would be considered a worst-case analysis.[44] Hand sanding was not evaluated but would result in lower, if any, exposure.

Encapsulated Materials - Friction Material, Brake Shoes and/or Pads

Another major historical use of hard or rigid asbestos-reinforced plastic resins has been in brakes, clutches, and other friction materials. Although Dr. Irving J. Selikoff was quoted as saying in 1969 that "Brake linings do not constitute a hazard", the exposures of brake mechanics were vigorously studied in the 1970's and 1980's and even later.[4546] Airborne asbestos exposure during aircraft brake replacement has been studied as well.[47]

It is now well-established in the scientific literature that the time-weighted average asbestos exposures of brake mechanics have historically been low, as initially surmised by Selikoff. A comprehensive review of the state-of-the-art use of asbestos in brakes and an exhaustive review of the historical exposures of mechanics to asbestos in brake dust have been published in the peer-reviewed scientific literature.[4849] The work of brake mechanics on passenger automobiles and light trucks has been associated with direct exposures of 0.03 f/cc[50], 0.04 f/cc,[5152] and 0.05 f/cc[53] as an eight-hour time-weighted average. Heavy tractor truck brake work had exposures as high as an 8-hour time-weighted average mean of 0.2 f/cc.[54]

Exposures associated with non-wear dust from friction materials have been found to be low as well, from 0.021 to 0.368 f/cc as a task average.[55] One study was available for

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[44] Spielman, H. Industrial Hygiene Study. Asbestos Exposures during Field Installation of Bondstrand Pipe and Flanges. Conducted at Kerr-McGee Chemical Corp., Trona, CA. Conducted by Health Science Associates, Inc., for Ameron Corrosion Resistant Piping Division, Brea, CA. October 24, 1977. Unpublished.
[45] Walther 1969. Excerpts from Proceedings of International Conference in Johannesburg 1969.
[46] Numerous studies including Moore LL: Asbestos Exposure Associated With Automotive Brake Repair In Pennsylvania. Am Ind Hyg Assoc J 49:AI2-AI3 (1988); Sheehy JW, et al: Control of Asbestos Exposure During Brake Drum Service. Appl Ind Hyg 4(12): 313-319 (1989); Kauppinen 1987 Exposure to Asbestos During Brake Maintenance of Automotive Vehicles by Different Methods, AIHA Journal 1987; and Roberts 1982 NIOSH Industrial Hygiene Summary Report Of Asbestos Exposure Assessment For Brake Mechanics. Blake, C.L., et al. Airborne asbestos concentration from brake changing does not exceed permissible exposure limit. RegToxPhar2003.
[47] Blake, C.L., et al. Airborne asbestos exposure during light aircraft brake replacement. Reg. Tox. and Pharm. 2009.
[48] Paustenbach, D. J., et al. Environmental and Occ Health Hazards Associated with the Presence of Asbestos in Brake Linings and Pads (1900 to Present): A "State-Of-The-Art" Review. J Tox Env Hlth. 2004.
[49] Paustenbach, D.J., Evaluation of the Historical Exposures of Mechanics To Asbestos In Brake Dust. Applied Occupational And Environmental Hygiene. 18: 786-804. 2003.
[50] OSHA Occ. Exp. to Asbestos. Preamble, Final Rule. 29 CFR 1910, 1926. OSHA data from 1979-84. Mean 8-hr TWA. Page 104. 51 FR 22612-01. 6/20/1986.
[51] Paustenbach, D.J., Evaluation of the Historical Exposures of Mechanics To Asbestos In Brake Dust. Applied Occupational And Environmental Hygiene. 18: 786-804. 2003.
[52] Asbestos Exposure – Brakes and Ambient. Memorandum dated Oct 17, 1985. From Chief, Chemical Review Branch and Exposure Assessment Branch to Regulatory Impacts Branch. United States Environmental Protection Agency. "0.04f/cc is a reasonable estimate of the exposure of workers in shops doing brake work".
[53] Paustenbach, D. J., et al. Environmental and Occ Health Hazards Associated with the Presence of Asbestos in Brake Linings and Pads (1900 to Present): A "State-Of-The-Art" Review. J. Tox Env Hlth. 2004.
[54] Paustenbach, D.J., Evaluation of the Historical Exposures of Mechanics To Asbestos In Brake Dust. Applied Occupational And Environmental Hygiene. 18: 786-804. 2003.
[55] Madl, A.K., et al. Exposure to Chrysotile Asbestos Associated with Unpacking and Repacking Boxes of Automobile Brake Pads and Shoes. Annals of Occupational Hygiene. 2008.

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the power-sawing of friction material. The sawing of friction material with a band saw was noted to produce an exposure of 0.7f/cc.[56]

Encapsulated Materials - Asphalt-Based Roofing Materials

A review of the available scientific literature pertaining to exposures from asphalt-based roofing products is contained in a recent paper in the peer-reviewed industrial hygiene literature. This comprehensive review of the scientific literature pertaining to hand-applied asphalt-based and encapsulated-asbestos coatings and mastics indicate that worker exposures to asbestos associated with these materials are negligible.[57]

a) Asphalt-Saturated Asbestos Roofing Felt

The exposure of workers associated with the use of asphalt-saturated asbestos roofing felt was first reported in the scientific literature in 1982. In a study commissioned by the Environmental Protection Agency, Anderson reported on studies at 11 separate construction sites and evaluated both worker exposure during removal of old roofing and subsequent replacement. In this study of the installation and removal of roofing felts, the geometric mean of 78 samples was reported as less than <0.1f/cc as a time weighted task-based average.[58] However, it is important to note that the laboratory analysis methodology used only had a detection limit of 0.1f/cc and actual asbestos levels associated with asbestos felt installation were even lower.[59] Airborne concentrations of asbestos associated with the removal of roofing were noted as 0.01 to 0.03 f/cc for area or bystander samples.

An analysis of hundreds of samples of Built-Up-Roof roof removals indicate the exposure associated with the removal of the asbestos-containing felts within this material averages 0.024f/cc generally as a task based average.[60] Installation of asphalt-saturated asbestos roofing felt was measured as non-detectable (0.00f/cc) by electron microscopy in this study conducted for the US Environmental Protection Agency.[61]

b) Asphalt Mastic

A study in 2004 evaluated the potential exposure from use of asphalt mastic that contains encapsulated asbestos. This study indicated that the airborne concentrations of asbestos from activities such as the sanding of this material produce exposures far less than the OSHA PEL of 0.1 fibers per cc, and there is no airborne concentration associated with the installation of such a product.[62]

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[56] Results of USPHS Air Samples, Raybestos-Manhattan, Manheim, PA. NIOSH-105135. Dec70.
[57] Mowat, F., et al. Simulation Tests to Assess Occupational Exposure to Airborne Asbestos from Asphalt-Based Roofing Products. Annals of Occupational Hygiene. Vol. 51, No. 5. 2007.
[58] Anderson, P.H. et al. Analysis of Fiber Release from Certain Asbestos Products. Prepared for the US EPA by GCA Corp. December, 1982. Table 3.7. Page 3.18. 1982.
[59] Exposure to Asbestos During Roofing Removal. By SRI International and Fowler Associates. For NRCA. Final Report. September 1990.
[60] Objective Data Demonstration for Certain Roofing Materials and Operations Under OSHA's 1994 Asbestos Standard. Data collected 1986-91 by the member companies of NRCA. William A. Good, EVP., National Roofing Contractors Association. Dec 14, 1994; Re-Submitted to OSHA, March 31, 1995. Affidavit of Carl Good, before USDOL OSHA, Docket No. H-033E. Page 20.
[61] Anderson, P.H. et al. Analysis of Fiber Release from Certain Asbestos Products. Prepared for the US EPA by GCA Corp. December, 1982. Page 88. Table 19, GCA data beginning on page 92.
[62] Paustenbach, D. Occupational Exposure to Airborne Asbestos from Coatings, Mastic, and Adhesives. Journal of Exposure Analysis and Environmental Epidemiology. 2004.

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c) Asphalt Shingles

At least one early study by NIOSH in 1984 indicated that there might be exposure associated with the tear-off of old asbestos-containing asphalt shingles. [63] Results similar to the chart in this study were later reported in the CONSAD 1984 study for OSHA. According to the NIOSH study in 1984, electron microscopy results for personal samples during the tearoff operation indicated a mean task time-weighted average of 0.09 f/cc. The mean concentration for the task of shingle application was 0.05 f/cc. Area samples were both <0.02 f/cc. [64]

Numerous subsequent studies conducted over the next ten years, including studies from my own personal experience, consistently demonstrated the absence of any significant exposure. Indeed, of a large database of asbestos exposure monitoring records collected from its members by the National Roofing Contractors Association, "not a single one of the several thousand air samples" exceeded the current OSHA PEL of 0.1f/cc 8hrTWA or the current 1.0f/cc OSHA Excursion Limit, an typical exposures are generally less than 1% to 10% of these limits.[65] In summary, it has now been well-established that the potential exposure, if any, associated with the removal of asbestos-containing asphalt shingles is less than any exposure that might be regulated by the Occupational Safety and Health Administration's asbestos standard that is in effect today.[66]

Using modern methods, a study by Lange in the peer-reviewed scientific literature determined that such direct exposures during the removal of asbestos-containing roofing materials were approximately 0.011f/cc and area or indirect exposures were approximately 0.004f/cc.[67]

Encapsulated Materials - Asbestos Cement Pipe and Sheet

In 1977, the A/C Pipe Producers Association utilized Equitable Environmental to evaluate the worst-case airborne concentrations of asbestos associated with the power cutting of A/C pipe.[6869] The results of these studies have been frequently summarized and reported within the federal regulatory record and have been relied upon by OSHA and EPA.[70]

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[63] Reed, L.D. NIOSH HHE Report 84-321-1590. Asbestos Shingle Tear-off, Rockford IL.. 1984.
[64] Reed, L.D. NIOSH HHE Report 84-321-1590. Asbestos Shingle Tear-off, Rockford Illinois. 1984. Table 1 headings of PCM and TEM appear transposed and the correct data is provided in the body of the report.
[65] Objective Data Demonstration for Certain Roofing Materials and Operations Under OSHA's 1994 Asbestos Standard. Data collected 1986-91 by the member companies of NRCA. William A. Good, EVP., National Roofing Contractors Association. Dec 14, 1994; Re-Submitted to OSHA, March 31, 1995. Introduction. Page 2-3.
[66] Corporate-Wide Settlement Agreement. US OSHA and National Roofing Contractors Association. In the US 5th Circuit Court of Appeals. No. 94-40793. March 15, 1995.
[67] Lange, J.H. and Thomulka, K.W. Area and Personal Airborne Exposure During Abatement of Asbestos-Containing Roofing Material. Bull. Env. Contam. Tox. 2000.
[68] Noble, W.M., et al. Asbestos Exposures During the Cutting and Machining of Asbestos Cement Pipe. By Equitable Env. Health, Inc.(EEH) for the A/C Pipe Producers Assoc. 3/16/1977.
[69] Kawahara, B.L., Flanery, J., Dust Exposures During the Cutting and Machining of Asbestos/Cement Pipe. Prepared by Equitable Env. Health, Inc., (EEH) for the Asbestos Cement Pipe Producers Association (ACPPA).. December 15, 1977.
[70] CONSAD Research. Prepared for US Department of Labor, OSHA. Economic and Technological Profile Related to OSHA's Revised Permanent Asbestos Standard for the Construction Industry and Asbestos Removal and Routine Maintenance Projects in General Industry. Contract # J-9-F-4-0024, Task Order 3 Option Year 1. December 1985.

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Clearly, all A/C pipe operations other than cutting with a gas-powered abrasive saw blade produce negligible exposures. The Equitable study recognized this by the statement "It is obvious that such operations could be continued through an 8-hour working day without exceeding the present TWA of 2.0f/cc, the proposed TWA of 0.5f/cc, or even the stringent NIOSH recommendation of 0.1f/cc." Such exposure is so low as to not meet the historical definition of "exposed to asbestos."[71]

A study prepared for OSHA by CONSAD recognized that the Equitable studies provided valuable data from which to calculate the magnitude of likely exposures in the workplace, but that the levels in the Equitable studies did not directly represent workplace conditions or exposures. The typical exposure that was provided to OSHA in the conclusion chart in this study was 0.035f/cc 8hrTWA for the total task of "A/C Pipe Installation" and 0.13f/cc 8hrTWA for the total task of "A/C Sheet Installation" and assumed that no respiratory protection was used.[72]

Likewise, the Equitable studies indicate that the exposure of persons that directly cut A/C pipe once per day with a gas-powered saw would have an 8-hour TWA exposure in a range of up to 0.07f/cc, the typical exposure associated with the total task of A/C pipe installation was 0.13f/cc as an 8hrTWA, and persons that cut many pieces of A/C pipe with a gas-powered saw in a particular day could have an exposure of 0.2 to 0.3f/cc for that day.

NIOSH evaluated the airborne concentrations of asbestos associated with the powered-saw cutting of A/C pipe in 1985. With no exposure controls, the average exposure of the cutter operator for the one hour duration of the task equates to an 8-hour TWA of 0.42f/cc for the saw operator doing the tasks in this study.[73] Unfortunately it is unknown how many cuts were made in this study. Based upon the simultaneous noise sample results, the cuts certainly numbered more than just a few and the cutting was likely to have been almost constant for the one hour period.[74] This study does not provide adequate data for utilization in exposure assessments of persons cutting A/C pipe unless an estimate can be made of the number of cuts that were made during this study. However, the study did verify earlier results that found levels in conformance with 8-hour time-weighted exposure standards in effect at the time.

The removal of a large amount of transite sheet has been associated with a geometric mean of 0.077f/cc.[7576] The cleanup of transite pipe has been associated with a task

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[71] 1978 OSHA compliance directive re: interpretation of medical monitoring, 1972-76 standard.
[72] CONSAD Research. Prepared for US Department of Labor, OSHA. December 1985. Page 5.3. Table 5.1. Occupational Exposure to Asbestos during Construction Work.
[73] NIOSH Health Hazard Evaluation. Denver Water Department. Denver, CO. HETA 84-257-1650. 1985.
Operator one hour task average of 3.4f/cc /8hrs per day = 8-hour TWA of 0.42f/cc.
Assistant one hour task average of 2.4f/cc /8hrs per day = 8-hour TWA of 0.3f/cc.
[74] According to the Noise Management in the Construction Industry generic presentation authored by the Australian government WorkCover agency in New South Wales, a brick saw produces a noise level of 96 to 100dbA, depending on what blade is used. The 60 minute average in this NIOSH report averaged 95 to 109dbA. Therefore, this surrogate value is indicative of near constant saw noise during the asbestos sampling period.
[75] Toxicological Profile for Asbestos. US Dept. of Health and Human Services. Public Hlth Service. ATSDR. Sept 2001. Table 6-6. Page 173.
[76] Lange, J.H. et al. A study of personal and area airborne asbestos concentrations during asbestos abatement: a statistical evaluation of fibre concentration data. Ann. Occ. Hyg. 1996.

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average exposure of 0.046f/cc for 29 minutes, a 30-minute excursion concentration of 0.073, and an 8-hour time-weighted average of 0.0074f/cc.[77]

Encapsulated Materials - Asbestos-Containing Gaskets

There is a significant body of published scientific literature regarding worker exposure to asbestos-containing gasket material.[78798081828384858687888990919293949596] A significant number of studies have been conducted in actual work environments. Some have been published in governmental publications. Others have been conducted in simulation environments to assess worker exposure to asbestos during the use of gaskets. Recent comprehensive reviews indicate that exposure from asbestos during the installation and removal of pipe flange gaskets is very low. [9798] Direct use of such gaskets has been associated with exposures of less than 0.1 f/cc and generally less than 0.03 f/cc as an 8-hour time-weighted average. Such exposure is so low as to not meet the historical OSHA definition of "exposed to asbestos."[99]

Surface Characteristics of Fibers Released from Encapsulated Products

It has been recognized that fibers combined with other materials may influence the ability of the fibers to have biological effects. Encapsulated materials such as asbestos cement pipe have been recognized as having such altered emissions. While some have

[77] Mlynarek,S. et al. Asbestos Exposure of Building Maintenance Personnel.Reg.Tox.Pharm.1996.
[78] Liukonen, L. R., et al. Asbestos Exposure From Gasket Operations. Report by the Industrial Hygiene Branch, Occ and Env Health Svc, Naval Regional Med Cntr, Bremerton, WA. May 1978.
[79] Jones, DR.Assessment of Asbestos Concentrations on Marine Vessels.USMaritimeAdmin.1981.
[80] Anderson, PH. Analysis of Fiber Release from Certain Asbestos Products. US EPA,GCA. 1982.
[81] Asbestos Task Order For Construction Alternatives, Contract # J-9-F-4-0024. Prepared For US Department Of Labor, Occ Safety And Health Administration By CONSAD Research. May 1984.
[82] Cheng RT And McDermott HJ: Exposure To Asbestos From Asbestos Gaskets. AOEH. 1991.
[83] McKinnery, W.N. And Pisano, R.W.. Evaluation Of Airborne Asbestos Fiber Levels During Removal And Installation Of Valve Gaskets And Packing. Amer Ind Hyg Assoc Journal. 1992.
[84] Millette, J.R. And Mount, M.D. A Study Determining Asbestos Fiber Release During The Removal Of Valve Packing. Applied Occupational And Environmental Hygiene. 1993.
[85] Kinney, P. L., et. al. Airborne Fiber Levels During Asbestos Operations And Maintenance Work In A Large Office Building. Applied Occ And Environmental Hygiene. 9:825–835. 1994.
[86] Spence, S.K., et. al. Exposure To Asbestos Fibres During Gasket Removal. AnnOccHyg.1996.
[87] Yeung, P., et. al. An Australian Study To Evaluate Worker Exposure To Chrysotile In The Automotive Service Industry. Applied Occupational And Environmental Hygiene. 1999.
[88] Fowler, D.P. Exposure To Asbestos Arising From Bandsawing Gasket Material. AOEH. 2000.
[89] Boelter, F.W., et. al. Airborne Fiber Exposure Assessment Of Dry Asbestos-containing Gaskets And Packings Found In Intact Industrial And Maritime Fittings. AIHAJournal. 2002.
[90] Longo,W.,et.al. Fiber Release During the Removal of Asbestos-Containing Gaskets.AOEH2002
[91] Liukonen, L. R. And Weir, F.W. Asbestos Exposure From Gaskets During Disassembly Of A Medium Duty Diesel Engine. Regulatory Toxicology And Pharmacology. 41:113-121. 2005.
[92]Paustenbach, D.J., et. al. Chrysotile Asbestos Exposure Associated with Removal of Automobile Exhaust Systems (Ca. 1945-1975) By Mechanics: Results Of A Simulation Study. J Exp Anal Env Epi. 2005.
[93] Mangold C, Clark K, Madl A, Paustenbach D. An Exposure Study Of Bystanders And Workers During The Installation And Removal Of Asbestos Gaskets And Packing. J Occup Env Hyg. 2006.
[94] Blake, C.L., et al. Assessment Of Airborne Asbestos Exposure During The Servicing And Handling Of Automobile Asbestos-Containing Gaskets. Reg Tox Pharmacology. 45:214-22. 2006.
[95] Williams, Pamela R. D., et. al. (2007). A Review Of Historical Exposures To Asbestos Among Skilled Craftsmen (1940-2006). Journal Toxicology Environmental Health, Part B.
[96] Madl AK, et al. Exposure To Airborne Asbestos During Removal And Installation Of Gaskets And Packings: A Review Of Published & Unpublished Studies. J.Tox.Env.Hlth B.Crit.Rev.2007.
[97] Madl AK, et al. Exposure to airborne asbestos during removal and installation of gaskets and packings: a review of published and unpublished studies. J Tox Env Hlth B Crit Rev.2007 Jun-Jul.
[98] Williams, Pamela R. D., et al. (2007). A Review of Historical Exposures to Asbestos among Skilled Craftsmen (1940-2006). Journal of Toxicology and Environmental Health, Part B.
[99] 1978 OSHA compliance directive re: interpretation of medical monitoring, 1972-76 standard.

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speculated that asbestos fibers that are released from A/C pipe are so profoundly altered by the cement that they are no longer even asbestos, a report by the Health and Safety Laboratory of the Health and Safety Executive in the UK refuted this view as not factual but noted rather that "it may be more accurate to consider them as still encapsulated in the cement matrix" as "Often the dispersed fibres would have…attached particles of the cement matrix." [100]

So while the analysis by the regulatory authorities in the UK indicates that encapsulation by cement cannot and does not change the chemistry of the fibers, at least some portion of the very small portion of fibers that are ever released from A/C pipe continue to have "particles or agglomerates" of cement still attached. These fibers, bundled together with agglomerations of cement or aerodynamically-altered by particles of still attached cement, present a quite different industrial hygiene exposure than one from aerodynamically-clean asbestos.[101]

A paper by Weir notes the inseparability of plastic resins from asbestos fibers. Once fibers are encapsulated, the release of aerodynamically clean fibers without globules of resin is exceedingly unlikely. Weir's paper suggests that it remains an open question if asbestos fibers that have been impregnated, coated and encapsulated into binding material can ever again be biologically available for inhalation even if subsequently released.[102] Helsen notes the same for cement encapsulating and/or binding materials.[103] A major publication of the current science of asbestos acknowledges these phenomena as well.[104]

These papers continue what a paper by Baeten demonstrated over 30 years ago, that indicated that only about 10% of the particles from asbestos encapsulated cement dust are "optically virgin" which is a term Baeten used to describe that 90% of the dust particles released from the asbestos-cement have the behavior of cement and only about 10% of the particles behave as asbestos fibers.[105]

Indeed, a recent paper from the peer-reviewed scientific literature that actually measured this phenomenon for sanded joint compound dust again tends to validate the visual "order of magnitude" estimate provided by Baeten for cut encapsulated-asbestos cement dust. Berman found that from 57% to 83% (described in the conclusions as "a majority") of the airborne asbestos fibers generated were not clean fibers but rather still had "mud"

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[100] Burdett, G. Investigation of the Chrysotile Fibres in an Asbestos Cement Sample. Health and Safety Laboratory. Health and Safety Executive. United Kingdom. HSL/2007/11. Crown © 2006. www.hse.gov.uk. Accessed December 12, 2010. Page iv. Page 26.

[101] Burdett, G. Investigation of the Chrysotile Fibres in an Asbestos Cement Sample. Health and Safety Laboratory. Health and Safety Executive. United Kingdom. HSL/2007/11. Crown © 2006. www.hse.gov.uk. Accessed December 12, 2010. Page 27.

[102] Weir F.W. and Meraz, L.B. Morphological Characteristics of Asbestos Fibers Released During Grinding and Drilling of Friction Products. Applied Occupational And Environ Hygiene. 2001.

[103] Helsen, J.A., et al. Surface Characteristics of Asbestos Fibers Released from Asbestos-Cement Products. AIHA Journal. 50 (12) p655-663. 1989.

[104] Toxicological Profile for Asbestos. US Dept. of Health and Human Services. Public Hlth Service. ATSDR. Sept 2001. Table 6-6. Page 173. Bioavailability from Environmental Media. Page 182. It is possible that adsorption of fibers onto other dust particles could influence the location of deposition in the lung, and might even influence the cellular response to the fibers.

[105] Beaeten, J., et al. Nature, structure, and properties of asbestos cement dust. Brit.J.IndMed.1980.

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matrices or particles attached that would significantly alter the aerodynamic properties of the fibers.[106]

In essence, the evidence suggests that once such altered material reaches the breathing zone, it is less respirable than fibers that have not been previously encapsulated in a binder. From an industrial hygiene perspective, the degree of encapsulation as a significant factor of exposure assessment should be considered an increasingly important attribute of asbestos-containing materials as well.

Conclusion - Encapsulated Materials

In summary, information is available in the industrial hygiene scientific literature to estimate a likely quantitative range of exposure, if any, for a wide variety of described work tasks. Qualitatively, in consideration of the range of factors evaluated in the governmental and peer-reviewed scientific literature, the industrial hygiene exposures, if any, associated with the use of encapsulated asbestos-reinforced/filled materials are typically low. Unless a large quantity of such materials are disturbed in any 8-hour period, the exposures associated with most such materials will be so low as to result in direct personal 8-hour time weighted average exposures that do not even meet the historical OSHA definition of "exposed to asbestos."[107]

These findings are consistent with the lack of any significant exposure expectation that in 1970 resulted in OSHA specifically exempting substances such asbestos-reinforced plastics from all warning labeling requirements, [108] was reconfirmed in the 1980s [109] and represents a broad exemption that continues in the US asbestos regulations in force today.[110]

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[106] Berman, D.W., et al. More on the Dynamics of Dust Generation: The Effects of Mixing and Sanding Chrysotile, Calcium Carbonate, and Other Components on the Characteristics of Joint-Compound Dusts Page 11, 16. Ann. Occup. Hyg. 2012.

[107] 1978 OSHA compliance directive re: interpretation of medical monitoring, 1972-76 standard.

[108] OSHA Standard for Exposure to Asbestos Dust. Federal Register, Vol. 37, No. 110, June 7, 1972. (2) Caution labels – (i) Labeling. Caution labels shall be affixed to all raw materials, mixtures, scrap, waste, debris and other products containing asbestos fibers, or to their containers, except that no label is required where asbestos fibers have been modified by a bonding agent, coating, binder, or other material so that during any reasonably foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section will be released.

[109] OSHA Hazard Communication Standard. 29 CFR 1910.1200. Effective 1983 for chemical manufacturers and 1986 for all manufacturers. Compliance required by non-manufacturer employers by 1988. The Standard applies to any chemical known to be present in the workplace that employees may be exposed to under normal conditions of use, or may be exposed to in a foreseeable emergency.

[110] OSHA Occupational Exposure to Asbestos. Federal Register, 59:40964-41162. 1910.1001; 1915.1001; 1926.58, August 10, 1994. (6) The provisions for labels required by paragraph (j)(2) of this section or for material safety data sheets required by paragraph (j)(5) of this section do not apply where: (i) Asbestos fibers have been modified by a bonding agent, coating, binder, or other material provided that the manufacturer can demonstrate that during any reasonably foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of fibers of asbestos in excess of the TWA permissible exposure level and/or excursion limit will be released or (ii) Asbestos is present in a product in concentrations less than 1.0%.

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From an industrial hygiene perspective, it is well-established that along with the primary exposure factors of concentration intensity and duration, the characterizations of asbestos fiber type and length have long been known to represent considerable differences in the accurate assessment of industrial hygiene exposure and risk of asbestos-related disease. As lower and lower cumulative exposures of asbestos from multiple different and discrete sources receive increased scrutiny, the degree of encapsulation as a significant factor of exposure assessment should be considered as an increasingly important attribute of asbestos-containing materials as well.

Literature Review of Industrial Hygiene Bystander Exposure to Asbestos

The first speculation that persons not working directly with asbestos might have any significant indirect exposure was in 1964 when Selikoff first noted that a number of construction trades might be expected to have some degree of indirect exposure simply from being near insulators that were working directly with asbestos insulation.[111] This notation by Selikoff of the "possible exposure" of bystander trades such as electricians and "perhaps even the supervising architect" was un-quantified and its significance unknown. This indirect exposure, as well as the other direct exposures among trades other than insulators, was certainly not considered of any significance at the time. In fact, Selikoff later in 1968 described an electrician stripping asbestos-covered wire and cable as one example of someone not usually considered prone to asbestos exposure.[112]

The first "bystander" reference in the scientific literature that quantified any such exposures was by Harries in 1968. The conditions described by Harries during construction of British ships were extreme by American standards, did not exist in the US, and represented conditions in which such British "bystander" trades had exposures that exceeded those of insulators in the US.[113]

The potential for "bystander" exposure in the construction industry was recognized in 1972 for workers in the vicinity of insulators involved in spray application of asbestos fireproofing.[114] In the early 1980's, it was recognized that the removal of fireproofing

[111] Selikoff, I. J. et al. Asbestos Exposure and Neoplasia. Journal of the American Medical Association. 188: p 22-26. 1964.

[112] Selikoff, I. J. and Hammond, E. C. III - Community Effects of Non-Occupational Environmental Asbestos Exposure". American Journal of Public Health. Vol 58. No. 9. September 1968.

[113] Harries, P.G. Asbestos Hazards in Navel Dockyards. Ann. of Occupational Hygiene V.11, p 135-145. April 1968. British study reviewing materials and processes. Selikoff referred to this study in 1979 as the first to suggest the possibility that asbestos associated disease might be an important problem of shipyard workers. Harries found it in ships "difficult to find a compartment in which there is no asbestos". Suggests that first indications previously had been that only men continuously working with asbestos were at risk, but now seems many more have been at risk. First article to significantly discuss potential exposure to other trades that might be bystanders of insulators. Concerned about asbestosis, lung cancer and mesothelioma since much spray-applied blue (crocidolite) asbestos is used. Gives exposures in fibers/cc. Notes removal or tearing down is most dusty. Mesothelioma was reported in a boilermaker, a fitter, a shipwright, a welder and a laborer. Questions crocidolite use.

[114] Reitze, W.B., et al. Application of Sprayed Inorganic Fiber Containing Asbestos: Occupational Health Hazards. AIHA Journal, p 178-191, March 1972. First major exposure study from an asbestos product that was not a thermal insulation asbestos product. Notes that nearby workers may be indirectly exposed. 70 f/cc 10 feet from spraying, 46 f/cc 75 feet away. But also as low as 3 f/cc 25 feet away. Material is 5-30% chrysotile. Time effect 30 minutes after completion was 1-4 f/cc, and less than 1 f/cc after 1 hour.

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material could potentially cause at least some level of bystander exposure to other trades.[115]

The first "bystander" epidemiology study in the US was by Selikoff in 1979.[116] In this paper, Selikoff reported x-ray findings among 1000 shipyard workers who were in the first medical exam volunteers of the over 13,000 personnel at the shipyard. Approximately half of the 1000 showed evidence of changes regularly seen following direct or indirect occupational exposure to asbestos with no specific differentiation between the trades. Lung cancer and mesothelioma were not included as topics of this study of asbestotic x-ray changes.

The first epidemiology study of insulators and non-insulators in the chemical industry was published by Lilis in 1979.[117] This study found radiologic evidence of possible asbestos-related fibrosis in both the study group of chemical plant maintenance workers and also in what was believed to be a group of bystander maintenance workers without any other previous known asbestos exposure. The study concluded that the risk of lung cancer and mesothelioma remained to be studied.

The term "bystander" is a relatively new term as it pertains to the description of "indirect" asbestos exposure in crafts and trades other than the "direct" user of asbestos products, such as by insulators. In 1986, Grandjean reviewed the bystander literature but presented no new information.[118] A search of the global scientific literature detected only a few industrial hygiene references pertaining to both asbestos and cancer in bystanders, and all were well after 1986.[119][120][121][122][123][124]

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[115] Paik, N.W., et al. Worker Exposure to Asbestos During Removal of Sprayed Material and Renovation Activity in Buildings Containing Sprayed Material. AIHAJ. 44(6). p428-432.1983.

[116] 1979 Selikoff, Lilis and Nicholson. Asbestos Disease in United States Shipyards. Annals of the NY Academy of Sciences, V 330, Health Hazards of Asbestos Exposure. "In 1968, (Harries) the possibility that asbestos associated disease might be an important problem of shipyard workers was suggested". Notes that Harries found mesothelioma in non-asbestos workers in shipyards. Notes the curiously few reports in the US, although there is known widespread asbestos exposure in WW II US shipyards and that Selikoff (1972) has found serious disease in shipyards. Notes very little data of shipyard exposure for before and until twenty years after WW II. Notes that amosite was added to chrysotile just before and during WW II to make it suitable for the shipyards. (Crocidolite also used in US shipyards). Notes few precautions were taken to avoid asbestos exposure in shipyards. Notes in 1967-76 comparison of shipyard workers to non-shipyard workers that extent of asbestosis was a better indicator of exposure intensity than was cancer, and as a whole did not detect substantially different rates for shipyards vs other insulation workers; latency period noted as an issue. Concluded that many former shipyard workers may be at risk to cancer in the future.

[117] Lilis, R. et al. Asbestos Disease in Maintenance Workers of the Chemical Industry. Volume 330. Health Hazards of Asbestos Exposure. Annals of the NYAS. 1979. This epidemiology study found radiologic evidence of possible asbestos-related fibrosis in both the study group of chemical plant maintenance workers and the group of maintenance workers without any previous known asbestos exposure; there was no statistically significant difference between the groups. 142 of the 184 members of the study group were smokers or ex-smoker's.

[118] Grandjean, P. and Bach, E. Indirect Exposures: The Significance of Bystanders at Work and at Home. AIHAJ 47(12):819-824. 1986.

[119] Arndt, V., et al. All-Cause and Cause Specific Mortality in a Cohort of 20000 Construction Workers; Results from a 10 Year Follow Up. Occup Environ Med. 61(5):419-25. 2004.

[120] Mangold, C., et al. An Exposure Study of Bystanders and Workers during the Installation and Removal of Asbestos Gaskets and Packing. J Occup Environ Hyg. Feb;3(2):87-98. 2006.

[121] Paustenbach, D.J., et al. Chrysotile Asbestos Exposure Associated with Removal of Automobile Exhaust Systems (1945-1975) by Mechanics: Results of a Simulation Study. J Expo Sci Env Epid. 16(2):156-71. 2006.

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Rapid Settling of Particles Reduces Bystander Exposure, if Any

Baeten and others have also observed for asbestos cement dust that "the asbestos content will change with distance from the dust source." [125][126] It is intuitively obvious to most observers that the airborne concentration of dust near a source is much higher than the concentrations at locations that are more distant from the source.[127] As an industrial hygienist, I certainly know this statement to be true. Well-experienced industrial hygiene professionals recognize that bystander indirect exposures are generally an order of magnitude (1/10th) less than the exposures of the directly exposed worker that is closest to the source of the dust.[128]

It has been frequently repeated that asbestos fibers float for extended periods of time in the ambient air. Such a statement is more of a theoretical concept that fibers are aerodynamically different from other particles than one based on actual practical and empirical observations from the real world. Actual observations remind us that it is important to consider the significant reductions on the fiber concentrations in the air caused by the fact that most settle out of air rather quickly and the larger they are the faster they settle.[129] Evidence of this general principle can be found in many historical asbestos exposure references in the scientific literature.[130][131][132][133][134] NIOSH has recognized this same fundamental relationship in similar studies of other fiber exposures in the workplace.[135] A recent paper reviewed the bystander literature and found that the average bystander exposure was 8.2% of the directly exposed worker and was less than 1% at a distance of 30 feet.[136]

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[122] Madl, A.K., et al. Exposure to Chrysotile Asbestos Associated with Unpacking and Repacking Boxes of Automobile Brake Pads and Shoes. Ann Occup Hyg. 52(6):463-79. 2008.
[123] Jiang, G.C., et al. A Study of Airborne Chrysotile Concentrations Associated with Handling, Unpacking, And Repacking Boxes of Automobile Clutch Discs. Regul Toxicol Pharmacol. 2008.
[124] Madl, A.K., et al. Airborne Asbestos Concentrations Associated with Heavy Equipment Brake Removal. Ann Occup Hyg. 53(8):839-57. 2009.
[125] Beaeten, J., et al. Nature, structure, and properties of asbestos cement dust. British Journal of Industrial Medicine. 37:33-41. 1980.
[126] Helsen, J.A., et al. Surface Characteristics of Asbestos Fibers Released from Asbestos-Cement Products. AIHA Journal. 50 (12) p655-663. 1989. "The concentration of fibers in the air of is a function of the distance from the source. Page 1.
[127] Jayjock, M.A. Assessment of Inhalation Exposure Potential from Vapors in the Workplace. AIHAJ. 1988.
[128] Williams, P.R.D., et al. A Review of Historical Exposures to Asbestos among Skilled Craftsmen (1940-2006). Journal of Toxicology and Environmental Health. Part B Critical Reviews. 10:5, 319 – 377. 2007.
[129] Industrial Hygiene Engineering: Recognition, Measurement, Evaluation and Control. 2nd Edition. John J. Talty, Editor. ISBN: 0815511752. 1999.
[130] Harries, P.G. Asbestos Hazards in Navel Dockyards. Ann. Occ. Hygiene V.11, p 135-145. April 1968.
[131] Roberts, D.R. and Zumwalde, R.D. Industrial Hygiene Summary Report of Asbestos Exposure Assessment for Brake Mechanics. NIOSH Report 32.4. November 22, 1982.
[132] Hervin, R.L. et al. National Institute of Occupational Safety and Health (NIOSH) Health Hazard Evaluation/Toxicity Determination Report 72-91-37. Mobil Oil Corporation Refinery, Augusta, Kansas. Area samples are about 20% of personal samples in this report.
[133] Mangold C, et al. An Exposure Study of Bystanders and Workers during the Installation and Removal of Asbestos Gaskets and Packing. J Occup Environ Hyg. 2006 Feb;3(2):87-98. Breathing zone avgs 0.03f/cc and 0.023f/cc. Background avgs 0.004 and 0.003f/cc.
[134] Rohl, A.N., et al. Asbestos Content of Dust Encountered in Brake Maintenance and Repair. Proceedings of the Royal Society of Medicine. Volume 70. January 1977.
[135] NIOSH. Criteria for a Recommended Standard: Occupational Exposure to Refractory Ceramic Fibers. NIOSH Pub. No. 2006-123. Ch. 4: Assessing Occupational Exposure. P33. The close exposures had median concentrations of 0.26 to 1.2 f/cc. Secondary exposures median concentrations 0.03 to 0.24 f/cc.
[136] Donovan, E.P., et al. Evaluation of bystander exposures to asbestos in occupational settings: A review of the literature and application of a simple eddy diffusion model. Crit Rev Toxicol. 2010.

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A chart depicting this well-known phenomenon can be seen in a chart of real world friable asbestos fiber sampling data published by Sawyer in 1977.[137] Sawyer observed that the settling rate of asbestos resulted in peak airborne concentrations to be reduced by 85% within one hour and to less than the background ambient concentration essentially within a day. Another dramatic example in the scientific literature is the findings by Reitz in 1972. Reitz observed that the settling rate of friable asbestos caused task average airborne concentrations from fireproofing spray operations to be reduced by 95% in only 30 minutes and by 99% in only 60 minutes.[138] Such rapid settling rates are among the predominant reasons that it is common practice for industrial hygienists to appropriately assume zero exposure during those times other than the actual task or area sampling time.

In summary, dense particles that may contain fibers but are aerodynamically non-fibrous, such as particles of relatively large mass mean diameter from the sawing of asbestos cement pipe, will settle much faster than many other more common friable asbestos-containing materials. This is not to say that all particles will rapidly settle. Only the 90% of Baeten's particles that act like cement particles rather than the 10% that act like asbestos fibers can be expected to rapidly settle close to the source of the dust.

In summary, the normal diffusive effect of distance, combined with the enhanced settling rate of high density particles both with and without asbestos fibers attached, serve to reduce bystander exposure to these materials by at least one and generally two orders of magnitude (10X-100X).

Literature Review of Industrial Hygiene Exposure to Asbestos - Take-Home

The first speculation of the possibility that asbestos-related disease might result from indirect "take-home" exposure to others occupationally exposed to asbestos was first raised in the asbestos scientific literature by Newhouse in 1965.[139] This study was not capable of focusing on "take-home" exposure; the population studied by Newhouse had significant "community" environmental exposure from the crocidolite asbestos factory in the neighborhood. As we now know the "community" exposure from living near an asbestos factory or mine can pose a significantly greater risk than any other "take-home" or "household" exposure that might occur within a home, and in fact can be so profound to have exceeded the current occupational exposure limit as well.[140][141]

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[137] Sawyer, R. N. Asbestos exposure in a Yale building. Environmental research. 13, 146 -- 169. 1977.

[138] Reitze, W.B., et al. Application of Sprayed Inorganic Fiber Containing Asbestos: Occupational Health Hazards. AIHA Journal, Mar. 1972, p 178-191. First major exposure study from an asbestos product that was not a thermal insulation asbestos product. Notes that nearby workers may be indirectly exposed as 70 f/cc was found 10 ft from spraying and 46 f/cc 75 ft away, but also as low as 3 f/cc 25 ft away. Notes material is 5-30% chrysotile. Counts 30 minutes after completion were 1-4 f/cc, and less than 1 f/cc after 1 hour.

[139] Newhouse, M.L. and Thompson, H. Mesothelioma of Pleura and Peritoneum Following Exposure to Asbestos in the London Area. Brit. J. of Ind. Med. 22:261-269. October 1965. Nine family member cases among 76 mesothelioma cases versus only 1 control who was an asbestos worker's family member.

[140] Magnani, C, et al. A Cohort Study on Mortality Among Wives of Workers in the Asbestos Cement Industry in Casale Monferrato, Italy. Br J Ind Med 50(9):779-784. 1993. A retrospective cohort mortality study of 1,964 wives of asbestos cement workers in Italy. Cancer of the pleura was significantly elevated. The women who died from respiratory disease had washed their husband's work clothes in the home for more than 10 years.

[141] Camus, M., et al. Nonoccupational Exposure to Chrysotile Asbestos and the Risk of Lung Cancer. New England Journal of medicine. Vol. 338. No. 22. 1998.

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As of 1969, virtually nothing was known about “take-home” exposure to asbestos. Selikoff expressed doubt about cases of disease without occupational exposure to asbestos and considered the issue “overrated.” His comments at an international conference in 1969 indicated that he did not believe at the time that there was any indication of any significant risk associated with “take-home” exposure to asbestos.[142]

In 1972, OSHA established a requirement for separate clothing systems for persons with the highest exposures that were involved in spraying, demolition, or removal of equipment covered by asbestos or which was exposed to asbestos greater than the OSHA Ceiling Limit of 10f/cc for any 15-minute period. No mention was noted in the OSHA standard of potential household exposure to other persons in the 1971 or 1972 and 1976 OSHA asbestos standards.[143][144]

In 1976, Anderson published the first take-home exposure study of household contact with asbestos, and in 1979 and 1983, published the results of the continuing investigation. [145][146][147][148] In 1978, Vianna evaluated cases primarily associated with insulators and noted that there was no convincing evidence that indirect exposures

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[142] Shapiro, H.A., Editor. Pneumoconiosis. Proceedings of the International Conference, Johannesburg 1969. Oxford University Press. Published 1970. Discussion: Symposium on Asbestosis. Page 214 – 215. Comments of Irving J. Selikoff. "On the other hand, I would like to introduce a second caution. I do not think we are justified, at this time, in giving any estimate of the magnitude of the risk associated with environmental and indirect occupational or family exposure. All we can say at this time is that there is a significant occupational risk. We have as yet no cohort studies on how many people have been exposed in neighborhood areas or in family exposures and it probably is very much less than we think. I have discussed this with Dr. Newhouse, these data alerted us to this problem, because in our own studies in New York, in attempting to study families, namely exposure and neighborhood exposure, we find that people who live in the neighborhood of an asbestos plant tend to have worked in that plant many years ago and, unless you know their entire occupational histories, you will never be able to spot those cases who 30 – 35 years ago worked on an asbestos plant for one, two, or three months when their own trade was slow. Moreover, who is more likely to have worked 30 – 35 years ago in an asbestos plant then the family member of somebody who has already worked in that plant? He would most likely have known when an opening existed. Therefore, unless we can identify true absence of occupational exposure, we have to regard labels of family or neighborhood exposure with caution. I think this is very important.” “At the present time our definition is only that, in specific industrial circumstances, a significant risk occurs. This, I think, can be controlled if we put our minds to it. On the other hand, much more data are necessary before we can label the magnitude of nonoccupational exposures with any degree of accuracy.”

[143] OSHA Occupational Safety & Health Standard for Exposure to Asbestos Dust. 37FR11318. Jun 7, 1972. Requirements for change rooms and lockers at 29CFR1910.93(a)(d). Requirement for separate clothes at 29CFR1910.93(a)(d)(3).

[144] Martonik, J.F., et al. “The History of OSHA’s Asbestos Rulemakings and Some Distinctive Approaches That They Introduced for Regulating Occupational Exposure to Toxic Substances.” AIHAJ. 2001.

[145] Anderson, H.A., et al. 1976. Household-Contact Asbestos Neoplastic Risk. In: Saffiotti U, Wagoner JK, Eds. Occupational Carcinogenesis. Ann NY Acad Sci 271:311-323.

[146] Anderson, H.A., et al. Asbestosis Among Household Contacts of Asbestos Factory Workers. Ann NY Acad 330:387-399. We do know from our own studies and those of others, that household asbestos contact as well as other environmental exposure is associated with an increased risk of mesothelioma, especially pleural mesothelioma. 5 deaths from mesothelioma out of 550 total deaths. Not to be considered a definitive study, additional questions were raised such as why sons had twice the prevalence of daughters with the same duration of exposure. The actual extent and intensity of each household residents asbestos exposure was unavailable. As a surrogate index, each household contact was assigned a duration of exposure which was equivalent to the length of time lived in the household while a worker was actively employed and the first year of onset of exposure was also considered.

[147] Anderson, H.A., et al. Household Exposure to Asbestos and Risk of Subsequent Disease. In: Lemen R, Dement J, Eds. Dusts and Disease. Chicago, Pathotox Publishers, Inc. Pages 145-156. 1979.

[148] Anderson, H.A. Family Contact Exposure. In: Proceedings of World Symposium on Asbestos. Montreal, Canada, Canadian Asbestos Information Center. Pages 349-362. 1983.

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contributed to the occurrence of mesothelioma.[149] In 1980-83, Nicholson first reported measurements made of asbestos levels in the homes of asbestos mine workers.[150151152153] In 1985, Kilburn reported that the families of shipyard workers could be at increased risk for asbestos-related disease.[154]

In 1986, the preamble of the revised OSHA Asbestos standard noted the potential for household exposure, but also noted that the only scientific evidence presented were verbal comments and that the evidence relating dose to household disease was limited. The requirement for protective clothing that was laundered by the employer was required only in order to protect employees. Showering was required because it provided "added protection to employees and their families."[155]

In 1989, Huncharek indicated that while the risk of mesothelioma associated with occupational exposure is well documented, the risk posed by domestic exposure is uncertain but presented a case report demonstrating that under extreme conditions it is possible for substantial exposure to result from domestic contact.[156] In 1989, Grandjean reviewed in a section of his paper the existing take-home literature and concluded that the general significance of household exposures, while difficult to ascertain in any detail, were probably more frequent and significant than had been suggested by the only occasional reports published in the scientific literature before 1989.[157] In 1991, Joubert

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[149] Vianna, J. C., Polan. A. K. Non-occupational exposure to Asbestos in Malignant Mesothelioma in Females. Lancet: 1061-1067. 1978. Notes case reports that are mixtures of domestic and community environmental exposures from asbestos mines and asbestos factories. Only possibility is assessed.
[150] Nicholson, W.J., et al. Environmental Asbestos Concentrations in the United States. In: Wagner, J.C. ed. Biological Effects of Mineral Fibers, Vol 2. IARC Scientific Pub No. 30, Lyon, France, International Agency for Research on Cancer. pages 823-827. 1980. Airborne concentrations in asbestos mine/mill employees homes. Neighbor non-employees were lower.
[151] Nicholson, W.J. Tumor Incidence after Asbestos Exposure in the USA: Cancer Risk of the Non-Occupational Population. VDI-Berichte Nr 475:161-177. 1983.
[152] Asbestiform Fibers: Nonoccupational Health Risks Committee, National Research Council (1984). 30 light micro f/ng, page 62. Footnote B, 30ug/m3 = 1f/cc. Per EPA blue book, page A-1, the density of asbestos 0.0026 ng/ug3. 2 million fibers weighs about 1800 ng. 1ng = 30f. ATSDR 2001 Tox Profile. Adopts NRC 1984 regarding conversion from units of ng/m3 but says 60f/ng. p88-89.
[153] McDonald, J.C. Health Implications of Environmental Exposure to Asbestos. Environmental Health Perspectives. Vol 62, pp 319-328. 1985.
[154] Kilburn, K.H., et al. Asbestos Disease and Family Contacts of Shipyard Workers. AJPH. 1985.
[155] US Dept of Labor, OSHA 29 CFR Parts 1910, 1926. Occupational Exposure to Asbestos, Tremolite, Anthophyllite, and Actinolite. Friday, June 20, 1986. 51 FR 22612-01. Preamble page 227. 8. Paragraph (h). Protective work clothing and equipment. Protective clothing cared for by the employer required to "eliminate any potential exposure that might result were the clothing to be laundered by the employee at home." Wearing contaminated clothing outside the work area would "lengthen the duration of exposure" of the employee. Showers required to "minimize employee exposure to asbestos after the work shift ends" and because it removes asbestos which accumulates on the skin and hair." The shower requirement by OSHA is based on OSHA's statement that "Evidence has shown that family members of asbestos workers face a substantially increased risk of cancer and other asbestos-related diseases from exposure to asbestos carried home on work clothes," but it is important to note that the reference to the previous statement is "The only scientific evidence cited by the AFL-CIO was the statement of Dr. Nicholson, discussed above, and Dr. Selikoff's testimony that mesotheliomas have appeared in a few workers with very short exposures and in household contact with peak exposures from laundering asbestos contaminated clothing. However the evidence relating dose to these diseases is limited."
[156] Huncharek, M., et al. Domestic Asbestos Exposure, Lung Fibre Burden, and Pleural Mesothelioma in a Housewife. Br J Ind Med. 46(5): 354–355. 1989. In this case report, Huncharek established that for the wife of a heavily exposed shipyard worker that washed his clothes from 1935 to 1969, her lungs were found to contain crocidolite and other fiber types that totaled greater than 1 million fibers per dry gram.
[157] Grandjean, P., and Bach, E. Indirect exposures: The Significance of Bystanders at Work and at Home. AIHAJ 47(12):819-824. 1986.

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noted that quite limited epidemiologic investigations had been done to date to assess the risk of living in the same house as an asbestos worker. The four cases noted by Joubert were the same cases previously reported by Anderson two decades before.[158][159] In 1992, Dodoli reported on cases mostly associated with shipyard and insulator workers.[160] In 1993, Magnani reported on asbestos exposure among a residential population located near an asbestos cement factory in Italy.[161]

In 1995, NIOSH published a report for Congress that reviewed the current state of the art regarding what was known about the issue of take-home exposures. Contaminated work clothing was noted as the primary means in which it would be possible for industrially exposed workers to "take home" some amount of dust into a family home. Anderson was noted by NIOSH as the first to infer that asbestos-related diseases were due to home contamination emanating from clothes contaminated at work, especially due to laundering the clothes.[162]

No studies as of 1995 had evaluated the relationships between home contamination by asbestos, contamination of clothing brought home from work, and exposures during home laundering.[163] NIOSH indicated in its 1995 report to Congress that it had performed approximately 40 health hazard evaluations to address potential home contamination. My search of the NIOSH database of 3355 health hazard evaluations indicated that 257 pertained to asbestos but that only several asbestos-related NIOSH Health Hazard Evaluations even referenced potential home contamination. The asbestos exposures of the workers in this particular case were minimal and the take-home exposure, if any, was not evaluated.[164] In 1997, NIOSH published a summary of the 1995 study. This guide recognized that few studies document the frequency and distribution of health effects among the families of workers and that existing reports contain little information about the levels of contamination in workers' homes.[165]

Miller in 2005 discussed 27 pleural mesothelioma cases from 1990 to 2005 with more than half directly associated with an asbestos factory or shipyard.[166] A similar number

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[158] Joubert, L., H. Seidman, and I. J. Selikoff. 1991. Mortality Experience of Family Contacts of Asbestos Factory Workers. Ann. N.Y. Acad. Sci 643: 416-418. "Only limited epidemiologic investigations have been undertaken to assess the risks of nonmalignant and malignant disease associated with low levels of exposure to asbestos dust from living in the same house with an asbestos worker; we refer to those secondarily exposed persons as household contacts." Studied were the families of the UNARCO amosite insulation plant in Paterson, NJ.

[159] Miller, A. Mesothelioma in Household Members of Asbestos-Exposed Workers: 32 United States Cases Since 1990. Amer. J. Ind. Med. 47:458–462 (2005).

[160] Dodoli, D., et al. Environmental Household Exposure to Asbestos and Occurrence of Pleural Mesothelioma. Am. J. Ind. Med 21: 681-687. 1992.

[161] Magnani, C, et al. A Cohort Study on Mortality Among Wives of Workers in the Asbestos Cement Industry in Casale Monferrato, Italy. Br J Ind Med 50(9):779-784. 1993.

[162] Report to Congress on Workers' Home Contamination Study Conducted Under The Workers' Family Protection Act (29 U.S.C. 671a). US Dept. of HHS. PHS/CDC/NIOSH. September 1995. Pub. No. 95-123.

[163] Report to Congress on Workers' Home Contamination Study Conducted Under The Workers' Family Protection Act (29 U.S.C. 671a). US Dept. of HHS. PHS/CDC/NIOSH. September 1995. Pub. No. 95-123.

[164] Belanger, P.L., and Elesh, E. NIOSH Health Hazard Evaluation. HETA report no. HHE-78-73-612, Kentile Floors, Inc., Chicago, Illinois. 1978. Seven of the samples exceeded 0.1f/cc that was the NIOSH REL for asbestos in 1978. As a result of the sampling data, the government investigators recommended protective clothing, in part to prevent home contamination.

[165] Reduce Contamination at Home. A Summary of a Study Conducted by the National Institute for Occupational Safety and Health. DHHS (NIOSH) Pub. No. 97-125.

[166] Miller, A. Mesothelioma in Household Members of Asbestos-Exposed Workers: 32 United States Cases Since 1990. Amer. J. Ind. Med. 47:458–462. 2005.

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had been reported by the NIOSH report to Congress in 1995.[167] In 2006, Marchevsky comprehensively reviewed the historical non-occupational case reports in the scientific literature and found 150 of 287 meeting some criteria of take-home exposure with 124 of 150 or 83% associated with asbestos workers including miners, product manufacturing and shipyards. Most were from asbestos miners and factory workers; less than 7% of these cases were associated with asbestos insulators that lived in the home.[168]

In 2011, NIOSH published its most recent review on the state of the science of asbestos, and referenced no additional information from the scientific literature on take-home exposure since its 1995 report.[169] In 2012, Donovan published a comprehensive review of the take-home literature, including case reports and exposure studies.[170] A recent study has continued to review the potential exposure risk from handling of clothes previously contaminated with asbestos-containing material.[171]

Industrial Hygiene Studies of Asbestos Pertaining to the Laundering of Clothes

It has been demonstrated that the clothes washing exposure period of primary concern is that of the handling of asbestos contaminated clothing before it becomes wet. [172] Sawyer demonstrated in 1977 that the handling associated with laundering contaminated coveralls for an asbestos abatement work crew of 40 persons was associated with task-based mean fiber counts of 0.4 f/cc.[173]

In 1998, Grosse found that the portion of exposure attributable to the dryer exhaust is unlikely to contribute any appreciable portion to the airborne concentrations of fibers greater than 5µ in length. [174]

Madl demonstrated in 2008 that personal and area task sample results from handling of the clothes worn during the handling of a large number of brake shoes were 0.011 and 0.01 f/cc, respectively.[175] The handling of contaminated work clothing resulting from heavy equipment brake work, including the shaking, turning inside out and folding of the coveralls, was also studied by Madl in 2009 and has been associated with handling task airborne concentrations of 0.01f/cc-0.036 f/cc for bystander and worker clothes, respectively.[176] Jiang demonstrated in 2008 that the handling of clothes associated with

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[167] Report to Congress on Workers' Home Contamination Study Conducted Under The Workers' Family Protection Act (29 U.S.C. 671a). US Dept. of HHS. PHS. CDC. NIOSH. Sept. 1995. Pub No. 95-123.
[168] Marchevsky, A.M., et al. Mesothelioma in Patients with Non-occupational Asbestos Exposure- An Evidence-Based Approach to Causation Assessment. Annals of Diagnostic Path. 10: 241–250. 2006.
[169] Asbestos Fibers and Other Elongate Mineral Particles: State of the Science and Roadmap for Research. Current Intelligence Bulletin 62. Department of Health and Human Services. Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 2011–159. March 2011.
[170] Donovan, E.P., et al. Evaluation of take home (para-occupational) exposure to asbestos and disease: a review of the literature. Critical Reviews in Toxicology, 2012; 42(9): 703–731.
[171] Sahmel, J., et al. Evaluation of Take-Home Exposure and Risk Associated with the Handling of Clothing Contaminated with Chrysotile Asbestos. Risk Anal. 2014.
[172] Grosse, I., et al. Asbestos on Textiles: Is There an Endangering During Washing and Wearing? Journal Of Hazardous Materials A:63 (1998) 119-130.
[173] Sawyer, R. N. Asbestos Exposure in a Yale Building. Environmental Research. 13, 146-169. 1977.
[174] Grosse, I., et al. Asbestos on Textiles: Is There an Endangering During Washing and Wearing? Journal Of Hazardous Materials A:63 (1998) 119-130.
[175] Madl, A.K., et al. Exposure to Chrysotile Asbestos Associated with Unpacking and Repacking Boxes of Automobile Brake Pads and Shoes. Annals of Occupational Hygiene. 2008.
[176] Madl, A.K., et al. Airborne Asbestos Concentrations Associated with Heavy Equipment Brake Removal. Annals of Occupational Hygiene. 2009.

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asbestos-containing automobile clutch discs produced 0.003f/cc and 0.002f/cc exposures for 15 and 30 minute durations for the dirty clothes handler.[177] In 2012, Donovan published a comprehensive review of the take-home literature, noted the paucity of studies correlating worker exposure to take-home exposure, and offered an assumption for the purposes of analysis that the airborne concentration while handling clothing might be approximately an order of magnitude less than the average airborne concentration in the workplace.[178]

Summary of Industrial Hygiene Studies of Take-Home Exposure to Asbestos
In summary, very little empirical evidence exists today for asbestos take-home contamination outside of the scenarios of grossly-contaminated clothing of asbestos mine workers, shipyard insulator workers, and asbestos product factory workers.

There are other documented "domestic" cases in the scientific literature, such as the sad case of a family that manufactured asbestos cement in an unventilated basement of the family home for over 15 years, which is arguably an occupational rather than a "domestic" example of exposure.[179] The extreme exposures in such cases should not be confused with the relatively tiny exposures associated with "take-home" events beyond those associated with grossly-contaminated clothing of asbestos miners, career insulators, and asbestos factory workers.

Take-home exposure cases that do not fall into one of the three broad categories of asbestos miners, career insulators, and asbestos factory workers appear to be, based on the currently available scientific literature and governmental regulatory history for asbestos, very rare events indeed.

[177] Jiang, G.C., et al. A Study of Airborne Chrysotile Concentrations Associated with Handling, Unpacking, And Repacking Boxes of Automobile Clutch Discs. Regul Toxicol Pharmacol. 2008.
[178] Donovan, E.P., et al. Evaluation of take home (para-occupational) exposure to asbestos and disease: a review of the literature. Critical Reviews in Toxicology, 2012; 42(9): 703–731.
[179] Otte, K.E., et al. Malignant Mesothelioma - Clustering in a Family Producing Asbestos Cement in Their Home. British Journal of Industrial Medicine. 47:10-13. 1990.

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