Dr. Hart's Supplemental Disclosure

Dr. Julie Hart is a Ph.D in Toxicology and a M.S. in Industrial Hygiene. She is certified by the American Board of Industrial Hygiene in Industrial Hygiene, Comprehensive Practice. She has served as a faculty member in the Safety, Health and Industrial Hygiene Department at Montana Tech since 2000 and was appointed department chair in 2014. In addition, she currently serves as the Montana Local Education Officer for the American Industrial Hygiene Association – Pacific Northwest Section.

Dr. Julie Hart has experience in the field of industrial hygiene and exposure science. In 2005, her research team discovered amphibole contamination on the surface of tree bark in the forested area near the former vermiculite mine, and a majority of her research focused on the potential for human exposures related to this source. She has been successful in securing funding from external sources for this research from the United States Department of Agriculture Forest Service, National Institute for Occupational Safety and Health and The Rocky Mountain Center for Occupational and Environmental Health, University of Utah School of Medicine. She is a co-author on seven peer-reviewed publications pertaining to Libby amphibole asbestos and is currently involved in research in the Libby area. She has presented this Libby amphibole exposure work at regional and national conferences.

Dr. Hart is expected to testify that Mr. Boswell and Ms. Kenworthy had multiple Libby amphibole asbestos exposure pathways at the lumbermill and in the community. She is expected to testify that it is more probable than not that each plaintiff had exposure to asbestos emanating from the lumbermill sufficient to cause their ARD, and that each of the Plaintiffs have suffered serious injury as a result of these exposures.

Dr. Hart is expected to opine to the following information:

Toxicity of Libby Amphibole Asbestos

Libby Amphibole Epidemiology Studies

One of the earliest publications associating Libby vermiculite with pulmonary changes focused on a worker population from a Marysville, Ohio fertilizer plant that had utilized vermiculite from the Libby mine and South Africa (Lockey et al., 1983). This cohort became the basis for the proposed RfC discussed in Section 2.2. Significant correlations were observed with respiratory symptoms (shortness of breath and pleuritic chest pain) and cumulative fiber exposures (Lockey et al., 1984). Studies focusing on Libby workers soon followed. McDonald et al. (1986) included a cohort of 406 men employed at the mine for at least one year prior to 1963 and followed them until 1983. Compared with white men in the U.S., the cohort experienced excess mortality, with standard mortality ratios (SMRs) of 2.45, 2.55, 2.14 for respiratory cancer, non-malignant respiratory disease (NMRD), and accidents, respectively. Standard mortality ratios are defined as the observed number

of cases over expected. The proportional mortality for the four identified mesothelioma deaths was 2.4%. Data collection for a parallel study sponsored by the National Institute for Occupational Safety and Health (NIOSH) was initiated at approximately the same time (Amandus et al. 1987; Amandus and Wheeler, 1987) and included 575 men employed at the mine for a minimum of one year prior to 1970. Similar to the McDonald et al. (1986) study, SMRs were 2.23, 2.43, and 1.44 for respiratory cancer, non-malignant respiratory disease and accidents, respectively (Amandus and Wheeler, 1987). These early occupational-based studies demonstrated strong exposure years/response relationships (McDonald et al., 1986; Amandus and Wheeler, 1987; Antao et al., 2012).

McDonald published additional work in 2004 in which he updated epidemiology data for his original 406 man cohort, following them until 1999 (McDonald et al., 2004). The SMRs reported in this update for lung cancer and non-malignant respiratory disease were 2.40 and 3.09, respectively. The proportional mortality for the 12 identified mesothelioma deaths was 4.21%. An all-cause linear model implied a 14% increase in mortality for mine workers exposed occupationally to 100 f/mL/yr and approximately 3.2% increase for the general population exposed to 0.1f/mL for 50 years (McDonald et al., 2004).

An additional NIOSH sponsored study included a cohort of 1,672 Libby miners, millers, and processors in 1982 and followed subjects through 2001 (Sullivan, 2007). Compared with U.S. white men, SMRs for asbestosis, lung cancer, and cancer of the pleura were 165.8, l.7, and 23.3, respectively, with observed dose related increases in asbestosis and lung cancer. An update of the Sullivan (2007) cohort was published recently (Moolgavkar et al., 2010), revealing similar SMRs to Sullivan. In addition, estimates of relative risk for lung cancer, non-malignant respiratory disease, and total mortality were 1.2, 1.4, and 1.06, respectively, with 95% confidence intervals of [(1.06, 1.17), (1.09, 1.18), and 1.04, 1.08)] (Moolgavkar et al., 2010).

One of the latest updates regarding vermiculite worker mortality (Larson et al., 2010), with a cohort of 1862 Libby miners, demonstrated a clear exposure response relationship between cumulative Libby amphibole fiber exposure and asbestosis, lung cancer, mesothelioma, and NMRD mortality. A limitation noted for earlier epidemiology studies evaluating lung cancer SMRs in Libby mine and mill workers was the lack of control for cigarette smoking. Bias analysis revealed that cigarette smoking had minimal impact on the exposure response relationships reported in this study (Larson et al., 2010; reviewed by Antao et al., 2012). An additional conclusion from this study was the association between Libby amphibole fiber exposure and cardiovascular mortality based on a rate ratio of 1.5 with a 95% confidence interval of 1.1 to 2.0 (Larson et al., 2010).

A follow-up to the Lockey et al. (1984) Marysville, Ohio fertilizer plant study revealed pleural changes in 28.7% of the cohort (Rohs, et al., 2008). As noted previously, this cohort was the basis for the proposed Libby amphibole RfC. Pleural changes were originally reported in 2.2% of the overall cohort and 8.4% of the highest cumulative fiber exposure group (Lockey et al., 1984). The study is significant in that the cohort was based on exfoliation plant workers outside of Libby, MT, with relatively low cumulative fiber exposure levels compared to those described in the Libby mine and mill worker studies.

In addition to epidemiology studies that considered Libby mine and mill workers, research has also included studies evaluating ARD mortality among Libby community members. A cross-section interview and medical testing of 7,307 persons who had lived, worked or played in Libby for at least six months prior to 1991 was conducted in 2000 and 2001 by the Agency for Toxic Substance and Disease Registry (ATSDR) investigators (Peipins et al., 2003). Of the 6,668 participants $\geq$ 18 years of age who received chest radiographs, pleural abnormalities and interstitial abnormalities were observed in 17.8% and < 1% of the participants, respectively. Participant interviews revealed that the factors most strongly associated with pleural abnormalities were being a former vermiculite mine or mill worker, age, having been a household contact of a former vermiculite mine or mill worker, and being male (Peipins et al., 2003).

In 2008, a clinical and exposure summary report for 11 individuals diagnosed with mesothelioma who were not Libby mine or mill employees was published (Whitehouse et al., 2008). All cases were non-occupationally exposed individuals. The authors concluded that exposure most likely resulted from Libby amphibole contamination in the community, the surrounding forested area, and areas in proximity to the Kootenai river and railroad tracks that were used to transport vermiculite concentrate (Whitehouse et al., 2008). The mean LA occupationally related mesothelioma latency period has been reported as 35 years (Case, 2006). The latency period reported for these non-occupational cases was 13-67 years from the first known exposure (Whitehouse et al., 2008).

In terms of both occupational and non-occupational mesothelioma cases, current mortality figures indicate one new case per year in Lincoln, County, Montana (McDonald et al., 2004; Case, 2006; Whitehouse et al., 2008). Lincoln County has the third highest age-adjusted mesothelioma death rate in the nation with a rate of 56.1 per million population (NIOSH, 2008).

A community study of Libby residents who were children ($\leq$ 18 years) when the vermiculite mine closed in 1990 revealed a positive association between self-reported respiratory outcomes and certain activities with potential Libby amphibole exposure pathways (Vinikoor et al., 2012). Of the 1,003 study participants, 10.8% reported usually having a cough, 14.5% reported experiencing shortness of breath when walking up a slight hill or hurrying while on level ground, and 5.9% reported having coughed up bloody phlegm in the past year. Handling vermiculite insulation was positively associated with three of the four outcomes examined compared with never handling vermiculite insulation. No association was found between vermiculite insulation in the home and respiratory symptoms and no association was found between any of the activities and abnormal spirometry (Vinikoor et al., 2012).

A community study was conducted in a densely populated urban residential neighborhood in Minneapolis, Minnesota where an expansion facility processed Libby vermiculite ore from 1938 to 1989 (Alexander et al., 2012). In addition to commercial vermiculite products such as Zonolite® insulation and Monokote® fireproofing, the facility produced a waste material reported by the Minnesota Department of Health to contain 10% amphibole asbestos (Alexander et al., 2012). The waste product was piled on the property and offered to the community for use in gardening, driveway fill materials, etc. The prevalence of pleural abnormalities obtained for the 461 participants was 10.8%. The odds ratio associated with direct contact

with vermiculite ore waste or ever playing in waste piles and pleural abnormalities was 2.78 (95% CI: 1.26, 6,10) and 2.17 (95% CI: 0.99, 4.78) when adjusted for background exposure. Although this study was conducted outside of Libby, MT, the results suggest that community exposure to Libby vermiculite is associated with measurable effects (Alexander et al., 2012).

In addition to pulmonary based ARD, rates of systemic autoimmune diseases (SAID) have been evaluated in the Libby community. A follow-up case-control study was conducted among the participants in the 2000/2001 ATSDR study (Peipins et al, 2003) with cases including subjects that reported one of three (SAIDs) in the initial screening; systemic lupus erythematosus, scleroderma, or rheumatoid arthritis, and controls including subjects in the initial screening that responded negatively to questions regarding SAIDs (Noonan et al., 2005). Odds ratios among former Libby mine and mill workers $\geq$ 65 years of age of 2.14 (95% CI, 0.9-5.1) for all SAIDs and 3.23 (95% CI, 1.31 7.96) for rheumatoid arthritis, suggest that LA exposure is associated with SAIDs (Noonan et al., 2005). Increasing SAIDs risk estimates were reported for participants with relative increases in reported vermiculite exposure pathways.

These epidemiologic studies demonstrate clear and significant increases in ARD, including asbestosis, lung cancer, and mesothelioma among former mill and mine workers. In addition, ARD has been observed in area residents with no direct occupational exposures. The most common health outcome among Libby residents and others with low lifetime cumulative fiber exposure levels are pleural changes.

Current Toxicological Knowledge of Libby Amphibole Asbestos

A toxicological review of Libby amphibole asbestos was published in 2014 (EPA/IRIS, 2014b). This review includes the non-cancer and cancer health effects for the inhalation route of exposure and resulted in a published reference concentration (RfC) and inhalation unit risk (IUR) for non-cancer and cancer risk, respectively. The RfC of 9×10^{-5} fibers/cc is defined as "an estimate of an exposure that is likely to be without an appreciable risk of adverse health effects over a lifetime and is expressed as a lifetime daily exposure in fibers/cc (due to measurement by phase contrast microscopy (PCM))."

The RfC for Libby amphibole represents the first published non-cancer reference inhalation concentration for a mineral fiber. Asbestosis, pleural thickening, and other nonmalignant respiratory disease in populations exposed to Libby amphibole asbestos were considered in the development of the RfC, with localized pleural thickening selected as "the critical effect (EPA/IRIS, 2014b)." Cohorts considered included two occupationally exposed groups; Libby, MT workers and Marysville, OH workers; and one non-occupational exposure group which consisted of residents near an exfoliation plant in Minneapolis, MN. The Marysville cohort was selected due to higher occupational exposures to Libby amphibole asbestos and unquantified community exposures. The Marysville cohort considered workers who were hired after 1972 and who participated in health evaluations in 2002-2005.

The IUR is typically defined as "a plausible upper bound on the estimate of cancer risk per $\mu g/m^3$ air breathed for 70 years" and is expressed as cancer risk per fibers/cc as measured by PCM (EPA/IRIS, 2014b). The combined upper bound IUR for Libby amphibole asbestos, considering mesothelioma and lung cancer models,

is 0.169 fiber/cc as measured by PCM (EPA/IRIS, 2014b). Cohorts selected for Libby amphibole asbestos lung cancer and mesothelioma IUR models were workers employed at the Libby vermiculite mine and mill (EPA/IRIS, 2014b).

The significance of this toxicological review is that it is specific for Libby amphibole asbestos, a unique mixture of amphibole minerals (as defined in Section 4.1). The RfC represents the first non-cancer reference concentration for mineral fibers and it is substantially lower than historic exposure limits for asbestos.

Summary of Inhalation Exposure Factors and Proposed Mechanisms of Toxicity

Exposure to Libby amphibole asbestos is associated with nonmalignant and malignant asbestos related disease including; asbestosis, lung cancer, mesothelioma and pleural plaques (McDonald, 1986; Amandus et al., 1987; Amandus and Wheeler, 1987; McDonald et al., 2004; Case, 2006; Sullivan, 2007; Whitehouse et al., 2008; EPA/IRIS, 2014b). As described above, localized pleural thickening was selected as the critical effect for the RfC. Work published prior to 2002 referenced earlier International Labour Organization guidelines for defining pathological alterations of lung parenchyma and pleura; therefore, pleural plaques reported in literature prior to 2002 describe what is currently called localized pleural thickening (EPA/IRIS, 2014b).

The primary exposure route for asbestos mineral fibers is through inhalation. While other exposure routes and related health outcomes have been reported in literature, inhalation of asbestos fibers is the main route of human exposure, and as a result, was the basis of the toxicological assessment described above. When characterizing the inhalation exposure risk to asbestos fibers, as with other aerosols, there are many variables to consider. These include, but are not limited to the concentration of asbestos measured in the breathing zone and the dose inhaled, physical and chemical characteristics of the fibers (shape, length, diameter and surface properties that are influenced by mineral composition and charge), nasal or oral breathing patterns (or both), respiration rate, specific anatomical and physiological features of the respiratory tract, fiber deposition and clearance mechanisms, and individual susceptibility (immune status, genetics) (Liu et al., 2013).

While epidemiologic studies have established that exposure to asbestos causes the ARDs summarized above, the pathogenic mechanisms of these diseases are not completely understood. Asbestosis is one type of pulmonary fibrosis. The hallmark of pulmonary fibrosis is excess collagen in the alveolar interstitium, which may also extend to the alveolar ducts and respiratory bronchioles (Klaaseesn, 2013). Proposed mechanisms of collagen deposition involve epithelial cell injury and macrophage activation. Asbestos elicits a macrophage response to phagocytize and clear fibers, but this response may result in reactive oxygen species production, inflammasome activation and the release of cytokines and growth factors. Asbestos can also induce alveolar epithelial cell apoptosis, which in turn can result in additional growth factors and cytokines. These signaling pathways are considered important for myofibroblast differentiation, collagen deposition by myofibroblasts, and ultimately fibrosis (Liu et al., 2013). Fibrosis of the lungs impairs the ability for efficient oxygen/carbon dioxide exchange and leads to progressive stiffness.

Complexity in defining the mechanisms of toxicity also exits for malignant ARDs. Proposed mechanisms for the carcinogenicity of asbestos fibers as defined by the International Agency for Research on Cancer (IARC, 2012; EPA/IRIS, 2014b) include direct fiber-cell interaction with target cells and indirect interaction generated from cellular signaling pathways. The surface of asbestos fibers deposited in the lungs acquires iron that that cycles between the reduced and oxidized forms (Shannahan, 2011). This redox cycle may result in DNA lesions which may lead to apoptosis, gene mutations, chromosomal abberations, and cell transformation (Huang et al., 2011). Asbestos-induced reactive oxygen species (ROS) production may also result in p53 activation, and other cellular signals including cytokines, chemokines and growth factors (Liu, 2013). As was noted with the proposed mechanisms of fibrosis, mechanistic events for asbestos carcinogenicity also include macrophage interaction, inflammasome activation associated with frustrated phagocytosis, release of cytokines and growth factors, and subsequent inflammation. Asbestos is considered to be both an initiator and a promotor of the carcinogenic process (Mossman et al., 2011).

Early Knowledge of Toxicity

Asbestos Contamination in the Rainy Creek Complex

The asbestos contamination within the Rainy Creek alkaline-ultramafic igneous complex, where the Zonolite mine was located, was well known in early literature (Pardee and Larson (1929), Kreigel (1940). In fact, in the 1920s, there were two mines on the complex, the Zonolite Company, founded by Edward Alley, and the Vermiculite and **Asbestos** Company of Libby, Mont. (Kriegel, 1940). Geologists initially classified the amphibole contaminants as tremolite, tremolite/actinolite, or soda-rich tremolite (Pardee and Larsen, 1929; Bassett, 1959; Boettcher, 1966b). Additional amphibole minerals; richterite (Larsen, 1942; Deer et al., 1963; Langer et al., 1991; and Nolan et al., 1991) and winchite were eventually identified (Wylie and Verkouteren, 2000; and Gunter et al., 2003). An extensive systemic evaluation of the Rainy Creek amphibole minerals was conducted by Meeker et al. (2003) and approximated the respirable fraction of Rainy Creek Complex amphiboles as winchite (84%), richterite (11%) and tremolite (6%), with possible magnesioriebecktite, edenite, and magnesio-arfvedsonite components. Regardless of the mineral classification that evolved with Libby amphibole asbestos, the fact that Libby vermiculite was contaminated with asbestos minerals was well documented early in the lifespan of the vermiculite mine.

Early Knowledge of Asbestos Hazards in Industrial Hygiene and Occupational Medicine Literature

The asbestos industry started in the 1870s with asbestos components used in insulation, materials to withstand high temperatures, and numerous other industrial applications (Castleman, 1996). The earliest case study reports potentially linking asbestos exposure with pulmonary disease were published in Great Britain. The Lady Inspectors of Great Britain provided some of the earliest documentation of asbestos related health hazards when they included asbestos work as one of the four dusty occupations under investigation in 1898 due to “injury to bronchial tubes and lungs medically attributed to employment” (Deane, 1898 as

reported by Castleman, 1996 and Greenburg, 1999). In the early 1900s, there were case study reports of pulmonary disease in asbestos plant workers in Great Britain, France, Italy, and Germany (Castleman, 1996). In the U.S. in 1917, Pancoast, Miller and Landis, in an attempt to characterize increased thickening observed in individuals examined for tuberculosis and other conditions (pneumoconiosis), examined the chests of workers engaged in dusty occupations in a roentgenologic study. Fifteen asbestos workers were included in the 137 individuals examined. Fibrous tissue and localized fibrosis was observed in asbestos workers (Pancoast, et al., 1918).

By 1918, Hoffman, a statistician with the Prudential Life Insurance Company, recognized asbestos work as a hazardous trade. "In the practice of American and Canadian life insurance companies, asbestos workers are generally declined on account of the assumed health-injurious conditions of the industry" (Hoffman, 1918). While there was documentation of pulmonary disorders associated with asbestos exposure in the early 20th century, Dr. W.E. Cooke, an English pathologist, was the first to describe fibrosis of the lungs due to asbestos exposure in medical literature (Cooke, 1924 and Cooke, 1927). The subject of Cooke's papers was a 33 year old female that worked in the spinning room of a Rochdale asbestos company. Additional case reports soon followed, including work by Thomas Oliver, an M.D. who focused on occupational disease. His work, which was published in British and U.S. medical journals (Oliver, 1927a; 1927b) described asbestos manufacturing as a "familial" occupation with generations of females. Two of these women who worked in the asbestos industry, were the subject of his case studies describing pulmonary asbestosis (Oliver, 1927a; 1927b). While Cooke is cited in some textbooks as being the first to coin the term "asbestosis", some credit it to Oliver (Bartrip, 2003). Gloyne (1933) described the microscopic appearance of asbestosis and anatomical changes observed with various stages of the disease.

Soon after the Cooke and Oliver publications, Dr. Merewether, as British medical inspector, was instructed to determine whether or not a health risk was truly present in the asbestos industry. Meriwether and Price examined 363 asbestos workers who did not have previous work in dusty occupations. Variables considered included length of employment and dustiness of the job. Twenty six percent of those examined had asbestosis. When subjects working less than five years were excluded, the incidence of asbestosis increased to 35 percent. The number of years employed in the asbestos industry was a primary risk factor for disease (Merewether, 1930a; Merewether, 1930b). In addition, to illustrating the incidence of asbestosis in the asbestos industry, Merewether and Price discussed the importance of dust suppression tactics, focused on the importance of clinical exams in diagnosis of disease, and associated the inhalation of asbestos dust with a fatal disease. In addition to British publications, Merewether's work was published in the U.S. Journal of Industrial Hygiene (Merewether, 1930b).

Although the "deadly nature of asbestos dust was widely known in medical, public health and industry circles in the 1930s, the consumption of asbestos rebounded strongly after the worst years of the great depression" (Castleman, 1996).

Drinker and Hatch (1936) described the disabling pneumoconiosis associated with asbestos exposure as asbestosis with characteristic symptoms and chest X-rays in their book "Industrial Dust."

In 1938, an epidemiologic study of 541 workers in four asbestos textile plants in North Carolina was published (Dreessen et al., 1938). Along with job classifications and work history data, dust sampling was conducted in the plants. The primary variables identified in occupational groups affected by asbestosis were average concentration of dust exposure and length of employment. Since only three cases of asbestosis were observed at dust exposure concentrations less than 5 million particles per cubic feet (5 mppcf), Dreessen et al., (1938) proposed that "if asbestos dust concentrations were kept below this limit new asbestosis cases would not appear." This was the first federally proposed recommended exposure limit for asbestos. The Dreessen et al., (1938) study also described the discrepancies between U.S. and British factories in terms of dust control practices, with British factories employing greater dust control measures.

In the 1930s through the early 1940s, individual case reports describing lung cancer in the presence of pulmonary asbestosis were frequently published in literature (Lynch and Smith, 1935; Gloyne, 1935; Gloyne 1935b; Egbert and Geiger, 1935; Gloyne, 1936; Nordman, 1938a; Nordman, 1938b; Lynch and Smith, 1939; Holleb and Angrist, 1942). Subjects in the 1930s case reports worked as weavers, spinners, and misc. areas of asbestos plants. In the 1940s, pipe insulators were included in these case reports (Holleb and Angrist, 1942). In a summary of three additional case reports, Homburger (1943), noted that the total number of case reports describing the co-incidence of primary carcinoma of the lungs and pulmonary asbestos was up to 19. While Lynch and Smith (1939) suggested that asbestosis was a predisposing factor in carcinoma of the lung, Homburger (1943) concluded that "statistical calculations and morphologic studies did not reliably answer the question of whether asbestosis has to be considered as an etiologic factor in pulmonary carcinoma."

In a 1942 U.S. publication, Hueper (1942) cited case reports to suggest occupational causation of an asbestos cancer hazard. However, Hueper further noted the need for more clinical, pathological and statistical studies to define cancer risks associated with asbestos exposure. A year later, in Germany, "asbestos in combination with lung cancer" was considered a state compensable occupational disease (Castleman, 1996; Literature of Industrial Hygiene Abstracts, 1944).

In 1944, asbestos was identified as a physical or chemical agent known to or suspected of causing occupational cancer in the Journal of the American Medical Association (JAMA, 1944). Occupational cancers were defined as those "elicited by exposure to the agents in the course of regular occupations."

In 1946, Wyers, the medical advisor to the South African crocidolite Cape asbestos fields, recommended that, for humanitarian reasons, additional preventive action might be implemented promptly rather than waiting for further evidence of the carcinogenicity of asbestos (Greenberg, 1999; Wyers, 1946).

In 1951, Vorwald et al. published a summary of case studies conducted at the Saranac lab describing experiments conducted on animals exposed to various kinds of asbestos dust. Inhalation and intratracheal injection techniques were used on guinea pigs, rabbits, cats, dogs, rats and mice to investigate tissue reactions. Vorwald et al. concluded that the rabbit, guinea pig and rat animals, but not the mouse and dog, developed peribronchial lung fibrosis similar to human asbestosis after being exposed to chrysotile asbestos. In addition, he concluded that long fibers (20 to 50 microns) were essential in the production of this fibrosis and that as the asbestos concentration increased, the pulmonary reaction time decreased. While chrysotile

asbestos was the primary mineral discussed in Vorwald's comment and summary, it is important to note that similar peribronchial lung fibrosis observations were made with amphibole mineral species, including tremolite (Vorwald, et al., 1951 (Tables 15 and 16)). At the time of Vorwald's publication, tremolite was reported to be the primary amphibole contaminant within the Rainy Creek Complex (Pardee and Larsen, 1929; Bassett, 1959; Boettcher, 1966b).

Doll (1955) is credited with the first published epidemiologic study of lung cancer mortality and asbestos workers. Doll noted that from 1935 to the time of his publication, among the study group, there were 61 cases of lung cancer in individuals with asbestosis. His review of 105 mortality records for Turner Brothers asbestos workers identified 18 lung cancer cases, 15 in association with asbestosis. He followed up with a group of 113 workers that were employed for a minimum of 20 years in scheduled areas of the factory (those scheduled under 1931 British Asbestos Industry Regulations as being "dusty"). There were 11 lung cancer deaths among this group, (all with asbestosis). Doll also defined an average period between the worker's initial employment in the asbestos industry and death.

Wagner et al., (1960) discussed 33 histologically proven case studies of mesothelioma of the pleura. An association with asbestos originating from the South African Cape crocidolite asbestos field was observed in 28 of the cases, while four cases were associated with the asbestos industry. While this was the first major summary of mesothelial case studies observed, individual cases, (one to two workers) were reported as early as 1933 (Gloyne); however, asbestos was not reported to be associated with pleural mesothelioma until 1943 (Wedler). In terms of the association between asbestosis and mesothelioma, Cartier (1952) described this relationship as "minimal" and "none" in a summary of two Canadian case studies.

In 1963, a study of asbestos insulation workers in New York and New Jersey revealed 10 mesothelioma deaths (Selikoff et al. 1963). With this and subsequent publications (Selikoff et al., 1964; Selikoff and Hammand 1965-66) asbestos exposure and disease research extended from asbestos mining and asbestos factory workers to those that used asbestos containing materials in their occupations (Bartrip, 2003).

Dust Standards

In 1967, the published threshold limit value from the American Conference of Governmental Industrial Hygienists (ACGIH) was 5 mppcf for asbestos-bearing dusts when collected conventionally with the impinger or midget impinger and counted conventionally with the standardized microscope counting method. What the number concentrations represented were the visible fragments of asbestos fibers plus the many associated mineral dust particles.

In 1968, the published "notice of intended changes" proposed (1) that the 5 mppcf be dropped to 2 mppcf; and (2) an alternative figure of 12 fibers/ml greater than 5 microns in length be adopted. This TLV figure was to be determined by the membrane filter method at 430x phase contrast magnification. These two proposed changes remained in 1969. In 1970, the published proposed changes (1) dispensed entirely with the impinger sampling method and its number concentration figure; and (2) recommended that the TLV be changed from 12 fibers/ml greater than 5 microns in length. The fiber concentration figures were to be

determined by the membrane filter method at approximately 430x phase contrast magnification (USBOM Health Study, 5/18/1971) The requirements for dust and asbestos standards continued to change over the years. The following chart tracks the standards from the ACGIH and
OSHA.

Year	Agency/ Organization	Standard
1948	ACGIH MAC for Dust Containing Asbestos	5 mppcf
1968	ACGIH Proposed Standard	12 fibers/ml greater than 5 micrometers
1971	OSHA Regulations Take Effect	12 f/ml
1972	OSHA Exposure Limit Reduced	5 f/ml
1976	OSHA Exposure Limit Reduced	2 f/ml
1986	OSHA Exposure Limit Reduced	.2 f/ml during shift or up to 1 f/ml for short durations of up to 30 min.
1994	OSHA Exposure Limit Reduced	.1 f/ml during shift or up to 1 f/ml for a short duration of up to 30 min.

Dr. Hart is expected to rely on the following references:

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