A report prepared for the

National Association of Home Builders

Is Fiberglass Exposure a Carcinogenic Risk to Humans?

by

Steven H. Lamm, MD, DTPH

of

Consultants in Epidemiology
and Occupational Health, Inc.
Washington, D.C.

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Fiberglass - A man-made vitreous fiber used for building insulation and other uses.

Fiberglass is one of the man-made vitreous fibers (MMVF) that are used for the insulation of homes and buildings. The man-made vitreous fibers consist of the aluminum-silicate refractory ceramic fibers (RCF), continuous glass filaments (textile fibers), and the magnesium-calcium-silicate rock, slag, and glass wools. This report on the carcinogenicity risk assessment of glass wool, known more commonly in the United States as fiberglass, is limited to glass wool as distinguished from RCF, textile fibers, rock wool, and slag wool.

Fiberglass (glass wool) is primarily used for insulation of homes and buildings. It is a non-metallic vitreous silicate fiber. Supplied as batts, blankets, or blowing materials, it is used to prevent the movement of heat (and sound) in or out of buildings, particularly residences. It is also used to insulate air handling ducts and for ceiling and acoustical panels. Because it is so frequently used around human habitation and because certain natural silicate fibers used for insulation have been found to cause cancer in man, many studies of both animals and man have been conducted to determine whether the use of fiberglass for such insulation produces a carcinogenic risk to the workers or the residents.

Summary of Information about the Carcinogenicity of Fiberglass.

Three bodies of information have been used to assess this question of risk. (1) Long-term studies of animals exposed to fiberglass by either inhalation or other routes of exposure; (2) Long-term epidemiological mortality studies of workers who manufacture fiberglass; and (3) Industrial hygiene and other studies of the comparative exposure levels of exposed animals, employees of fiberglass manufacturers, fiberglass installers, and residents of homes with fiberglass. In total, the results of these studies find the following:

(1) The lung cancer risk for animals that inhaled fiberglass, the route by which man is exposed, was no greater than that of controls. Local cancers have been seen in animals in which fiberglass fibers were injected into their abdomens or chest cavities or instilled down their windpipes, routes of exposure not common to man.

(2) No statistically significant lung cancer risk was found among workers who manufacture fiberglass, in excess of that which would be expected based on their localities and their smoking habits. Cigarette smoking is the only exposure factor found to be a significant determinant of their respiratory cancer risk.

(3) Fiberglass exposure levels to residents of homes with fiberglass are considerably lower than those of fiberglass workers, much lower than those of animals that inhaled fiberglass and did not get cancer, and markedly lower than those animals that received fiberglass down their windpipe and did get cancers.

In toto, these findings do not indicate a respiratory cancer risk to humans (or animals) from the inhalation of fiberglass. Rather, they indicate that fiberglass exposure is unlikely to be a carcinogenic risk to humans.

The evidence for these statements follows:

Toxicology (Animal Studies)

At least eight animal studies have been conducted in which animals (rats or hamsters) have had long-term inhalation exposures to fiberglass. These animals have been exposed to levels of 3 to 3,000 fibers/ml. The largest (704 exposed rats), most recent (1993), most precise (exposure given with confidence limits), and most detailed study found no evidence of mesotheliomas (chest wall cancers) in the exposed rats and found no significant differences in the lung cancer frequencies of the high dose rats, the low dose rats, and the control rats (Bunn et al., 1993)[1]. Similarly, the previous seven studies had shown no significant increase in cancers. Across all the studies, lung cancers were as frequent among the exposed animals as among the unexposed animals.

The recent study of rats with long-term inhalation exposure to fiberglass was conducted by the Research and Consulting Company (RCC) in Geneva, Switzerland and published in detail by Hesterberg et al., 1993[2] and in the context of the other toxicological literature by Bunn et al., 1993.[3] These investigators exposed Fischer 344 rats for two years to nasal inhalation of two different types of fiberglass at three different exposure levels and then compared the pathological findings with those of air control rats that received no fiberglass exposure. Rats were exposed either to JM 901 insulation wool at levels of 29 +/- 8 f/ml, 145 +/- 35 f/ml, or 232 +/- 57 f/ml or to InsulSafe III blowing wool at levels of 41 +/- 29 f/ml, 153 +/- 69 f/ml, or 246 +/- 76 f/ml. The JM901 fibers had a geometric mean diameter of 1.22 +/- 0.14 um and a geometric mean length of 12.4 +/- 2.2 um. The InsulSafe III had a geometric mean diameter of 0.72 +/- 0.07 um and a geometric mean length of 11.7 +/- 2.0 um. These sizes are consistent with the sizes of fibers found in workplace air and that are respirable to rats. The highest concentrated selected was the "maximum tolerated dose" (MTD), while lower concentrations were 50% of the MTD and multiples of the projected occupational and environmental exposure levels.

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1 Bunn, WB, Bender, JR, Hesterberg, TW, Chase, GR, and JL Konzen. Recent Studies of Man-Made Vitreous Fibers Chronic Animal Inhalation Studies. Journal of Occupational Medicine, 1993; 35(2):101-113.

2 Hesterberg TW, McConnell EE, Chevalier J, Hadley J Thevenaz P, and R Anderson. Chronic inhalation toxicity of size-separated glass fibers in Fischer 344 rats. Fundamental and Applied Toxicology, 1993; 20:464.

3 Bunn, WB, Bender, JR, Hesterberg, TW, Chase, GR, and JL Konzen. Recent Studies of Man-Made Vitreous Fibers Chronic Animal Inhalation Studies. Journal of Occupational Medicine, 1993; 35(2):101-113.

Lung Tumor Frequencies among Rats Inhaling Fiberglass

Type of Glass	*Exposure Level*	*Number of Animals*	*Animals with Lung Tumors*	*Percent with Lung Tumors*
InsulSafe	*246 f/ml*	*112*	*3*	*2.7 %*
InsulSafe	*153 f/ml*	*120*	*9*	*7.5 %*
InsulSafe	*41 f/ml*	*118*	*4*	*3.4 %*
JM 901	*232 f/ml*	*119*	*7*	*5.9 %*
JM 901	*145 f/ml*	*118*	*1*	*0.8 %*
JM 901	*29 f/ml*	*117*	*0*	*0.0 %*
Air Control	*- f/ml*	*123*	*4*	*3.3 %*

The RCC study had 740 exposed rats and 123 rats. Twenty-four (3.4%) of the exposed rats and four (3.3%) of the control rats developed lung tumors. No exposure group had statistically significantly more animals with lung tumors than the air control group. Prior to the RCC study, eight other animal inhalation studies had been reported. These studies had 1531 exposed rodents (1140 rats and 391 hamsters) and 421 control rodents (363 rats and 58 hamsters). The frequency of lung tumors in the exposed rodents was no greater than the frequency of lung tumors in the control rodents

Previously, animal studies with fiberglass instilled down the trachea (windpipe) or injected into the abdomen or the chest cavity showed increases in lung or chest wall cancers in some, but not all, studies in rats, hamsters, and mice[4].

The International Agency for Research on Cancer (IARC), a branch of the World Health Organization (WHO), assesses the cancer study data on chemicals and classifies them as to their likely carcinogenicity status using the following classifications: Group I (carcinogenic to humans), Group 2A (probably carcinogenic to humans), Group 2B (possibly carcinogenic to humans, and Groups 3 and 4 (not classifiable or probably not carcinogenic to humans). Based on the above findings, IARC in 1988 labeled fiberglass (glass wool) as being "possibly carcinogenic to humans (Group 2B)"[5].

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4 International Agency for Research on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Man-made Mineral Fibres and Radon, 1988; 43: 87-97.

5 International Agency for Research on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Man-made Mineral Fibres and Radon, 1988; 43: 152.

Epidemiological Studies

Epidemiological studies of workers at fiberglass manufacturing plants have been conducted in Europe, the United States, and Canada. The European studies[6] have involved five glass wool plants in five different countries (Sweden, Norway, Finland, the United Kingdom, and Italy) with a total of 6278 workers whose mortality experience was followed from the 1940s to the 1980s.

Glass Wool Plants of the IARC MMMF Study

Plant	Country	Process	Subjects	Start Yr Process	Final Year of Follow-Up Mortality	Incidence
D 07	Sweden	Glass Wool	1480	1933	1982	1983
L 06	Norway	Glass Wool	525	1935	1982	1983
F 02	Finland	Glass Wool	603	1941	1981	1981
E 10	U K	Glass Wool	3253	1943	1983	n a
N 14a	Italy	Glass Wool	417	1946	1983	n a
Total			6278			

The lung cancer experiences of the workers at the plants were compared with that which would have been expected of persons who lived in the same area. A statistically significant increase in the lung cancer experience compared with local residents would suggest an employment-related risk. The lung cancer experiences of the workers were also compared within the plant in order to determine whether the risk[7] appeared to be related to the exposure, i.e., increased with level or amount of exposure, increased with duration

6. L Simonato et al. The International Agency for Research on Cancer Historical Cohort Study of MMMF Production Workers in Seven European Countries: Extension of the Follow-up. Annals of Occupational Hygiene, 1987; 31(4b):602-623.

7 The standard statistic for measuring or describing the risk of dying from a specific disease (such as lung cancer) is called the standardized mortality ratio (SMR). It is calculated as 100 times the ratio of the observed number of deaths to the expected number, where an SMR = 100 would mean that as many cases were observed as would normally have been expected for the age and time distribution of the population. An excess risk, or a statistically significantly increased risk, is represented by an SMR statistically significantly greater than 100. A similar calculation based on the number of lung cancer cases diagnosed would be called the standardized incidence ratio (SIR).

of exposure, and increased with time since first exposure. A statistically significant increase in risk following these factors would suggest an exposure-related risk.

Analysis of the lung cancer deaths of the workers in the European glass wool plants revealed that the risk was no different from that which would have been expected for other persons living in the same area. Ninety-three lung cancer cases were observed and 90.5 had been expected, based on local rates, for an SMR = 103. The risk did not increase by duration of exposure for those who had been followed for at least 20 years. While comparison with national rates had shown a statistically significantly increased risk in lung cancer mortality, those analyses had not taken into consideration the regional differences in lung cancer risk factors (such as cigarette smoking). The lung cancer mortality risk did not show a strong association with increasing time since first exposed.

Regression analysis was conducted to identify those exposure variables that might be predictive of the lung cancer mortality risk among glass wool employees in the European studies[8]. There was no significant linear trend with either time since first employment (p=0.21) or duration of employment (p=0.70). Even restriction of the analysis to the workers with at least one year of employment and at least twenty years of observation since employment began did not produce a significant association with time since first employed or trend with duration of employment (p=0.20).

Lung cancer incidence was also examined among these plant workers. The observed number of lung cancer cases did not differ from the number expected. Fifteen cases were observed with 18.8 cases expected, for an SIR = 80. Thus, the European studies did not show an excess of lung cancer deaths or of lung cancer cases.

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8 Bofetta et al. Lung Cancer Mortality among Workers in the European production of Man-Made Mineral Fibers - a Poisson regression analysis. Scandanavian Journal of Work Environment and Health, 1992; 18:279-86.

The United States studies[9] involved six fiberglass plants with a total of 4,864 workers followed for mortality experience from about 1945-52 through 1982 and two plants which manufactured both fiberglass and glass filaments with a total of 6,585 workers similarly followed.

Glass Wool Manufacturing Plants in US MMMF Study

St	Location	Product	Start	Cohort	Conc	Ca	SMR
WV	Parkersburg	Glass	1951	682	0.027	13	108.5
KA	Kansas City	Glass	1946	1874	0.008	41	87.6
CA	Santa Clara	Glass	1949	1167	0.061	15	105.3
OH	Waterville	Glass	1952	96	0.293	0	00.0
IN	Shelby	Glass	1952	335	0.023	3	63.3
KA	Kansas City-7	Glass	1951	710	0.026	7	90.2
		Glass		4,864		79	108.5
OH	Defiance	Glass+Filament	1950	865	0.005	10	119.1
OH	Newark	Glass+Filament	1938	5720	0.067	178	109.7
		Glass+Filament		6,585		188	109.7
		Total Glass Wool		11,449		267	109.3

Conc = concentration in f/ml   Ca = number of lung cancer deaths
SMR = standardized mortality rate for lung cancer, based on local rates

Overall, the lung cancer mortality risk observed through 1982 was not significantly different from that which would have been expected for persons living in the same area. Two hundred and sixty-seven lung cancer deaths were observed, whereas 244.2 would have been expected, giving an SMR of 109.3. Thus, no significant excess risk of lung cancer was observed among the workers at the US fiberglass factories.

The lung cancer risk that was observed was unrelated to the duration of exposure, the time since first exposure, or the cumulative amount of exposure to fiberglass. The workers at the plants with both fiberglass and glass filament exposure had no significant excess lung cancer mortality when compared with local rates, no association

9 Enterline PN, Marsh GM, Henderson V, and C. Callahan. Mortality Update of a Cohort of US man-made mineral fiber workers. Annals of Occupational Hygiene, 1987; 31:625-656.

with duration of exposure or with cumulative amount of exposure, and only a mild association for time since first exposed for short-term workers (< 10 years employment).

A later follow-up report[10] of these workers' experiences through 1985 also found that the lung cancer mortality (SMR = 111.4) among the fiberglass workers was also not statistically significantly elevated. A Poisson regression analysis was conducted to identify the factors that were predictive of the mortality risk. This analysis showed that neither the worker's average exposure nor his total exposure was a significant explanatory factor for the risk based on local rates.

They undertook a special study to examine the role of cigarette smoking in the risk of lung cancer at these plants. Workers or their relatives were interviewed about the worker's smoking history. Analysis revealed that smoking was the only consistently significant explanatory variable of lung cancer among the fibrous glass workers. The worker's age and his year of birth were significant risk variables when national rates were used but not when local rates were used. However, the amount of exposure measured in fibers per milliliter or as cumulative exposure was not a significant explanatory variable with either set of rates.

A case/control study[11] was conducted of the lung cancer cases at the largest plant in the study (Newark, Ohio). This plant manufactured fiberglass and glass filaments of various sizes. This study found that cigarette smoking was the only statistically significant non-occupational risk factor for lung cancer among these workers. A historical environmental reconstruction of the plant was

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10 Marsh GM, enterline PE,Stone RA, and VL Henderson. Mortality among a cohort of US Man-Made Mineral Fiber Workers: 1985 Follow-Up. Journal of Occupational Medicine, 1990; 32(7):594-604.

11 Chiazzi L, Watkins DK, and C Fryar. A Case-control study of malignant and non-malignant respiratory diseases among employees of a fibreglass manufacturing facility. British Journal of Industrial Medicine, 1992; 49:326-331.

conducted that profiled the workers' exposures from 1934 when the plant began until 1987.[12] Exposures included respirable fibers, fine fibers, asbestos, talc, formaldehyde, silica, and asphalt fumes. The only variables found to be statistically significantly associated with lung cancer death were the smoking variables and year and age at hire.

The Canadian study[13] reported on the mortality experience through 1984 of 2,557 men who had been employed at an insulating glass wool plant in Sarnia, Ontario, for at least 90 days between 1955 and 1977. The lung cancer risk at the plant was statistically significant (SMR = 176) compared to the risk for Ontario males (21 cases observed and 11.9 expected). In order to determine whether the observed risk was an employment-related risk or an exposure related risk, they separately examined the risk for the employees who worked only in the plant, those who worked only in the office, and those with mixed exposures and found no difference in the lung cancer risk of those who worked only in the plant and those who worked only in the office. Further, because the risk showed no relationship with either the duration of employment or the time since first employed, the authors concluded that the results were not consistent with an occupational cause or with a causal relationship[14].

These three studies together do not show a statistically significant respiratory cancer mortality excess among the cohorts of workers in plants that manufacture fiberglass in comparison to the

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12 Chiazzi L, Watkins DK, and C Fryar. A Case-control study of malignant and non-malignant respiratory diseases among employees of a fibreglass manufacturing facility. II. Exposure Assessment. British Journal of Industrial Medicine, 1993; 50:717-725.

13 Shannon HS, Jamieson E, Juilan JA, Muir DCF, and C Walsh. Mortality Experience of Ontario Glass Fibre Workers - Extended Follow-Up. Annals of Occupational Hygiene, 1987; 31(4b):657-662.

14 Employment related, but not exposure related, risk factors for lung cancer would include, for instance, a preferential hiring of cigarette smokers or of persons who have a history of multiple short-term employments that would provide a range of prior experiences. See Steve H. Lamm et al. Analysis oof Excess Lung Cancer Risk in Short-Term Employees. American Journal of epidemiology, 1988; 127 (6):1202-1209.

number expected for persons from those localities. Three hundred eighty-one cases were observed where 346.6 were expected (SMR = 109.9; $p>0.05$). As these findings are suggestive (but not demonstrative) of an increased risk of lung cancer among the employees of the fiberglass manufacturing industry, many studies and analyses have been undertaken to determine whether fiberglass exposure is the determinative risk factor in these studies.

Nested case/control studies and Poisson regression analyses have been conducted for the European studies, for the USA studies, and for the Newark, Ohio plant which had contributed the most cases to the USA study in order to identify the likely determinative factors. Each attempt to examine whether fiberglass exposure is a significant determinant of lung or respiratory cancer in these worker groups has failed to find it to be so. These studies have not found exposure related factors to be significant determinants of the risk, whether these employment related factors are duration of exposure, time since first exposure, average amount of exposure, or cumulative amount of exposure. Studies and analyses by both Enterline[15] and Chiazzi[16] have found cigarette smoking to be the only identifiable exposure factor significantly related to the risk of lung cancer mortality among these workers.

No mesothelioma excess was seen among the fiberglass workers[17]. Similarly, none had been seen in the rodents that had inhaled fiberglass, although they had been seen in the rodents that had fiberglass injected into their abdominal or chest cavities.

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15 Enterline PN, Marsh GM, Henderson V, and C. Callahan. Mortality Update of a Cohort of US man-made mineral fiber workers. Annals of Occupational Hygiene, 1987; 31:625-656.

16 Chiazzi L, Watkins DK, and C Fryar. A Case-control study of malignant and non-malignant respiratory diseases among employees of a fibreglass manufacturing facility. British Journal of Industrial Medicine, 1992; 49:326-331.

17 Richard Doll. Symposium on MMMF, Copenhagen, October 1986: Overview and Conclusions. Annals of Occupational Hygiene, 1987; 31(4B):812. and GM Marsh et al. Mortality among a Cohort of US Man-Made Mineral Fiber Workers: 1985 Follow-Up. Journal of Occupational Medicine, 1990; 32(7):600.

Exposure Studies

The rats studied in the long-term toxicology studies were regularly exposed to fiberglass at concentrations of about 25 to 250 f/ml for two years without developing a statistically significant increase in lung tumors[18].

Occupational epidemiological studies of workers at fiberglass manufacturing plants were exposed to fiberglass at concentrations of 0.005 to 0.3 f/ml (see table above). A detailed analysis of exposures during the manufacturing operations involving glass wool insulation has distinguished between concentrations of total fibers, total glass, respirable particles, and respirable glass[19]. The arithmetic mean concentration during operations ranged from 0.02-0.2 f/ml total airborne fibers (up to 50% glass fibers), 0.002-0.014 f/ml glass fibers, and 0.001-0.07 f/ml respirable glass. Concentrations during fiberglass removal had a mean of 0.29 f/ml total fibers and 0.042 f/ml respirable fiber.

The exposure levels for workers installing fiberglass have been measured by a number of investigators. One exposure study found that during the installation of batt-type insulation exposures averaged 0.22 f/ml total fibers, of which 60% were glass fibers and 20% were respirable glass fibers[20]. During the installation of blown wool exposures, the exposure levels were higher with 1.0-2.0 f/ml total fiber, 0.7-1.7 f/ml glass fibers, and 0.3-0.8 f/ml respirable glass fiber. They concluded that respirable glass fiber exposures were generally well below the 1.0 f/ml for batt-type insulation but not for

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18 Bunn, WB, Bender, JR, Hesterberg, TW, Chase, GR, and JL Konzen. Recent Studies of Man-Made Vitreous Fibers Chronic Animal Inhalation Studies. Journal of Occupational Medicine, 1993; 35(2):101-113.

19 Jacob TR, Hadley JG, Bender JR, and W Eastes. Airborne Glass Fiber Concentrations During Manufacturing Operations Involving Glass Wool Insulation. Am Ind Hyg Assoc J, 1993; 54(6):320-326.

20 Jacob TR, Hadley JG, Bender JR, and W Eastes. Airborne Glass Fiber Concentrations During Installation of Residential Insulation. Am Ind Hyg Assoc J, 1992; 53(6):519-523.

blown insulation. Similarly, a team of researchers from Johns Hopkins found that, except for installers of loose fiberglass or mineral wool, the 8-hr TWA exposures for residential insulation installers were less than 0.3 f/ml[21]. Measurements cited by the Canadian government review of mineral fibers[22] include one measurement of 0.04 f/ml airborne fiber concentration during the installation of a glass fibre blanket insulation and levels of 0.05-0.4 f/ml total fibres or 0.005-0.025 f/ml respirable fibres during the installation of blown glass or rock wool. Thus, the exposure levels for fiberglass installers are at the same level or lower than those of fiberglass manufacturers.

Measurements have been made of the levels of airborne fibers in houses insulated with fiberglass[23]. The total airborne fiber level was found to measure 0.01 f/ml or less, of which only 20% or so was of a respirable size. That is, the airborne respirable fiber concentration was found to be about 0.002 f/ml or less. The airborne respirable fiber count includes both airborne respirable glass fibers and non-glass respirable fibers. The level of respirable glass fibers was below the level of detection (generally 0.001 f/ml). They reported that fiber levels were the same the night after installation as they had been the night before installation. Thus, the residential exposures are much lower than occupational exposure levels and not detectably greater than background levels.

The exposure data demonstrate that the exposure levels for residents of insulated homes, for installers of fiberglass insulation, and for manufacturers of fiberglass insulation are orders of

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21 Lees PSJ, Breysse PN, McAthur BR, Miller ME, Rooney BC, and CA Robbins. End User Exposures to Man-Made Vitreous Fibers: 1. Installation of Residential Insulation Products. Appl. Occup. Environ. Hyg., 1993; 8(12):1022-1030.

22 Canadian Environmental Protection Act. Mineral Fibres (Man-Made Vitreous Fibres) (Priority substances list assessment report) Environment Canada, Health Canada, Minister of Supply and Services Canada 1993, page 33.

23 Jacob TR, Hadley JG, Bender JR, and W Eastes. Airborne Glass Fiber Concentrations During Installation of Residential Insulation. Am Ind Hyg Assoc J, 1992; 53(6):519-523.

magnitude lower than the exposure levels at which rodents did not develop a statistically significant increase in lung tumors. These data also demonstrate that the intermittent exposure levels of installers are similar to or less than the exposure levels at which fiberglass manufacture employees did not demonstrate a statistically significant excess of respiratory cancers. Finally, these data demonstrate that the exposure levels for residents of fiberglass insulated homes are significantly lower than those of occupational exposed workers.

Conclusion:

Based on the information above, the Canadian Government, in its assessment of the carcinogenic risk of fiberglass concluded that fiberglass is "unlikely to be carcinogenic to humans" and does not enter the environment "in quantities or under conditions that may constitute a danger in Canada to human life or health"[24].

IARC concluded that fiberglass is a possible carcinogen but is not a probable carcinogen. Based on that classification, commercial fiberglass has had a cancer hazard warning since the late 1980s. The new findings since that classification was assigned in 1987 include toxicologically the demonstration of no increased lung tumor risk in rats that inhaled fiberglass and epidemiologically the demonstration of cigarette smoking as the only statistically significant exposure determinant for lung or respiratory cancer in fiberglass manufacture workers.

The current data do not demonstrate an increased risk of lung cancer from the inhalation of fiberglass fibers in either rats or humans. Thus, review of the toxicological studies, epidemiological studies, and industrial hygiene studies do not predict an increased risk of lung cancer from fiberglass exposure for insulation installers

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24 Ibid, pages 33 and 34.

or building residents. This conclusion is based on the large amount of currently available data from both animal and human studies. These epidemiological studies continue to be carried out and reported in the peer-reviewed medical and scientific literature so that the assessments of risk can continue. The scientific information indicates that fiberglass exposure is unlikely to be a carcinogenic risk to humans and does not constitute a danger to human life or health.

The significance of the current findings can serve as the basis for assessing or classifying the carcinogenic risk potential to humans from fiberglass exposure.

Steven H. Lamm, MD, DTPH

Steven H. Lamm, MD, DTPH, is president of Consultants in Epidemiology and Occupational Health, Inc. (CEOH) in Washington, DC. An occupational health physician specializing in epidemiology, he is board-certified in preventive medicine, occupational medicine, and pediatrics and is a charter fellow of the American College of Epidemiology. He has been an epidemiologist at both the Centers for Disease Control and the National Institutes of Health. He is on the teaching faculties of local universities[25] and active in professional associations[26]. CEOH provide consultative and research services to companies and governments in the areas of occupational epidemiology, environmental epidemiology, and pharmaco-epidemiology.

Consultants in Epidemiology and Occupational Health, Inc., since 1981, has been providing consultative and research services directed towards identifying the causal relationships between human diseases and exposures to chemical and biological substances.

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25 Associate at the Johns Hopkins School of Hygiene and Public Health (Department of Health Policy and Management, Preventive Medicine Residency Program), adjunct associate professorthe Uniformed Services University of the Health Sciences (Department of Preventive Medicine and Biometrics) and clinical assistant professor at Georgetown University School of Medicine (Department of Pediatrics).

26 Past secretary-treasurer of the Society for Epidemiological Research and chairman of the occupational epidemiology and occupational medicine committees of the American Industrial Hygiene Association; Currently member of the epidemiology committee of the American College of Occupational and Environmental Medicine and member of the Board of Reviewers for the American Industrial Hygiene Association Journal.