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Certainly Not Probable:

Causation, Bayes' Theorem, and Theory of Probability

A Commentary by Mark G. Zellmer of Husch Blackwell LLP

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According to plaintiffs, proof of causation of cancer by asbestos exposure is not complicated. If there is exposure, it must have caused the disease. Even if asbestos-associated malignancies are actually diseases without any threshold for causation by asbestos exposure, plaintiffs must still prove that the exposure caused the disease under applicable legal standards. Of course, no one should really expect that the concept of a "no threshold" cancer is scientifically valid. Whether the problem is injury, infection, or cancer, the human body has any number of defenses against abnormal insults to the body's normal function. These defenses physiologically suggest the existence of a threshold.[1] Even accepting the "no threshold" concept, the result of an asbestos-associated disease from some exposures is so improbable that plaintiffs cannot meet appropriate legal standards for proof of causation.

Legal Standards of Causation

Unfortunately, the standards of causation in toxic tort cases and asbestos cases in particular are not a picture of clarity. What is crystal clear is that "but for" causation simply cannot be proven. Namely, an expert cannot fairly and honestly testify that but for the exposure, plaintiff would not have contracted the tumor.[2] The courts have generally looked to "substantial factor" causation as the relevant legal standard. These courts have varied their verbiage to express what is, or is not, an exposure that satisfies the legal standards of causation. Labelled the *Lohrman* standard for the first case expressing the standard, most courts have required plaintiff to show frequency, proximity and regularity of the exposure to establish causation.[3] Illinois courts have followed this same standard, just renaming it the *Thacker* standard.[4] Interestingly, a recent ruling from the Fourth District Illinois Court of Appeals gave further emphasis to the term "substantial." The Court noted that proving some exposure was simply not enough; rather, plaintiff must prove inhalation of "enough asbestos fibers" from the product to be "a material element and a substantial factor in bringing . . . about" mesothelioma.[5]

Other courts have taken a stricter view requiring that plaintiff prove that the exposure from the defendant was sufficient to cause the disease.[6] This is appropriately analogous to the famous "two fires" exception to "but for" causation. If two fires start and then join to destroy a building, the defendants responsible for each of the fires may be held liable if each fire was sufficient to destroy the building. The Missouri Supreme Court has treated this as the only exception to "but for" causation.[7]

The California Supreme Court has refused to provide much, if any, definition of the term "substantial factor," only saying that something that only plays an "infinitesimal" or "theoretical" part in causing harm is not substantial. The Court cautioned that undue emphasis should not be placed on the term "substantial."[8] These and other iterations of the "substantial factor" test led the authors of the Restatement of Torts to consider rejecting the "substantial factor" test altogether, stating that a trivial contribution to causing the harm is not within the defendant's scope of liability.[9] Although "trivial" under the Restatement Third seems like more than "infinitesimal" or "theoretical" under California law, one would be hard pressed to provide any quantification of the difference.

One court has attempted to provide some quantification of the minimum requirement for a plaintiff to satisfy standards of causation. In *Borg Warner Corp. v. Flores*, the Texas Supreme Court required that the exposure attributable to a defendant must have doubled plaintiff's risk of contracting the disease.[10] The Texas standard brought science, rather than speculation, into the courtroom; however, the standard is not without its limitations. If plaintiff's risk of the disease is extraordinarily low, a doubling of the risk will not be substantial. As an example, if the probability of contracting the disease is 0.01 percent, doubling that risk means that the probability of contracting the disease is 0.02 percent. In the words of the Restatement, the increased probability of the disease will be trivial.

Although not quantifying any standards, somewhat similarly, the 6th Circuit U.S. Court of Appeals in *Stallings v. Georgia Pacific Corp.* made it quite clear that the exposure must be proven to make the occurrence of the disease not just possible, but probable.[11] Similarly, the Supreme Court of Alabama in *Sheffield v. Owens-Corning Fiberglass Corp.*, quoting comment (a) from the Restatement (Second) of Torts, section 433B, ruled that causation is not proven when the "probabilities are at best evenly balanced."[12]

Even jury instructions are written in terms of probability. For example, the burden of proof under Illinois Pattern Instruction 21.01 tells the jury that it must find a proposition to be "more probably true than not true." Michigan Civil Jury Instruction 8.01 is written similarly, instructing the jury that a proposition must be proven to be "more likely true" than not true. The calculation of probability can assist the court and the jury to analyze whether a proposition about causation is true or not true, consistent with the dictates of the court's own instructions.

Without proof that an exposure-in-fact caused the disease, courts and juries are left to judge causation based upon the severity of the risk and, hence, the probability of the disease resulting from the exposure. What really is the probability of the occurrence of asbestos-associated malignancies from various exposures? Is the probability from the exposure sufficient to be labelled "substantial" or "probable" or at least more than "trivial" or "infinitesimal"?[13]

Dose Response and Probability

Various organizations and agencies, including OSHA and EPA, have constructed, or at least rely upon, dose response equations. These equations suggest a linear cause-effect relationship between exposure to asbestos at various doses and the likely incidence of disease. These are exactly the dose response equations upon which experts for plaintiffs rely in giving their opinions on causation.[14]

The OSHA dose response equation for mesothelioma per 100,000 people exposed is the following:[15]

Asbestos fibers/cc-years	Mesothelioma
0.1	6.9
0.2	13.8
0.5	34.6
1.0	68
2.0	138
4.0	275

The number of cases of mesothelioma basically doubles from 0.1 to 0.2 f/cc-years and for 2.0 and 4.0 f/cc-years. In fact, each doubling of exposure doubles the expected number of occurrences of tumors resulting from the exposure. As a result, the equation is linear. Assuming that OSHA's numbers are accurate, this allows a calculation of the probability of contracting the disease from a particular cumulative dose of exposure. As an example, the probability of contracting mesothelioma from a cumulative exposure of 1.0 f/cc-years is determined by dividing the expected disease total by 100,000, to-wit: 68/100,000=0.00068 or 0.068 percent.

It is important to recognize that the linear nature of the equation is more of "a cautious default assumption than anything more soundly based."[16] Similarly, the Health Effects Institute notes that "'dose-linearity' is more of a scientifically reasonable compromise . . . than an established scientific principle of carcinogenesis."[17]

Certainly, plaintiffs wish to recover for the disease and the exposure allegedly causing or contributing to cause the disease. On the other hand, if the probability of getting the disease from an exposure is low, plaintiffs cannot persuasively argue that they can meet the burden of proof that the exposure likely caused the disease. Courts should carefully consider risk and probability. In the face of a low probability result, courts should not find that the exposure caused the disease simply because plaintiff has the disease.

Introduction to Bayes' Theorem

Probability applied to causation based only upon these dose response equations raises disturbing questions about proof of causation in toxic tort cases and asbestos cases in particular. The application of Bayes' Theorem to the problem of causation raises another magnitude of questions about a plaintiff's ability to meet the burden of proof.

Bayes' Theorem is a mathematical formula to determine the probability of an event based upon prior knowledge of the conditions that might be related to the event. Simply, Bayes' Theorem in terms of probability judges the degree to which an event is related to prior events, conditions or occurrences. The formula is the following:

$$P(A/B) = \frac{P(B/A)P(A)}{P(B)}$$

P(A/B) is the likelihood of A given that B is true. P(B/A) is the likelihood of B given that A is true. P(A) is the probability of observing A. P(B) is the probability of observing B. This formula is actually elegant in its simplicity, requiring only multiplication and division, not calculus or trigonometry.

The theorem was the conception of Reverend Thomas Bayes who lived in England from 1701 through 1761. First presented after his death in "An Essay Towards Solving a Problem in the Doctrine of Chances" (1763), the theorem found other adherents including Pierre-Simon Laplace who published the modern formulation in "Théorie Analytique des Probabilités" in 1812. British mathematician Sir Harold Jeffreys lauded Bayes' Theorem, explaining that it "is to the theory of probability what the Pythagorean theorem is to geometry."[18]

Bayes Theorem is so well accepted that it is an undercurrent that affects and improves our very lives on daily basis. The list cannot be exhaustive, but a sample of areas involving the use of Bayes' Theorem includes:

- Spam filters for our emails
- Calculation of the risk of lending money to borrowers
- Efficacy of cancer and other medical screening
- Effects of pharmaceutical drugs
- Learning by artificial intelligence

In possibly the most famous and important application, Bayes' Theorem was used to track likely and unlikely relationship between code symbols, cracking the German enigma code and bringing an earlier end to World War II in Europe. Bayes' Theorem has even found acceptance in U.S. courts.[19]

Application of Bayes' Theorem to Causation of Mesothelioma Using U.S. Government Data and Methods

To apply Bayes' Theorem to the problem of causation, the terms in the equation must be defined as follows:

- P(A/B), being the likelihood of A given that B is true, may be defined as the probability of getting mesothelioma given that there has been a particular dose of asbestos exposure.
- P(B/A), being the likelihood of B given that A is true, may be defined as the probability of having been exposed to a particular dose of asbestos given that mesothelioma has been contracted.
- P(A), being the probability of observing A, may be defined as the unconditional probability of getting mesothelioma given asbestos exposure.
- P(B), being the probability of observing B, may be defined as the unconditional probability of experiencing such a dose of asbestos exposure.

To explore the probable effect of doses at the lowest levels of the dose response equations, P(B/A) can be studied at 1 f/cc-year. Of course, those who authored the dose response equations started with high dose epidemiological studies of the occurrence of mesothelioma and extrapolated to the likelihood of the occurrence of mesothelioma at lower levels of exposure. The value of P(B/A) for a cumulative of dose of asbestos exposure of 1 f/cc-year can be determined from the highest cumulative doses of exposure in the underlying epidemiology utilized by the government. These are the highest cumulative doses of exposure in the studies:

- Dement study of textile factory: more than 274 f/cc-years;
- McDonald study of chrysotile mining: more than 900 f/cc-years;
- Finkelstein study of cement factory: 420 f/cc-years;
- Weill study of cement factory: more than 280 f/cc-years.

In addition, the creation of the dose response curve included reliance upon the studies of the New Jersey amosite insulation plant with average exposures of 50 f/cc. At such average exposure, two years of work at the facility would amount to 100 f/cc-years.[20] The dose response curves are applied to cumulative asbestos exposures in a linear relationship. As a result, the mathematic relation between 1 f/cc-year of exposure and the average of these four high cumulative exposures (1 f/cc-year/468.5 f/cc-years) is 0.0021344.

Some mesotheliomas occur without asbestos exposure.[21] To calculate P(B/A) accurately, only those tumors caused by asbestos exposure must be included. McDonald and McDonald found that the background rate of mortality from spontaneous mesothelioma was 1-2 per million of population.[22] In a source often quoted by plaintiff's counsel and experts, an agency of the U.S. government concluded that approximately 15 percent of the mesotheliomas occurred without any known exposure to asbestos.[23] Any number used to represent asbestos-caused mesotheliomas must therefore be no greater than 85 percent of total cases of mesothelioma. This is particularly important for mesothelioma associated with smaller and smaller doses of asbestos exposure. As doses become smaller, the likelihood that the exposure did not cause the disease increases. Not accounting for the possibility that the mesothelioma was not caused by the low dose would skew any statistical analysis.

Calculation of P(A) requires information on the number of mesotheliomas. A reasonable start date is 1951 since prior to the 1950s, malignant mesothelioma was a very rare tumor.[24]

- The estimated number of cases of mesotheliomas from 1951 through 1997 was approximately 115,500.[25]
- From 1999 through 2015, another 45,221 deaths occurred due to mesothelioma.[26]
- Using the average yearly death rate from 1999 through 2015, another 5300 malignant mesothelioma cases can be added for 2016 and 2017.

Counting the number of deaths rather than the number of diagnoses is reasonable since the death rate from diffuse malignant mesothelioma is 100 percent.[27] This is a total of approximately 120,800 deaths due to malignant mesothelioma. Of course, death certificates have not always been an accurate reflection of the diagnosis of mesothelioma. In fact, in the past, diagnoses on death certificates may have understated mesothelioma by as much as 35 percent. Since diagnosis of mesothelioma has improved substantially over the years, the understatement of the disease may be as much as 35 percent; however, to use numbers that are conservative, this understatement of 35 percent would mean another 42,280 cases for a total of 163,080 cases of the disease from 1951 through 2017.

Determining the number of persons occupationally and para-occupationally exposed to asbestos is necessary to calculate P(B). The number which Nicholson et al determined from 1940-1979 was 27.5 million.[28] Citing OSHA in 1990, the Agency for Toxic Substances & Disease Registry noted that 568,000 workers in manufacturing and 114,000 workers in construction were still being exposed to asbestos. Assuming the accuracy of these numbers and using employment turnover statistics for manufacturing and construction, an additional 1.5 million workers were exposed from 1980 through 2000.[29] The total exposed to asbestos from 1940 through 2000 would be 29 million.

Of that 29 million, the number of people exposed to 1 fiber/cc-years of asbestos may be approximated from articles that have attempted to study the risk of "low dose" exposures.[30] Of the subjects and controls, 61.38 percent had exposures at or below 1 f/cc-years.[31] Although usable for the purposes of this article, that percentage is likely lower than would be expected since the Lacourt authors in studying people with mesothelioma have an unavoidable selection bias toward people with asbestos exposure.

Using these statistics, the equation is listed below.[32]

$$\left[\frac{0.0021344 \times 0.85 \times 163{,}000/328{,}000{,}000}{0.6138 \times 29{,}000{,}000/328{,}000{,}000}\right] = \frac{0.2957146}{17800} = 0.0000166$$

The result is a 0.0000166 probability that this exposure caused mesothelioma. According to this calculation using Bayes' Theorem, the probability of contracting mesothelioma calculated by the OSHA dose response equation is at least 41 times too high.[33]

Application of Bayes' Theorem to a Specific Study: Chrysotile Only

This is an application of Bayes' Theorem to the results of a specific study dealing with chrysotile exposure. In 2008 Pira et al published the results of their study of the workers at the Balangero chrysotile mine.[34] The cohort was 1056 workers. Deaths were 590 among whom 237 were exposed in excess of 400 f/cc-yrs. These deaths included 5 cases of mesothelioma. One of those cases had exposure less than 400 f/cc-yrs. Bayes' Theorem may be used to determine probability as follows:

P(B/A): 1 case of mesothelioma below 400 f-yrs exposure/5 cases total = 0.20

P(A): 5 cases of mesothelioma / total work force of 1056 = 0.0047348

P(B): 353 deaths exposed to less than 400 f-yrs / total deaths of 590 = 0.598305

Then the product of the calculation is divided by 400 f-yrs to give probability for 1 f-yr. (0.2 x 0.0047348/0.598305)/400 = 0.0000039

The product of this calculation is almost a full order of magnitude (10 times) less than the prior calculation. Compared to the prior calculation based on all mesotheliomas, this result represents a closer approximation of the probability of mesothelioma from low level chrysotile exposure.[35]

Comparison to Studies of Heavier Dose Exposure

Of course, the scientific and medical literature contains any number of studies of workers and facilities in which asbestos exposures accumulated to doses that were clearly not low dose. These studies include workers in the mines of Wittenoom, Australia and asbestos insulation manufacturing plants in Tyler, Texas and Berlin, New Jersey as well as others. Undoubtedly, the most famous of these studies is the Selikoff insulator study. In the 1960s and 1970s, Dr. Irving Selikoff investigated the occurrence of mesothelioma among the insulation trade.[36] Of the 17,800 insulators in the studies, 4951 died by December 31, 1986, with 458 insulators or 9.3 percent dying of mesothelioma. Virtually all of them (100 percent) were exposed to asbestos, well in excess of 1 f/cc-year. How many of them incurred mesothelioma due to their asbestos exposure? With so many of them having underlying asbestosis, the number would be high. Plaintiffs and their experts would argue all of them. Considering the doses of exposure to these insulators, an assumption would be that only a few of these insulators could be expected to contract mesothelioma without such exposure. A plaintiff-friendly estimate would be that only one in one hundred (1 percent) of these insulators would get mesothelioma without such exposure.

That estimate provides a basis for comparison to low dose exposures. Comparing a 99 percent probability that asbestos exposure caused mesothelioma in the heavier dose situations with probability that an exposure of 1 f/cc-year caused disease raises serious questions that causation of mesothelioma can be legally proven at low doses of exposure. In fact, it is more than 50,000 times more likely that asbestos exposure caused mesothelioma in a "Selikoff" insulator than 1 f/cc-year of asbestos caused someone's mesothelioma (0.99/0.0000166).[37]

Do the Selikoff insulator studies represent the "gold standard" for proof of causation? If so, the burden of proof should at least be a probability equivalent to just over 50 percent of the probability that an insulator in the Selikoff studies contracted mesothelioma from asbestos exposure.

Comparison to Epidemiology

Some authors have attempted to determine the rectitude of the results of EPA's dose response equation. EPA, like OSHA, used high dose studies and extrapolated to risks from low dose exposures. Camus et al in 2002 studied the occurrence of mesothelioma among women living around the Canadian chrysotile mines in Asbestos and Thetford, Canada to compare the number of those women contracting mesothelioma with the number of cases of mesothelioma predicted by EPA's dose response equation. These women sustained an average dose of 105 f/cc-years. With such exposure Camus et al tested the linear dose response equation at the higher doses from which the government extrapolated risk at lower doses. For this exposure EPA predicted 150 cases of mesothelioma in Asbestos, Canada and 500 cases of mesothelioma in Thetford, Canada. The occurrence of mesothelioma was actually much less. In fact, EPA's number was 150 times too high for Asbestos, Canada, 35 times too high for Thetford, Canada and 50 times too high when the numbers were combined for both locales.[38]

If the linear dose response equation is so wrong for higher exposures, then assumptions for extrapolating risk and causation from high to low doses are also wholly deficient. If the equation gives results so wrong for higher doses, it is then equally wrong for low dose exposures, if not more so. Epidemiology as well as calculation of probability shows the low probability of disease occurrence, too low to presume any basis for causation.

Calculation of Bayes' Theorem with Amphibole Exposure

Use of asbestos over the years in the United States has been approximately 90 percent chrysotile and 10 percent amphibole. Assuming on that basis that a person's cumulative dose from a particular source was 90 percent chrysotile and 10 percent amosite, the probability of mesothelioma from that source can be determined using the Hodgson and Darnton ratio for the relative potency of fibers.[39] Recalculation of P(B/A) in the equation from the Balangero study may be done as follows:

Calculate the value of 10 percent of the chrysotile exposure:
$$0.2 \times 0.10 = 0.02$$

Deduct that amount from the prior value of P(B/A):
$$0.2 - 0.02 = 0.18$$

Using the ratio 100 to 1 for amosite to chrysotile, calculate the new value of potency of amosite:
$$0.02 \times 100 = 2.0$$

Add the 90 percent chrysotile potency to 10% amosite potency:
$$0.18 + 2.0 = 2.18$$

Insert the new value P(B/A) in the Bayes' equation:

$$\left[\frac{2.18 \times 0.0047348}{0.598305}\right] = 0.0172517$$

Then, to each a result for 1 f/cc-yrs, divide 0.0172517 by 400 f/cc-yrs which is 0.0000431.

A small amount of amphibole yields a greater probability of occurrence of mesothelioma, i.e. 0.0000431 versus 0.0000039; however, that probability of mesothelioma from such low dose is still extraordinarily low.

Comparison to Background Incidence of Mesothelioma

When the data from Bayes' Theorem is compared to the incidence of spontaneous mesothelioma, courts and litigants find how truly improbable it is that low doses of asbestos exposure cause mesothelioma. The background rate of mesothelioma calculated as the lifetime rate per million population is approximately 140 to 360.[40] This is an average number of 250 lifetime risk per million of population. The fraction 250/1,000,000 yields 0.00025. Here is the comparison to the probabilities calculated earlier:

- For 163,000 cases of mesothelioma in the US population: 0.0000166
- For mesothelioma in the Balengero chrysotile mine: 0.0000039
- For mesothelioma with 10% amosite exposure using the Hodgson/Darnton ratio: 0.0000431

These numbers are not even as great as the probability of contracting spontaneous mesothelioma which is admittedly low. To establish the probability of causation, plaintiffs should be required to prove much more than such minimal possibilities.

"Even accepting the 'no threshold" concept, the result of an asbestos-associated disease from some exposures is so improbable that plaintiffs cannot meet appropriate legal standards for proof of causation."

Conclusion

As courts have expressed, the occurrence of disease due to exposure must be proven probable, and not the subject of speculation and conjecture. These pronouncements must be taken seriously. Defense counsel in depositions and at trial, when confronted with an issue of causation, must treat causation as an issue of probability, to-wit: what effort has the plaintiff's expert made to determine the probability that the dose of exposure attributable to a defendant actually caused the disease. Whether applying dose response equations, Bayes' Theorem or epidemiology, the probability that a low dose of asbestos exposure caused mesothelioma is too low to justify any finding of causation.

Endnotes

1 Genetic conditions impair these defenses in some people, but evidence is lacking that they are impaired enough to make a person susceptible to mesothelioma from low doses of asbestos exposure. Zellmer M. "Toward a Defense of Mesothelioma Cases on Causation: Implications of Genetics." *HarrisMartin's COLUMNS-Asbestos*. (October 2016) at 4, 7-8.

2 For example, Dr. Arthur Frank, certainly not a defense friendly witness, has opined in deposition that there is "no way of knowing" that but for an exposure plaintiff would have contracted his cancer. Deposition of Dr. Arthur Frank in James Barkley v. A.W. Chesterton, Inc. consolidated with other cases in the Circuit Court for Madison County, case no. 07-L-126, July 7, 2007 at 122.

3 *Lohrman v. Pittsburgh Corning Corporation*, 782 F.2d 1156 (4th Cir. 1986).

4 *Thacker v. UNR Indus., Inc.*, 151 Ill. 2d 343, 603 N.E.2d 449 (Ill. 1992).

5 *McKinney v. Hobart Brothers Company*, Case no. 4-17-0333 (September 5, 2018) at 28.

6 *Moeller v. Garlock Sealing Technologies, L.L.C.,* 660 F.3d 950, 952 (6th Cir. 2011).

7 *Callahan v. Cardinal Glennon Hospital*, 863 S.W.2d 852, 862-863 (1993); see also *Wagner v. Bondex International, Inc.*, 368 S.W. 2d 340 (Mo.App. 2012) (suggesting that a standard of "but for" causation can be satisfied in asbestos cases).

8 *Rutherford v. Owens-Illinois, Inc.* 16 Cal. 4th 957, 969, 67 Cal. Rptr. 2d 16, 941 P.2d 1203 (1997).

9 Restatement (Third) of Torts, Section 36 (2005). Comment b limits the exception to cases of multiple tortfeasors.

10 232 S.W.3d 765 (Tex. 2007).

11 No. 15-6387 (6th Cir. 2017).

12 595 So.2d 443, 450-451 (Ala. 1992).

13 This analysis is made in large part based upon data from sources upon which plaintiff attorneys and their experts rely. Citation to such data should not be taken as agreement. In fact, defendants have numerous disagreements with counsel representing plaintiffs including, but not limited, to the accuracy of many dose response curves and equations, concepts of threshold for asbestos associated diseases and the reliability of data from studies of mesothelioma from low doses of asbestos exposure.

14 Deposition of Dr. Brent C. Staggs in *Kimberly Plant v. Ameron International Corp.* consolidated with other cases in the Circuit Court for Madison County, case no. 16-L-1084, October 23, 2018 at 137. ("OSHA specifically says . . . that at the current permissible exposure limit of .1 fibers per cc . . . for one year, that that is causative of disease, mesothelioma.")

15 https://www.federalregister.gov/documents/2005/07/29/05-14510/asbestos-exposure-limit. OSHA did not provide the number of expected tumors for 1.0 f/cc-years; however, since the equation is essentially linear, the number of expected tumors is easily determined by doubling the number of tumors corresponding to 0.5 f/cc-years or halving the number corresponding to 2.0 f/cc-years.

16 Hodgson, J. et al. "The Quantitative Risks of Mesothelioma and Lung Cancer in Relation to Asbestos Exposure." Annals of Occupational Hygiene. Vol. 44:8 (2000) at 565, 576.

17 Health Effects Institute. Asbestos in Public and Commercial Buildings: A Literature Review and Synthesis of Current Knowledge. (Health Effects Institute, Cambridge, Mass: 1991).

18 H. Jeffreys. *The Theory of Probability*. 3rd ed. (Oxford: 1961) at 432.

19 For a list of cases discussing/applying Bayes Theorem, see https://sites.google.com/site/bayeslegal/legal-cases-relevant-to-bayes. Famously, in one instance, the prosecution argued that the death of her two children due to natural causes was so unlikely that the mother must have killed them. The defense, using Bayes' Theorem, argued that it was equally if not more unlikely that the mother was in fact a double murderer.

20 *Federal Register*, vol. 51, June 20, 1986 at 22612.

21 Hirsch A. et al. "Features of Asbestos-exposed and Unexposed Mesothelioma." *American Journal of Industrial Medicine*. Vol. 3 (1982) at 413, 421 (work and exposure histories of those with mesothelioma thoroughly examined for source of asbestos exposure).

22 McDonald J.C. et al. "The Epidemiology of Mesothelioma in Historical Context." *European Respiratory Journal*. Vol. 9 (1996) at 1932, 1937.

23 NIOSH, Public Health Service, Center for Disease Control, U.S. Department of Health, Education and Welfare. Revised Recommended Asbestos Standard (December, 1976) at 32. Attanoos R. et al. "Malignant Mesothelioma and Its Non-Asbestos Causes." Archives of Pathology & Laboratory Medicine. Vol. 42, no. 6 (2018) at 753, see table assessing percentage of mesotheliomas occurring without asbestos exposure.

24 Carbone, M. et al. "Malignant Mesothelioma: Facts, Myths and Hypotheses." *Journal of Cellular Physiology*. Vol. 227(1) (January 2012) at 44-58.

25 Nicholson, W. J. et al. "Cancer from Occupational Asbestos Exposure Projections 1980-2000." *Banbury Report 9* (Cold Spring Harbor Laboratory: 1981) at 106.

26 https://www.cdc.gov/mmwr/volumes/66/wr/mm6608a3.htm.

27 Carbone, *supra*.

28 https://www.atsdr.cdc.gov/csem/csem.asp?csem=29&po=7. Lilienfield, D.E. et al. "Projection of Asbestos Related Diseases in the United States, 1985-2009 I. Cancer." *British Journal of Industrial Medicine*, Vol. 45 (1988) at 283-291.

29 ATSDR. Toxicological Profile for Asbestos (September, 2001) at 168; Akerlof, G. et al. "An Experience-Weighted Measure of Employment and Unemployment Durations." *The American Economic Review* (December, 1981) at 1003, 1006 (568,000x20 years/18.4 years duration of employment=1.185 million and 114,000x20 years/11.9 years duration of employment=305,000).

30 Again, this is cited because it is used by plaintiff's experts and related sources, not because it is necessarily accurate.

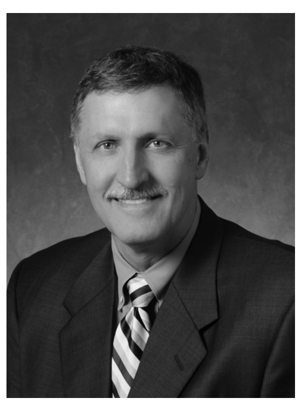
31 Lacourt, A. et al, "Attributable Risk in Men in Two French Case-Control Studies on Mesothelioma and Asbestos." *European Journal of Epidemiology*. (September 7, 2010).

32 U.S. population is included at 328 million in both the numerator and the denominator and, hence, does not affect the final statistical product and is dropped from the calculation.

33 A couple words of caution are necessary about this calculation. First, these are 163,000 cases of mesothelioma without regard for the fiber type potentially causing the disease. Second, this whole analysis of course assumes, but does not endorse that chrysotile is in fact causative of mesothelioma. For example, see Yarborough, C. "The Risk of Mesothelioma for Exposure to Chrysotile Asbestos." Current Opinions on Pulmonary Medicine. Vol. 13 (2007) at 334, 337.

34 Pira E. et al. "Mortality from Cancer and Other Causes in the Balangero Cohort of Chrysotile Asbestos Miners." Occupational and Environmental Medicine. Vol. 66 (2008) ar 805. The possible and even likely impact of

Mark G. Zellmer is a Partner in the St. Louis, Missouri, office of Husch Blackwell LLP. He is admitted to practice in Missouri (1982) and Illinois (1978) as well as in federal courts in those states. Zellmer earned his J.D. from Saint Louis University School of Law (1978). He earned his B.A. from the University of Notre Dame (1975).



Zellmer speaks and writes extensively on products liability law and asbestos litigation. Such writing and presentation on asbestos litigation include subjects such as premises liability, application of statutes of limitations, medical causation, the litigation in historical context, and exclusivity of remedies under workers' compensation.

Zellmer defends toxic tort cases, particularly relating to asbestos, as well as other substances and chemicals. Zellmer also defends various defendants in product liability regarding vehicular and industrial equipment. Zellmer's trial practice is active in state and federal courts from coast to coast, and he has acted as national counsel in asbestos litigation.

Balangeroite, a tremolite-like contamination of the Balangero ore, is ignored for purposes of this calculation.

35 Although beyond the point of this article, the effects of Balangeroite, a fibrous contaminate of the ore, may mean that the probability of mesothelioma from chrysotile may be even lower, maybe even zero. Pira et al published a later study. Pira E. et al. "Mortality from Cancer and Other Causes Among Italian Chrysotile Asbestos Miners." Occupational and Environmental Medicine. Vol. 74 (2017) at 558. For a number of reasons, the latter study is not usable for these Bayesian calculations. First, the authors do not update the dose of exposure to the people who died from all causes. Second, there was a peritoneal case in the 2008 study but it was removed in the 2017 study. Maybe it was a misdiagnosis. Maybe it was an inconvenient suggestion that peritoneal mesothelioma only occurs at high doses of amphibole asbestos exposure, validating the effects of Balangeroite. Third, while the 2008 study showed statistically significant effects of chrysotile causing lung cancer, those effects completely disappeared in the 2017 study. Why would that happen? Fourth, any pretense of a dose response for mesothelioma was non-existent in the 2017 study. There were three cases for exposures less than 100 f/cc-yrs, 1 case for exposure greater than 100 f/cc-yrs but less than 400 f/cc-yrs, and 3 cases for exposure greater than 400 f/cc-yrs. Using duration, there were 3 cases for those working for less than 10 years, no cases for those working 10-19 years, 2 cases for those working 20-29 years, and 3 cases for those working 30+ years.

36 Selikoff, I.J. et al. "Asbestos-Associated Deaths among Insulation Workers in the United States and Canada, 1967-1987." *Annals of the New York Academy of Sciences*. Vol. 643 (1991) at 7.

37 Bayes' Theorem cannot be used in exactly the same manner for lung cancer unless adjusted for the confounding factors such as cigarette smoking.

"Whether applying dose response equations, Bayes' Theorem or epidemiology, the probability that a low dose of asbestos exposure caused mesothelioma is too low to justify any finding of causation."

38 Camus, M. et al. "Risk of Mesothelioma Among Women Living Near Chrysotile Mines Versus EPA Asbestos Risk Model: Preliminary Findings." *Annals of Occupational Hygiene*. VoI. 46, Supp. 1 (2002) at 95, 98.

39 Hodgson, supra. at 565-601 (500 to 100 to 1 for crocidolite to amosite to chrysotile respectively). Some studies suggest that amosite and other amphiboles are not as potent as reflected in this ratio. See studies cited in earlier articles by Zellmer M. "Any Exposure Above Background: Is It Really Causative?" *HarrisMartin's COLUMNS-Asbestos*. (February 2015) at 4-10.

40 Jasani B. et al. "Mesothelioma Not Associated With Asbestos Exposure." Archives of Pathology & Laboratory Medicine, Vol. 136 (2012) at 262.