ASBESTOS AND ADDITIVE MANUFACTURING: ADDRESSING EARLY CONCERNS SURROUNDING MANUFACTURING 3D-PRINTING TECHNOLOGY USING ASBESTOS AS A LITIGATION MODEL

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I. INTRODUCTION

It's so difficult, isn't it? To see what's going on when you're in the absolute middle of something? It's only with hindsight we can see things for what they are.[1]

Here we stand, at the very precipice of the next asbestos litigation crisis,[2] and we have critical decisions to make. Will we reproduce the mistakes of the past, subjecting millions of Americans to the medical and financial uncertainty that accompanies latent-disease litigation?[3] Or, will we instead take steps to prevent the causes of latent diseases, to simplify the laws surrounding latent-disease litigation, and to provide both plaintiffs and defendants with fast, efficient, and predictable outcomes? This Article addresses how industrial additive manufacturing, colloquially known as "3D printing," may trigger the new generation of latent-disease litigation. Further, this Article highlights key issues in asbestos litigation that require substantial clarification to operate effectively in the industrial 3D-printing context.

Asbestos, once thought to be a magical material,[4] quickly rose to prominence after the Industrial Revolution.[5] Lauded for its low flammability and high tensile strength, manufacturers across numerous industries used asbestos in everyday products including insulation and automobiles.[6] Although previously unknown or ignored during asbestos's rise, today it is well-known that there are severe health implications of exposure to asbestos. The miniscule asbestos fibers have been labeled as a cause of several diseases, namely asbestosis, lung cancer, and, perhaps most notably, mesothelioma.[7]

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[1] S.J. WATSON, BEFORE I GO TO SLEEP 266 (2011).

[2] James L. Stengel, *The Asbestos End-Game*, 62 N.Y.U. ANN. SURV. AM. L. 223 (2006); *see also* Victor E. Schwartz, *A Letter to the Nation's Trial Judges: Asbestos Litigation, Major Progress Made over the Past Decade and Hurdles You Can Vault in the Next*, 36 AM. J. TRIAL ADVOC. 1 (2012) (asserting that asbestos litigation had reached "crisis proportions" around the year 2000).

[3] Francis E. McGovern, *The Tragedy of the Asbestos Commons*, 88 VA. L. REV. 1721, 1725 (2002).

[4] Daniel King, *History of Asbestos*, THE MESOTHELIOMA CENTER (Aug. 8, 2019), https://www.asbestos.com/asbestos/history/.

[5] *Id*.

[6] *Id*; *see also* Stengel, *supra* note 2, at 226–27 (discussing the growth in the use of asbestos across various industries).

[7] *See* Daniel J. Penofsky, *Asbestos Injury Litigation*, 60 AM. JUR. TRIALS 73, § 1 (2018).

Similar to the rise of asbestos, 3D-printing technologies are rapidly growing in popularity[8] and have already garnered the label of miracle-maker.[9] Perhaps to a much larger degree, 3D printing has the potential to forever change the world's manufacturing landscape.[10] However, 3D printing is not without its concerns, and those concerns may mirror the same risks posed by asbestos exposure. Notably, 3D printers can be categorized as "high emitters" of ultra-fine particles, or particles small enough to penetrate the lungs and reach the bloodstream.[11] Many of these particles come from known or suspected carcinogens which, in time, can lead to the development of various cancers.[12]

However, because the diseases in these contexts do not manifest until years and sometimes decades later, unique and difficult issues have arisen in these latent-disease cases.[13] Among those difficulties are two issues that plague both plaintiffs and defendants alike: identifying the true party at fault[14] and applying a proper standard in establishing causation.[15]

In Part II, this Article will fully illustrate the similarities between the rise of asbestos and the present ascension of 3D printing in manufacturing contexts. Additionally, it will explore the latent dangers of both asbestos

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[8] Thomas Campbell et al., *Could 3D Printing Change the World? Technologies, Potential, and Implications of Additive Manufacturing*, STRATEGIC FORESIGHT REPORT, (The Atl. Council of the U.S., D.C.), Oct. 2011, at 9, http://www.cbpp.uaa.alaska.edu/afef/Additive%20MFG%20.pdf.

[9] Beth Stackpole, *3D Printing: The Next Medical Miracle?*, DIGITAL ENGINEERING 247 (May 1, 2015), https://www.digitalengineering247.com/article/3d-printing-the-next-medical-miracle/.

[10] Joel Fyke et al., *Searching For a Predictable Liability Regime: Direct-to-Consumer 3D Printing Protection*, 58 NO. 11 DRI FOR DEF. 45 (2016) (stating "[t]he potential for 3D printing, formally known as additive manufacturing, to forever change traditional manufacturing processes has been well documented"); *see also* Barack Obama, President, United States of America, State of the Union Address, (Feb. 12, 2013), https://www.whitehouse.gov/the-press-office/2013/02/12/remarks-president-state-union-address (stating that "3D printing . . . has the potential to revolutionize the way we make almost everything").

[11] *See 3D Printer Safety – Pollution and Their Health Risks*, BOX3D (Nov. 1, 2017), https://box3d.eu/3d-printing-safety-pollution-health/.

[12] *See id*.

[13] *See generally* Donald G. Gifford, *The Peculiar Challenges Posed by Latent Diseases Resulting from Mass Products*, 64 MD. L. REV. 613, 613 (2005).

[14] *Id*. at 653–54.

[15] *Id*. at 688–89.

and 3D printing to give the reader a more complete understanding of the parallel risks that arise in each context.

Part III will explore two key issues affecting plaintiffs and defendants: identifying the party at fault and establishing a proper causation standard. This section will also highlight how these issues have created critical problems in asbestos litigation.

Part IV will then illustrate why those two issues are likely to arise in litigation involving industrial 3D printing. This section will further provide suggestions that help clarify the law surrounding these issues and allow for a more efficient and fair assessment of both causation and liability in the 3D-printing context.

Finally, Part V will outline other potential issues that are presented by the rise in 3D printing.

II. Overview of Asbestos and 3D-Printing

The rise of asbestos before, during, and after the Industrial Revolution and the current emergence of industrial-based 3D printing share a startling number of parallel themes. Ultimately, the similarities in emergence, widespread adoption, and long-term exposure-related risks are the factors that make asbestos litigation a proper model for analyzing and solving future problems in the industrial 3D-printing context. It is critical, then, to explore the development of each respectively.

a. Asbestos: An Overview

Asbestos is a naturally occurring mineral that has been in use for approximately 10,000 years.[16] In ancient times, potters and alchemists alike noticed the heat-resistant nature of asbestos as well as its ability to seemingly improve various products in every way imaginable.[17] Indeed,

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[16] King, *supra* note 4.

[17] *Id.* (stating that "[i]t is believed that as early as 4000 B.C., asbestos' long hair-like fibers were used for wicks in lamps and candles. Between 2000–3000 B.C., embalmed bodies of Egyptian pharaohs were wrapped in asbestos cloth to protect the bodies from deterioration. In Finland, clay pots dating back to 2500 B.C. contained asbestos fibers, which are believed to strengthen the pots and make them resistant to fire. Around 456 B.C., Herodotus, the classical Greek historian, referred to the use of asbestos shrouds wrapped around the dead before their bodies were tossed onto the funeral pyre to prevent their ashes from being mixed with those of the fire itself.").

asbestos-woven materials were used in varying context throughout history to contain fire.[18]

Asbestos was used throughout the Middle Ages, by the likes of King Charlemagne and Russia's Peter the Great.[19] Charlemagne used asbestos for tablecloths to prevent fires at large feasts, but asbestos ultimately found its way into numerous medieval contexts—even war.[20] It is evident that the ability of asbestos to be used in a myriad of products had been recognized even in ancient times.

The versatility of asbestos became its greatest asset during the Industrial Revolution, as demand for the material skyrocketed.[21] Once the mid-to-late 1800s arrived, worldwide demand grew from steady to explosive.[22] By the twentieth century, asbestos was widely used across several industries as insulation for buildings, steam engines, turbines, and electrical generators, among other applications.[23]

However, throughout asbestos's history, the negative effects of its use and exposure thereto have been extensively noted. Strabo, a Greek geographer, and Pliny the Elder, a Roman historian and naturalist, spoke of a "disease of slaves" among enslaved persons who worked with or around asbestos-containing materials.[24] Both men also described the disease as a "sickness of the lungs"[25] and discussed how some slaves would use a thin

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18 *Id.*

19 *Id.*

20 *Id.* ("By the end of the first millennium, cremation cloths, mats and wicks for temple lamps were fashioned from chrysotile asbestos from Cyprus and tremolite asbestos from northern Italy. In 1095, the French, German and Italian knights who fought in the First Crusade used a catapult, called a trebuchet, to fling flaming bags of pitch and tar wrapped in asbestos bags over city walls during their sieges. In 1280, Marco Polo wrote about clothing made by the Mongolians from a 'fabric which would not burn'").

21 King, *supra* note 4.

22 *Id.*

23 *Id.*; Paul D. Carrington, *Asbestos Lessons: The Unattended Consequences of Asbestos Litigation*, 26 REV. OF LITIG. 583, 585 (2007) ("In 1931, a technique was developed for mixing the [asbestos] in cement. It came to be used in brake linings that might overheat. And it was also widely used to cover pipes used to transmit heated air or fluids."). For a longer list of the uses of asbestos see *Fact Sheet: Asbestos*, UNIV. OF KY. OCCUPATIONAL HEALTH & SAFETY, https://ehs.uky.edu/ohs/fs_asbestos.php (last visited Jan. 16, 2010).

24 *Earliest Known Facts About Asbestos*, UNIV. OF MONT. ETHICS & ENVTL. HEALTH, http://www.umt.edu/bioethics/libbyhealth/introduction/background/asbestos_timeline.aspx (last visited Jan. 16, 2020); King, *supra* note 4.

25 King, *supra* note 4.

membrane from the bladder of a goat or lamb as a make-shift respirator to protect them from inhalation of the fibers.[26] In the early twentieth century, Dr. Montague Murray became the first physician to report a case of asbestosis.[27] As of the 1930s, executives of the major manufacturers using asbestos, such as Johns-Manville Corp., were likely aware of the risks to workers exposed to the material.[28]

Initially, the fears surrounding asbestos exposure were stifled by a belief that the only people at risk of coming in contact with dangerous levels of asbestos were people exposed in occupational contexts.[29] However, it would become clear over the coming decades that asbestos fibers were somewhat ubiquitous[30] and that millions of people had been exposed to asbestos.[31] As a result, those millions of people were all at an increased risk

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[26] *Id*.

[27] Richard A. Lemen, *Challenge for the 21st Century – A Global Ban On Asbestos*, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.565.5820&rep=rep1&type=pdf.

[28] Carrington, *supra* note 23, at 585.

[29] Penofsky, *supra* note 7, at § 1 ("It was once thought that only asbestos miners, shipyard workers, and pipe fitters were in danger, because of their occupations, of coming into contact with dangerous levels of asbestos fibers").

[30] *Id*. ("However, it is now known that asbestos fibers are a ubiquitous pollutant of the air we breathe, the food we eat, and the water we drink. According to Laurence Malloy, a New York-based asbestos investigator, asbestos fibers are in the air throughout the U.S. and we breathe them in on a daily basis without realizing it. Consider, for example, that every single time an automobile or train applies its brakes, thousands of potentially lethal asbestos fibers from the brake linings are released into the atmosphere. Every time there is an unskilled effort to remove or abate asbestos from a building—a dangerous process that involves ripping and scraping asbestos fibers from a building's superstructure—hundreds of thousands of asbestos fibers may be released. It is estimated that significant amounts of asbestos are present in 20% of all U.S. public and commercial buildings, a total of 733,000 structures. At present, there is considerable debate as to the true hazard of the millions of tons of such "in place" asbestos. Every time there is a rainfall or windstorm, there is an erosion of asbestos fibers from asbestos mining sites. As a result of this activity, it is estimated that the typical American breathes in, unwittingly, about one million asbestos fibers a year.").

[31] Gifford, *supra* note 13, at 620 ("Millions of people were exposed to asbestos dust generated, for example, by insulation materials").

of developing asbestosis, mesothelioma,[32] and other cancers and lung conditions.[33]

At this point, it is critical to discuss exactly how asbestos fibers cause this catastrophic harm. This explanation will be integral to understanding why asbestos is a proper model for the problems facing industrial 3D printing. Ultimately, both products are fraught with risks due to the particulate nature of their dangerous components.

Dangerous exposure to asbestos, whether occupational or otherwise,[34] usually results from the inhalation of asbestos fibers.[35] Asbestos fibers can be "hundreds of times thinner than a human hair"[36] and, after entering the body through inhalation, can become lodged in the pleura.[37] These fibers, after some time, can cause inflammation, scarring, and genetic

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[32] Curtis W. Noonan, *Environmental Asbestos Exposure and Risk of Mesothelioma*, 5 ANNALS TRANSLATIONAL MED. 1, 1 (2017) ("Malignant mesothelioma is an aggressive form of cancer that typically originates in the pleural but can also occur in the peritoneum, pericardium and around the testes. Asbestos exposure is the only established risk factor known to be causally related to mesothelioma.").

[33] Gifford, *supra* note 13, at 620–21 ("The inhalation of asbestos fibers causes diseases ranging from asbestosis, a lung disease resulting in the destruction of air sacs in the lung, to mesothelioma and other lung cancers. Medical research had begun to reveal the health hazards resulting from exposure to asbestos by the early decades of the twentieth century. Manufacturers of asbestos products not only failed to warn consumers of these hazards, but also actively concealed the risks of exposure to asbestos by, among other means, altering and censoring research results.").

[34] *See* Noonan, *supra* note 32, at 2 (describing para-occupational exposure to asbestos stating that "[t]he term para-occupational exposure refers to an asbestos exposed worker serving as a vector for the transport of fibers to the household setting.").

[35] Kristina Luus, *Asbestos: Mining Exposure, Health Effects and Policy Implications*, 10 MCGILL J. MED. 121, 122 (2007) ("Exposure to asbestos fibres occurs through ingestion, skin contact or inhalation. Inhalation of asbestos fibres is dangerous and results in asbestos related diseases. Skin contact with raw asbestos fibres results in relatively harmless epidermal overgrowth. Ingestion of water from asbestos-contaminated pipes has not been found to increase the incidence of asbestos-related diseases.").

[36] *Causes of Mesothelioma*, MESOTHELIOMA GRP. (last visited Dec. 30, 2019), https://www.mesotheliomagroup.com/mesothelioma/causes/.

[37] *Id.* ("After inhalation, roughly two-thirds of the fibers are breathed out from the body. Some fibers remain and become lodged in the lining of the lungs (the pleura), abdominal cavity (the peritoneum) or heart (pericardium).").

changes that lead to the development of mesothelioma along with other cancers and lung conditions.[38]

Another crucial attribute of asbestos is the existence of multiple strains of asbestos, each of which possibly have a different effect on those exposed. Asbestos fibers can be categorized as either chrysotile or amphibole.[39] The amphibole category can be divided into five sub-strains, named actinolite, amosite, anthophyllite, crocidolite, and tremolite.[40] While many studies indicate that all forms of asbestos are equally dangerous,[41] some studies indicate and some organizations maintain that the chrysotile form of asbestos is safer than the amphibole forms.[42] Despite the lingering belief that some forms of asbestos may be safe enough for use, many countries around the globe have banned asbestos entirely, suggesting that there is no way to safely use the material.[43]

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[38] *Id*. (Additionally, while research has not yet revealed how exactly the fibers cause the requisite genetic changes to produce mesothelioma, a few theories exist such as: "(1)The microscopic size and needle-like shape of asbestos could prevent cells in the immune system from clearing the fibers out. Cells in the mesothelial lining then absorb the fibers, which in turn interfere with normal cellular division; (2) Inhaled fibers irritate mesothelial cells, causing them to swell. This results in cellular damage and tumor development; (3) Asbestos fibers may influence the production of molecules that damage DNA and disrupt cellular reproduction. This damage leads to the production of tumors; (4) Asbestos fibers may also influence the production of proteins that can mutate regular mesothelial cells into tumor cells.") (numerals and semi-colons added); *see also* Piero Mustacchi, *Lung Cancer Latency and Asbestos Liability*, 17(2) J. LEGAL MED. 277, 278 (1996).

[39] *See* IARC MONOGRAPHS ON THE EVALUATION OF CARCINOGENIC RISKS TO HUMANS, INT'L AGENCY FOR RESEARCH ON CANCER, WORLD HEALTH ORG., ARSENIC, METALS, FIBRES, AND DUSTS: A REVIEW OF HUMAN CARCINOGENS 219 (2012), https://www.ncbi.nlm.nih.gov/books/NBK304374/.

[40] *Id.*

[41] *See id*. at 294 ("There is sufficient evidence in humans for the carcinogenicity of all forms of asbestos (chrysotile, crocidolite, amosite, tremolite, actinolite, and anthophyllite).").

[42] *See* Ferro et al., *Amphibole, But Not Chrysotile, Asbestos Induces Anti-Nuclear Autoantibodies and IL-17 in C57BL/6 Mice*, 11 J. IMMUNOTOXICOLOGY 283 (2014). *See also* Faith Franz, *Study Revisits Health Risk of Chrysotile: Why is This Still a Debate in 2013?*, THE MESOTHELIOMA CTR. (Feb. 1, 2013), https://www.asbestos.com/news/2013/02/01/health-risk-of-chrysotile/; Luus, *supra* note 35, at 123 ("Research on in vivo rats has found that chrysotile promotes genotoxicity more rapidly than crocidolite.").

[43] Lemen, *supra* note 27, at 2 ("Austria, Belgium, England, The Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, New Zealand, Poland, Saudi Arabia, Sweden, and Switzerland have all banned asbestos. . . . Further substantiation that asbestos cannot be used safely comes from the most recent International Programme for Chemical

Whatever the case may be regarding the effects of different strains of asbestos, one absolute certainty is that asbestos use has led to an overwhelming amount of litigation. In 1973, the United States Court of Appeals for the Fifth Circuit ruled against asbestos manufacturers in *Borel v. Fibreboard Paper Products Corp.*[44] This decision "began the onslaught" of asbestos litigation.[45] Following the *Borel* decision in 1973, and since 2005, more than 600,000 claims based on allegations of asbestos-related illnesses were filed.[46] During that same timeframe, sixty different companies filed for bankruptcy due to asbestos litigation and more than fifty-four billion dollars were paid in litigation expenses and compensation.[47] In the 1990s alone, the number of pending asbestos cases in the United States doubled from 100,000 to 200,000.[48] The asbestos litigation problem resulted in a full-blown crisis.[49]

The problems caused by the glut of asbestos litigation have been borne by both claimants and defendants, and the litigation itself has been "a disaster of major proportions to both the victims and the producers of asbestos products."[50] Our court systems are not equipped to handle this "avalanche of litigation,"[51] and as a result, claimants have been left to claim mere pennies on the dollar in compensation for their injuries.[52] The litany

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Safety Environmental Health Criteria 203-Chrysotile Asbestos (IPCS, 1998). The document concluded 'Exposure to chrysotile asbestos poses increased risks for asbestosis, lung cancer and mesothelioma in a dose dependent manner. No threshold has been identified for carcinogenic risks.'").

44 Borel v. Fibreboard Paper Prods. Corp., 493 F.2d 1076 (5th Cir. 1973).

45 Gifford, *supra* note 13, at 620.

46 *Id*. at 621.

47 *Id*.

48 Schwartz, *supra* note 2, at 1–2 (also noting that "[t]he vast majority of asbestos claimants in that era had little or no actual physical impairment. Mass screenings arranged by personal injury law firms and their agents drove the litigation.").

49 Stengel, *supra* note 2, at 226.

50 *Id*. at 226 (noting that "absent some solution, litigation will continue into the foreseeable future: 'It is possible that millions of claims have yet to be made.'").

51 Jenkins v. Raymark Indus., Inc., 782 F.2d 468, 470 (5th Cir. 1986).

52 *Id*. at 483; Mark A. Behrens & Phil Goldberg, *The Asbestos Litigation Crisis: The Tide Appears to be Turning*, 12 CONN. INS. L.J. 477, 482 (2005–2006) ("The current asbestos litigation system is a tragedy for our clients. . . . It used to be that I could tell a man dying of mesothelioma that I could make sure that his family would be taken care of. . . . Today, I often cannot say that any more. And the reason is that other plaintiffs' attorneys are filing tens of thousands of claims every year for people who have absolutely nothing wrong with them.").

of problems embedded in this litigation has led courts, including the United States Supreme Court, to call for Congress to provide answers to the growing problems.[53] Nevertheless, asbestos litigation has persisted and continues to present problems for our judiciary that we cannot afford to recreate in other contexts.

b. 3D Printing: An Overview and Analog to Asbestos

3D-printing technologies share many of the same qualities that contributed to the rise in use of asbestos. Before addressing those similarities, this section provides a brief primer on the function of 3D printers. A foundation on how 3D printers operate will allow for an easier understanding of similarities between the health risks associated with exposure to asbestos and those associated with exposure to 3D printers. Moreover, the ongoing proliferation of 3D printers makes for a helpful comparison to asbestos.

3D printers create objects by referencing digital blueprints, which are often stored as Computer-Aided-Design (CAD) files.[54] Once a blueprint has been chosen, a 3D printer will construct the desired product layer-by-layer, or in a material-binding fashion, cutting down on waste and making the process more cost-effective.[55] Due to its ground-up manufacturing scheme, 3D printing avoids the waste typically created by the usual

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[53] *Id.* at 865 (highlighting that the problems in asbestos litigation "[cry] out for a legislative solution.") (Rehnquist, J., concurring); Ortiz v. Fibreboard Corp., 527 U.S. 815, 821 (1999) (noting that the "elephantine mass of asbestos cases . . . defies customary judicial administration and calls for national legislation.") (Souter, J).

[54] Shen Wang, *When Classical Doctrines Of Products Liability Encounter 3d Printing: New Challenges In The New Landscape*, 16 HOUS. BUS. & TAX L.J. 104, 105 (2016).

[55] *See generally id.* at 105*;* James M. Beck & Matthew D. Jacobson, *3D Printing: What Could Happen To Products Liability When Users (And Everyone Else In Between) Become Manufacturers*, 18 MINN. J. L. SCI. & TECH. 143, 149 (2017) (While 3D printing is almost always a layer-by-layer process, there are various methods used in additive manufacturing such as: "(1) Material extrusion—material is selectively dispensed through a nozzle or orifice; (2) Material jetting—droplets of build material are selectively deposited; (3) Binder jetting—a liquid bonding agent is selectively deposited to join powder materials; (4) Sheet lamination—sheets of material are bonded to form an object; (5) Vat photopolymerization—liquid photopolymer in a vat is selectively cured by light-activated polymerization; (6) Powder bed fusion—thermal energy selectively fuses regions of a powder bed; (7) Directed energy deposition—focused thermal energy is used to fuse materials by melting as the material is being deposited.") (numerals and semi-colons added).

subtractive manufacturing processes.[56] Furthermore, because creators and manufacturers are dealing with digital CAD files, the designs stored in those files can be duplicated, modified, and shared by designers collaborating around the world.[57]

In addition to the various cost-effective ways by which 3D printers can create products, 3D printers can use a wide range of manufacturing materials. At a basic manufacturing level, 3D printers can use sawdust, metals, cements, plastics, and powders.[58] However, as the technology develops and becomes more sophisticated, 3D printers are beginning to find use with electric materials, silicone, biomaterials, and carbon fiber.[59] Perhaps most indicative of 3D printing's potential is the fact that 3D printers are being used to print "organoids"—small scale models of human organs and tissues—using actual living tissues as a construction material.[60]

With the world of materials and designs at the fingertips of creators everywhere, it is not hard to see why then-President Barack Obama stated that 3D printing "has the potential to revolutionize the way we make almost everything."[61] Indeed, observers have remarked on the arrival of the new manufacturing method by consistently singing the praises of 3D printing.[62] 3D printing is today's manufacturing miracle and its arrival has already begun to take the world by storm in the same way that asbestos did after the

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56 Beck & Jacobson, *supra* note 55, at 150 ("Because additive manufacturing only uses materials that are needed for the final object, the process can be more efficient and cost-effective, and waste can be reduced.").

57 Wang, *supra* note 54, at 105.

58 Lucas S. Osborn, *Regulating Three-Dimensional Printing: The Converging Worlds of Bits And Atoms*, 51 SAN DIEGO L. REV. 553, 559 (2014).

59 Beck & Jacobson, *supra* note 55, at 151.

60 Allie Nawrat, *3D Printing in the Medical Field: Four Major Applications Revolutionising the Industry*, VERDICT MED. DEVICES (Aug. 7, 2018), https://medicaldevicescommunity.com/md_news/3d-printing-in-the-medical-field-four-major-applications-revolutionising-the-industry/ (3D printers are capable of printing shapes and objects that would be impossible to create using traditional machining and molding, and allow manufacturers to mix materials in complex fashions leading to wholly new construction choices.).

61 Obama, *supra* note 10.

62 Osborn, *supra* note 58, at 560 ("3D printing will revolutionize society, affecting manufacturing, the environment, 3D art, entrepreneurship, and global trade."); Beck & Jacobson, *supra* note 55, at 152 ("Simply put, 3D printing is a potentially disruptive technology, and we undoubtedly have not yet envisioned all the changes it will bring."); Wang, *supra* note 54, at 105 ("In short, 3D printing signals a new era of manufacturing, production, and commercial activities.").

Industrial Revolution.[63] Additionally, it is worth noting that as efficiency and applications continue to rise, use of 3D-printing technology will also expand.[64] Put simply, "[3D-printing] technology brings hope of new freedoms, innovation, and creativity."[65]

The market has taken notice of the new hopes brought by 3D printing. Sales of simple desktop 3D printers continue to rise as industrial applications burst onto the scene. According to a Wohlers Associates report in 2018, the additive manufacturing industry experienced 21% growth over the previous year, exceeding $7.3 billion in sales.[66] In fact, sales of metal additive manufacturing systems alone had increased 80% from 2017 to 2018.[67] Roughly forty new companies had begun constructing 3D printers in 2018 and it is estimated that approximately 529,000 printers were sold between 2016 and 2018.[68] Although studies suggest that 3D printers are more widely used for prototyping and product testing, companies like Bentley are already looking to incorporate the technology in their vehicle parts.[69] Ubiquitously, 3D printers now have applications in homes,[70] hospitals,[71]

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[63] Osborn, *supra* note 58, at 560 ("The coming ubiquity of 3D printing signals a new era of individual empowerment and creativity.").

[64] *Id*. at 561 ("Already, 3D printers can make a remarkable range of products. Fascinating examples include food, shoes, human body parts, working guns, clothes, and bicycles. Of course, at this stage, inexpensive home 3D printers are relatively simple and print only in plastic. But over time, the costs will fall, and the capabilities will rise.").

[65] *Id*. at 562.

[66] TJ McCue, *Wohlers Report 2018: 3D Printer Industry Tops $7 Billion*, FORBES (June 4, 2018), https://www.forbes.com/sites/tjmccue/2018/06/04/wohlers-report-2018-3d-printer-industry-rises-21-percent-to-over-7-billion/.

[67] *Id*.

[68] *Id*.

[69] Miller Allen et al., *3D Printing Standards and Verification Services*, 2 APPLIED INNOVATION REV. 34, 38 (June 2016), http://scet.berkeley.edu/wp-content/uploads/AIR-2016-3D-Printing.pdf.

[70] YaleGlobal Online, *Beyond the Hype: The Industrial Challenges for 3D Printing*, YALE UNIV. (Apr. 16, 2014), https://yaleglobal.yale.edu/content/beyond-hype-industrial-challenges-3d-printing.

[71] *3D Printing*, 8 E. VA. MED. SCH. MAG. 13, 13–17 (2015–2016), https://www.evms.edu/uploads/magazine/8-5/downloads/evmsMag_8.5.pdf.

and schools.[72] Suffice it to say, 3D printers are going to be everywhere; however, where the printers go, so do their risks.[73]

This newfound miracle is not without its Achilles heel. Unfortunately, much like asbestos, 3D printers come with latent dangers. If latency is not accounted for, and if our current law in these contexts does not adapt, these dangers are likely to usher in the next era of asbestos-like litigation.

Most 3D printers operate by taking the reagent materials—such as metals, dusts, cements, thermoplastics[74] or otherwise—heating them, and then depositing those materials layer-by-layer to build the desired product. As those materials are heated, they release gas and particulate emissions as they experience both physical and chemical changes in their structures.[75] These emissions are referred to as "volatile organic compounds" (VOCs), and exposure to the emissions in indoor environments "is of concern for workplaces, public venues, and private homes."[76] Exposure to these VOCs can potentially lead to the development of respiratory and mucous membrane irritation, asthma,[77] and, most notably, cancer.[78] Some studies suggest

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[72] *See, e.g.*, *MSU Libraries offers 3D printing*, MISS. ST. UNIV. (Aug. 24, 2015), http://lib.msstate.edu/news/2015/3d.php; *Is the Implementation of 3D Printing in Education a Necessity*, 3D NATIVES (Aug. 29, 2018), https://www.3dnatives.com/en/3d-printing-in-education-290820184.

[73] *See* Aleksandr B. Stefaniak et al., *Characterization of chemical contaminants generated by a desktop fused deposition modeling 3-dimensional Printer*, 14 J. OCCUPATIONAL & ENVTL. HYGIENE 540, 541 (July 2017) ("3-dimensional (3-D) printers are becoming common in offices, libraries, schools, universities, and the home. With increased use of desktop and small-scale 3-D printers in non-industrial settings comes the concern for user health and safety.").

[74] *Id.* ("Thermoplastics are composed of a polymer that is mixed with a complex blend of materials known collectively as additives.").

[75] *Id.*

[76] *Id.*

[77] *Id.*

[78] *3D Printer Safety – Pollution and Their Health Risks*, *supra* note 11 ("The chemicals that are released during the heating of thermoplastic materials are known or suspected irritants and carcinogens, therefore exposure to 3D printer emissions should be minimized."); *see also* Janet Pelley, *Safety Standards Aim to Rein in 3-D Printer Emissions*, 4 ACS CENT. SCI. 134, 134–35 (Feb. 15, 2018) ("Petroleum-based acrylonitrile butadiene styrene (ABS), a plastic used in Lego blocks, gives off styrene and formaldehyde the first a suspected human carcinogen and the second a known one.").

that 3D-printing technology will cause cancer in approximately 4.45 out of every 10,000 people that come into contact with 3D printers.[79]

Further, these emissions often spread in the form of "ultrafine particles" (UFPs), which are particles less than 100 nanometers in diameter, allowing them to penetrate the lung tissue and enter the bloodstream.[80] This means that these cancer-causing particles can reach virtually every inch of the human body.[81] 3D printers are duly categorized as high emitters of ultrafine particles, even at the desktop size.[82] A rapidly growing and expanding product, heralded as the next manufacturing miracle, is pumping out high amounts of carcinogenic and otherwise disease-causing emissions. Does this sound familiar?

Some studies suggest that different filaments in 3D printing, and even different colors of the filaments, can affect particle output.[83] However, while these factors can affect the amount or size of particles released, it is not clear that these changes affect the release of carcinogens like styrene.[84] Thus, much like the studies indicating that there may have been a safe form of chrysotile asbestos, there are studies that indicate not all 3D-printing reagents are created equally dangerous.

Both asbestos and 3D printing are respectively viewed as manufacturing miracles. Asbestos rose to prominence and found itself ubiquitously involved in manufacturing processes and structures post-Industrial Revolution. Similarly, 3D printers are becoming universally adopted throughout this country in nearly every industry imaginable—including hospitals,

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[79] Beuy Joob & Viroj Wiwanitkit, *Estimation of Cancer Risk Due to Exposure to Airborne Particle Emission of a Commercial Three-dimensional Printer*, 38 INDIAN J. MED. PAEDIATRIC ONCOLOGY 409 (Jul–Sep. 2017), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5686999/.

[80] Pelley, *supra* note 78, at 134–35 ("And all the filament types spew UFPs, particles with a diameter less than 100 nm that can penetrate deep into the lungs and enter the bloodstream. *These particles are known to cause respiratory and cardiovascular diseases.*") (emphasis added).

[81] *See generally* Jinghai Yi et al., *Emission of Particulate Matter From a Desktop Three-Dimensional (3D) Printer*, 79 J. TOXICOLOGY & ENVTL. HEALTH 453, 463 (2016), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4917922/pdf/uteh-79-453.pdf.

[82] *Id*. at 453; *see also 3D Printer Safety – Pollution and Their Health Risks*, *supra* note 11.

[83] *See* Yi et al., *supra* note 81, at 456–57; *see also* Pelley, *supra* note 78, at 135 (suggesting that "manufacturers can substitute better, safer filaments").

[84] Stefaniak et al., *supra* note 73, at 540 (stating "3-D printed objects continued to off-gas styrene, indicating potential for continued exposure after the print job is completed").

schools, libraries, and factories. The miniscule asbestos fibers, when inhaled, wrought havoc by causing mesothelioma, other cancers, and other lung conditions in those exposed. Likewise, the ultra-fine emissions from 3D printers have the capability to cause asthma, cancer, and various other diseases and irritations in those exposed. With the similarities of both form and effect now in frame, we turn to two befuddling legal issues that plagued both claimants and defendants in asbestos litigation: identifying the party at fault and establishing causation. These two prominent problems in asbestos litigation are likely to arise in the 3D-printing context.

III. Critical Issues in Asbestos Litigation: Identifying Party at Fault and Establishing Causation

a. The Role of Defendant Indeterminacy in the Asbestos Litigation Crisis

The early stages of latent-disease litigation involved plaintiffs who are, in many cases, incapable of identifying the precise defendants who caused their ailments—otherwise known as "defendant indeterminacy." Latent-disease cases present defendant indeterminacy issues for plaintiffs. When products are fungible, numerous manufacturers use or produce them. When injuries and harms are latent, exposure to various offending products over time is likely. As such, identifying the actor who caused injury becomes a herculean task. Plaintiffs involved in latent-disease litigation—namely "Agent Orange," asbestos, cigarettes, and lead pigment litigation—have been unable to obtain recovery because of their inability to prove which specific defendant manufactured the product that caused their harm.[85]

Because of defendant indeterminacy, new legal theories have emerged to establish liability. Plaintiffs' lawyers have tried to impose liability upon entities who did not actually cause injury by applying legal theories that assign liability to manufacturers of the offending products for their roles in the market.[86] The first such theory was aptly called the doctrine of "market share liability."[87]

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[85] Gifford, *supra* note 13, at 653–54.
[86] Victor E. Schwartz & Mark A. Behrens, *Asbestos Litigation: The Endless Search for a Solvent Bystander*, 23 Widener L.J. 59, 62–63 (2013).
[87] *Id*. at 63; *see also* Gifford, *supra* note 13, at 654–56.

Market share liability was first introduced by the Supreme Court of California in *Sindell v. Abbott Laboratories*.[88] In *Sindell*, the plaintiffs were women who alleged that the drug DES,[89] ingested by their mothers during pregnancy, caused birth defects.[90] Both the fungibility of DES and the delay of its harmful effects created problems with assessing liability in *Sindell*.[91] The plaintiffs could not point to any defendant as the precise entity that had manufactured the DES taken by any individual mother.[92] Typically, if the plaintiff cannot identify the entity that caused her harm, she cannot meet her burden in establishing liability.

The California Supreme Court, however, permitted liability based on a theory of market share liability.[93] This theory can be best articulated as holding each defendant "liable for the proportion of the judgment represented by its share of that market unless it demonstrates that it could not have made the product which caused [the] plaintiff's injuries."[94] In adopting this theory, the court shifted the burden to defendants to prove that their product had not caused the injury or harm at issue.[95] The court reasoned that the imposition of liability, should a defendant fail to meet its burden, would only amount to that defendant's share of the product's market.[96]

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[88] Sindell v. Abbott Laboratories, 607 P.2d 924, 937 (Cal. 1980).

[89] Schwartz & Behrens, *supra* note 86, at 63 ("DES was the common name for diethylstilbestrol, an artificial hormone that was widely prescribed to pregnant women from about 1950 to 1970 to prevent miscarriages or premature deliveries.").

[90] *Id.* at 63 ("Unfortunately, some two decades after DES was first widely prescribed, it was discovered that the drug was associated with a rare form of vaginal cancer and abnormalities of the reproductive tract in so-called 'DES daughters' who had been exposed to the drug in utero.").

[91] *Sindell*, 607 P.2d at 937.

[92] *Id.*

[93] *Sindell*, 607 P.2d 924, 937–38 (Cal. 1980).

[94] *Id*. at 937.

[95] *Id*. at 936.

[96] *Id*. at 938; *see also* Gifford, *supra* note 13, at 656 ("In *Sindell*, the court justified its adoption of this theory on the basis of Calabresian concepts—primary cost avoidance and the determination of the cheapest cost avoider: 'The manufacturer is in the best position to discover and guard against defects in its products and to warn of harmful effects; thus, holding it liable for defects and failure to warn of harmful effects will provide an incentive to product safety.'") (quoting *Sindell*, 607 P.2d at 936).

In the asbestos context, courts have "almost uniformly" rejected the theory of market share liability.[97] In effect, courts have barred this convenient option from plaintiffs' arsenal, reasoning that application of this "novel theory of causation would raise serious questions of fairness due to the fact that different manufacturers' asbestos products differ in degrees of harmfulness."[98]

Courts have likewise refused to adopt other similar theories in asbestos cases. Of note is "enterprise liability," which stems from a New York federal case, *Hall v. E.I. Du Pont De Nemours & Co*.[99] In *Hall*, children were injured by exploding blasting caps.[100] These explosions made the manufacturer of the caps impossible to determine.[101] "Because there was a strong likelihood that the blasting caps were produced by one of six major manufacturers, the court . . . indicated that it might be appropriate to shift the burden of causation to the defendants."[102] Courts have almost universally determined that this doctrine was inappropriate in asbestos cases, reasoning the case it springs from dealt with a very limited number of manufacturers in a tightly-centralized industry.[103] Additionally, courts have

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[97] Schwartz & Behrens, *supra* note 86, at 64–65. *See generally* Celotex Corp. v. Copeland, 471 So. 2d 533, 537, 539 (Fla. 1985); Goldman v. Johns-Manville Sales Corp., 514 N.E.2d 691, 702 (Ohio 1987); Case v. Fibreboard Corp., 743 P.2d 1062, 1067 (Okla. 1987); Sholtis v. Am. Cyanamid Co., 568 A.2d 1196, 1204 (N.J. Super. Ct. App. Div. 1989); Stark v. Armstrong World Indus., Inc., 21 F. App'x 371, 375 n.4 (6th Cir. 2001); Cimino v. Raymark Indus., Inc., 151 F.3d 297, 314 (5th Cir. 1998); Jackson v. Anchor Packing Co., 994 F.2d 1295, 1303 (8th Cir. 1993).

[98] Blackston v. Shook and Fletcher Insulation Co., 764 F.2d 1480, 1483 (11th Cir. 1985) (referencing Starling v. Seaboard Coast Line R.R. Co. et al., 533 F. Supp. 183, 191 (S. D. Ga. 1982))

[99] Hall v. E.I. Du Pont De Nemours & Co., 345 F. Supp. 353, 379 (E.D.N.Y. 1972).

[100] *Id.* at 358.

[101] *Id*.

[102] Mark A. Behrens & Christopher E. Appel, *The Need for Rational Boundaries in Civil Conspiracy Claims*, 31 N. ILL. U. L. REV. 37, 57 (2010).

[103] *Id*. at 68. For courts rejecting the application of enterprise liability to asbestos see generally Case v. Fibreboard Corp., 743 P.2d 1062, 1067 (Okla. 1987); Gaulding v. Celotex Corp., 772 S.W.2d 66, 70 (Tex. 1989); Celotex Corp. v. Copeland, 471 So.2d 533, 535 (Fla. 1985); Thompson v. Johns-Manville Sales Corp., 714 F.2d 581, 583 (5th Cir. 1983); Univ. Sys. Of N.H. v. U.S. Gypsum Co., 756 F.Supp. 640, n.16 at 657; Marshall v. Celotex Corp., 651 F. Supp. 389, 395 (E.D. Mich. 1987).

mostly rejected plaintiffs' attempts to use "alternative liability"[104] as a basis for recovery in asbestos cases.[105]

Despite major setbacks in latent-disease cases, defendant indeterminacy has not deterred plaintiffs from pursuing litigation. Rather, plaintiffs and their lawyers have sought new answers and pathways to trial litigation, making adjudication of these cases more complex. This has led to an inefficient and overwhelmed system as a whole.[106]

Nevertheless, plaintiffs may avoid complex litigation issues by seeking an administrative scheme to receive compensation for asbestos injuries, similar to the so-called "black lung"[107] legislation.[108] The Supreme Court of the United States has also called for national legislation in the face of asbestos litigation issues.[109] Moreover, lawmakers in the United States made mention of the black lung scheme as being one that could benefit the asbestos litigation crisis.[110]

However, to this point, no such national legislation has been passed. And, despite the refusal of courts to apply plaintiff-friendly doctrines such as market share liability and enterprise liability, plaintiffs have not relented. Instead, they have focused on their various exposures to asbestos and, using expert testimony, have attempted to sway courts into creating very low thresholds for causation in asbestos-related, latent-disease cases. In sum, the battle between exposure-related causation theories demonstrates yet another

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104 Summers v. Tice, 33 Cal.2d 80, 199 P.2d 1 (1948) (introducing alternative liability doctrine).

105 *See*, *e.g.*, Black v. Abex Corp., 603 N.W.2d 182, 191 (N.D. 1999); Nutt v. A.C. & S. Co., 517 A.2d 690, 694 (Del. Super. Ct. 1986); U.S. Gypsum Co., 756 F. Supp. at 654–55; *Case*, 743 P.2d at 1067; Rutherford v. Owens-Ill., Inc., 941 P.2d 1203, 1220–21 (Cal. 1997); *Gaulding*, 772 S.W.2d at 69; *Copeland*, 471 So.2d at 535.

106 *See* Schwartz, *supra* note 2, at 2.

107 *See generally Black Lung*, UNIV. OF LOUISVILLE SCHOOL OF MED.(2018) ("Black lung, or coal workers' pneumoconiosis, is the name given lung diseases caused by inhaling coal-mine dust. Only the smallest dust particles make it past the nose, mouth and throat to the alveoli deep in the lungs."), https://louisville.edu/medicine/departments/medicine/divisions/pulmonary/clinical-services/pulmonary/ild/black-lung (last visited Jan. 16, 2020).

108 The "black lung" legislation was an act passed to ensure compensation of coal miners who developed "black lung" sickness during work in their occupation. *See* Allen R. Prunty & Mark E. Solomons, *The Federal Black Lung Program: Its Evolution And Current Issues*, 91 W. VA. L. REV. 665, 667 (1989).

109 Ortiz v. Fibreboard Corp., 527 U.S. 815, 821 (1999).

110 Stengel, *supra* note 2, at 223 n.4.

sticking point in addressing the glut of asbestos cases in the American judicial system.

b. Difficulties With Theories of Causation Exacerbated Asbestos Litigation Crisis

Since *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993), courts across the United States have taken on the duty of acting as a gatekeeper to junk science presented by experts-for-hire.[111] Because of this new standard,[112] courts have been thrust into the duty of playing "amateur scientists."[113] This role has extended prominently into asbestos litigation, as claimants and defendants alike battle over which exposure theory is proper to establish causation. The two main theories adopted by the courts are the "any-exposure" theory[114] and the *Lohrmann*[115] "frequency-regularity-proximity" test.[116]

As asbestos litigation has carried on, courts have developed entirely new sets of rules to attempt to efficiently manage their asbestos dockets; almost all of these rule changes have consistently favored plaintiffs.[117] One of these plaintiff-friendly developments was the adoption of the any-exposure theory, otherwise known as the "any fiber" theory."[118] This theory asserts that asbestos-related diseases are a result of the cumulative build-up of asbestos fibers inhaled by an individual; thus, no matter how trivial one's exposure might have been to a particular asbestos-containing product, they

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[111] *See* Sofia Adrogue, *The Post-Daubert Court-"Amateur Scientist" Gatekeeper or Executioner?*, 35-APR HOUS. LAW. 10 (Mar.–Apr. 1998) ("The Ninth Circuit on remand in *Daubert II*, stated that 'federal judges ruling on the admissibility of expert scientific testimony face a far more complex and daunting task in a post-Daubert world than before.'").

[112] *Id.* (In *Daubert*, the United States Supreme Court rejected the previously acceptable *Frye* test which rendered expert scientific testimony admissible if the expert used generally accepted scientific methods in reaching the conclusion.) (referencing Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579, 601 (1993)).

[113] *Daubert*, 509 U.S. at 601 (Rehnquist, J., concurring in part and dissenting in part).

[114] Mark A. Behrens & William L. Anderson, *The "Any Exposure" Theory: An Unsound Basis for Asbestos Causation and Expert Testimony*, 37 SW. U. L. REV. 479, 486 (2008).

[115] Lohrmann v. Pittsburgh Corning Corp., 782 F.2d 1156, 1163 (4th Cir. 1986).

[116] Charles T. Greene, *Determining Liability in Asbestos Cases: The Battle to Assign Liability Decades After Exposure*, 31 AM. J. TRIAL ADVOC. 571, 573 (2008).

[117] *See id.* at 580; Behrens & Anderson, *supra* note 114, at 479–80 (worth noting is that, because the litigation became so "malleable and lucrative," plaintiffs' attorneys have spent several years searching for the "next asbestos.").

[118] Behrens & Anderson, *supra* note 114, at 479–80.

should be able to hold the manufacturer of that product liable for their disease.[119] This theory blew the doors of asbestos litigation wide open. Plaintiffs were able to sue countless defendants based on each individual claim since, due to the widespread nature of asbestos-containing products, each plaintiff had come in contact with several manufacturers' asbestos products.[120]

Courts have had mixed responses to the any-exposure theory, though initially the theory found limited success.[121] The court in *Celotex Corp. v. Tate*[122] is a good example of a court that embraced this theory. In *Tate*, a plaintiff unloaded bags of asbestos from boxcars and poured the asbestos into mixers.[123] The defendant argued that the plaintiff needed to establish that it was, in fact, its product (to the exclusion of others) that caused the plaintiff's injury. The Texas appellate court disagreed, holding that "when a defendant has in fact caused harm to the plaintiff, he may not escape liability merely because the harm he has inflicted has combined with similar harm inflicted by other wrongdoers."[124] Thus, courts adopting this theory shifted the burden to defendants to prove, much like the burden in alternative liability, that it was not their product that caused the harm.[125]

Another prominent standard, the *Lohrmann* standard, has received more widespread adoption in asbestos cases. "Courts in every circuit but the D.C. Circuit, and the First, Second, and Fifth Circuits have adopted the *Lohrmann* test."[126] In *Lohrmann*, the plaintiff had been an employee for a shipyard for nearly forty years.[127] Once the shipyard worker had been diagnosed with both asbestosis and chronic pulmonary disease, he sought recovery based upon negligence and strict liability.[128] The real issue, however, was whether the plaintiff needed to show by way of "substantial evidence"

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[119] *Id.*
[120] *See id.*
[121] *Id.* at 480–82.
[122] Celotex Corp. v. Tate, 797 S.W.2d 197, 204 (Tex. App.—Corpus Christi 1990, writ dism'd by agr.).
[123] *Id.* at 200.
[124] Greene, *supra* note 116, at 585 (quoting *Tate*, 797 S.W.2d at 203).
[125] *Id.* at 585–86.
[126] Slaughter v. S. Talc Co., 949 F.2d 167, 171 n.3 (5th Cir. 1991) (also noting that "Michigan, Massachusetts, New Jersey, Illinois, Pennsylvania, Maryland, Nebraska, and Oklahoma" had adopted the test as of that case).
[127] Greene, *supra* note 116, at 573.
[128] *Id.*

that the defendant's product was a factor in causing his injuries.[129] The shipyard worker asserted that all he needed to do was present evidence that the company's asbestos-containing product was present at the workplace while the plaintiff was present. The court ultimately disagreed and instead applied the frequency-regularity-proximity rule.[130] The frequency-regularity-proximity rule applies a much higher burden for plaintiffs to meet. Yet, perhaps ironically, that standard has led to more confusion, not less, about when a plaintiff can and cannot bring a claim.[131] The any-exposure theory allows a plaintiff to bring a claim if he's been exposed to the product at all; the *Lohrmann* test requires, vaguely, more.

Between the two standards, the *Lohrmann* standard is more widely accepted among jurisdictions.[132] Twenty-seven states have explicitly adopted the test, while others, like Texas, have adopted an even more stringent standard.[133] Texas's standard, adopted in *Borg-Warner Corp. v. Flores*,[134] requires more than simple frequency, regularity, and proximity.[135] It additionally requires that the plaintiff prove that the product at issue was a "substantial factor" in causing the harm.[136]

This step is perhaps a step that many legal observers have been waiting to see adopted nationwide. Much has been written about genuine plaintiffs at the beginning of asbestos litigation's rise. However, also heavily

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129 *Id*. at 574.

130 *Id*. (The *Lohrmann* standard states that "there must be evidence of exposure to a specific product on a regular basis over some extended period of time in proximity to where the plaintiff actually worked." The court noted that "[i]n effect, this is a de minimis rule since a plaintiff must prove more than a casual or minimum contact with the product.") (quoting Lohrmann v. Pittsburgh Corning Corp., 782 F.2d 1156, 1162–63 (4th Cir. 1986)).

131 DiMasi, Brian M., *The Threshold Level of Proof of Asbestos Causation: The "Frequency, Regularity and Proximity test" and a Modified Summers v. Tice Theory of Burden-Shifting*, 24 CAP. U. L. REV. 735, 752–53 (1995) ("Furthermore, the *Lohrmann* test, which was synthesized by the *Lohrmann* district court to aid in the determination of 'substantial factor' causation, injects confusion and complexity into the weighing of evidence of asbestos exposure, effectively denying asbestos victims the opportunity to present their cases to a jury.").

132 Jason Litt et al., *Returning to Rutherford: A Call to rejoin California Courts to Rejoin the Legal Mainstream and Require Causation be Proved in Asbestos Cases Under Traditional Torts Principles,* 45 Sw. L. Rev. 989, 1011 (2016).

133 *Id.*

134 Borg-Warner Corp. v. Flores, 232 S.W.3d 765 (Tex. 2007).

135 *Id.* at 769.

136 Greene, *supra* note 116, at 576–78.

noted has been the effect, on dockets everywhere, of non-sick claimants.[137] Commentators assert that "Today, the vast majority of new asbestos claimants—up to [90%]—are 'people who have been exposed to asbestos, and who (usually) have some marker of exposure . . . but who are not impaired by an asbestos-related disease and likely never will be.'"[138] Indeed, the differing standards of causation, along with the unclear standards surrounding who can and cannot be sued by claimants, has led to the wild-west of litigation within the asbestos context.

Whatever courts' responses have been to the two issues explored above, they seemingly only further complicate the issue. Asbestos litigation ran rampant and continues to clog through the United States judiciary today. These two problems, defendant indeterminacy and establishing causation, will also be pivotal problems in 3D-printing litigation. The next part of this Article will address why these two issues are likely to plague 3D-printing litigation and will then make suggestions as to what steps manufacturers and courts should be taking to (a) avoid the litigation from the outset and (b) clarify the law to provide for more efficient judicial processes.

IV. AVOIDING ASBESTOS CONSUMER SAFETY ISSUES AND LITIGATION INEFFICIENCIES IN THE 3D-PRINTING CONTEXT

The American judiciary, when faced with the widespread problem of asbestos litigation, has done little to clarify the law and make the adjudication of such cases more efficient. Indeed, in the entire context of latent-disease jurisprudence, courts have consistently found themselves bogged down by problems identifying rightful defendants and establishing causation in a manner fair to both parties.[139] As a result, plaintiffs and defendants alike will want to take preventative steps and vie for favorable theories and doctrines in the wake of 3D printing's ascension to popularity. "As 3D printing develops, the law will also have to develop in order to continue to maintain its relevance."[140]

The issue in identifying who caused the resulting harm will be a question that could become far more complicated in 3D-printing litigation than in the asbestos context. In asbestos litigation, claimants could often

137 Behrens & Goldberg, *supra* note 52, at 478–79.
138 *Id.*
139 *See generally* Gifford, *supra* note 13.
140 Beck & Jacobson, *supra* note 55, at 147.

point to particular products, or genres of products, that caused their harm.[141] However, many asbestos products were fungible and therefore recreated by various manufacturers—plaintiffs often could not meet the burden of identifying a liable manufacturer.[142] Imagine that same problem when almost anyone and everyone, across all kinds of professions and in homes, hospitals, factories, and otherwise, are using 3D printers.[143] This search for a party from which to recover for one's injuries becomes theoretically more difficult than finding a needle in a haystack.

Further complicating the issue is that this new form of latent-disease litigation will focus not on the actual products created by the manufacturer, but rather on the means of creation used by the manufacturer. It is exposure to the emissions from 3D printers—created and emitted during the creation process—that is dangerous to human beings.[144] So, when everyone—from one's neighbor to one's doctor and employer—is using 3D printers, how exactly is a claimant to identify the manufacturer liable for his or her harm? This is far more complicated than trying to establish a list of possible parties responsible for creating the asbestos-containing insulation one was exposed to. Plaintiffs will now need to identify whose act(s) of creation contributed to their disease or condition.

Additionally, courts will likely be faced with the question of whether to blame the 3D-printer manufacturers or the manufacturers of the reagents that release carcinogens when run through a 3D printer. As discussed above, there are differences in the emissions of various materials used in 3D printing.[145] Thus, our issue is further complicated since courts could potentially point the finger at two groups of manufacturers: manufacturers of 3D printers and manufacturers who produce 3D-printing reagents that are carcinogenic or otherwise dangerous to humans. This kind of issue is just the tip of the iceberg for claimants and defendants facing the preeminent industrial 3D-printing regime.[146]

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141 *See* Gifford, *supra* note 13, at 653–654.

142 *Id.*

143 *See generally* Beck & Jacobson, *supra* note 55, at 144–45 ("3D printing is already in the process of becoming a significant industry with tremendous innovative potential for many applications, from dental and medical, to automotive, aerospace/aviation, toys, military, fashion, food, eyewear, and construction.).

144 *See generally* Joob & Wiwanitkit, *supra* note 79.

145 *See generally* Stefaniak et al., *supra* note 73.

146 Beck & Jacobson, *supra* note 55 at 147–48 ("One of the biggest legal areas where 3D printing will have an impact is tort liability. The legal implications will include what is

The logical first step in approaching these problems is to prevent, as much as possible, the emissions from causing harm in the first place. Many 3D printers can be sold with enclosures or can be safely operated in a self-made enclosure appropriate for the product.[147] Furthermore, it may be appropriate to use creation processes, where possible, that operate at lower temperatures. Doing so can cut down on the amount of emissions created by the printer and, thereby, further lower people's exposure to its harmful chemicals.[148] Other obvious and important precautions to take have been set out by the National Institute for Occupational Safety and Health (NIOSH) and range from following the printer-manufacturer's controls to turning off the printer nozzle during jams.[149] While some of these preliminary steps are obvious, they are still critical to note. Also important, though not explored in this Article, are any future Occupational Safety and Health Administration (OSHA) guidelines and regulations put in place for 3D printers in the workplace. This Article does not discuss in-depth OSHA or other possible

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exactly a 'product,' who is the 'manufacturer,' what is the 'marketplace,' and who should be potentially liable for a defective 3D-printed product (once 'product' is defined). These legal implications are only heightened for more complex and technical products such as drugs and medical devices. Although it is unclear, at this point in the absence of precedent, exactly how the law will change, what is certain is that the law will need to adapt or change as 3D printing becomes commonplace.").

[147] This is a logical step because "[h]eating of certain thermoplastic filament can generate toxic vapors and vapors with high volatile organic compounds (VOCs). Most 3D printers do not come with an enclosure, exhaust ventilation or any filters." *See 3D Printer Safety*, UNIV. OF VT., https://www.uvm.edu/riskmanagement/3d-printer-safety ("To reduce the potential for nano particles to aerosolize or be inhaled by users, it is best to purchase 3D printers with an enclosure or have an enclosure made.") (last visited Jan. 16, 2020).

[148] *Id.* ("Nanoparticles (ultrafine particles less than 1/10,000 of a millimeter) are one of the by-products emitted during the 3D printing process. Recent studies have shown that 3D printing using a low-temperature polylactic acid (PLA) feedstock can release 20 billion particles per minute, while a higher temperature acrylonitrile butadiene styrene (ABS) feedstock can release 200 billion.").

[149] *Control Measures Critical for 3D Printers*, 1 NIOSH RESEARCH ROUNDS 12 (June 2016), https://www.cdc.gov/niosh/research-rounds/resroundsv1n12.html#a ("To reduce emissions, the investigators recommend five specific steps: (1) Always use the manufacturer's supplied controls (full enclosure appears more effective at controlling emissions than a cover). (2) Use the printer in a well-ventilated place, and directly ventilate the printer. (3) Maintain a distance from the printer to minimize breathing in emitted particles, and choose a low emitting printer and filament when possible. (4) Turn off the printer if the printer nozzle jams, and allow it to ventilate before removing the cover. (5) Use engineering measures first, such as manufacturer-supplied equipment and proper ventilation, then use materials with lower emissions. Finally, wear protective equipment, such as respirators.").

regulations because this Article is more concerned with clarifying litigation issues not related to compliance with these kinds of regulations.

The next logical step, again a preventative one, will be to try to use, where possible, materials that are less dangerous to humans. It is well documented, and discussed in-depth above, that different materials can have various different potentials for harm.[150] Thus, it is important that innovators in this space continue to identify and develop 3D-printing reagents that emit particles that are not known or suspected carcinogens. Should courts decide that the proper parties for suit are the manufacturers of these reagents, this step may be paramount. Outside of these common-sense measures, however, plaintiffs and defendants are likely to disagree on what standards or doctrines courts ought to apply.

Plaintiffs, for instance, are likely to encourage courts to adopt broader theories of liability such as the previously discussed market share liability theory.[151] Using this theory, and others like it, plaintiffs would be given wide discretion as to which manufacturers they elect to sue, as many of these doctrines provide for joint and several liability.[152] This freedom would assist plaintiffs, and courts, in circumventing the problems in attempting to adequately identify each individually-liable party. However, plaintiffs will face almost universal rejection of such doctrines by the American judiciary.[153] Plaintiffs will need to provide compelling reasons for the adoption of these theories in the 3D-printing, latent-disease context.

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150 *Id.* ("The emissions also varied by filament type and color. Filaments made from natural materials like corn emitted smaller particles than plastic filaments did. . . . Calculations showed that the risk of the particles lodging in the lungs was 3 times higher for the small particles made from natural substances compared with the larger plastic particles. Color also affected particle size, with natural corn-based filaments in the color true red emitting the smallest particles, on average. In contrast, blue plastic filaments emitted the largest particles"); *see also* Joob & Wiwanitkit, *supra* note 79.

151 *See* Gifford, *supra* note 13 at 654–56 ("Despite the traditional requirement that a claimant identify the specific product manufacturer whose product caused her harm, manufacturers of mass products may be held liable without proof of specific identification on legal theories including civil conspiracy or concert of action, alternative liability, enterprise or industry-wide liability, and market share liability.").

152 *Id.* at 655 ("Even if courts impose liability on mass products manufacturers collectively, with the exception of market share liability, such liability is joint and several.").

153 *Id.* at 655–56 ("Each of these theories for holding manufacturers of mass products liable, however, has been applied only in cases with specific (and generally unusual) circumstances. . . . Market share liability has inspired considerable academic attention, despite its

Furthermore, plaintiffs are likely to advocate for a less restrictive test for causation than the *Lohrmann* standard.[154] The frequency-regularity-proximity test set out by the court in *Lohrmann*[155] will be too cumbersome, plaintiffs will argue, in determining which of several commonly encountered 3D printers caused each plaintiffs' injuries. In rejecting *Lohrmann*, plaintiffs are likely to argue, as is asserted in the *Lohrmann* case itself, that an any-exposure theory will be proper for establishing liability.[156] Much like the court in *Lohrmann*, and the many courts that have since adopted the *Lohrmann* standard, plaintiffs are likely to face a high bar in asking courts to move away from that standard.[157]

A final suggestion that may be agreeable to plaintiffs would be an adoption of a similar regime to the black lung legislation.[158] However, an application of this theory is likely to require that 3D-printer emissions become a known cause of a unique disease or form of cancer. Even in the latter situation, Congress has not adopted similar legislation in response to asbestos's known causation of mesothelioma.[159]

By contrast, defendants are likely to want courts to move away from broad theories like market share liability and adhere to the *Lohrmann* standard, or perhaps even more restrictive standards, in assessing liability. These blanket suggestions may also prove unreliable, as asbestos litigation has clogged our court system even with the judiciary's move away from broader liability theories and, simultaneously, towards the narrow *Lohrmann* causation theory. The first issue courts will need to decide, however, is which party or parties to identify as defendants.

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virtually universal subsequent rejection by the courts in cases other than those against DES manufacturers.").

154 *See generally* Greene, *supra* note 116.

155 Lohrmann v. Pittsburgh Corning Corp., 782 F.2d 1156, 1156 (4th Cir. 1986).

156 Greene, *supra* note 116, at 574 ("The plaintiffs asserted that the court should 'adopt a rule that if the plaintiff can present any evidence that a company's asbestos-containing product was at the workplace while the plaintiff was at the workplace, a jury question [had] been established as to whether that product contributed as a proximate cause to the plaintiff's disease'").

157 The court in *Lohrmann* called it's new standard a "de minimis rule" that required plaintiffs to "prove more than a casual or minimum contact with the product." *Lohrmann*, 782 F.2d at 1162.

158 *See generally Black Lung*, *supra* note 107; Prunty & Solomons, *supra* note 108, at 667; Ortiz v. Fibreboard Corp., 527 U.S. 815, 821 (1999).

159 *See* Prunty & Solomons, *supra* note 108, at 666–68.

Because 3D printers will likely pervade every important space in humans' lives[160] it will be impossible to distinguish which printers are the primary cause of any individual's diseases. Courts cannot simply ignore these likely widespread claims because it is difficult to identify specific defendants. As such, liability is likely to be thrust upon one of two parties, or some combination thereof: 3D-printer manufacturers and/or manufacturers of 3D-printing reagents. Parties in this position should consider several recommendations for courts to adopt.

First, 3D-printer manufacturers should assert sole liability upon the manufacturers of the dangerous reagents. It would be an extreme undertaking for courts to evaluate every 3D printer that each individual plaintiff was exposed to and then identify which printer caused the plaintiff's harm. Furthermore, where claimants may possibly encounter any number of different 3D printers, many of those printers will be using the same reagents as their construction materials.[161] Thus, where there will be fluctuation in 3D printers, there will be less uncertainty as to what reagents were being used and, thus, what parties may be liable.

Fungibility will likely be the primary issue with 3D printers. Fungibility creates issues in assessing causation and liability in cases involving multiple defendants. If 3D printers are everywhere, how can any claimant identify a defendant with specificity? While courts have notably shown a reluctance in applying theories such as market share liability,[162] such a theory may be the only rational choice. A clear certainty in all of this is that there will be plaintiffs who have been harmed by 3D-printer emissions. Courts cannot simply shut the courtroom doors to potentially millions of plaintiffs under the premise that 3D printers are just too ubiquitous to assess liability. Additionally, by applying market share liability, courts can encourage manufacturers of reagents to continuously research and develop safer materials while simultaneously encouraging employers and others using this technology to ensure they are using it in the safest way possible.

If courts do elect to hold 3D-printer manufacturers themselves liable, those manufacturers will then want courts to adopt the *Lohrmann*

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[160] Nora Freeman Engstrom, *3-D Printing And Product Liability: Identifying The Obstacles*, 162 U. PA. L. REV. ONLINE 35, 35 (2013) ("Brook Drumm, the founder of one 3-D printing company, for example, envisions 'a printer in every home.'").
[161] *See generally* Stefaniak et al., *supra* note 73.
[162] *See* cases cited *supra* note 97.

standard in establishing causation.[163] This too could be a rational pairing for courts. By applying something akin to the frequency-regularity-proximity test to 3D printers, plaintiffs will be required to identify a certain manufacturer and the printer that they were exposed to at a higher rate than others. However, such a standard will likely prove too burdensome for plaintiffs, due to the aforementioned problem of ubiquity. This further demonstrates why the burden should lie with reagent manufacturers. We can be certain, regardless of which printer is being used, that consumers will be consistently exposed to the emissions from these same materials.

Regardless of the decision on which manufacturers to properly hold liable, perhaps the best answer for the courts would be to adopt some middle-ground between both the desires of the plaintiffs and the defendants to create a more efficient, predictable standard. By applying the *Lohrmann* standard, courts can ensure that plaintiffs identify 3D printers that they more than casually or minimally experience on a daily basis.[164] This will put a defendant-friendly restriction on plaintiffs, while maintaining the narrow *Lohrmann* standard.

However, as discussed, it is likely that plaintiffs will encounter several printers on a more than casual basis.[165] As such, there may be several manufacturers potentially liable. This is a situation in which defendants may be amenable to a market share liability theory, since that theory does not include joint and several liability.[166] A market share liability standard may ultimately be a more economically advantageous choice than a standard that leaves major manufacturers of 3D printers on their own to bear the costs for diseases they didn't uniquely cause.

Thus, perhaps by combining a restrictive and narrow causation theory, such as the *Lohrmann* standard, and pairing it with a broad theory of liability such as market share liability, courts may be able to strike a balance between identifying the limited possible causes of plaintiffs' latent diseases and holding more parties responsible for their contributions instead of leaving one manufacturer "caught holding the bag." In so doing, courts can operate more efficiently, as calculation of damages will be far simpler, and the

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[163] *See generally* Greene, *supra* note 116.
[164] *See generally* Lohrmann v. Pittsburgh Corning Corp., 782 F.2d 1156, 1162 (4th Cir. 1986).
[165] *See* Engstrom, *supra* note 159, at 35–36.
[166] *See* Gifford, *supra* note 13, at 655.

motivation to settle will increase once litigants pass the initial phases of trial.

Finally, as noted above, Congress could pass legislation akin to the black lung legislation that was used to compensate injured miners.[167] This solution would likely be agreeable to both plaintiffs and defendants alike. However, such legislation will likely require 3D printers to be uniquely identified as the cause for a specific kind of disease or cancer. While not altogether unlikely, this Article cannot purport to predict such an outcome. If it were to arise, though, similar legislation would be appropriate, agreeable, and perhaps the best choice to avoid any massive influx of nationwide litigation.

V. CONCLUSION

Worth briefly mentioning is that the issues discussed at length in this Article, i.e. the latent-disease litigation implications of the rise of 3D printing, are only the tip of the iceberg.[168]

3D printing will likely require pivotal changes in how courts approach tort liability.[169] Because anyone can share their creations, including schematics for those creations, online, "anyone can manufacture a product."[170] As such, it becomes extremely difficult to determine who is liable. There are several parties who could bear liability, including the manufacturer, the creator of the schematic who shared it online, and the 3D-printer manufacturer itself, among others.[171] This, in turn, will present many other issues such as establishing jurisdiction, identifying the party at fault, or identifying a liable party capable of paying the judgment.[172]

3D printers are likely to cause many problems in the realm of intellectual property.[173] In the realm of trademarks alone, it will be tremendously hard for trademark owners to track users who are printing similar products and using them in public spaces without the rights to do so.[174] Copyrights may also prove to be difficult since CAD files, the usual mode of storage

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[167] *See* Prunty & Solomons, *supra* note 108, at 667.
[168] *See supra* note 62 and accompanying text.
[169] *See* Beck & Jacobson, *supra* note 55, at 158–59.
[170] *Id.* at 158.
[171] *Id.* at 158–61.
[172] *Id.* at 160.
[173] *See* Osborn, *supra* note 58, at 582.
[174] *Id*. at 583–84.

for 3D-printer schematics, are likely utilitarian articles for which copyright law provides no protections.[175]

Thus, while the thrust of this Article focuses on the capability of 3D printers to become the subject of the next asbestos-like, latent-disease litigation, it is clear that 3D printing is poised to present numerous legal problems. From 3D-printed coffee cups to 3D-printed guns,[176] Congress and courts alike are certain to face numerous novel and unique problems as 3D printing continues to take the world by storm. However these groups choose to respond, it is critical that they ensure we do not create another court-clogging, inefficient, legal regime like the one that burdens asbestos litigation. In that scheme, both plaintiffs and defendants suffer from the mass uncertainty and inefficiency present in the system.

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175 *Id*. at 589.

176 Marrian Zhou, *3D-Printed Gun Controversy: Everything You Need to Know*, CNET (Sept. 25, 2018), https://www.cnet.com/news/the-3d-printed-gun-controversy-everything-you-need-to-know/.