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Asbestos: A Case of Adaptive Regulation

1. Introduction

Asbestos is a term used to classify six naturally occurring mineral silicates that are fibrous in nature (Virta, 2006). While these mineral forms were recognized to be notably different from one another, for example the two groups, serpentine and amphibole have distinct chemical and physical properties and toxicities, they have been collectively termed asbestos and it is still not common to differentiate between the various types (IARC, 1977). The use of asbestos in products began in the late 1800s, rising sharply in the early 1900s until reaching a peak in worldwide sales in 1980 (Virta, 2006). It was once widely referred to as the "miracle mineral" because of its ability to withstand heat. Due to its fire-retardant qualities asbestos was applied for insulation and fireproofing in ships and buildings, as well as in a range of products including cement, water pipes, clothes, cars, roofing, and wallboard among others. The numbers of Americans exposed to asbestos is estimated to range between 27 and 100 million (White, 2014).

The negative health effects associated with exposure to asbestos were first recognized in the early 1900s (Selikoff & Lee, 1978). Asbestos leads to a fatal cancer called mesothelioma where inhalation of fibers forms a malignant tumor typically in the area of the heart, lungs, or abdomen. Exposure to asbestos is also correlated with increased incidences of other types of cancers, most notably that of the lung (Weill & Hughes, 1986). It can further lead to asbestosis, a respiratory disease characterized by difficulties in breathing. The extremity of asbestosis is a direct function of the length of exposure. Unlike many other illnesses, asbestos induced illnesses typically appear only years after the onset of exposure (Selikoff & Lee, 1978). This property has made the assessment and medical case against asbestos particularly challenging. Difficulties in quantifying the risk of asbestos exposure are further compounded by the differing toxicities of the six minerals that are collectively termed asbestos.

2. A Brief History of Asbestos Regulation

2.1 Regulation prior to the 1960's

The first policy controlling the use of asbestos in the United States emerged in 1938 and is thought to primarily have been informed by "A Study of Asbestosis in the Asbestos Textile Industry" conducted by the U.S Public Health Service (Dreessen, W. C. ; Dallavalle, J. M. ; Edwards, T. I. ; Miller, J. W. ; Savers, 1938).

"A Study of Asbestosis in the Asbestos Textile Industry" was published by the Division of Industrial Hygiene of the National Institute of Health in 1938. This study investigated four asbestos textile factories in North Carolina. A multi-component radiological, clinical, and pathological evaluation of 447 workers was conducted. Dust counts in the work place were made using a newly developed PHS impinger method and particle sizes of dust were determined by an Owens jet apparatus. The evaluation found that there were three (classified as borderline) cases of asbestosis in workers who had been exposed to dust concentrations below 5 mppcf, and numerous cases of illness in patients exposed to over 5 mppcf . The results of this study are not considered to be representative of the actual prevalence of asbestosis in these factories since the health of 150 employees who had been discharged 15 months prior to this study was not evaluated or considered (Dreessen, W. C. ; Dallavalle, J. M. ; Edwards, T. I. ; Miller, J. W. ; Savers, 1938) .

The authors of this study suggested that "if asbestos dust concentrations in the air breathed are kept below this limit, new cases of asbestosis would not appear" (Dreessen, W. C. et al., 1938). Following this recommendation an occupational exposure limit (OEL) of 5 mppcf was adopted by the Public Health Survey and National Safety Council. As the first regulatory policy focusing on asbestos this was a notable step in the right direction but it did not impose any legal expectations on to the employer (Barlow et al., 2017)

Although the 1938 study of asbestos in textile factories was the first public health study that directed policy action in regulating asbestos, it was by no means the first indication of potential health consequences relating to asbestos. A number of case reports throughout the early 1900's suggested correlations between high exposure levels to asbestos fibers and incidences of lung disease, but provided limited information on the actual concentrations of particles that workers were exposed to through their activities in the workplace (Auribault, 1906; Cooke, 1924; Seiler, 1928). The lack of clear measurements and more definitive information on the link between asbestosis and exposure was in part due limitations in available technology to detect worker exposure prior to the 1930s. The state of X-ray quality at the time was also unable to differentiate between lung conditions of pneumonia, tuberculosis, asbestosis, and pneumonoconiosis, further complicating the issue (Walton, 1982).

Eight years prior to the U.S. Public Health Service study, Merewether, a general practitioner, and Price, an industrial engineer, published the first epidemiological study on asbestos in the United Kingdom. They found that over a quarter of manufacturer workers in the UK exposed to asbestos had developed pulmonary fibrosis. Length of exposure and concentration of dust in the air were identified as principal determinants in development of disease (Merewether, ERA & Price, 1930). Supporting these findings, in 1935, physicians working for the Metropolitan Life Insurance Company (Metlife), that were hired by the major asbestos manufacturing company Johns Manville , reported that among the US workers examined who had been exposed to asbestos for over three years approximately 53% were afflicted with asbestosis (Lanza et al., 1935). While reports from their own paid investigators confirmed the connection between disease and work-place, and raised clear warnings on health issues related to asbestos exposure, there was still not sufficient evidence to spur action in setting exposure limits. In a 1935 paper written by head physician Dr. Lanza at Metropolitan Life Insurance it was stated that "experience so far does not warrant an attempt to define a standard of dustiness for asbestos dust" (Lanza et al., 1935). Lanza, had previously been a member of the Public Health Survey (PHS) and was at the forefront of asbestos research in the United States. It is speculated that his opinions may have been guided by legal implications and papers subject to editing that obscured some of the data (Lilienfeld, 1991). Nevertheless, the information gathered up to this point did serve to increase awareness, and led to considerations of recommendations on maximum concentration limits.

The establishment of the National Conference of Governmental Industrial Hygienists (NCGIH) in 1938 arose from newfound concern over worker health that emerged with the Social Security Act of 1935. The Social Security Act was part of new legislation under the New Deal that offered states federal public health funding (Martonik et al., 2001). In 1946 the NCGIH changed their name to the American Conference of Governmental Industrial Hygienists (ACGIH). In 1946 the ACGIH also published the first asbestos exposure guideline, at the time referred to as a Maximum Allowable Concentration (MAC), of 5 mppcf based on the 1938 health study. MAC values were redefined as Threshold Limit Values (TLVs) in 1948 to avoid a misinterpretation that short-term exposure over this threshold could lead to health hazards. The TLVs on asbestos set by the ACGIH were not governmental enforceable standards (Barlow et al., 2017). This meant that industries were not required to adopt and follow them, and as a result companies rarely followed these guidelines in efforts to protect worker safety (Egilman et al., 2014).

2.2 Regulation in the 1960's

Significant progress in our knowledge of asbestos-related diseases was made in 1960 that linked case reports of rare pleural tumor, mesothelioma, to asbestos exposure in a mining region on the Cape of south Africa. This study was organized by the research unit of Johannesburg National Hospital and led by a British pathologist by the name of John Wagner (Wagner et al., 1960). In light of this, the U.S. conducted its first epidemiological study finding peritoneal mesotheliomas and 39 cases of asbestosis in asbestos exposed workers. A second study found that among 632 insulators who worked in exposure to asbestos, 45 of their deaths were due to lung cancer, 12 to asbestosis, and four due to mesothelioma (Lemen & Landrigan, 2017). Together these studies provided strong evidence for the correlation between mesothelium and asbestos.

In the late 1960's the original TLV for asbestos set by the ACGIH was reviewed. At the time the committee on Hygienic Standards of the British Occupational Hygiene Society (BOHS) began to issue exposure limits on the basis of fiber counts rather than total dust counts, a change made possible by the development of a new measurement technique with the membrane filter method (Ogden, 2003). The metric of fiber/cc-yr is quantified by using an average 8-hr daily work time weighted average (TWA) multiplied by the length of exposure in years, operating on an assumed 5-day work week, 50-week work year schedule (Ogden, 2003). In recognition of fiber/cc-yr being a more appropriate standard than mpccf the U.S. formally changed their way of setting guidelines during this time period. In 1968 based on new observations of the risk of asbestos, and particularly a recent review paper examining exposure potential to insulation workers by Balzer that among other studies at the time highlighted that a 5 mppcf was not founded on solid evidence, the ACGIH changed their TLV to a 8-hr TWA of 2 mppcf or an equivalent 12 f/cc (Balzer & Cooper, 1968; B. I. Castleman & Ziem, 1988; Egilman & Reinert, 1996). This more stringent limit was "intended to reduce to an insignificant risk, the occurrence of asbestos disease" (Martonik et al., 2001).

2.3 Asbestos regulation the Occupational Safety and Health Act

The rising concern over fatalities and injuries associated with the workplace in the late 1960s prompted the formulation and passage of the Occupational Health and Safety Act of 1970 (Lemen & Landrigan, 2017). This was signed by President Richard Nixon on December 29 of 1970 and marked the first step towards unified federal regulation of asbestos in the United States. Prior to this the regulations of threshold limit values on asbestos had merely been recommendations and not enforceable by government (Tweedale, 2002). As a result of the OSH Act, two new important regulatory agencies were created, the Occupational Safety and Health Administration (OSHA) which is part of the Department of Labor, and the National Institute for Occupation Safety and Health (NIOSH) a subdivision of the Department of Health, Education, and Welfare. OSHA was established with the authority to set safety and health standards for the work place, and to facilitate communication (Barlow et al., 2017). In contrast, the primary focus of NIOSH was on the research and training elements that were required to support and meet occupational safety standards.

In 1971 OSHA adopted the TLV set by ACGIH in 1968 of 12 f/cc as their federal occupation exposure limit, referred to as a Permissible Exposure Limit (PEL) (C.F.R, 1994). For the two years following the enactment of the Occupational Health and Safety (OSH) Act of 1970, OSHA was able to establish federal standards without adhering to the procedures outlined in the OSH act (Martonik et al., 2001). After this grace period OSHA had to detail reasons and evidence, along with provide public notice of new rule making – called an NPRM, for any new proposal. After a public hearing of the proposal, the public would have a new opportunity to provide feedback. Based on all of the feedback and data accrued through this process OSHA can publish a final standard. Under the OSH act, OSHA also gained the authority to issue emergency temporary standards (ETS) that are not subject to the same notice and comment procedure (Barlow et al., 2017). However, an ETS was only valid for a duration of six months, at which point OSHA would need to issue a permanent standard following the aforementioned procedure (Coplen, Herczeg, & Barnes, 2000).

Inspired by a report from Dr. Selikoff and Staff at Mt. Sinai Medical Center recommending a work practice standard rather than a standard that only set a permissible exposure limit, the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO) petitioned OSH on November 4, 1971 for an ETS to reduce the exposure limit (Hensler, 2007). A month later OSHA issued an ETS, but gave little scientific evidence or justification for it lowering the limit from 12 to 5 f/cc. Consistent with the regulation in their previous ETS, OSHA passed a new permanent asbestos standard in 1972 requiring an immediate reduction of asbestos exposure limits to 5 f/cc.

In the preamble of the published 1972 standard it was stated that the NIOSH recommended that the 5f/cc limit only be in place for two years, after which it should be reduced to 2 f/cc by July 1, 1976 (Martonik et al., 2001). The delay in reduction was to allow industries time to make the adjustment. Similar to the previous ETS, the new final standard was accompanied by little written justification. In October of 1975 OSH published a new proposed standard to revise the NPRM from 1972 and reduce the exposure limit to 0.5 f/cc. The updated proposal was based on new studies on the adverse effects of asbestos that designated asbestos as a human carcinogen, and for the first time this information was included in the report. The new proposal was met with a substantial amount of opposition. Industries argued that a limit of 0.5 f/cc was not achievable, and representatives from construction and maritime sectors sought less strict proposal rules that would be more suited to their individual workplaces. Faced with the large degree of disapproval OSHA didn't conduct a hearing and a new rule was never issued (Lemen & Landrigan, 2017).

In 1973, Stokinger wrote a letter to the TLV committee of the ACGIH urging them to reduce the 12 f/cc TLV that was set in 1968. He cited recent epidemiological studies in his argument to account for a "margin of safety", a value that he calculated at 5 f/cc, to avoid asbestos related disease and cancers (Stokinger, 1973). In response, the ACGIH adopted a new TLV of 5 f/cc in 1974. Six year later the ACGIH proposed revision of their TLVs, this time separating limits by major mineral fiber types: 0.2 f/cc for crocidolite, 0.5 f/cc for amosite, and 2 f/cc for chrysolite. The ACGIH's new standards were specific to each fiber type in acknowledgement of new evidence demonstrating that the various types of asbestos fibers had different levels of pathogenic potency. Epidemiologic evidence produced at this time indicated that the amphibole fibers, crocidolite and amosite, were more strongly linked to risk of mesothelioma than chrysotile asbestos, and thus required more stringent regulations. This approach of differentiated regulation for specific fiber types was adopted by most industrial countries, but not shared by OSHA and regulatory agencies apart from the ACGIH in the United States (Weill & Hughes, 1986). OSHA's resistance to distinguishing between the various fiber types in setting standards may be explainable by the obstacles this would have created for its management and labor divisions. Chrysotile asbestos accounted for the large majority of asbestos use. Banning amphibole fibers, or at the least more rigidly controlling their use, would prohibit the use of widespread mixed fiber products. Removing and replacing products with mixed composition would be time intensive and expensive. For instance, one of the major uses at the time for asbestos fibers containing crocidolite, was in cement pressure pipes, which for most applications would be exceedingly difficult to replace (Weill & Hughes, 1986).

The method for setting exposure limits to asbestos became stricter and increasingly standardized in the 1980's. In response to the 1980 U.S Supreme Court Case: *Industrial Union Department v. American Petroleum Institute,* OSHA was required to perform a quantitative risk assessment replacing the previously qualitative approach in estimating the rate of worker morbidity and mortality to asbestos exposure for all new proposed standards. The quantitative approach to risk assessment included dose-response models, and review of epidemiological studies.

A second asbestos ETS was petitioned for by the International Association of Machinists and Aerospace Workers in June of 1983, requesting a reduction of exposure limit to 0.1 f/cc. This ETS was granted in November of the same year, and as stipulated by the 1980 Supreme court decision included an estimation of the danger of disease that workers faced (Martonik et al., 2001). The estimate suggested that by reducing the limit to 0.5 f/cc 210 deaths due to cancer could be prevented. The ETS was subsequently vacated by the U.S court of Appeals after petition by the Asbestos Information Association. The reason given for this decision was that the quantitative estimate required peer-review. In response, OSHA provided additional supporting information on April 10, 1984 that was then subject to considerable comments and hearings (Leonardi, 2005). By June 20, 1986, OSHA was able to publish a new asbestos standard for general industry and a new standard for construction operations reducing exposure to 0.2 f/cc. The risk assessment behind these standards estimated that this could prevent 7815 cancer-related deaths in a 45-year working time frame (Twight, 1991). A significant difference to the previous 1972 asbestos standard was that rather than having employers monitor their employee's exposure level, under the 1986 standard, employers could use "objective data" to determine employee exposure levels. While no clear definition for objective data existed, it appears to have referred to information that estimated the upper limit of exposure that a certain operation involved (Dewees & Daniels, 1986).

The Court of Appeals was petitioned to review the 1986 Asbestos Standards both by industry and labor representatives. The AFL-CIO, which represented the labor side, argued that an exposure limit lower than 0.2 f/cc was possible. The Asbestos Information Association, which represented the manufacturing industry, contended that meeting the new exposure limit would not be economically or technologically achievable. The U.S court of Appeals decided to maintain most of the provisions of the new standards (Martonik et al., 2001).

In August of 1994 two final asbestos standards, again for industry and construction were published. These new standards reduced the permissible exposure limit to 0.1 f/cc, and required owners of buildings to identify asbestos in order to warn employees and contractors who might be put at risk (Tweedale, 2002). While this did not require owners to test material for asbestos it called for the assumption that thermal system insulation and sprayed on surface and resilient flooring material that was installed prior to 1981 contained asbestos. Consistent with OSHA standard the ACGIH published a new TWA TLV of 0.1 f/cc which was adopted in 1998.

A list of the revisions to asbestos limits set by two prominent regulatory agencies

Organization	Year	Rule	Limit
ACGIH	1946	TLV	5 mmpcf
ACGIH	1968	TLV	12 f/cc (2 mmpcf)
ACGIH	1974	TLV	5 f/cc
ACGIH	1980	TLV	0.2 f/cc – crocidolite 0.5 f/cc amosite 2 f/cc chrysolite
ACGIH	1995	TLV	0.1 f/cc
OSHA	1970	ETS	5 f/cc
OSHA	1983	ETS	.5 f/cc
OSHA	1972	PEL	5 f/cc
OSHA	Under 1972 act (started in 1976)	PEL	2 f/cc
OSHA	1986	PEL	.2 f/cc
OSHA	1994	PEL	.1 f/cc

3. Asbestos Lawsuits and Court Management

In the 1970's asbestos related court cases began to reach considerable numbers, on the order of 1,000 cases in federal courts and as much as twice that number were filed in state courts. Many of the cases were filed by employees of Johns-Manville who had begun to experience health consequences from inhalation of fibers in their workplace (Anderson, 1987). Major manufacturers of asbestos products, such as John-Manville, were known to conduct physical examinations of their employees. They have been criticized for failing to inform them of signs of asbestosis, likely as a way to keep down compensation claims. As a result, workers in these industries typically only realized years, sometimes even decades later, that they were sick (Castleman, 2005). The number of cases filed began to grow rapidly in the early 1980's. Between 1980 and 1984 another 10,000 cases had been filed in federal courts, followed by another 37,000 cases between 1985 and 1989. By 1990 the annual total federal court filings had reached 13,000 (Carrington, 2007).

Asbestos related cases were by their nature complex, and thus there was a significant incentive to settle the cases before trial. In each case, the plaintiffs claims presented a set of scientific questions regarding the nature, and length of exposure and coinciding harm, which required testimony by experts from scientific and medical fields in the adversary counsel (Carrington, 2007). These cases were also time intensive as they required reconstruction of events sometimes decades prior, in which the plaintiff was exposed to the risk.

Due to the myriad of issues of both scientific, and legal origin, and the difficulties associated with predicting the outcome of trials, most parties were interested in settling cases prior to trials. The results of the trials that did happen often appeared random, with diverse compensation outcomes arising from factors including the persuasiveness of witnesses, or the judge and jury's sympathy. An approximate 730,000 claims contending personal injury had been filed by the year 2002, amounting to $54 billion paid to claimants. Estimates predict that around a million more claims will be filed in the future, costing on the order of $300 billion dollars unless Congress develops an action plan to reduce costs (Carroll et al., 2002).

The number of plaintiffs, defendants, and high costs involved in the legal claims of asbestos make it one of the largest mass torts of US history. As a result of asbestos lawsuits, more than eighty-five corporations have filed for bankruptcy, and several insurance companies have failed or experienced considerable financial distress (White, 2006).

4. Asbestos – A Case of Adaptive Risk Management?

Over the past three-quarters of a century the policy regarding exposure limits has been in a state of continuous evolution. The earliest reports linking asbestos to disease emerged prior to the 1930's but the first guidance limit, issued by the ACGIH, was only established in 1946 (Barlow et al., 2017). The first federal enforceable limit created by OSHA was published in 1972, over forty years later. Since this time these two regulatory agencies have reduced their exposure limits in a stepwise manner, reaching present day regulations.

4.1 What lead to iterative adaptation with time?

The policies developed to manage asbestos have evolved with time for several reasons. The driving force behind the establishment of more stringent guidelines has most strongly correlated with new scientific findings linking adverse health effects with asbestos exposure. While the consequences of exposure to asbestos both at higher concentrations and for longer durations of time have been known for nearly a century, robust evidence and supporting studies have been building over time and led to changes in policy as they do. While doctors, and health institutes, have been driving the regulation of asbestos forward through dissemination of new scientific information to the community, industries that manufacture asbestos containing products appear to have been the main impediment to establishing safe asbestos regulations earlier on. Here I will examine each of these two opposing influences and how they have been integral to the history of asbestos management.

4.1.1 The Evolution and Diffusion of Scientific Information

It may initially seem surprising that it took over a half-century to demonstrate definitive evidence of the dangers of asbestos use and exposure, however, this can largely be explained by the absence of adequate sampling and analytical technology. Up until the early 1970's the study of asbestos mineral risk lacked a sampling method that was fiber-specific, as well as any analytic methods to examine full-shift exposures.

Until the mid 1960's the technology available for dust measurements included the electrostatic precipitator, the Owens jet dust counter, the konimeter impinger and the filter paper thimble, none of which were able to capture full-shift exposures (Bloomfield & DallaValle, 1935;

Walton, 1982). Between the 1930s and 60s asbestos dust was quantified in the unit of millions of particles per cubic foot of air (mppcf) which were counted by an optical microscope.

In the mid-1950s the membrane filter method was developed which allowed for the measure of quantity of fibers rather than particles. The development and application of the membrane filter method to enumerating asbestos concentrations was primarily driven by the Asbestosis Research Council of Great Britain. Over time the membrane filter method replaced other sampling systems and analytical tools, and became the standard for measuring asbestos. Along with the membrane filter method, battery-powered personal pumps opened the door for full-shift sampling which had previously been impossible with the use of the hand operated midget impinger. These developments were monumental improvements for assessing workplace exposure potential to particulates but more notably to fibers themselves.

In the 1980s the first standardized methods to analyze airborne asbestos concentrations with the use of transmission electron microscopy (TEM) were published, marking a significant step in the analysis of airborne dust. New TEM technology made it possible to examine the shape and structure of even the smallest asbestos fibers. The elemental composition and crystal structure were distinguishable through energy dispersive x-ray analysis and electron diffraction. To analyze airborne fibers, samples are typically collected onto polycarbonate membrane filters which catch fibers on the carbon coated film surface (Baron, 2016). The fibers are subsequently removed by dissolving the filter material and only the top film is then analyzed on the TEM. In contrast to phase contrast microscopy (PCM), TEM was a powerful and accurate method to differentiate between various types of asbestos mineral fibers. It was, however, also more expensive as well as inconvenient for analyzing large numbers of samples during field studies where quantitative accuracy may have suffered during sample preparation (Baron, 2016).

4.1.2 The influence of Industry on Asbestos Policy

The influence of corporations and lobbying by industries has played a notable role in slowing asbestos litigation over time. There are striking similarities in the way various companies have hidden the risks of asbestos and its relationship with cancer that have been widely noted in the literature, with actions seen in the tobacco industry. This has taken the form of petitioning court decisions, opposing warning labels, limiting the spread of evidence linking asbestos to disease, all of which have impeded in one way or another, actions to reduce exposure to asbestos (Markowitz & Rosner, 2016).

One example of this is the opposition to OSHA's NPRM to reduce the PEL to 0.5 f/cc. At that time advancements in monitoring techniques and protective technology along with new medical evidence of asbestos as a carcinogen gave new reasons for OSHA to revise their previously set PEL. The first legal challenge to OSHA was in response to the earlier 1972 standard which the Industrial Union Department of the AFL-CIO petitioned the Court of Appeals for the D.C. court to review. Although the court maintained the standard it did rule that OSHA be required to provide justification for the choice of limit based on ascertainable evidence, as well as demonstrate that rule is economically feasible. When OSHA proposed the new PEL of 0.5 f/cc in 1975 various industries commented that it was unachievable. The argument that an exposure limit of 0.5 f/cc was infeasible was in fact not true, as some occupations were already exposed below 0.1 f/cc (Lemen & Landrigan, 2017). Nevertheless, as a result of the industry push-back, two congressman and four senators requested that the proposal be altered to something more economically realistic. In face of the considerable opposition OSHA abandoned its 1975 proposal and turned its attentions for the time being to regulation of hazards associated with other compounds (Martonik et al., 2001).

Another example of industry impeding the regulation of asbestos is in the 1983 ETS. In this case the Asbestos Information Association (AIA) petitioned the U.S. court of Appeals for review which ended in the ETS being vacated in 1984. The AIA is an industry trade group that was established in December of 1970 (Markowitz & Rosner, 2016). The court's reasoning behind the actions in the case of the 1983 ETS was an incomplete quantitative risk assessment. This was a new element to rulemaking that was born from the Supreme Court's 1980 decision on benzene. Apart from this action, the AIA is frequently mentioned among parties that have attempted to hide information and delay actions that would lead to restriction on asbestos use (Castleman, 2005). Apart from their involvement in petitioning the second OSHA ETS, the AIA also opposed the OSHA Advisory Committees decision to place a warning label containing the word "cancer" on asbestos-related products. They argued that a label of this sort "would spell the demise of numerous major product lines of the industry, including vinyl asbestos floor tile, asbestos pipe, and any other product that is sold directly to the consumer market…" (Tweedale, 2002).

4.1.3 Where did information and research on asbestos come from?

National organizations were the funding source that supported many of the early studies that eventually uncovered significant correlations between asbestos and cancer. While there were many influential figures behind early asbestos-related disease research, two of the most prominent are Dr. Dreessen, and Dr. Selikoff.

Dreessen conducted and wrote the report on the study done on the asbestos textile factory workers in 1938 that became the foundation for the very first suggested limit of 5 million particles per cubic foot. This study was done under direction of the US Department of Public Health, and did not receive funding from any private sources (Dreessen et al., 1938).

Dr. Irving Selikoff was a physican based at Mount Sinai Hospital in NY, and was recognized by many as the leading American medical expert on asbestos related diseases, at least between the 1960s and 1990s. His research, which was conducted at Mount Sinai, was largely funded by the NIOSH and was instrumental to raising awareness for the risks of exposure to asbestos, especially in the workplace. Throughout his career Selikoff sustained criticism on the quality of his research, as well as his trustworthiness and reputation as a scientist by asbestos industries. He was accused of stirring up a "fiber phobia" and putting forth claims of unfounded risks of asbestos based on spurious medical evidence (McCulloch & Tweedale, 2007). In 1964, at an international asbestos conference in NYC, Selikoff presented on the cancer hazards of asbestos. Following the conference, Selikoff received a letter via attorneys from the Asbestos Textile Institute (an industry trade organization) cautioning them against the "innocent but unwise treatment of research data" (McCulloch & Tweedale, 2008).

Attempts of industry to stop the spread of information and results of research portraying asbestos as a hazard went beyond efforts to invalidate single doctors or studies. Activities of groups funded by industry had a heavy hand in combatting dissemination of research on larger scales, and conducting studies of their own. One example of this is research funded at the Saranac Laboratory in 1943 (Lilienfeld, 1991). The director of Saranac, Leroy Gardener, conducted a study where he found incidences of pulmonary cancer in white mice that were exposed to asbestos. His proposal of a follow-up study was however refused by the funding organization, and it took eight years for the results of the original work to reach the public (Schepers, 1995).

The Asbestos Information Association (AIA) was an organization established on December 4, 1970 during a meeting of John Manville (Martonik et al., 2001). The AIA operated on an annual budget of approximately $300,000 which it used to monitor medical conferences in North America in order to prepare to counter criticism against their products. The AIA also organized public relations campaigns which provided information on the risks of asbestos at odds with medical evidence that had existed since the 1930s (Markowitz & Rosner, 2016). One example is the answer given to the question "Can a little asbestos kill you" in their pamphlet which stated that "Long term medical studies of occupationally exposed workers show that low to moderate levels of exposure to asbestos do not lead to an increased rate of disease" (Asbestos Information Association, "Asbestos and Health: Questions & Answers," ca. October 1971.).

4.2 Framework for Policy and Rule Making

Prior to the development of OSHA in 1970 there was no federal regulation of asbestos, all policy on this topic took the form of recommendations. Updates to exposure limits through the decades have been driven by advances in the medical evidence of asbestos related disease. Given the lack of formal policy making framework that existed particularly prior to the 1970s there were no structured guidelines for assessing risks, or improving knowledge which are typically associated with adaptive risk management. Nevertheless, even without the formal framework the iterative changes in regulation suggest that policy has been fairly fluid in evolving to an improved understanding of asbestos, particularly when catalyzed by improved technological advancements in the 1960s.

Have the policy tools and rulings that have evolved since the 1970s aided in adapting policy to mitigate the risk of asbestos? OSHA has the authority to issue emergency temporary standards that take effect immediately. This lends a power to respond quickly and succinctly to new information without legislative hurdles. As such ETS as a tool should aid in efficiently adapting and responding to risk management. The proposal of new rules, which follow the issuance of ETS, are however subject to public hearings and extensive feedback and review processes. As illustrated by the times in which these have been petitioned in court, this process can be lengthy and cumbersome. Currently quantitative risk assessment comprises of four key steps: hazard identification, dose-response assessment, exposure assessment, and finally risk characterization (Abelson, 1990; Dewees & Daniels, 1986).

5. Conclusion

The case of asbestos spans the evolution of occupational safety regulations in the United States highlighting a transition from a mixture of voluntary and case specific exposure limits to the creation of nationwide mandatory regulations. During this time quantitative risk assessment has emerged as a necessary tool to lay the scientific foundation on which to base national standards. The shift to nationwide standards and requirements for scientifically robust evidence to support the proposal of new regulations has however clearly been accompanied by a slowing in the adoption of protective measures which may leave vulnerable parties unnecessarily exposed to risks.

Asbestos has been completely banned in over fifty-five countries in the world, starting with Iceland in 1983 (L. Frank & Joshi, 2014). Environmental health regulations viewed from a cost-benefit perspective examine a trade-off between the losses incurred by increased prices for having to adopt other material, or technologies, and the benefits which are defined by having a cleaner and safer work environment. In the case of asbestos, the lack of a ban in the United States relative to other countries would suggest a perhaps lower cost of the average human life than under other societal frameworks. In the United States, this may be possible due to entrenched inequality in our economic frameworks that allow for little mobility. The lenient setting of exposure limits may be sufficient to protect industry and firm managers, who are not directly exposed, leaving the actual workers at risk.

Similar to the United States, the regulation of asbestos in Europe was weakened by regulatory capture. Only when widespread bans on importation and use were adopted by European countries in the 1990s did exposure rates actually sharply fall (White, 2014). The high costs involved in the train of lawsuits in the case of asbestos in the United States serve to show that the worse the failure of legislation is, the higher the resulting liability costs. The negligence demonstrated by industry and producers in protecting their workers have ultimately made judges sympathetic to plaintiffs in trials.

Asbestos is unique from litigation surrounding other mass torts in the United States in several ways. One of the most notable differences is in the need to prove causation. Since signs of asbestosis, and other diseases or health consequences brought on by exposure to asbestos may only emerge years later, it is particularly difficult to prove causation. While a plaintiff bringing forth a case would normally have to demonstrate that a specific product or work environment of the defendant led to the harm, it is often sufficient in asbestos cases to provide evidence that asbestos products were present within the workplace (White, 2014). As such, asbestos differs from other mass torts involving personal injury cases, such as that of lead paint, or agent orange, where demonstrating what specifically caused the harm is more important. Asbestos is also a distinct case due to the high costs and the sheer number of plaintiffs, and defendants involved. By these criteria, asbestos may only be rivaled by tobacco.

The current rapid pace at which new technologies are emerging poses a problem for the sluggish pace at which governmental standards are set. This history of asbestos managements shows that an untimely and inadequate response to managing risks as they become apparent with new research can be extremely costly. In order to protect workers, and the public from the risks of emerging technologies a proactive approach to environmental policy setting must develop that involve strategies to quickly adapt to new information on risks and the ability to prompt voluntary participation from affected firms and shareholders.

References

IARC monographs on the evaluation of the carcinogenic risk of chemicals to man: some miscellaneous pharmaceutical substances. (1977). *IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Man*, *13*, 1–255. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16821

Occupational Exposure to Asbestos: Final Rule. (1994). *Federal Register*, *59*(153), 40965–41158.

Abelson, P. (1990). The asbestos removal fiasco. *Science*, *247*(4946), 1017–1017. https://doi.org/10.1126/science.2309114

Anderson, D. R. (1987). Financing Asbestos Claims: Coverage Issues, Manville's Bankruptcy and the Claims Facility. *The Journal of Risk and Insurance*, *54*(3), 429. https://doi.org/10.2307/253361

Auribault, M. (1906). *No Title*. *14*, 120–132.

Balzer, J. L., & Cooper, W. C. (1968). The Work Environment of Insulating Workers. *American Industrial Hygiene Association Journal*, *29*(3), 222–227. https://doi.org/10.1080/00028896809342992

Balzer, J. L., & Cooper, W. C. (1968). The Work Environment of Insulating Workers. *American Industrial Hygiene Association Journal*, *29*(3), 222–227. https://doi.org/10.1080/00028896809342992

Barlow, C. A., Sahmel, J., Paustenbach, D. J., & Henshaw, J. L. (2017). History of knowledge and evolution of occupational health and regulatory aspects of asbestos exposure science: 1900–1975. *Critical Reviews in Toxicology*, *47*(4), 286–316. https://doi.org/10.1080/10408444.2016.1258391

Baron, P. (2016). Measurement of Fibers. In *NIOSH Manual of Analytical Methods (NMAM)* (5th ed.).

Bloomfield, J. J., & DallaValle, J. M. (1935). *The determination and Control of industrial dust*.

Carrington, P. D. (2007). Asbestos lessons: The consequences of asbestos litigation. *The Review of LItigation*, 583–612.

Carroll, S., Hensler, D., Abrahamse, A., Gross, J., White, M., Ashwood, S., & Sloss, E. (2002). *Asbestos Litigation Costs and Compensation: An Interim Report*. Santa Monica: RAND Institue for Civil Justice.

Castleman, B. (2005). *Asbestos: Medical and Legal Aspects*. New York: Aspen Publishers.

Castleman, B. I., & Ziem, G. E. (1988). Corporate influence on threshold limit values. *American Journal of Industrial Medicine*, *13*(5), 531–559. https://doi.org/10.1002/ajim.4700130503

Cooke, W. E. (1924). Fibrosis Of The Lungs Due To The Inhalation Of Asbestos Dust. *BMJ*, *2*(3317), 147–140. https://doi.org/10.1136/bmj.2.3317.147

Cooper, W. C. (1967). Asbestos as a Hazard to Health. *Archives of Environmental Health: An International Journal*, *15*(3), 285–290. https://doi.org/10.1080/00039896.1967.10664919

Dewees, D. N., & Daniels, R. J. (1986). The Cost of Protecting Occupational Health: The Asbestos Case. *The Journal of Human Resources*, *21*(3), 381. https://doi.org/10.2307/145969

Dreessen, W. C. ; Dallavalle, J. M. ; Edwards, T. I. ; Miller, J. W. ; Savers, R. R. (1938). A Study of Asbestosis in the Asbestos Textile Industry. *Journal of the American Medical Association*, *112*(14), 1416. https://doi.org/10.1001/jama.1939.02800140114031

Egilman, D. S., & Reinert, A. A. (1995). The Origin and Development of the Asbestos Threshold Limit Value: Scientific Indifference and Corporate Influence. *International Journal of Health Services*, *25*(4), 667–696. https://doi.org/10.2190/EXVJ-RR1P-AYCG-1WH6

Egilman, D., Bird, T., & Lee, C. (2014). Dust diseases and the legacy of corporate manipulation of science and law. *International Journal of Occupational and Environmental Health*, *20*(2), 115–125. https://doi.org/10.1179/1077352514Z.000000000104

Egilman, D., & Reinert, A. (1996). Lung cancer and asbestos exposure: Asbestosis is not necessary. *American Journal of Industrial Medicine*, *30*(4), 398–406. https://doi.org/10.1002/(SICI)1097-0274(199610)30:4<398::AID-AJIM4>3.0.CO;2-S

Gardener, L. (1938). *Second Progress Report on Experimental Asbestosis by the Saranac Laboratory*.

Gardener, L. (1937). The similarity of the lesions produced by silica and by tubercle bacillus. *The American Journal of Pathology*, *13*(1).

Goetz, A. (1953). Application of Molecular Filter Membranes to the Analysis of Aerosols. *American Journal of Public Health and the Nations Health*, *43*(2), 150–159. https://doi.org/10.2105/AJPH.43.2.150

Hensler, D. (2007). *Asbestos Litigation in the United States: Triumph and Failure of the Civil Justice System*.

Hilt, B., Andersen, A., Rosenberg, J., & Langiird, S. (1991). Cancer incidence among asbestos-exposed chemical industry workers: An extended observation period. *American Journal of Industrial Medicine*, *20*(2), 261–264. https://doi.org/10.1002/ajim.4700200211

Koskinen, K., Pukkala, E., Martikainen, R., Reijula, K., & Karjalainen, A. (2002). Different Measures of Asbestos Exposure in Estimating Risk of Lung Cancer and Mesothelioma Among Construction Workers. *Journal of Occupational and Environmental Medicine*, *44*(12), 1190–1196. https://doi.org/10.1097/00043764-200212000-00015

L. Frank, A., & Joshi, T. K. (2014). The Global Spread of Asbestos. *Annals of Global Health*, *80*(4), 257. https://doi.org/10.1016/j.aogh.2014.09.016

Langer, A. M., Mackler, A. D., & Pooley, F. D. (1974). Electron microscopical investigation of asbestos fibers. *Environmental Health Perspectives*, *9*, 63–80. https://doi.org/10.1289/ehp.74963

Lanza, A. J., McConnell, W. J., & Fehnel, J. W. (1935). Effects of the Inhalation of Asbestos Dust on the Lungs of Asbestos Workers: A Preliminary Study. *Public Health Reports (1896-1970)*, *50*(1), 1. https://doi.org/10.2307/4581423

Lemen, R., & Landrigan, P. (2017). Toward an Asbestos Ban in the United States. *International Journal of Environmental Research and Public Health*, *14*(11), 1302. https://doi.org/10.3390/ijerph14111302

Leonardi, J. (2005). It’s Still Here - The Continuing Battle over Asbestos in America. *Villanova Environmental Law Journal*.

Lilienfeld, D. E. (1991). The silence: the asbestos industry and early occupational cancer research--a case study. *American Journal of Public Health*, *81*(6), 791–800. https://doi.org/10.2105/AJPH.81.6.791

Markowitz, G., & Rosner, D. (2016). "Unleashed on an Unsuspecting World": The Asbestos Information Association and Its Role in Perpetuating a National Epidemic. *American Journal of Public Health*, *106*(5), 834–840. https://doi.org/10.2105/AJPH.2015.303023

Martonik, J. F., Nash, E., & Grossman, E. (2001). The History of OSHA's Asbestos Rulemakings and Some Distinctive Approaches that They Introduced for Regulating Occupational Exposure to Toxic Substances. *AIHAJ - American Industrial Hygiene Association*, *62*(2), 208–217. https://doi.org/10.1080/15298660108984624

McCulloch, J., & Tweedale, G. (2008). Science is not Sufficient: Irving J. Selikoff and the Asbestos Tragedy. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, *17*(4), 293–310. https://doi.org/10.2190/NS.17.4.f

McCulloch, J., & Tweedale, G. (2007). Shooting the Messenger: The Vilification of Irving J. Selikoff. *International Journal of Health Services*, *37*(4), 619–634. https://doi.org/10.2190/HS.37.4.b

Merewether, ERA, & Price, C. (1930). *Report on effects of asbestos dust on the lungs and dust suppression in the asbestos industry.* London.

Niklinski, J., Niklinska, W., Chyczewska, E., Laudanski, J., Naumnik, W., Chyczewski, L., & Pluygers, E. (2004). The epidemiology of asbestos-related diseases. *Lung Cancer*, *45*, S7–S15. https://doi.org/10.1016/j.lungcan.2004.04.008

NIOSH. (2011). Asbestos FIbers and Other Elongate Mineral Particles: State of hte Science and Roadmap for Research. *Current Intelligence Bulletin*.

NRC. (1983). The nature of risk assessment. *NRC, Editor. Risk Assessment in the Federal Government: Managing the Process*, 17–50.

Ogden, T. (2003). Commentary: The 1968 BOHS Chrysotile Asbestos Standard. *The Annals of Occupational Hygiene*. https://doi.org/10.1093/annhyg/meg011

Schepers, G. W. H. (1995). Chronology of asbestos cancer discoveries: Experimental studies of the saranac laboratory. *American Journal of Industrial Medicine*, *27*(4), 593–606. https://doi.org/10.1002/ajim.4700270413

Seiler, H. E. (1928). A CASE OF PNEUMOCONIOSIS: RESULT OF THE INHALATION OF ASBESTOS DUST. *BMJ*, *2*(3543), 982–980. https://doi.org/10.1136/bmj.2.3543.982

Selikoff, I., & Lee, D. (1978). *Asbestos and disease*. New York, NY: Academic Press, Inc.

Stokinger. (1974). Threshold limit values for chemical substances in workroom air adopted by the American Conference of Government Industrial Hygienists for 1973. *Journal of Occupational Medicine. : Official Publication of the Industrial Medical Association*, *16*(1), 39–49. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/4814108

Stokinger, H. (1955). Standards for safeguarding the industrial worker. *Public Health Reports*.

Stokinger, H. (1956). Methods of Establishing Threshold Limits; Prepared Discussion. *American Industrial Hygiene Association Quarterly*, *17*(3), 284–286.

Talcott, J. A., Thurber, W. A., Kantor, A. F., Gaensler, E. A., Danahy, J. F., Antman, K. H., & Li, F. P. (1989). Asbestos-Associated Diseases in a Cohort of Cigarette-Filter Workers. *New England Journal of Medicine*, *321*(18), 1220–1223. https://doi.org/10.1056/NEJM198911023211803

Tweedale, G. (2002). Asbestos and its lethal legacy. *Nature Reviews Cancer*, *2*(4), 311–314. https://doi.org/10.1038/nrc774

Twight, C. (1991). From Claiming Credit to Avoiding Blame: The Evolution of Congressional Strategy for Asbestos Management. *Journal of Public Policy*, *11*(2), 153–186.

Virta, R. L. (2006). *Worldwide Asbestos Supply and Consumption Trends from 1900 through 2003*.

Wagner, J. C., Sleggs, C. A., & Marchand, P. (1960). Diffuse Pleural Mesothelioma and Asbestos Exposure in the North Western Cape Province. *Occupational and Environmental Medicine*, *17*(4), 260–271. https://doi.org/10.1136/oem.17.4.260

Walton, W. H. (1982). The nature, hazards and assessment of occupational exposure to airborne asbestos dust: a review. *The Annals of Occupational Hygiene*. https://doi.org/10.1093/annhyg/25.2.117

Weill, H., & Hughes, J. M. (1986). Asbestos as a Public Health Risk: Disease and Policy. *Annual Review of Public Health*, *7*(1), 171–192. https://doi.org/10.1146/annurev.pu.07.050186.001131

White, M. J. (2014). Mass Tort Litigation: Asbestos. In *Encyclopedia of Law and Economics* (pp. 1–11). https://doi.org/10.1007/978-1-4614-7883-6_72-1