Diseases Associated with Asbestos and the Current Regulations in Place to Control Them

Elements of Atmospheric Pollution: ENV4101

Team Name: Formaldehyde

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Responsibilities: Jewel Cumberbatch studied respiratory illness associated with asbestos. Anjali Modi researched cancer relating to asbestos. Chad Spreadbury discussed asbestos regulations. Bridget Wlosek documented the history of asbestos.

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Abstract

Asbestos is a material famously known for its thermal resistances as well as for its incredibly detrimental effect on human health. It has been widely used throughout history for its fire resistance and later its abundance and extensive utility within industry. Unfortunately, as time progressed, its hazardous nature to mankind was also realized. Due to its friable and fibrous structure which allows for easy inhalation passage into lung tissue, asbestos fibers have the capacity to enter the body and continuously breakdown into smaller and smaller particles. While some of these larger fibers are able to be removed by the body's normal defense mechanisms, the smaller fibers are able to sequester and damage lung tissue. Asbestos exposure has greatly impacted the health of many across the globe through respiratory diseases such as asbestosis and mesothelioma. The latency period of these diseases sometimes makes it difficult to associate them with the location of asbestos exposure. Fortunately, regulations imposed by the EPA *(Environmental Protection Agency)*, OSHA *(Occupational Safety and Health Administration)*, CPSC *(Consumer Product Safety Commission)*, and MSHA *(Mine Safety and Health Administration)* have greatly reduced and in some cases banned asbestos fibers from reaching susceptible public populations and employees exposed to concentrations that prove hazardous.

Objectives and Specific Aims

The objective of this study is to analyze asbestos related diseases and regulations based on those primarily affected. To achieve this objective, we will analyze literature reviews to:

1. Concisely define what asbestos is and its relevant physical and chemical properties.
2. Describe the history of asbestos and how it has been used and regulated in industrial application and consumer products.
3. Review diseases associated with asbestos exposure and identify emerging trends.

Background and Rationale

Asbestos is a common material present in buildings, electronics, and other public areas and goods.[1] While asbestos is usually contained in non-friable form, physical processes can occur to break the substance down to smaller fibers. These resulting fibers are small enough to become inhaled. When in the human body, asbestos causes numerous health issues. Particularly, asbestos fibers become embedded in lung tissue and cause disease.[2] Hence, protocols for *safe*

handling, disposing of asbestos, and knowing the diseases associated with its exposure are vital for upholding the safety, health, and welfare of the public.[3] Asbestos presence in today's society and over previous decades of development contributes to increasing disease likelihood and progression.[4] Since there is no threshold of its carcinogenicity, there is no exposure level below which it can be considered safe and thereby impacts other research areas in academia and industry and the global society.[5]

What is Asbestos?

Asbestos is a collective term used to describe a number of naturally occurring fibrous, silicate minerals. Asbestos, derived from the Greek term meaning "inextinguishable," can be put to an enormous number of uses due to its remarkable physical properties. Asbestos has unparalleled fireproofing and insulating capabilities, as well as being lightweight, abundant, cheap to mine and process, resistant to water and acids, electrically nonconductive, and unattractive to vermin.[3] Due to these indispensable properties, asbestos has been used in various products throughout history.

Asbestos, in its natural rock formation, is ultimately harmless. However, once altered and broken for textile use, small microscopic fibers are released into the air.[5] These suspended fibers can be inhaled and cause negative health effects. During the mid-20th century, asbestos emerged as a public health issue due to its capability of causing a range of diseases, including cancer. These diseases have been grouped together as asbestos-related-diseases (ARD).[1]

History of Asbestos

The use of asbestos dates back to more than 4000 years ago, starting with asbestos containing pottery originating from Africa and Finland. Asbestos also had huge popularity with the ancient Romans and ancient Greeks. For instance, lamps of the Vestal Virgins in ancient Rome had wicks made from asbestos and Charlemagne, Emperor of the Holy Roman Empire, possessed asbestos woven tablecloths.[6] Body armor from the 15th century contained asbestos, as well as wicks and paper produced in Norway in the 1700s. Benjamin Franklin was noted to have a purse made from asbestos, and Pope Pius IX was reported to have developed asbestos paper to keep important documents safe from fire in the Vatican.[6]

Modern history of asbestos can be traced back to the rediscovery of asbestos in Canada and South Africa. Specifically, in the 1870s, Canada was hit with a stroke of luck when a fire revealed a large deposit of asbestos.[5] Due to this discovery and emerging technologies, asbestos was back in the spotlight. By 1876, about 50 tons of asbestos were being mined in Canada, which increased to over 900,000 tons by the 1950s. Other locations with significant production include South Africa, with a production of *about* 80,000 tons by 1970, as well as Italy, Russia, the United States, and China.[6] In 2000, Russia led the world with 700,000 tons, followed by China with 450,000 tons, and 335,000 tons from Canada.[6] This increase in popularity of asbestos occurred in the last half of the 19th century when asbestos began to be used in many commercial settings. For instance, *after the invention* of the steam engine, asbestos was soon discovered as an excellent insulation material. Due to the various properties of asbestos, it became extremely useful in many situations. For example, in the later part of the 19th century, asbestos was used for sealing and packing materials, used in insulation for heat conservations, manufactured into roofing felt and cement, and developed into textiles.[6] With the turn of the century, asbestos allowed for the construction of lighter and thinner cement materials, as well as, brake linings in 1906, clutch facings in 1918, and as a fireproofing material in the 1930s. In World War II, a considerable amount of asbestos was used during the ship-building era where, for the first time, millions of people, including women, were exposed to asbestos.

After World War II, asbestos was discovered to be a great filtering agent. Over time, beer, wine, and pharmaceutical products were filtered with asbestos. It was also incorporated into many plastics, paints, and asphalt and, between 1952 and 1956, asbestos was even a component of cigarette filters. As time progressed, asbestos found its way into plasters, automobile body undercoatings, yarn, rope, sewing thread, gas mask filters, blankets, mailbags, theater curtains and even hair dryers, toasters, play sand and baby powders.[6] Fortunately, the use of asbestos is *now* being banned around the world due to evidence of health hazards. Despite this fact, some countries continue to mine and sell asbestos due to its economic value.

Types of Asbestos Fibers

There are six unique fibrous asbestos substances that belong to the serpentine (layered structure and curly fibers) and amphibole (long chain needle-like fibers) mineral families *where* only three have been used commercially. These include the chrysotile or white asbestos, amosite

or brown asbestos, and crocidolite or blue asbestos (Table 1, Appendix A).[4] Chrysotile is the only type of asbestos in the serpentine category and is the most commonly used form of asbestos found in construction products used in roofs, ceilings, walls, and floors of buildings. It was also used in brake linings, pipe insulations, gaskets and boiler seals. Amosite was used most frequently in cement sheet and pipe insulation but can be found today in insulating tape, ceiling tiles, and in thermal insulation products. Crocidolite is known for being the most efficient in heat resistance *which* is commonly used to insulate steam engines and found in spray-on coating, pipe insulation, and cement products. The three other non–commercially used asbestos forms include tremolite, anthophyllite, and actinolite and are typically found as a contaminant in other asbestos products. Tremolite can be found as a contaminant in chrysotile asbestos used in insulation products, paints, sealants, and roofing materials. It can be clear, white, green, gray, and transparent. Anthophyllite was mined primarily in Finland and has a gray-brown color. It was found as contaminant typically in composite flooring. Actinolite has a harsh texture and does not exhibit high flexible characteristics as the other asbestos forms. It is often found in metamorphic rock.[7]

Asbestos-Related Respiratory Diseases

When asbestos fibers are inhaled it becomes a health hazard. *Although chrysolite is seen most prevalently, previous* research revealed that it takes more exposure to chrysotile than other types of asbestos to develop related diseases. Crocidolite, *though less prevalent,* is seen as the most dangerous type of asbestos. The various types of asbestos vary in size and larger ones that are inhaled can be released by the body's natural defense mechanisms. The lining in the nose and the mucociliary cells in the lungs can evacuate and deposit larger fibers in the throat and phagocytes in the lungs to engulf and transport them to the lymphatics**.** Fibers settling in the throat can be coughed out, swallowed, or eliminated through the bowels.[5]

Smaller fibers pose greater health risks. When inhaled, they can become trapped in the lungs and stay there for many years. The smaller fibers are missed by the immune system and transfer deep into the sensitive areas of the lung, such as the respiratory bronchioles, the alveolar ducts, and the alveoli. This causes extensive tissue damage to the surrounding lung tissue leaving the asbestos unaffected. The fibers break down in the lung splitting, dividing, and dissolving deeper into the lung tissue where at this point it is considered highly dangerous and can trigger

pathological reactions reducing air capacity. As more asbestos is inhaled over an extended period of time, the fibers infiltrate and surround the lung tissue characteristic of a "spider web" type form. These webs destroy the lung's flexibility reducing its capacity for air intake producing a strangulation effect on the *person* affected. This eventually makes it extremely difficult to nearly impossible to speak and in time can result to death.[5]

As asbestos fibers burrow into the lung, *they can pierce through* into the mesothelium surrounding the abdomen and other organs of the body. Asbestos fibers are most commonly found in the pleura, which is the outer lining of the lungs and chest activity but it can also be found lining the abdominal cavity (pertoneuman) or in sacs surrounding the heart (pericardium).[5] This can cause asbestosis (Figure 1, Appendix A), pleural plaques (Figure 2, Appendix A), and pleural effusion.[4] Broadly, ARD can be classified as benign (asbestosis, benign pleural effusions, benign pleural plaques and diffuse pleural thickening) and malignant (lung cancer and pleural and peritoneal mesothelioma).[4] Asbestosis is the condition in which the lung tissue becomes scarred causing shortening of breath and coughing thus, making it hard to breathe. Asbestosis typically manifests in those with relatively high exposure, especially those with occupational exposure.[5] *During* pleural plaque, the tissue and muscles around and below the lung thicken and harden. It usually causes no immediate symptoms but *rarely it* has the potential to trap and compress part of the lung. Pleural effusion is caused when excess fluid builds up in the pleural space between the lungs and the chest wall.[8] Once located in the mesothelium, asbestos fibers aggravate the tissue, progressing quickly to a more rare form of cancer known as mesothelioma (Figure 3, Appendix A).[4,8] The period of time between exposure and ARD development can span to many decades making the health risks of asbestos relevant despite bans and *safety* regulations *over asbestos* use.

Mesothelioma Caused by Asbestos

In the United States, incidence of malignant pleural mesothelioma in 2008 was 1 in 100,000 people.[9] Throughout 2008, the incidence of malignant pleural mesothelioma decreased.[9] This suggests that the United States may have reached its peak incidence of mesothelioma. However, internationally, the incidence of mesothelioma is expected to continue to rise.[9] It is estimated that approximately 70% of mesothelioma cases can be attributed directly to asbestos

exposure.[9] Mesothelioma is also responsible for half of the occupational deaths relating to cancer.[10]

How Asbestos Causes Cancer

In order for asbestos fibers to affect the human respiratory system, they must first be able to enter it. The physical attributes of each individual fiber determine how deeply within the respiratory system the fiber can travel.[11] When inhaled, the fibers deposit on the epithelium through impaction.[12] Since asbestos fibers are insoluble, they do not dissolve with the mucus and travel out of the respiratory system. The most common area for asbestos to deposit and cause mesothelioma is in pleural tissues of the lung.[9] While the exact mechanism of asbestos fibers leading to mesothelioma is unknown, there are a few theories that are presented below.

As discussed previously, different fiber types make up the total composition of asbestos.[13] One of the most obvious differences between fiber types is their shape. Some asbestos fibers are serpentine and others are straight and rod-like.[13] The most dangerous fibers are long and thin because they have the ability to penetrate through the epithelium of the lung.[11] When these asbestos fibers are inhaled, they are able to repeatedly scratch the lungs.[9,11] This starts a cycle of damage, inflammation, and attempts at repair.[11] As the asbestos fibers damage the lungs repeatedly, scarring can lead to plaque buildup and cancer.[9,11] It is also thought that the inhalation of asbestos fibers and the resulting inflammation triggers the activation of certain macrophages in the epithelium. It is possible that the triggering of these macrophages is one of the first steps that lead to mesothelioma.[14]

Another mechanism through which asbestos fibers may lead to cancer is through the disruption of mitosis.[9,11] During mitosis, mitotic spindles form and connect to the chromosomes of the cell. The spindles then shorten and pull apart the chromosomes to complete cell division. Asbestos fibers are able to sever these mitotic spindles.[11] When this happens, aneuploidy occurs where the cells are either missing a chromosome or have an extra chromosome.[9,11] This type of cell chromosome damage is characteristic of mesothelioma.[11]

Asbestosis and Mesothelioma

Asbestosis refers to the fibrosis of the lungs due to the inhalation of asbestos fibers. A question plaguing scientists was whether or not asbestosis is a requirement for malignant

mesothelioma to occur. Through multiple studies, it seems like having asbestosis is not a requirement for the development of malignant mesothelioma resulting from asbestos exposure. However, there have been studies suggesting that there is a direct correlation between rate of asbestosis and mesothelioma.[13] This means that people with asbestosis have a higher risk of consequently developing malignant mesothelioma. In other words, asbestosis might be a better predictor of increased mesothelioma risk than measures of asbestos exposure.[13,14] While it is not completely clear whether or not asbestosis is needed for the development of malignant mesothelioma, it has been generally agreed upon that patients must have at least mild fibrosis of the lungs in order to develop malignant mesothelioma.[14]

Diagnosis and Treatment

As with many cancers, malignant mesothelioma relating to asbestos can be difficult to diagnose. One difficulty of diagnosis is that there is a latency period that lasts anywhere from 30 to 50 years from first exposure.[10] Another problem is that mesothelioma does not have a preference for the lobe of the lung in which it develops. This means that location cannot be used in determining whether or not the mesothelioma is caused by asbestos exposure or something else. In general, screening for lung cancer is not suggested when risk levels are low. *The Helsinki criteria have been created to determine if a patient should be monitored for mesothelioma from asbestos exposure*.[14] These criteria can be seen in Table 2 in Appendix A.

When looking for mesothelioma, CT scans are used to image the lungs and look for the tumors.[14] Unfortunately, the prognosis of patients diagnosed with malignant mesothelioma is poor: 9 to 12 months after diagnosis.[10] However, there are many different treatments used in attempts to increase the life expectancy of mesothelioma patients. Some of these treatments include chemotherapy, injection of white blood cells from the patient into the tumor, and gene therapy.[11,12]

Prevention

The best way to prevent the development of mesothelioma from asbestos is by avoiding contact with asbestos. Due to the restrictions on asbestos within the United States, the future exposure risk is relatively low. However, in countries where asbestos safeguards are not very prevalent, it is very important to be aware of the materials used in construction. The group that is

the most affected are people working in the construction and demolition of buildings that use asbestos.[13] *People who frequently work around asbestos* should wear personal protective equipment.[14] This equipment would consist of a mask that would be worn over the nose and mouth to avoid the inhalation of asbestos. It is also important to wear a special full-body outfit in order to prevent the transfer of asbestos fibers to the home on the workers' clothes.[14]

Multiple studies have also shown that when a person who has been exposed to asbestos smokes, their likelihood of developing mesothelioma increases significantly.[15] The effect of smoking on the lungs is additive to the effect of asbestos on the lungs.[15,16] In one study, it was shown that the mesothelioma mortality risk of insulation installers halved within 10 years of smoking cessation.[16] In 30 years, their risk converged with that of people who had never smoked.[16] This study clearly shows that in order to reduce the risk of developing mesothelioma induced by asbestos, one should quit smoking as soon as possible.

Asbestos Regulations

There are numerous regulations on asbestos under various government agencies. Some of these regulations limit asbestos exposure and usage while others outright ban its incorporation into products completely. All the regulations play a major role in preventing respiratory diseases and cancers resulting from asbestos exposure. Regulations implemented by the Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), Consumer Product Safety Commission (CPSC), and Mine Safety and Health Administration (MSHA) will be described along with their impacts.

EPA Regulations

The EPA was established in 1970 to protect human health and the environment within the United States. Since its establishment, the EPA has implemented several regulations addressing asbestos exposure and limiting it. One of these regulations was the Asbestos-Containing Materials in Schools Rule (40 CFR Part 763, Subpart E). Under the Asbestos Hazard Emergency Response Act (AHERA), this rule mandated schools to be inspected for potential asbestos construction material. If asbestos is found, management plans must be prepared and response activities implemented to prevent or mitigate asbestos exposure for those enrolled and employed at the school.

Under the Clean Air Act, NESHAPs have been established for multiple hazardous air pollutants with asbestos being no exception. The asbestos NESHAP (40 CFR Part 61, Subpart M) sets guidelines on renovation and demolition of buildings that contain asbestos with the goal of preventing or at least minimizing exposure to asbestos fibers.[17] All buildings are required to undergo inspection for asbestos prior to renovation or demolition. Furthermore, work practice procedures aimed at controlling asbestos emissions must be enforced during renovation or demolition. Discarded asbestos material must be processed correctly by thoroughly wetting it, sealing it in leak tight containers, and disposing in a landfill designed for asbestos waste.[17] Additionally, 40 CFR Part 61 sets standards for asbestos mills, roadways within asbestos mills or made with asbestos, and product manufacturing units stating that asbestos emissions from these sources must not release to outside air and asbestos particulate control methods must be utilized.[18]

In addition, the EPA is responsible for abandoned properties contaminated with asbestos as they pose a serious health and environmental hazard for those in the surrounding area. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or Superfund, was promulgated to remediate abandoned sites containing hazardous waste. 40 CFR Part 302.4 states that asbestos is a hazardous substance applicable to CERCLA intervention. *If asbestos concentrations are below 1 percent, the EPA employs a site-specific risk-based approach to determine if action is required. Otherwise, remediation normally occurs when concentrations exceed 1 percent.*[19] For employees under the EPA and other government agencies that must go on-site to assess and perform these remediation practices, the EPA established the Asbestos Workers Protection rule (40 CFR Part 763, Subpart G). Under Section 6 of the Toxic Substances Control Act (TSCA), the Asbestos Worker Protection rule mandates proper protections for state and local government employees that may be exposed to asbestos who were not previously covered by OSHA's asbestos regulations.[20] This regulation effectively applies the standards, including exposure limits, from 29 CFR 1910.1001 (Asbestos General Standard) and 29 CFR 1926.1101 (Asbestos Construction Standard) to uncovered state and local government employees.[20]

OSHA Regulations

OSHA is responsible for ensuring that working conditions for employees in the United States are acceptable and safe by establishing and overseeing occupational safety and health standards.[21] Two rules uphold worker safety and health when dealing with asbestos exposure*: the Asbestos General Standard and the Asbestos Construction Standard*. The Asbestos General Standard (29 CFR 1910.1001) outlines permissible exposure limits and procedures to control exposure including containment, respiratory protection, worker training, proper labeling, and disposal of asbestos.[21] Allowable exposure limits are 0.1 fibers per cubic centimeter of air in a standard eight hour working day or no more than one fiber per cubic centimeter.[22] The scope and application for 29 CFR 1910.1001 applies to all industries covered by OSHA besides construction work and ship manufacturing, repair, and destruction occupations.[22] OSHA ruling on asbestos exposure and destruction in construction occupations is outlined in the Asbestos Construction Standard (29 CFR 1926.1101) and covers proper practices to be used during demolition and renovation activities, worker training requirements, disposal guidelines, and allowable exposure limits.[21] The acceptable exposure limits for the Asbestos Construction Standard are the same as the ones listed under the Asbestos General Standard: 0.1 fibers per cubic centimeter in an eight hour working day or no more than one fiber in a 30 minute period.[23]

CPSC Regulations

The CPSC is responsible for establishing bans and restrictions on consumer products in order to protect people from electrical, chemical or mechanical hazards and also for products that may be harmful to children. Regulations associated with asbestos under CPSC ban particular products that have been shown to put consumers in danger by exposure to hazardous concentrations of asbestos fibers. One of these bans applies to consumer patching compounds containing respirable free-form asbestos (16 CFR Part 1304). 16 CFR Part 1304 requires the banning of patching products that contain purposely added asbestos due to the possibility of the asbestos in the patching substance becoming airborne under instructed use.[24] According to this rule, patching products are defined as anything used to eliminate cracks in buildings and in which the dried excess is sanded smooth after application. The patching compounds may also not be manufactured and shipped for sale to public consumers for eventual usage in buildings.[24] However, patching materials marketed, labeled, and sold only for industrial usage are not

subjected to the ban except when used in locations where consumers have open access such as schools, hospitals, personal residences, and other public buildings.[24]

Another ban under the CPSC is for artificial emberizing materials containing respirable free-form asbestos (16 CFR Part 1305). 16 CFR Part 1305 bans artificial emberizing materials, or ash and embers, containing asbestos which have the potential to become airborne under high temperatures. Emberizing materials will glow and smolder when undergoing combustion and were typically sold separately or applied to artificial fireplace logs.[25] This application of emberizing materials on artificial fireplace logs has no impact on its heat value and served a purely decorative purpose.[25] Speaking of decorative purposes, the CPSC also is responsible for 16 CFR § 1500.17(a)(7) which bans clothes that contain asbestos that do not serve the singular purpose of protection against fire and are made *poorly allowing asbestos fibers to become airborne under instructed use.*[26]

MSHA Regulations

MSHA is responsible for protecting the health and safety of miners within the United States. *The regulations* 30 CFR Parts 56 and 57, Subparts D safeguard miners exposed to asbestos within their working conditions. 30 CFR Part 56 Subpart D applies to surface mines while 30 CFR Part 57 Subpart D pertains to underground mining activity. Both regulations limit miners' chances of developing respiratory diseases and cancer from asbestos by establishing the requirement followed by OSHA that worker exposure cannot surpass an airborne concentration of 0.1 fibers per cubic centimeter in an eight hour working day or exceed one fiber per cubic centimeter of air within a 30 minute period.[27] These regulations also require that control strategies be used to limit exposure to asbestos fibers by various methods including dilution of contaminated air with uncontaminated air, ventilation, and prevention of fiber expulsion.[27] Furthermore, if the previous methods cannot be utilized feasibly, respiratory equipment must be provided if airborne conditions surpass acceptable concentrations.[27]

Conclusions

Asbestos enjoyed popularity throughout history due to its intrinsic properties as it encompassed numerous beneficial attributes such as being fire and chemical resistant. These characteristics made it highly useful in the products ranging from construction materials to

automobile engines and hence was most heavily mined and used during the industrial boom following the Second World War. Unfortunately, this is also when the extremely hazardous nature of asbestos was discovered as a result of its fibrous structure. Asbestosis and mesothelioma are the two major diseases resulting from extensive asbestos fiber exposure. The United States has reached its peak in incidence rate for these diseases due to regulations and protective equipment which limit and prevent asbestos exposure. However, this is not the case around the world where incidence rates continue to rise. A possible explanation for this trend is the lack of regulations in place by other, developing countries, eager to boost their economies from the lucrative global asbestos market. Additionally, this observation can be attributed to large smoking prevalence rates in some countries which aggravate and encourage these ailments further.

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(27) § 56.5001 Exposure limits for airborne contaminants; http://www.gpo.gov/fdsys/pkg/CFR-2011-title30-vol1/pdf/CFR-2011-title30-vol1-part56-subpartD.pdf.

Appendix A: Tables and Figures

Table 1: Fibre types and terminology of the major commercial forms of asbestos. Credit: E. Jamrozik, N. de Klerk, & A. W. Musk

Fiber type	Serpentine	Amphiboles	
Description	'White asbestos'	'Brown asbestos	'Blue asbestos'
Term	Chrysotile	Amosite	Crocidolite
Location(s) of production	Major current producers: Russia and China	South Africa	Wittenoom, Western Australia, South Africa
	(Historically more widespread)	(Minimal current production of amphiboles)	

Table 2: The Helsinki Criteria. Credit: J. Suvatne, & R.F. Browning.

Cumulative exposure of 25 fiber-years
Occupational history with 1 y of heavy exposure or 5-10 y of moderate exposure
Presence of asbestosis
Retained amphibole fiber levels of 2 million (>5 μm) per gram dry lung tissue, or 5 million if >1 μm, or 5-15 asbestos bodies per milliliter of bronchoalveolar lavage fluid

Figure 1-3: Asbestos Related Respiratory Diseases. Credit: E. Jamrozik, N. de Klerk, & A. W. Musk

		
Figure 1. Asbestosis in a 63-year-old woman	**Figure 2.** Pleural plaques in a 67-year-old man.	**Figure 3.** Left mesothelioma in a 60-year-old man with associated pleural effusion.

Appendix B: Responses to Peer Comments by Report Section

Abstract

- Added a comma after "progressed."
- Added the spelled out names of EPA, OHSA, CPSC, and MSHA to clarify what the acronyms stand for. "Fortunately, regulations imposed by the EPA *(Environmental Protection Agency)*, OSHA *(Occupational Safety and Health Administration)*, CPSC *(Consumer Product Safety Commission)*, and MSHA *(Mine Safety and Health Administration)* have greatly reduced and in some cases banned asbestos fibers from reaching susceptible public populations and employees exposed to concentrations that prove hazardous."

Objectives and Specific Aims

- No comments were made in this section of the report.

Background and Rationale

- In the following sentence, safely was changed to "*safe*" and commas were added to make the sentence flow better. "Hence, protocols for *safe* handling, disposing of asbestos, and knowing the diseases associated with its exposure are vital for upholding the safety, health, and welfare of the public."

What is Asbestos?

- Added a comma after "indistinguishable".

History of Asbestos

- Added a comma after "tons".
- Changed: "For instance, discovery of the steam engine, asbestos was soon discovered as an excellent insulation material." to "For instance, *after the invention* of the steam engine, asbestos was soon discovered as an excellent insulation material." to make the sentence flow better.

- Changed: “Fortunately, the use of asbestos is being banned around the world due to evidence of health hazards.” to “Fortunately, the use of asbestos is *now* being banned around the world due to evidence of health hazards.” to make the sentence flow better.

Types of Asbestos Fibers

- Removed “however” in first sentence and replaced with “*where”*.
- Added a comma after “ceiling tiles”

Asbestos-Related Respiratory Diseases

- Changed: “Previous research revealed that it takes more exposure to chrysotile than other types of asbestos to develop related diseases. Yet, crocidolite is seen as the most dangerous type of asbestos.” to “*Although chrysolite is seen most prevalently, previous* research revealed that it takes more exposure to chrysotile than other types of asbestos to develop related diseases. Crocidolite, *though less prevalent,* is seen as the most dangerous type of asbestos.”
- Added a comma after “size”.
- Added a comma after “swallowed”.
- Changed “affected person” to “*person* affected”
- Changed: “Though asbestos fibers burrow into the lung it can dig through the lung into the mesothelium surrounding the abdomen and other organs of the body.” to “As asbestos fibers burrow into the lung, *they can pierce through* into the mesothelium surrounding the abdomen and other organs of the body.”
- Changed “Pleural plaque develops when…” to “*During* pleural plaque, …”
- Changed “has the” to “*rarely it”*
- Changed “The period of time between exposure and asbestos-related disease development can span to many decades making the health risks of asbestos relevant despite bans and regulations for asbestos use and safety regulations.” to “The period of time between exposure and ARD development can span to many decades making the health risks of asbestos relevant despite bans and *safety* regulations *over asbestos* use.

Mesothelioma Caused by Asbestos

- Resolved double citation problem.

Diagnosis and Treatment

- Sentence about Helsinki Criteria reworded.
- Deleted unnecessary phrase from sentence.

Prevention

- Sentence about people working with asbestos reworded for better clarity.

Asbestos Regulations

- Extra space was deleted.

EPA Regulations

- The sentence discussing EPA's site-specific risk-based approach was reworded in order to make it flow better: "*If asbestos concentrations are below 1 percent, the EPA employs a site-specific risk-based approach to determine if action is required. Otherwise, remediation normally occurs when concentrations exceed 1 percent.*[19]"

OSHA Regulations

- OSHA's two regulations are on asbestos exposure are introduced and listed sooner: "Two rules uphold worker safety and health when dealing with asbestos exposure*: the Asbestos General Standard and the Asbestos Construction Standard*."

CPSC Regulations

- The meaning of the last sentence of this section was lost due to the confusing sentence structure. Hence, it was reworded to the following: "Speaking of decorative purposes, the CPSC also is responsible for 16 CFR § 1500.17(a)(7) which bans clothes that contain asbestos that do not serve the singular purpose of protection against fire and are made *poorly allowing asbestos fibers to become airborne under instructed use*.[26]"

MSHA Regulations

- Previously, the sentence began directly with listing the regulations with no explanation as to what they were. In order to clear up confusion, the following change was made: "*The regulations* 30 CFR Parts 56 and 57, Subparts D safeguard miners exposed to asbestos within their working conditions."

Conclusions

- Removed the word "*other"* to make the sentence more clear. "A possible explanation for this trend is the lack of regulations in place by *other*, developing countries, eager to boost their economies from the lucrative global asbestos market."

Appendix C: Team PM 2.5's Comments on Draft

Diseases Associated with Asbestos and the Current Regulations in Place to Control Them

Elements of Atmospheric Pollution: ENV4101

Team Name: Formaldehyde

Jewel Cumberbatch

Anjali Modi

Chad Spreadbury

Bridget Wlosek

Responsibilities: Jewel Cumberbatch studied respiratory illness associated with asbestos. Anjali Modi researched cancer relating to asbestos. Chad Spreadbury discussed asbestos regulations. Bridget Wlosek documented the history of asbestos.

April 22, 2015

Reviewers: Team PM 2.5 Judith Labrada, Ruhaani Bhula, Hannah Ray, Natalie Mecklenburg

Commented [CS1]: Judi & team, if you all could list everyone in your group that would be great! That way we make sure we include you all on this page.

Abstract

Asbestos is a material famously known for its thermal resistances as well as for its incredibly detrimental effect on human health. It has been widely used throughout history for its anti-inflammatory properties and within industry. Unfortunately, as time progressed its hazardous nature to mankind was also realized. Due to its friable and fibrous structure which allows for easy passage into lung tissue, asbestos fibers have the capacity to enter the body and continuously breakdown into smaller and smaller particles. While some of these larger fibers are able to be removed by the body's normal defense mechanisms, the smaller fibers are able to sequester and damage lung tissue. Asbestos exposure has greatly impacted the health of many across the globe through respiratory diseases such as asbestosis and mesothelioma. The latency period characteristic of these diseases sometimes makes it difficult to associate them with the location of asbestos exposure. Fortunately, regulations imposed by the EPA, OSHA, CPSC, and MSHA have greatly reduced and in some cases banned asbestos fibers from reaching susceptible public populations and employees exposed to concentrations that prove hazardous.

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Commented [H3]: Sounds weird. Consider taking out characteristic.

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Objectives and Specific Aims

The objective of this study is to analyze asbestos related diseases and regulations based on those primarily affected. To achieve this objective, we will analyze literature reviews to:

1. Concisely define what asbestos is and its relevant physical and chemical properties.
2. Describe the history of asbestos and how it has been used and regulated in industrial application and consumer products.
3. Review diseases associated with asbestos exposure and identify emerging trends.

Background and Rationale

Asbestos is a common material present in buildings, electronics, and other public areas and goods.[1]While asbestos is usually contained in a non-friable form, physical processes can occur to break the substance down to smaller fibers. These resulting fibers are small enough to become inhaled. When in the human body, asbestos causes numerous health issues. Particularly, asbestos fibers become embedded in lung tissue and cause disease.[2] Hence, protocols for safely handling and disposing of asbestos and knowing the diseases associated with its exposure are vital for upholding the safety, health, and welfare of the public.[3] Asbestos' presence in today's society and over previous decades of development has contributed to increasing likelihood of

Commented [R5]: Is this just a way of saying that it can't be burned?

Commented [H6]: Should be safe handling instead of safely.

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disease and its progression.[4] Since there is no threshold of its carcinogenicity, there is no exposure level below which it can be considered safe and thereby impacts other research areas in academia and industry and the global society.[5]

What is Asbestos?

Asbestos is a collective term used to describe a number of naturally occurring fibrous, silicate minerals. Asbestos, derived from the Greek term meaning "inextinguishable" can be put to an enormous number of uses due to its remarkable physical properties. Asbestos has unparalleled fireproofing and insulating capabilities, as well as being lightweight, abundant, cheap to mine and process, resistant to water and acids, electrically nonconductive and unattractive to vermin.[3] Due to these indispensable properties, asbestos has been used in various products throughout history.

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Asbestos, in its natural rock formation, is ultimately harmless. However, once altered and broken for textile use, small microscopic fibers are released into the air.[5] These suspended fibers can be inhaled and cause negative health effects. During the mid-20th century, asbestos emerged as a public health issue due to its capability of causing a range of diseases, including cancer. These diseases have been grouped together as asbestos-related-diseases (ARD).[1]

History of Asbestos

The use of asbestos dates back to more than 4000 years ago, starting with asbestos containing pottery originating from Africa and Finland. Asbestos also had huge popularity with the ancient Romans and ancient Greeks. For instance, lamps of the Vestal Virgins in ancient Rome had wicks made from asbestos and Charlemagne, Emperor of the Holy Roman Empire, possessed asbestos woven tablecloths.[6] Body armor from the 15th century contained asbestos, as well as wicks and paper produced in Norway in the 1700s. Benjamin Franklin was noted to have a purse made from asbestos, and Pope Pius IX was reported to have developed asbestos paper to keep important documents safe from fire in the Vatican.[6]

Modern history of asbestos can be traced back to the rediscovery of asbestos in Canada and South Africa. Specifically, in the 1870s, Canada was hit with a stroke of luck when a fire revealed a large deposit of asbestos.[5] Due to this discovery and emerging technologies, asbestos was back in the spotlight. By 1876, about 50 tons of asbestos were being mined in Canada, which increased to over 900,000 tons by the 1950s. Other locations with significant production

include South Africa with a production of about 80,000 tons by 1970, as well as Italy, Russia, the United States and China.[6] In 2000, Russia led the world with 700,000 tons, followed by China with 450,000 tons and 335,000 tons from Canada.[6] This increase in popularity of asbestos occurred in the last half of the 19th century when asbestos began to be used in many commercial settings. For instance, with the discovery of the steam engine, asbestos was soon discovered as an excellent insulation material., In the later part of the 19th century, asbestos was used for sealing and packing materials, used in insulation for heat conservations, manufactured into roofing felt and cement, and developed into textiles.[6] With the turn of the century, asbestos allowed for the construction of lighter and thinner cement materials, as well as, brake linings in 1906, clutch facings in 1918, and as a fireproofing material in the 1930s. In World War II, a considerable amount of asbestos was used during the ship-building era where, for the first time, millions of people, including women, were exposed to asbestos.

After World War II, asbestos was discovered to be a great filtering agent. Over time, beer, wine, and pharmaceutical products were filtered with asbestos. It was also incorporated into many plastics, paints and asphalt and between 1952 and 1956, asbestos was even a component of cigarette filters. As time progressed, asbestos found its way into plasters, automobile body undercoatings, yarn, rope, sewing thread, gas mask filters, blankets, mailbags, theater curtains and even hair dryers, toasters, play sand and baby powders.[6] Fortunately, the use of asbestos is being banned around the world due to evidence of health hazards. Despite this fact, some countries continue to mine and sell asbestos due to its economic value.

Commented [H9]: Add comma after tons

Commented [H10]: Consider using a different word than discovered because it was used earlier in the sentence and sounds redundant.

Commented [H11]: Consider saying "is now being banned"

Types of Asbestos Fibers

There are six unique fibrous asbestos substances that belong to the serpentine (layered structure and curly fibers) and amphibole (long chain needle-like fibers) mineral families however, only three have been used commercially. These include the chrysotile or white asbestos, amosite or brown asbestos, and crocidolite or blue asbestos (Table 1).[4]

Table 1: Fibre types and terminology of the major commercial forms of asbestos. Credit: E. Jamrozik, N. de Klerk, & A. W. Musk

Fiber type	Serpentine	Amphiboles	
Description	'White asbestos'	'Brown asbestos'	'Blue asbestos'

Term	Chrysotile	Amosite	Crocidolite
Location(s) of production	Major current producers: Russia and China	South Africa	Wittenoom, Western Australia, South Africa
	(Historically more widespread)	(Minimal current production of amphiboles)	

Chrysotile is the only type of asbestos in the serpentine category and is the most commonly used form of asbestos found in construction products used in roofs, ceilings, walls, and floors of buildings. It was also used in brake linings, pipe insulations, gaskets and boiler seals. Amosite was used most frequently in cement sheet and pipe insulation but can be found today in insulating tape, ceiling tiles and in thermal insulation products. Crocidolite is known for being the most efficient in heat resistance commonly used to insulate steam engines and found in spray-on coating, pipe insulation, and cement products. The three other non–commercially used asbestos forms include tremolite, anthophyllite, and actinolite and are typically found as a contaminant in other asbestos products. Tremolite can be found as a contaminant in chrysotile asbestos used in insulation products, paints, sealants, and roofing materials. It can be clear, white, green, gray, and transparent. Anthophyllite was mined primarily in Finland and has a gray-brown color. It was found as contaminant typically in composite flooring. Actinolite has a harsh texture and does not exhibit high flexible characteristics as the other asbestos forms. It is often found in metamorphic rock.[7]

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Asbestos-Related Respiratory Diseases

When asbestos fibers are inhaled it becomes a health hazard. previous research revealed that it takes more exposure to chrysotile than other types of asbestos to develop related diseases. Yet, crocidolite is seen as the most dangerous type of asbestos, because it is the most prevalent?. The various types of asbestos vary in size and larger ones that are inhaled can be released by the body's natural defense mechanisms. The lining in the nose and the mucociliary cells in the lungs can evacuate and deposit larger fibers in the throat and phagocytes in the lungs to engulf and transport them to the lymphatics**.** Fibers settling in the throat can be coughed out, swallowed or eliminated through the bowels.[5]

Commented [H14]: Add comma after size

Commented [H15]: Add comma after swallowed

Smaller fibers pose greater health risks. When inhaled, they can become trapped in the lungs and stay there for many years. The smaller fibers are missed by the immune system and transfer deep into the sensitive areas of the lung, such as the respiratory bronchioles, the alveolar ducts, and the alveoli. This causes extensive tissue damage to the surrounding lung tissue leaving the asbestos unaffected. The fibers break down in the lung splitting, dividing, and dissolving deeper into the lung tissue where at this point it is considered highly dangerous and can trigger pathological reactions reducing air capacity. As more asbestos is inhaled over an extended period of time, the fibers infiltrate and surround the lung tissue characteristic of a "spider web" type form. These webs destroy the lung's flexibility reducing its capacity for air intake producing a strangulation effect on the affected person. This makes it extremely difficult, to nearly impossible, to speak and can eventually result in death.[5]

Though asbestos fibers burrow into the lung it can dig through the lung into the mesothelium surrounding the abdomen and other organs of the body. Asbestos fibers are most commonly found in the pleura, which is the outer lining of the lungs and chest activity but it can also be found lining the abdominal cavity (pertoneuman) or in sacs surrounding the heart (pericardium).[5] This can cause and asbestosis (Figure 1) pleural plaques (Figure 2), and pleural effusion.[4] Broadly, asbestos-related disease can be classified as benign (asbestosis, benign pleural effusions, benign pleural plaques and diffuse pleural thickening) and malignant (lung cancer and pleural and peritoneal mesothelioma).[4] Asbestosis is the condition in which the lung tissue becomes scarred causing shortening of breath and coughing thus, making it hard to breathe. Asbestosis typically manifests in those with relatively high exposure, especially those with occupational exposure.[5] Pleural plaque develops when the tissue and muscles around and below the lung thicken and harden. It usually causes no immediate symptoms but has the potential to trap and compress part of the lung. Pleural effusion is caused when excess fluid builds up in the pleural space between the lungs and the chest wall.[8]

		
Figure 1. Asbestosis in a 63-	**Figure 2.** Pleural plaques in	**Figure 3.** Left mesothelioma

Commented [R16]: Consider adding a picture diagram, like those used in class powerpoint that shows the three respiratory regions.

Commented [JL17]: Rephrase sentence, the point of this sentence is not clear

year-old woman. Credit: E. Jamrozik, N. de Klerk, & A. W. Musk	a 67-year-old man. Credit: E. Jamrozik, N. de Klerk, & A. W. Musk	in a 60-year-old man with associated pleural effusion. Credit: E. Jamrozik, N. de Klerk, & A. W. Musk

Once located in the mesothelium, asbestos fibers aggravate the tissue, progressing quickly to a more rare form of cancer known as mesothelioma (Figure 3).[4,8] The period of time between exposure and asbestos-related disease development can span to many decades making the health risks of asbestos relevant despite bans and safety regulations over asbestos use.

Mesothelioma caused by Asbestos

In the United States, incidence of malignant pleural mesothelioma in 2008 was 1 in 100,000 people.[9] (Chen & Pace, 2012). Throughout 2008, the incidence of malignant pleural mesothelioma decreased.[9] (Chen & Pace, 2012). This suggests that the United States may have reached its peak incidence of mesothelioma. However, internationally, the incidence of mesothelioma is expected to continue to rise.[9] (Chen & Pace, 2012). It is estimated that approximately 70% of mesothelioma cases can be attributed directly to asbestos exposure.[9] (Chen & Pace, 2012). Mesothelioma is also responsible for half of the occupational deaths relating to cancer.[10] (Park et. al, 2012).

Commented [R18]: I'm not sure if the double citation is necessary? Keep going with the superscript numbers, instead of names.

Commented [H19]: I'm confused by the citation. It seems like a double citation with the number and parentheses.

How Asbestos Causes Cancer

In order for asbestos fibers to affect the human respiratory system, they must first be able to enter it. The physical attributes of each individual fiber determine how deeply within the respiratory system the fiber can travel.[11] (Robinson et. al, 2005). When inhaled, the fibers deposit on the epithelium through impaction.[12] (Davies, 1970). Since asbestos fibers are insoluble, they do not dissolve with the mucus and travel out of the respiratory system. The most common area for asbestos to deposit and cause mesothelioma is in pleural tissues of the lung.[9] (Chen & Pace, 2012). While the exact mechanism of asbestos fibers leading to mesothelioma is unknown, there are a few theories that are presented below.

As discussed previously, different fiber types make up the total composition of asbestos.[13] (Kamp, 2009). One of the most obvious differences between fiber types is their shape. Some asbestos fibers are serpentine and others are straight and rod-like.[13] (Kamp, 2009). The

most dangerous fibers are long and thin because they have the ability to penetrate through the epithelium of the lung.[11] (Robinson et. al, 2005). When these asbestos fibers are inhaled, they are able to repeatedly scratch the lungs.[9,11] (Chen & Pace, 2012; Robinson et. al, 2005). This starts a cycle of damage, inflammation, and attempts at repair.[11] (Robinson et. al, 2005). As the asbestos fibers damage the lungs repeatedly, scarring can lead to plaque buildup and cancer.[9,11] (Chen & Pace, 2012; Robinson et. al, 2005). It is also thought that the inhalation of asbestos fibers and the resulting inflammation triggers the activation of certain macrophages in the epithelium. It is possible that the triggering of these macrophages is one of the first steps that lead to mesothelioma.[14] (Suvatne & Browning, 2011).

Another mechanism through which asbestos fibers may lead to cancer is through the disruption of mitosis.[9,11] (Chen & Pace, 2012; Robinson et. al, 2005). During mitosis, mitotic spindles form and connect to the chromosomes of the cell. The spindles then shorten and pull apart the chromosomes to complete cell division. Asbestos fibers are able to sever these mitotic spindles.[11] (Robinson et. al, 2005). When this happens, aneuploidy occurs where the cells are either missing a chromosome or have an extra chromosome.[9,11] (Chen & Pace, 2012; Robinson et. al, 2005). This type of cell chromosome damage is characteristic of mesothelioma.[11] (Robinson et. al, 2005).

Asbestosis and Mesothelioma

Asbestosis refers to the fibrosis of the lungs due to the inhalation of asbestos fibers. A question plaguing scientists was whether or not asbestosis is a requirement for malignant mesothelioma to occur. Through multiple studies, it seems like having asbestosis is not a requirement for the development of malignant mesothelioma resulting from asbestos exposure. However, there have been studies suggesting that there is a direct correlation between rate of asbestosis and mesothelioma.[13] (Kamp, 2009). This means that people with asbestosis have a higher risk of consequently developing malignant mesothelioma. In other words, asbestosis might be a better predictor of increased mesothelioma risk than measures of asbestos exposure.[13,14] (Kamp, 2009; Suvatne & Browning, 2011). While it is not completely clear whether or not asbestosis is needed for the development of malignant mesothelioma, it has been generally agreed upon that patients must have at least mild fibrosis of the lungs in order to develop malignant mesothelioma.[14] (Suvatne & Browning, 2011).

Diagnosis and Treatment

As with many cancers, malignant mesothelioma relating to asbestos can be difficult to diagnose. One difficulty of diagnosis is that there is a latency period that lasts anywhere from 30 to 50 years from first exposure.[10] (Park et. al, 2012). Another problem is that mesothelioma does not have a preference for the lobe of the lung in which it develops. This means that location cannot be used in determining whether or not the mesothelioma is caused by asbestos exposure or something else. In general, screening for lung cancer is not suggested when risk levels are low. In order to determine if a patient is at high enough risk to be monitored for mesothelioma from asbestos exposure, the Helinski criteria have been created.[14] (Suvatne & Browning, 2011). These criteria can be seen in the table below:

Commented [H20]: Strangely phrased

Table 2: The Helsinki Criteria. Credit: J. Suvatne, & R.F. Browning.

TABLE 1. Evidence of significant exposure according to Helsinki Criteria[49]
Cumulative exposure of 25 fiber-years
Occupational history with 1 y of heavy exposure or 5-10 y of moderate exposure
Presence of asbestosis
Retained amphibole fiber levels of 2 million (>5 μm) per gram dry lung tissue, or 5 million if >1 μm, or 5-15 asbestos bodies per milliliter of bronchoalveolar lavage fluid

When looking for mesothelioma, CT scans are used to image the lungs and look for the tumors (Suvatne & Browning, 2011).[14] Unfortunately, the prognosis of patients diagnosed with malignant mesothelioma is poor: 9 to 12 months after diagnosis.[10] (Park et. al, 2012). However, there are many different treatments that are being used in attempts to increase the life expectancy of mesothelioma patients. Some of these treatments include chemotherapy, injection of white blood cells from the patient into the tumor, and gene therapy.[11,12] (Davies, 1970; Robinson et. al, 2005).

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Prevention

The best way to prevent the development of mesothelioma from asbestos is by avoiding contact with asbestos. Since asbestos has been banned in the United States, the future exposure risk is relatively low. However, in countries where asbestos has not been banned, it is very important to be aware of the materials used in construction. The group that is the most affected

are people working in the construction and demolition of buildings that use asbestos.[13] (Kamp, 2009). Workers that are around asbestos often, should wear personal protective equipment.[14] (Suvatne & Browning, 2011). This equipment would consist of a mask that would be worn over the nose and mouth to avoid the inhalation of asbestos. It is also important to wear a special full-body outfit in order to prevent the transfer of asbestos fibers to the home on the workers' clothes.[14] (Suvatne & Browning, 2011).

Multiple studies have also shown that when a person who has been exposed to asbestos smokes, their likelihood of developing mesothelioma increases significantly.[15] (Yano et. al, 2010). The effect of smoking on the lungs is additive to the effect of asbestos on the lungs.[15,16] (Yano et. al, 2010; Markowitz et. al, 2013). In one study, it was shown that the mesothelioma mortality risk of insulation installers halved within 10 years of smoking cessation.[16] (Markowitz et. al, 2013). In 30 years, their risk converged with that of people who had never smoked.[16] (Markowitz et. al, 2013). This study clearly shows that in order to reduce the risk of developing mesothelioma induced by asbestos, one should quit smoking as soon as possible.

Asbestos Regulations

There are numerous regulations on asbestos under various government agencies. Some of these regulations limit asbestos exposure and usage while others outright ban its incorporation into products completely. All the regulations play a major role in preventing respiratory diseases and cancers resulting from asbestos exposure. Regulations implemented by the Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), Consumer Product Safety Commission (CPSC), and Mine Safety and Health Administration (MSHA) will be described along with their impacts.

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EPA Regulations

The EPA was established in 1970 to protect human health and the environment within the United States. Since its establishment, the EPA has implemented several regulations addressing asbestos exposure and limiting it. One of these regulations was the Asbestos-Containing Materials in Schools Rule (40 CFR Part 763, Subpart E). Under the Asbestos Hazard Emergency Response Act (AHERA), this rule mandated schools to be inspected for potential asbestos construction material. If asbestos is found, management plans must be prepared and response

activities implemented to prevent or mitigate asbestos exposure for those enrolled and employed at the school.

Under the Clean Air Act, NESHAPs have been established for multiple hazardous air pollutants with asbestos being no exception. The asbestos NESHAP (40 CFR Part 61, Subpart M) sets guidelines on renovation and demolition of buildings that contain asbestos with the goal of preventing or at least minimizing exposure to asbestos fibers.[17] All buildings are required to undergo inspection for asbestos prior to renovation or demolition. Furthermore, work practice procedures aimed at controlling asbestos emissions must be enforced during renovation or demolition. Discarded asbestos material must be processed correctly by thoroughly wetting it, sealing it in leak tight containers, and disposing in a landfill designed for asbestos waste.[17] Additionally, 40 CFR Part 61 sets standards for asbestos mills, roadways within asbestos mills or made with asbestos, and product manufacturing units stating that asbestos emissions from these sources must not release to outside air and asbestos particulate control methods must be utilized.[18]

In addition, the EPA is responsible for abandoned properties contaminated with asbestos as they pose a serious health and environmental hazard for those in the surrounding area. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or Superfund, was promulgated to remediate abandoned sites containing hazardous waste. 40 CFR Part 302.4 states that asbestos is a hazardous substance applicable to CERCLA intervention. Traditionally, remediation would normally occur when asbestos concentrations exceeded 1 percent but now the EPA employs a site-specific risk-based approach to determine if action is required if concentrations are below 1 percent.[19] For employees under the EPA and other government agencies that must go on-site to assess and perform these remediation practices, the EPA established the Asbestos Workers Protection rule (40 CFR Part 763, Subpart G). Under Section 6 of the Toxic Substances Control Act (TSCA), the Asbestos Worker Protection rule mandates proper protections for state and local government employees that may be exposed to asbestos who were not previously covered by OSHA's asbestos regulations.[20] This regulation effectively applies the standards, including exposure limits, from 29 CFR 1910.1001 (Asbestos General Standard) and 29 CFR 1926.1101 (Asbestos Construction Standard) to uncovered state and local government employees.[20]

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OSHA Regulations

OSHA is responsible for ensuring that working conditions for employees in the United States are acceptable and safe by establishing and overseeing occupational safety and health standards.[21] Two rules uphold worker safety and health when dealing with asbestos exposure. The first rule is the Asbestos General Standard (29 CFR 1910.1001) which outlines permissible exposure limits and procedures to control exposure including containment, respiratory protection, worker training, proper labeling, and disposal of asbestos.[21] Allowable exposure limits are 0.1 fibers per cubic centimeter of air in a standard eight hour working day or no more than one fiber per cubic centimeter.[22] The scope and application for 29 CFR 1910.1001 applies to all industries covered by OSHA besides construction work and ship manufacturing, repair, and destruction occupations.[22] OSHA ruling on asbestos exposure and destruction in construction occupations is outlined in the Asbestos Construction Standard (29 CFR 1926.1101) and covers proper practices to be used during demolition and renovation activities, worker training requirements, disposal guidelines, and allowable exposure limits.[21] The acceptable exposure limits for the Asbestos Construction Standard are the same as the ones listed under the Asbestos General Standard: 0.1 fibers per cubic centimeter in an eight hour working day or no more than one fiber in a 30 minute period.[23]

CPSC Regulations

The CPSC is responsible for establishing bans and restrictions on consumer products in order to protect people from electrical, chemical or mechanical hazards and also for products that may be harmful to children. Regulations associated with asbestos under CPSC, ban particular products that have been shown to put consumers in danger by exposure to hazardous concentrations of asbestos fibers. One of these bans applies to consumer patching compounds containing respirable free-form asbestos (16 CFR Part 1304). 16 CFR Part 1304 requires the banning of patching products that contain purposely added asbestos due to the possibility of the asbestos in the patching substance becoming airborne under instructed use.[24] According to this rule, patching products are defined as anything used to eliminate cracks in buildings and in which the dried excess is sanded smooth after application. The patching compounds may also not be manufactured and shipped for sale to public consumers for eventual usage in buildings.[24] However, patching materials marketed, labeled, and sold only for industrial usage are not

Commented [H25]: I'm confused as to what is the second rule. May want to state both in the sentence.

Commented [NM26]: What are the concentrations of asbestos that lead to human health problems in comparison to the standards?

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subjected to the ban except when used in locations where consumers have open access such as schools, hospitals, personal residences, and other public buildings.[24]

Another ban under the CPSC is for artificial emberizing materials containing respirable free-form asbestos (16 CFR Part 1305). 16 CFR Part 1305 bans artificial emberizing materials, or ash and embers, containing asbestos which have the potential to become airborne under high temperatures. Emberizing materials will glow and smolder when undergoing combustion and were typically sold separately or applied to artificial fireplace logs.[25] This application of emberizing materials on artificial fireplace logs has no impact on its heat value and served a purely decorative purpose.[25] Speaking of decorative purposes, the CPSC also is responsible for 16 CFR § 1500.17(a)(7) which bans clothes that contain asbestos that do not serve the singular purpose of protection against fire and are made so that asbestos fibers can become airborne under intended usage.[26]

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MSHA Regulations

MSHA is responsible for protecting the health and safety of miners within the United States. 30 CFR Parts 56 and 57, Subparts D safeguard miners exposed to asbestos within their working conditions. 30 CFR Part 56 Subpart D applies to surface mines while 30 CFR Part 57 Subpart D pertains to underground mining activity. Both regulations limit miners' chances of developing respiratory diseases and cancer from asbestos by establishing the requirement followed by OSHA that worker exposure cannot surpass an airborne concentration of 0.1 fibers per cubic centimeter in an eight hour working day or exceed one fiber per cubic centimeter of air within a 30 minute period.[27] These regulations also require that control strategies be used to limit exposure to asbestos fibers by various methods including dilution of contaminated air with uncontaminated air, ventilation, and prevention of fiber expulsion.[27] Furthermore, if the previous methods cannot be utilized feasibly, respiratory equipment must be provided if airborne conditions surpass acceptable concentrations.[27]

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Conclusions

Commented [NM33]: Good conclusion. Consider including future direction for this research topic.

Asbestos enjoyed popularity throughout history due to its intrinsic properties as it encompassed numerous beneficial attributes such as being fire and chemical resistant. These characteristics made it highly useful in the products ranging from construction materials to

automobile engines and hence was most heavily mined and used during the industrial boom following the Second World War. Unfortunately, this is also when the extremely hazardous nature of asbestos was discovered as a result of its fibrous structure. Asbestosis and mesothelioma are the two major diseases resulting from extensive asbestos fiber exposure. The United States has reached its peak in incidence rate for these diseases due to regulations and protective equipment which limit and prevent asbestos exposure. However, this is not the case around the world where incidence rates continue to rise. A possible explanation for this trend is the lack of regulations in place by other, developing countries, eager to boost their economies from the lucrative global asbestos market. Additionally, this observation can be attributed to large smoking prevalence rates in some countries which aggravate and encourage these ailments further.

Commented [H34]: The use of "other "suggests that the US is a developing country. Consider taking "other" out.

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Appendix D: Peer Review Agreement

Team Formaldehyde authorized Team PM 2.5 to review and provide comments for this report. Likewise, Team PM 2.5 authorized Team Formaldehyde to review and provide comments for their respective report.