Black Lung Incidence Literature Review

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LIST OF ACRONYMS

CDC – Centers for Disease Control and Prevention

CMDLD – coal mine dust lung disease

COPD – chronic obstructive pulmonary disease

CWHSP – Coal Workers Health Surveillance Program

CWP – coal workers' pneumoconiosis

DCMWC – Division of Coal Mine Workers' Compensation

DDF – dust-related diffuse fibrosis

DOL – U.S. Department of Labor

EPA – Environmental Protection Agency

HRSA – Health Resources & Services Administration

ICD – International Classification of Diseases

ICD-CM – International Classification of Diseases, Clinical Modification

ILO – International Labour Office

MSHA – Mine Safety and Health Administration

NIOSH – National Institute for Occupational Safety and Health

PM – particulate matter

PMF – progressive massive fibrosis

EXECUTIVE SUMMARY

One component of the Mine Safety and Health Administration's (MSHA's) mission to "prevent death, illness, and injury from mining and promote safe and healthful workplaces for U.S. miners" is protecting coal miners and coal mining communities from black lung disease ("Mission"). In support of that mission, this literature review expands DOL's knowledge base by synthesizing the available evidence related to black lung disease; coal mining and black lung disease; black lung incidence related to residential coal use; black lung incidence in Appalachia; and black lung incidence among Navajo Nation residents. Table 1 lists the key findings from this literature review.

Table 1: Key literature review findings

Literature review topic	Key findings
Black lung disease overview	• The narrowest definition of black lung disease describes diagnoses of coal workers' pneumoconiosis (CWP), but a broader set of illnesses and health impacts are associated with coal mining and use. • Because the symptoms and respiratory illnesses associated with coal dust can often resemble other illnesses, a well-documented history of exposure or an autopsy is the only conclusive way to determine the cause. • Undercounts in the caseload of black lung disease in the United States are attributed to factors including low uptake of screenings from the Coal Workers' Health Surveillance Program (CWHSP) and low compensation approval rates
Link between coal mining and black lung disease	• The link between coal dust and CWP is well established and accepted by the medical community, though no definitive scientific explanation for this connection has been identified. • CWP prevalence has been increasing in the United States since the 1990s.
Black lung incidence related to residential coal use	• Residential coal burning poses a significant risk to public health. • Indoor air pollution from residential coal use has been shown to increase the risk of lung cancer and respiratory illness, particularly among women and children.
Black lung incidence in Appalachia	• Central Appalachia is experiencing a sharp rise in CWP cases after the late 1990s, as shown in a prevalence study of radiographs collected from 1970 to 2017; one in five long-tenured central Appalachian coal miners has evidence of CWP. • Appalachian communities in close proximity to coal mines experience higher rates of mortality and morbidity from a range of respiratory and other illnesses.
Black lung incidence among Navajo Nation residents	• Coal mining has historically been important to the Navajo economy. • Available studies show high levels of residential coal use in the Navajo Nation. • There is a high public health burden in the Navajo Nation related to coal use and coal mining.

This report supports the conclusion that unsafe practices in coal mining, coal processing, and residential coal burning continue to put people at risk of black lung disease. The information from this literature review can support MSHA's efforts to address the rise in black lung prevalence by shedding light on where this challenge exists and reasons why some communities have higher rates of black lung disease.

1 INTRODUCTION

The Federal Mine Safety and Health Act of 1977 (Mine Act) chartered the Mine Safety and Health Administration (MSHA), whose mission is to "prevent death, illness, and injury from mining and promote safe and healthful workplaces for U.S. miners" (29 U.S.C. § 557a; 30 CFR § 72.1; 30 CFR § 72.510; "Mission"). One component of this mission is to protect coal miners and coal mining communities from black lung disease, which encompasses respiratory diseases (such as coal workers' pneumoconiosis and silicosis) associated with exposure to coal dust. The Mine Act included a provision for benefits to be provided to coal miners and their families due to death or disability from black lung disease (30 U.S.C. § 901). Recent MSHA efforts to combat black lung disease include issuing a final rule in 2014 that mandates increased dust sampling in mines and reduced respirable dust standards (30 CFR § 70.202(c), 30 CFR § 70.203(c). In support of these efforts, Summit Consulting (Summit) conducted this literature review to explore the current state of knowledge on black lung definitions, diagnosis, and measurement; coal mining and black lung disease; the link between residential coal use and black lung disease; black lung incidence in Appalachia; and black lung incidence among Navajo Nation residents.

In conducting this literature review, Summit followed a rigorous methodology and documentation process. Our methodology—documented in more detail in Appendix B—included (1) developing key search terms, (2) identifying inclusion and exclusion criteria, (3) conducting the initial literature search, (4) performing analysis, and (5) completing additional literature searches as needed. Summit also solicited relevant sources from the project subject matter expert, Dr. Robert Finkelman, a research professor at the University of Texas at Dallas Department of Geosciences with expertise on the social and health impacts of coal and black lung disease. Dr. Finkelman's research has focused on the health impacts of coal, including residential coal use. The full list of all sources reviewed is included in Appendix C. The list of sources cited within this literature review is included in Appendix A.

The remainder of this paper synthesizes the available literature on black lung disease to answer the research question "What is the current state of knowledge on black lung disease, particularly as it relates to coal mining, residential coal use, Appalachian populations, and Navajo Nation residents?" Findings are organized as follows:

(1) Black lung disease definitions, including relevant respiratory illnesses, diagnosis, and measurement challenges
(2) Coal mining and black lung disease
(3) Black lung incidence related to residential coal use
(4) Black lung incidence in Appalachia
(5) Black lung incidence among Navajo Nation residents

2 BLACK LUNG DISEASE OVERVIEW

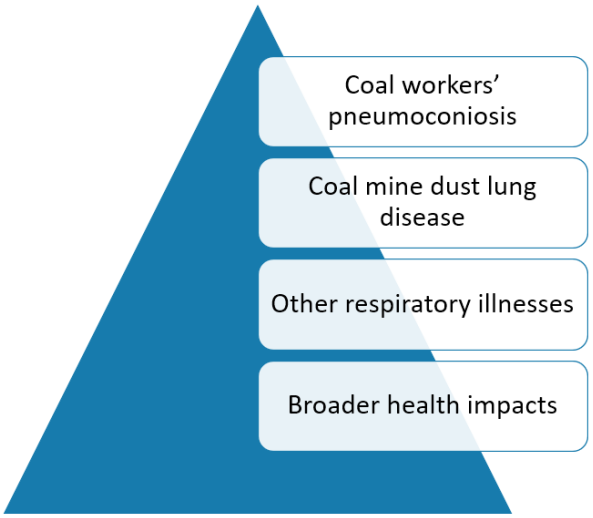
The term black lung disease is commonly used to describe a wide variety of respiratory diseases associated with exposure to coal dust via mining activities and residential coal use. For example, MSHA's definition of black lung disease includes diseases caused by respirable coal mine dust such as coal workers' pneumoconiosis, emphysema, silicosis, and bronchitis (MSHA, "End Black Lung"). However, variation in definitions of black lung disease allow for inconsistency across measures of nationwide incidence.[1] Definition, diagnosis, and measurement challenges make it difficult to capture the full universe of black lung incidence in the United States.

Black lung disease definition. For the purposes of this literature review, any discussions of "black lung" or "black lung disease" include the spectrum of illnesses covered by Coal Mine Dust Lung Disease (CMDLD), unless otherwise specified (e.g., if a source specifically discussed CWP, the term "CWP" is used).

Diseases associated with exposure to coal dust. There is a wide variety of respiratory diseases associated with exposure to coal dust, whether due to coal mine employment or non-occupational exposure. As Chris Hamby points out in his book *Soul Full of Coal Dust*, "there is not *one* disease that afflicts coal miners; it is a *family* of diseases, all with the same cause" (Hamby 2020, 55). This wide range of diseases is organized in Figure 1 from the narrowest possible definition of black lung disease at the top of the pyramid, to the broadest at the bottom.

Coal Worker's Pneumoconiosis (CWP). The narrowest interpretation of black lung disease is coal workers' pneumoconiosis[2] (CWP), a lung disease caused by chronic inhalation of coal dust for which there is no cure (Paul, Adeyemi, and Arif 2022; Cecil 2021; Finkelman, Wolfe, and Hendryx 2021; Arif et al. 2020; Zosky et al. 2016; Laney and Weissman 2014; Lockwood 2012, 52, 125-6; Huang et al. 2006; Royal 2019). CWP is shown at the top of Figure 1. Inhaled coal dust accumulates in the lungs, causing inflammation and the formation of lesions called coal macules (McCunney, Morfeld,

Figure 1: Categorizing the health impacts of coal dust exposure, from narrowest to broadest interpretation



Coal worker's pneumoconiosis represents the narrowest interpretation of black lung disease. Coal mine dust lung disease captures a broader spectrum of disease, which can include CWP, silicosis, mixed-dust pneumoconiosis, PMF, dust-related diffuse fibrosis (DDF), COPD, and chronic airway diseases. Other respiratory diseases associated with coal dust exposure include lung cancer, asthma, decreased lung function, and acute lower respiratory infections. Finally, coal dust exposure is also associated with broader health impacts including low birthweight in newborn infants, increased infant mortality, neurological effects, mental illness, cataracts and immune system impairment.

[1] Summit also conducted a statistical analysis of black lung prevalence across the United States. The findings of this quantitative analysis can be found in the separate Black Lung Incidence Study final report.
[2] The etymological roots of the term "pneumoconiosis" are *pneumo* meaning "relating to the lungs" and *konis* meaning "dust" (Hamby 2020, 127; Akgun 2018).

and Payne 2009). Although the link between CWP and coal dust is well established and accepted by the medical community, no definitive scientific explanation for this link has been identified[3] (Song et al. 2022; Sun, Kinsela, and Waite 2022; Zosky et al. 2021 Harrington et al. 2012; Cohn et al. 2006; Kuempel et al. 2003).

CWP cases can be classified as simple or complicated, based on the size of the lesions (Arif et al. 2020; NIOSH 2020). Simple CWP is characterized by small nodules (1- to 2-mm) made up of immune and inflammatory cells, collagen fibers, and coal dust (Arnold 2016). Symptoms can include chronic cough, increased phlegm production, and shortness of breath (Arnold 2016). Simple CWP can also be asymptomatic, which could lead to undercounts of the true number of cases if asymptomatic cases are not diagnosed (Paul, Adeyemi, and Arif 2022; Zosky et al. 2016; Hendryx et al. 2013; Finkelman et al. 2002). Simple CWP can develop into progressive massive fibrosis (PMF)—otherwise known as complicated CWP—as the size of coal nodules increase and begin to tear the surrounding lung tissue (Zosky et al. 2016; McCunney, Morfeld, and Payne 2009; Finkelman et al. 2002). As the most severe form of CWP, PMF is a "rapidly progressive and often fatal disease" (Cecil 2021; Reynolds et al. 2018; Lockwood 2012, 126). The risk of developing PMF increases the longer a coal miner has worked, due to a direct relationship between the amount of coal dust inhaled and the incidence and severity of CWP (Lockwood 2012, 52; Finkelman et al. 2002).

Although CWP represents the narrowest definition of black lung disease, there is some variation in how the term black lung disease is used. CWP itself has differing clinical and legal meanings in the United States, as shown in Table 2 (Laney and Weissman 2014).

Table 2: Clinical versus legal definition of CWP

Clinical definition	Legal definition
"interstitial disease caused by inhalation of coal mine dust" (Laney and Weissman 2014).	"chronic dust disease of the lung and its sequelae, including respiratory and pulmonary impairments, arising out of coal mine employment" (30 U.S.C. §902(b)).

The legal definition of CWP is broader than the clinical definition in terms of specific diagnoses, as it encompasses additional diseases, such as Chronic Obstructive Pulmonary Disease (COPD) (Laney and Weissman 2014).[4] Even within some government sources, the definition of black lung disease varies. For example, although many government sources (such as the Black Lung Benefits Act) borrow the definition of CWP to define black lung disease, a definition from an archived MSHA website titled *End Black Lung: Act Now* (accessed January 24, 2023) defines black lung disease as CWP, emphysema, silicosis, and bronchitis.

Coal Mine Dust Lung Disease (CMDLD). In its lay usage, "black lung" can also be used to refer to other forms of pneumoconiosis as well as other diseases such as emphysema and chronic bronchitis (Hamby 2020, 185). According to Petsonk, Rose, and Cohen (2013), the "spectrum of lung disease associated with coal mine dust exposure is broader than generally recognized," including more than just the "historical interstitial lung diseases" CWP, silicosis, and mixed-dust pneumoconiosis. The term CMDLD—shown in the second row in Figure 1—has been introduced to capture this broader spectrum of disease, which can include CWP, silicosis, mixed-dust pneumoconiosis (associated with exposure to

[3] Quartz, pyrite, and bioavailable iron have been theorized to be potential causal factors of illness (Harrington et al., 2012; Schoonen et al. 2010; Cohn et al. 2006).
[4] The legal definition, however, is narrower in terms of disease origin, focusing on coal mine employment.

both coal and crystalline silica dusts), PMF, dust-related diffuse fibrosis (DDF), COPD, and chronic airway diseases, such as emphysema and chronic bronchitis (Karatela, Caruana, and Paul 2022; Somers 2017; Laney and Weissman 2014; Petsonk, Rose, and Cohen 2013).

While CWP is specific to coal workers, the term pneumoconiosis itself represents a variety of respiratory pathologic diagnoses resulting from the inhalation of coal dust, including asbestosis, silicosis, CWP, and pneumosiderosis ("welder's lung" from inhalation of iron dust) (Arif et al. 2020; Hamby 2020, 127; Congressional Research Service 2019; Cohen 2016). This broader definition includes respiratory illnesses related to non-occupational exposure but could capture respiratory illness not due to coal dust specifically (given the potential inclusion of pneumosiderosis).

Other respiratory illnesses. Exposure to coal through coal mining, residential coal use, or outdoor air pollution can also increase rates of other respiratory illnesses not typically included in the definitions of black lung disease or CMDLD. This category is shown in the third row in Figure 1. These other respiratory illnesses include:

- Lung cancer (Finkelman, Wolfe, and Hendryx 2021; Buchanan, Burt, and Orris 2014; Petsonk, Rose, and Cohen 2013; Hosgood et al. 2010; Galeone et al. 2008; Torres-Duque et al. 2008)
- Asthma (particularly in young children) (Buchanan, Burt, and Orris 2014)
- Decreased lung function (Finkelman, Wolfe, and Hendryx 2021; Kerimray et al. 2017; Buchanan, Burt, and Orris 2014)
- Acute lower respiratory infections (particularly in children under 5) (Finkelman, Wolfe, and Hendryx 2021; Buchanan, Burt, and Orris 2014)

Broader health impacts. Beyond respiratory illnesses, there is literature documenting other negative health impacts from coal exposure, including low birthweight in newborn infants (Finkelman, Wolfe, and Hendryx 2021), increased infant mortality (Finkelman, Wolfe, and Hendryx 2021), neurological effects (Finkelman, Wolfe, and Hendryx 2021), mental illness (Braithwaite et al. 2019), cataracts (Finkelman, Wolfe, and Hendryx 2021; Torres-Duque et al. 2008), immune system impairment (Kerimray et al. 2017), cardiovascular problems (Zierold, Hagemeyer, and Sears 2020), and chronic heart, lung, and kidney diseases among coal mining communities (Karatela, Caruana, and Paul 2022). Additionally, if coal has been mineralized, it can release toxic trace elements, such as arsenic, fluorine, mercury, antimony, and thallium upon burning (Finkelman et al. 2002). Exposure to these toxins can lead to additional negative health impacts (Finkelman et al. 2002). Although these additional health impacts are outside of the scope of this literature review, their existence should be noted. These category of health impacts is shown at the bottom of the triangle in Figure 1.

Note on silicosis:
MSHA recently announced a proposed rule change to address health hazards from silica dust exposure, which can lead to severe illness including silicosis and PMF (MSHA 2023). This rule change was announced after this literature review had been completed. This literature review focused on black lung diseases that include silicosis, though sources that solely discussed silicosis were not reviewed. While some literature defines which specific illnesses are included in their use of the term black lung disease, others use this term without providing a definition. Unless otherwise noted throughout this report (usually in specific references to CWP), silicosis is included in the discussion of black lung disease more generally. Given the announced rule change, MSHA may consider conducting a follow-on literature review that focuses specifically on silicosis—rather than on black lung disease more broadly—to supplement the findings of this report.

Diagnosis. Extensive documentation exists providing detailed instruction on interpreting the specific size, location, and appearance of lesions and other symptoms to diagnose black lung disease. According to Petsonk, Rose, and Cohen (2013), the diagnosis of respiratory diseases due to coal mine exposure requires two factors: medical tests such as lung imaging and pulmonary function testing coupled with a detailed history of exposure (often occupational) and respiratory symptoms. The symptoms and respiratory illnesses associated with exposure to coal dust can easily resemble other respiratory illnesses; the only way to conclusively pinpoint the cause to coal dust is through a well-documented history of exposure (Arnold 2016) or through autopsies. This makes the history of exposure "a critical component in the diagnosis" (Petsonk, Rose, and Cohen 2013).

International Labour Office standards and B readers. The International Labour Office (ILO) publishes standards for classifying pneumoconiosis to ensure uniformity in the description and recording of "radiographic abnormalities in the chest provoked by the inhalation of dusts" (ILO 2011). To ensure that the ILO classification scheme is applied consistently, the National Institute for Occupational Safety and Health (NIOSH) created the B Reader Program in 1974 to teach physicians the ILO classification system and certify them as "B readers" upon completion of their training (Chest Radiography 2022; Zosky et al. 2016). For a coal worker to be eligible for compensation under the Federal Black Lung Program, NIOSH requires two certified B readers to classify radiographs "for the presence, profusion, and type of lung parenchymal abnormalities" (Blackley, Halldin, and Laney 2018).

Even with sophisticated imaging technology following the ILO standards, there is evidence of underdiagnosis of black lung disease among coal miners, as discussed in the sub-section below titled "Challenges in measuring black lung incidence."

Medical diagnostic codes. The Federal Black Lung Program pays Medicare disability claims based on specific medical codes used to indicate the presence of black lung disease (Kurth and Casey 2020). The International Classification of Diseases (ICD) classification system includes diagnostic codes for relevant diseases. Table 3 identifies the relevant black lung disease diagnostic codes (CMS 2022).[5]

[5] The universal use of ICD-10 codes was mandated in 2015 (CMS 2021), but the preceding ICD-9 codes may also be relevant in studies of historical black lung disease prevalence.

Table 3: Black lung disease diagnostic codes

Diagnosis Description*	ICD-9 CM** code	ICD-10*** CM code
Coal Workers' Pneumoconiosis	500	J60
Asbestosis (Pneumoconiosis due to asbestos and other mineral fibers)	501	J61
Pneumoconiosis due to talc dust	-	J620
Pneumoconiosis due to other silica or silicates****	502	J62.8
Pneumoconiosis due to other inorganic dust	503	J636
Pneumonopathy due to inhalation of other dust	504	-
Pneumoconiosis, unspecified	505	J64

*Table sources: CMS 2022, Kurth and Casey 2020

**International Classification of Diseases (ICD) Clinical Modification (CD) is a diagnostic system used to code and classify medical diagnoses.

*** The universal use of ICD-10 codes was mandated in 2015 (CMS 2021), but the preceding ICD-9 codes may also be relevant in studies of historical black lung disease prevalence.

****Also known as silicosis

With the exception of the final row in the above table, all the ICD codes require exposure for diagnosis; for example, ICD-10 CM code J62.8 requires pneumoconiosis to be attributed to other silica or silicates. According to Kurth and Casey (2020), there may be instances where a healthcare professional is unable to make a causal connection to talc dust, silica, other dust, etc. due to lack of medical records or awareness of a patient's occupational history. In these instances, the healthcare professional may use other ICD codes related to respiratory and cardiovascular diagnoses, but not associated with talc dust, silica, other dust, etc. This can potentially result in a misclassification of disease (Kurth and Casey 2020).

Overall, the diagnosis of black lung disease is a complex process, relying on certified B readers following ILO standards to examine specific size, location, and appearance of lesions in addition to other common symptoms, such as a chronic cough or shortness of breath. Because the symptoms and respiratory illnesses associated with coal dust can often resemble other illnesses, a well-documented history of exposure or an autopsy is the only conclusive way to determine the cause (Arnold 2016; Petsonk, Rose, and Cohen 2013).

Undercounts in black lung incidence. Undercounts in diagnosed black lung cases makes it difficult to measure the full universe of incidence in the United States. Blackley, Halldin, and Laney (2018); Shriver and Bodenhamer (2018); and Hendryx et al. (2013) have written about the reasons for likely undercounts among miners. Firstly, there is low uptake of the voluntary, free radiograph screenings which the NIOSH Coal Worker's Health Surveillance Program (CWHSP) offers to coal miners. Although these screenings are crucial in identifying CWP and determining disease prevalence, the CWHSP has had an annual participation rate of only 30% to 40% of miners in recent decades (Potera 2019; Blackley, Halldin, and Laney 2018). Shriver and Bodenhamer (2018) theorize several reasons for the low participation rate, including a disincentive to seek detection or diagnosis opportunities due to the risk of being fired,[6] and logistical difficulties in traveling to distant screening facilities.

Low worker's compensation approval rates may lead to undercounting of cases. The rate of miners successfully receiving a CWP diagnosis and approval for compensation through the Federal Black Lung Program is relatively low, although it has improved since the 1990s. In the 1990s, only 4% of initial

[6] Some states like Kentucky have a statute of limitations requiring miners to make a worker's compensation claim within a certain timeframe, which could make it more difficult to successfully file a claim (Shriver and Bodenhamer 2018).

benefit applications were approved (Toler 2002), compared to 15% of claims in 2013 (Hamby, Ross, and Mosk 2013), and 32% in 2022 (U.S. DOL 2023). The appeals process for denied claims is often lengthy, expensive, and unsuccessful for many miners (Royal 2019, Cartwright 2016). Cartwright (2016) points out that by the time a miner's case is won on appeal, coal mining companies have gathered evidence to reappeal and win based on a radiograph that has been reexamined by a different expert who has come to the opposite conclusion. In a letter to the editor of the *Social Determinants of Health* journal, an academic descended from Appalachian coal miners reported that in his experience miners feel that the Division of Coal Mine Workers' Compensation (DCMWC) request system is "unjust and biased against them" (Royal 2019). Low approval rates and the complex appeals process may discourage miners suffering from black lung disease from seeking the care and benefits to which they are entitled under the Black Lung Program (Royal 2019).

Additionally, miners have reported fears of workplace retaliation upon seeking diagnoses (Shriver and Bodenhamer 2018). In a 2016 PBS NewsHour interview, National Public Radio's (NPR's) Howard Berkes explained that although it is illegal for mining companies to fire miners due to a black lung disease diagnosis, "every single miner I have talked to in Appalachia in the last six years has said the same thing…What they fear is just even going to the NIOSH vans that come into their communities with x-ray equipment and being seen going into those vans—just that—can cause the mining company to say 'this guy might have black lung'" (PBS NewsHour 2016). The miners' opinion was that "if the mining company finds out, they'll lose their jobs, so they don't get tested" (PBS NewsHour 2016).

Because undercounts of black lung disease may conceal the full scope of disease incidence in the United States, comprehensive data collection and future rigorous research on this topic is needed to drive policy and industry change to mitigate the health impacts of coal on American workers.

Key takeaways:

- The narrowest definition of black lung disease describes diagnoses of coal workers' pneumoconiosis (CWP), but a broader set of illnesses and health impacts are associated with coal mining and use.
- Because the symptoms and respiratory illnesses associated with coal dust can often resemble other illnesses, a well-documented history of exposure or an autopsy is the only conclusive way to determine the cause.
- Undercounts in the caseload of black lung disease in the United States are attributed to factors including low uptake of screenings from the Coal Workers' Health Surveillance Program (CWHSP) and low compensation approval rates.

3 COAL MINING AND BLACK LUNG DISEASE

Historically, high rates of pneumoconiosis have occurred in mining settings with coal dust exposure (Perret et al. 2017; Patra et al. 2016; M. H. Ross and Murray 2004). As described in Section 2, illnesses included in the black lung disease umbrella such as CWP are associated with chronic inhalation of coal dust that causes inflammation and lesions in the lungs (Paul, Adeyemi, and Arif 2022; Cecil 2021; Finkelman, Wolfe, and Hendryx 2021; Arif et al. 2020; Royal 2019; Zosky et al. 2016; Laney and Weissman 2014; Lockwood 2012, 52, 125-6; McCunney, Morfeld, and Payne 2009; Huang et al. 2006). No definitive scientific explanation for this connection has been identified, despite the fact that the causal link between CWP and coal dust is well established and accepted by the medical community (Song et al. 2022; Sun, Kinsela, and Waite 2022; Zosky et al. 2021 Harrington et al. 2012; Cohn et al. 2006; Kuempel et al. 2003).

The mining methods used by a company and the job duties assigned to a worker impact coal miners' exposure to dust. (NIOSH 2020). For example, underground miners generally have greater exposure than surface miners (NIOSH 2020; Huang et al. 2006). Additionally, some duties such as those at coal transfer points on conveyer systems may lead to higher dust exposure (Huang et al. 2006). The Federal Mine Safety and Health Act of 1977—which chartered MSHA—includes provisions intended to protect coal miners exposed to coal dust. Under Part 90 of this legislation, coal miners who have been diagnosed with pneumoconiosis are eligible for a transfer to a different mine or position without discrimination, including pay reduction or termination (30 CFR § 90.103).

Figure 2 shows the nationwide prevalence of CWP among coal miners over time, starting shortly after the 1969 Federal Coal Mine Health and Safety Act.[7] The source of this data is a prevalence study using radiographic data collected by the CWHSP from working underground miners during 1970 to 2017 (Blackley, Halldin, and Laney 2018). The prevalence of the disease decreased after this legislation's provisions reducing the permissible limit for dust exposure (Shriver and Bodenhamer 2018; Laney and Weissman 2014). However, there has been a rise in prevalence since the 1990s (Laney and Attfield 2010; Laney and Attfield 2014). A study conducted by the Surveillance Branch of NIOSH's Division of Respiratory Disease Studies which combined data from the CWHSP and the Energy Information Administration to examine influence of variable worker participation on observed disease prevalence concluded that this increased trend in disease prevalence is accurate and does not reflect an upward bias due to CWHSP surveillance efforts (Laney and Attfield 2014). Although there is no clear explanation for the increase in CWP cases, theories include miners drilling through rock to access thinner coal seams, longer working hours leading to increased coal dust exposure, and lack of compliance with safety regulations (see Section 5).

[7] Summit's scan of datasets for use in a separate quantitative analysis found no available data prior to 1970.

Figure 2: Nationwide prevalence of CWP among coal miners with 25+ years of experience

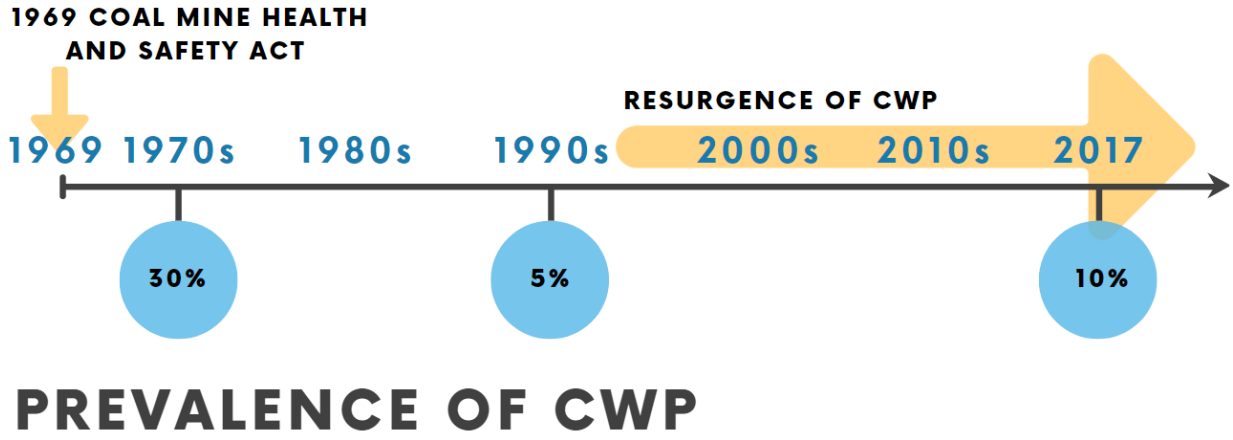


Figure source: Blackley, Halldin, and Laney 2018

While the incidence of CWP has grown notably since the 1990s (Laney and Attfield 2014; Laney and Attfield 2010), records of diagnosed incidences likely undercount the true number of black lung incidences in the United States, as discussed in Section 2. Although increased CWP prevalence is nationwide, the Appalachian region and the Navajo Nation are of specific interest to MSHA and are discussed in Sections 5 and 6, respectively. A prevalence study of radiographs collected from 1970 to 2017 showed a sharp rise in CWP cases in central Appalachia after the late 1990s (Blackley, Halldin, and Laney 2018).

Key takeaways:

- The link between coal dust and CWP is well established and accepted by the medical community, though no definitive scientific explanation for this connection has been identified.
- CWP prevalence has been increasing in the United States since the 1990s.

4 BLACK LUNG INCIDENCE RELATED TO RESIDENTIAL COAL USE

Not only are coal miners at risk of contracting black lung disease due to their profession, but black lung incidence is also associated with residential coal use (Chen et al., 2013, Hosgood et al. 2011, World Health Organization 2010, Zhang and Smith 2007). This section uses the broadest definition of black lung disease presented in Section 2, as studies focusing on respiratory disease due to residential coal burning generally do not use the term "black lung." These studies focus on illnesses such as COPD, lung cancer, and asthma, rather than CWP (which requires a mining-related occupation for a diagnosis).

There is evidence that coal burned in residential settings can create indoor air pollution resulting in negative health effects for people in the home.[8,9] The 2019 Global Burden of Disease Study ranked household solid fuels in the top 10 risk factors for global deaths, years of life lost, and disability-adjusted life years ("Household air pollution from solid fuels" 2020). Similarly, a 2010 report from the World Health Organization's International Agency for Research on Cancer concluded that emissions from indoor coal burning are carcinogenic (World Health Organization 2010).

Although research on residential coal use in the United States is scarce, there is a growing body of research from China and other countries on this topic. A review paper by Zhang and Smith (2007) identified around 200 such publications. While this section will focus largely on publications from China and other countries outside the United States, conclusions drawn from these data are applicable regardless of their country of origin.

Researchers have conducted extensive reviews of publications on the health effects of residential coal use. For example, a meta-analysis conducted by Hosgood et al. (2011) reviewed 25 studies from around the world and found a strong connection between residential coal burning and the risk of lung cancer. In another review study, Zhang and Smith (2007) reviewed approximately 200 publications and found evidence that, in addition to lung cancer, solid fuel use in China contributes to respiratory illness, acute respiratory infections, COPD, and lung function and immune system impairments. The release of toxic trace elements from burning coal residentially can also lead to arseniasis, fluorosis, selenosis, and mercury poisoning (Finkelman et al. 2002).

Residential coal burning creates a notable public health burden. The use of coal for residential cooking and heating is a primary source of indoor air pollution (Kerimray et al. 2017; Galeone et al. 2008; Torres-Duque et al. 2008; Zhang and Smith 2007). A 2013 study by Chen et al. analyzed total suspended particulate (TSP) data collected in China between 1991 and 2000 and found that average life expectancy is 5.5 years (95% CI: 0.8, 10.2) lower in northern China where the Chinese government provided free coal to homes for heating than in southern China, where coal was not provided. This difference was

[8] There is also evidence that indoor residential coal burning can contribute to outdoor air pollution levels in the surrounding community (Kerimray et al. 2017; Zhang and Smith 2007; Baker et al. 2006).

[9] There were several complicating factors in how the literature discussed this topic. For example, publications on residential coal burning often discuss "respiratory illnesses" as a broad group of negative health impacts. The phrase "black lung disease" was not commonly used, due to black lung disease's connection to coal mining. This required us to expand our search beyond just "black lung disease" to adequately capture the health effects of residential coal burning. Similarly, many publications focusing on this topic did not specifically explore coal burning, but instead explored "biomass" or "solid fuel," which include other fuels (such as wood or animal dung) in addition to coal. Taken together, these factors made it sometimes difficult to draw connections specifically between respiratory illnesses and the burning of coal in the home.

"almost entirely due to an increased incidence of cardiorespiratory mortality," or deaths caused by poor ambient air quality (Chen et al., 2013). In 2019, the Global Health Observatory estimated that in China, household air pollution alone was responsible for 727,845 deaths (World Health Organization, accessed January 24, 2023). Our review found that women and children are particularly vulnerable to these negative health impacts; the following subsections will focus on these specific populations.

Women. Our review found that women—particularly women in China—are vulnerable to the health impacts of residential coal use. As Torres-Duque et al. (2008) notes in their review of 157 publications, "lung cancer in women has been clearly associated with household coal use." In their literature review, Zhang and Smith (2007) note that Xuanwei, China has undergone decades of scientific research to determine why non-smoking women in the region have uncommonly high rates of lung cancer. Women in Xuanwei rely on coal for heating and cooking, and they face increased exposure as they are primarily responsible for maintaining open ash pits used in agriculture (Barone-Adesi et al. 2012; Large et al. 2009).

Emissions and dust from "smoky" (bituminous) coal have been shown to be especially harmful. A respective cohort study comparing lung cancer mortality between 27,310 individuals using smoky coal and 9,962 users of smokeless coal found a "99-fold increase" in lung cancer mortality among Xuanwei women who were lifelong bituminous coal users, compared to "smokeless" (anthracite) coal users[10] (Barone-Adesi 2012). The differential impact on women is also notable here, as the same study found only a 36-fold increase for men (Barone-Adesi et al. 2012). The absolute risks of lung cancer death before aged 70 for bituminous coal users was 18% for men and 20% for women, compared to less than 0.5% among smokeless coal users of both sexes (Barone-Adesi et al. 2012). The researchers accounted for smoking habit and gender, two potential confounding factors, and found that those who burn smoky coal had higher rates of lung cancer regardless of those factors (Barone-Adesi et al. 2012). A review of seven studies from the International Lung Cancer Consortium (5,105 cases and 6,535 controls) had similar results: never smoking women in Asia who used coal had an associated risk of lung cancer (OR = 5.41; 95% CI, 3.65–8.00) (Hosgood et al. 2010). This research supports the connection between residential coal burning and coal-related respiratory illnesses. Although the research cited in this section predominantly focuses on women in Xuanwei, the scientific conclusions regarding the health risks of residential coal burning are relevant and applicable to all who burn coal in their homes.

Children. Research also indicates that children are particularly susceptible to coal-related illness due to residential coal exposure. In 2020, the World Health Organization estimated that the inhalation of particulate matter from household air pollution is responsible for almost half of all fatal lower respiratory infections among children under 5 years of age (World Health Organization 2022). Several studies from around the world point to residential coal burning as a source of respiratory illness and death in young children, especially in developing countries. A literature review by Zhang and Smith (2003) identified 13 studies in developing countries that suggest young children who live in homes that burn solid fuels have up to triple the risk of serious acute respiratory infections compared to children without solid fuel emissions exposure, even after accounting for confounding factors (Zhang and Smith 2003).

In China, a large epidemiologic study analyzing the respiratory health of 7,058 school children living in four Chinese cities found that monotonic, positive exposure-response relationships between exposure to residential coal burning for heat and cough with phlegm, bronchitis, wheezing, and asthma (Qian et al. 2004). Similarly, a study that followed a birth cohort of 452 children for three years in two districts of

[10] The study authors did not indicate whether this finding was statistically significant.

the Czech Republic found that "children exposed to indoor coal combustion experience a greater incidence of pediatrician-diagnosed [lower respiratory infection] during the first 3 years of life" (rate ratio = 1.45; 95% confidence interval, 1.07–1.97) (Baker et al. 2006). Additionally, they noted that "children living in homes where coal was used as the primary heating fuel experienced 45% greater [lower respiratory infection] incidence…compared with children whose homes were heated" by other methods (Baker et al. 2006).

Household air pollution in the U.S. Available literature suggests that—as with countries such as China and India—rural and poor areas of the United States, which burn solid fuel in the home, are at risk of similar negative health outcomes (Rogalsky et al. 2014). A 2014 study found concentrated solid fuel use in Appalachia (particularly parts of West Virginia and Kentucky) and the Four Corners region (New Mexico, Arizona, Utah, and Colorado), along with several other small pockets of concentration (Rogalsky et al. 2014). Although most of the solid fuel examined by this study was wood, the remainder was coke or coal. The burning of these materials is likely to expose households to "health effects similar to those elsewhere in the world who use coal as their primary household energy source" (Rogalsky et al. 2014). Additionally, rural areas with high proportions of solid fuel use in the home may "significantly contribute to ambient air pollution," increasing the risk of negative health impacts for the entire community (Rogalsky et al. 2014).

Key takeaways:

- Residential coal burning poses a significant risk to public health.
- Indoor air pollution from residential coal use has been shown to increase the risk of lung cancer and respiratory illness, particularly among women and children.

5 BLACK LUNG INCIDENCE IN APPALACHIA

Appalachian coal mines. As noted in Section 3 above, Appalachia is experiencing a resurgence of CWP cases, beginning with a sharp rise after the 1990s (Blackley, Halldin, and Laney 2018). Based on data collected between 2013 and 2017, one in five central Appalachian coal miners with over 25 years of experience have evidence of CWP, which is "the highest level recorded during the past 25 years" (Blackley, Halldin, and Laney 2018). Large clusters of severe CWP have also been observed in the region. In 2017, NIOSH and members of the Stone Mountain Health Services published a study of the demographic and radiographic characteristics of a cluster of 416 miners with PMF, identified by CWHSP pneumoconiosis screening (Blackley, Reynolds, et al. 2018). This was the "largest cluster of PMF reported in scientific literature" (Blackley, Reynolds, et al. 2018). The size of the cluster was not the only noteworthy finding; a high proportion of cases were found to be "exceptionally severe and rapidly progressive" (Blackley, Reynolds, et al. 2018). The authors emphasize that even as shocking as these results are, they likely undercount the true severity of PMF, given the data were only compiled from three clinics in one state. Additionally, some miners' cases were excluded because they fell outside the time range of the study, had non-B Reader classifications, or were missing a B Reader classification form (Blackley, Reynolds, et al. 2018). There are several theories to explain the increase in CWP cases among Appalachian coal miners, as described in the paragraphs below.

Drilling through rock to access thinner coal seams. Because many of the easily accessible and purer coal seams have already been mined, some of the remaining coal in Appalachia is in thinner or narrower seams buried beneath layers of silica-rich rock. The emergence of more powerful machines allows miners to drill through this rock to reach these coal seams, increasing their exposure to mixed-dust particulate matter and increasing silica-related lung health risks (Sisk 2023; Hamby 2020, 275; Ranavaya II, Ranavaya, and Chongswatdi 2020; Shriver and Bodenhamer 2018; Somers 2017; Cartwright 2016). Studies specifically focusing on Appalachia suggest this silica exposure can lead to increased prevalence of coal dust diseases (Cohen et al. 2022; Hall et al. 2019).

Long working hours. Present-day miners are working longer hours than they did prior to the resurgence of black lung disease (Hamby 2020, 274; Arnold 2016; Cartwright 2016). In the early 1980s, U.S. coal miners worked on average 1,800 hours per year; in 2008, they worked an average of 2,400 hours (Hamby 2020, 274). Researchers theorize that working longer hours increases overall exposure and decreases physical recovery time between mining shifts, potentially leading to higher rates of CWP (Hamby 2020, 274).

Lack of compliance with safety regulations. There is evidence of systematic disregard of legally mandated safety regulations, such as personal dust monitors—which track exposure to dust particles—being routinely left in another room with less dust (Hamby 2020, Reynolds et al. 2018). One study interviewed 19 miners to identify common practices in their Virginia workplaces and to describe their respiratory health (Reynolds et al. 2018). Of the 19, 14 reported consistent ventilation was not maintained in the mines; eight reported work practices were improved when MSHA or corporate officials were visiting; 13 reported "personal dust samplers were not worn properly in an effort to ensure compliance with the [permissible exposure limit]," meaning the devices were worn in a way that would cause records to incorrectly reflect a lower amount of exposure; and nine reported dust samplers were located in low-dust areas of the mine, such as air intake locations or power centers. Similarly, Hamby (2020, 166) documents a regular practice of dust samplers "[ending] up in the intake air not far from the mine's entrance, in dinner buckets, anywhere but in the dusty atmosphere where miners

actually worked." Disregarding or incorrectly following safety regulations designed to protect miners may increase the risk of CWP and contribute to higher rates of disease.

In addition to the above theories for the increase in CWP prevalence, it is worth noting that the size of the coal mines in Appalachia also contributes to safety-related issues. Hendryx et al. (2013) note that the mines "most likely to show increases [in CWP prevalence] are smaller coal mines (those with fewer than 50 employees) located in some areas of central Appalachia." Laney et al. (2012) explain that small mines often means "the potential for limited knowledge of, and resources for, dust reduction and disease elimination. Although larger mines can employ trained industrial hygienists and purchase state-of-the-art dust suppression measures, small mines may not have such opportunities." Employees in small Appalachian mines with fewer resources to comply with minimum health and safety requirements may have an increased risk for coal-related health impacts (Hendryx et al. 2013, Laney et al. 2012).

Undercounts CWP diagnoses among Appalachian coal miners. There is also evidence of undercounts in CWP diagnoses among Appalachian coal miners, due to the low uptake of CWHSP screening, as discussed in Section 2. In addition to fears of retaliation, there is evidence that feelings of personal and familial pride as well as fatalism in coal miners are a barrier to screening (Shriver and Bodenhamer 2018). The daughter of a coal miner summarized her father's attitude: "I'll work until they carry me out of there because that's what I'm supposed to do. I've got to provide for my family" (Shriver and Bodenhamer 2018).

Appalachian coal mining communities. There is evidence that coal mining, processing, and transportation activities can have an impact on local air pollution. Studies have shown that coal dust produced by mining can disperse to nearby communities (Huertas et al. 2014; Huertas et al. 2012). Several studies have used satellite imagery and other geospatial methods to show that activities such as ore excavation, transportation, and processing contributes to increased dust in and around coal mines (Huertas et al. 2014; Mandal et al. 2012).

Given the increase of air pollution near coal mining facilities, it is unsurprising that residential proximity to coal mines also results in higher disease burden. A systematic review of ecological studies found villages closer to coal mines had higher risks of mortality and morbidity from diseases including circulatory and respiratory diseases, congenital abnormalities, and cancer (Cortes-Ramirez 2018). This finding holds true when looking at Appalachia in particular. A study by Hendryx et al. (2008) conducted a national county-level analysis to identify the impact of coal mining intensity and other variables of interest on age-adjusted lung cancer mortality. This study found that areas of Appalachia with high levels of coal mining had significantly higher lung cancer mortality than the rest of Appalachia and the United States after adjusting for covariates such as smoking, poverty, and presence of current or former coal miners (Hendryx et al. 2008). Similarly, another study by Hendryx (2009) which investigated county-level, age-adjusted mortality rates between 2000 and 2004 for heart, respiratory, and kidney disease in relation to tons of coal mined found significantly higher levels of heart disease, respiratory disease, and kidney disease mortality rates among areas of Appalachia with high levels of mining compared to other populations.

It should also be noted that covariates specific to the Appalachian region may impact prevalence of respiratory illnesses. These include behavioral, demographic, or cultural factors; tobacco use; and poverty (Hendryx 2009; Hendryx et al. 2008).

Residential coal use. While there is a lack of literature focusing on the health impacts of residential coal use in this region, the clear evidence of residential coal burning suggests this is a topic deserving further

study. American Community Survey data from 2021 shows almost 59,000 households across 13 Appalachian states use coal for home heating or cooking. A 2013 study estimated that up to 30% of homes in Central Appalachia use wood or coal as their primary fuel for heating (Paulin et al. 2013).

As shown in this section, Appalachian populations have a high risk of black lung disease compared to the rest of the population due to a resurgence of CWP among coal miners, as well as exposure to coal processing activities and residential coal burning among coal mining communities.

Key takeaways:

- Central Appalachia is experiencing a sharp rise in CWP cases after the late 1990s, as shown in a prevalence study of radiographs collected from 1970 to 2017; one in five long-tenured central Appalachian coal miners has evidence of CWP.
- Appalachian communities in close proximity to coal mines experience higher rates of mortality and morbidity from a range of respiratory and other illnesses.

6 BLACK LUNG INCIDENCE AMONG NAVAJO NATION RESIDENTS

In comparison to the published literature on black lung disease among coal miners, the available information on black lung disease in the Navajo Nation is extremely limited, representing a gap in the available evidence.[11] This highlights the need for further research on black lung disease (and other respiratory illnesses associated with coal exposure) within the Navajo Nation. However, this gap in published literature is not evidence against the impact of black lung disease in this population. Li et al. (2018) noted that "while the health effects of indoor air pollution in urban environments has received great attention, the same cannot be said for the rural Native American communities where residents are directly exposed to pollutants from solid fuel combustion." Similarly, they noted that although the number of studies examining the health impacts of solid fuel use on Navajo residents is limited, the studies that are available "have consistently found an association between respiratory disease burdens and the use of wood and coal in several Navajo communities" (Li et al. 2018; Bunnell et al. 2010). Despite the relatively limited amount of published evidence, the studies that are available indicate high levels of residential coal use in the Navajo Nation and high public health burden among this population related to coal use and coal mining.

Coal mining. Coal mining has historically been important to the Navajo economy. The Black Mesa Coal Field, located largely in the Navajo Nation, is the principal coal-bearing region in Arizona (Finkelman and Simoni n.d.). Rekow (2019) describes the Navajo economy as "dependent on fossil fuel" with more than half of the Nation's annual revenue coming from coal mining and thousands of Navajo Nation residents relying on coal mines for employment. As with coal miners in other parts of the country, this is associated with a higher incidence of black lung disease and other respiratory diseases among Navajo coal miners. As Patel explains, "the Navajo Nation continues to suffer from the abusive policies of coal companies. Their already decreasing population has suffered from multiple diseases related to mining, such as black lung, asthma, and cancer" (Patel 2015).

Residential coal burning. It is well documented that many homes in the Navajo Nation continue to use solid fuels such as wood and coal for cooking and heating (Li et al. 2018; Champion et al. 2017; Finkelman and Bunnell 2003; Finkelman and Simoni n.d.). Coal is commonly used in Navajo Nation homes due to its low cost and wide availability; in some cases, residents receive coal for free from nearby mines or can purchase coal inexpensively at local flea markets (Li et al. 2018; Champion et al. 2017; Bunnell et al. 2010; Bunnell and Garcia 2006; Finkelman and Simoni n.d.).

There are several factors that may exacerbate exposure to fine particulates from coal burning in Navajo Nation homes. For example, Bunnell et al. (2010) noted that residents desiring to lose as little heat as possible during the winter may close controller dampers on coal stoves, which can lead to higher levels of Particulate Matter 2.5 ($PM_{2.5}$) inside the home. The same study conducted $PM_{2.5}$ monitoring with 18 of 137 Navajo Nation households participating in a survey on home heating methods. The authors observed that although visible smoke rarely entered the room even when stoves had observable cracks,

[11] It is worth noting that our search for relevant literature often turned up papers on uranium mining within the Navajo Nation. Uranium mining resulting in radon exposure can lead to respiratory illnesses similar to black lung disease. While the topic of uranium mining is out of scope for this project, it may be of potential interest for future research, given it may be a factor for higher rates of respiratory illness among former uranium miners in the Navajo Nation (there are no longer active uranium mines in the Navajo Nation) (Dr. Robert Finkelman, personal communication with author, January 4, 2023).

there was "evidence of soot, sometimes quite heavy" on surfaces within the home, indicating exposure to fine particulate matter from coal burning. Finally, the authors found that a quarter of coal stoves in the study "were not designed to operate properly at the higher temperatures at which coal burns … and in many instances [were] in states of disrepair" (Bunnell et al. 2010). Based on the evidence that residential coal burning for cooking and heating creates indoor air pollution (Li et al. 2018; Champion et al. 2017; Bunnell et al. 2010; Finkelman and Bunnell 2003; Finkelman and Simoni n.d.), it is not unreasonable to suggest that the same respiratory illnesses discussed in Section 4 are likely also present within the Navajo Nation.

Outdoor air pollution. In addition to indoor air pollution due to residential coal use, two studies discuss coal-related outdoor air pollution in Shiprock, New Mexico (a town in the Navajo Nation). Several nearby coal-fired power plants[12] often produce "noticeable amounts of smog" that can be trapped low along the San Juan Basin due to thermal atmospheric inversions (Bunnell et al. 2010; Finkelman and Simoni n.d.). Because they were built before the legislation's effective date, these power plants are exempt from EPA regulation under the 1990 American Clean Air Act (Bunnell et al. 2010). One study examining hospital records from April 1997 to December 2002 among Navajo residents seen at the Northern Navajo Medical Center Indian Health Service (IHS) Hospital found that out of all 37 communities in the IHS's Shiprock Service Area, the town of Shiprock ranked in the top 10 for all seven of the diseases and conditions analyzed for the study (Bunnell et al. 2010). The overall conclusion of the study was that residents of Shiprock and nearby towns are at greater risk for respiratory disease than residents of Navajo Nation communities not subject to thermal inversions (Bunnell et al. 2010).

Public health burden of coal in the Navajo Nation. Taken together, coal mining, residential coal burning, and coal-related outdoor air pollution lead to a high public health burden in the Navajo Nation. As Li et al. (2018) notes, the evidence of higher rates of exposure to $PM_{2.5}$ due to residential coal use "may be major contributing factors to public health burdens observed in the Navajo Nation, such as the higher death rates due to cardiovascular and respiratory illness compared to the rest of the US." The literature shows that Navajo people suffer "high levels of respiratory disease", despite low rates of cigarette smoking (Bunnell and Garcia 2006). When compared with the general U.S. population, the Navajo Nation and other Native Americans "suffer disproportionately from respiratory morbidity" (Finkelman and Simoni n.d.).

Additionally, it is possible that the public health burden of coal in the Navajo Nation is not fully documented, given the underreporting of health problems due to lack of healthcare access and reluctance to trust healthcare providers. While most research on this is focused on Native American populations more generally, the findings may still be relevant when discussing the Navajo Nation more specifically. Many Native Americans live in areas lacking healthcare providers, requiring them to travel long distances to access healthcare (Arambula Solomon et al. 2022; Whitney 2017). In the Navajo Nation, the Navajo Area Indian Health Service—the region's primary health care provider—serves over 244,000 American Indians but only has 222 beds across five hospitals, representing 0.91 beds per 1000 people (Arambula Solomon et al. 2022). In comparison, the American Hospital Association estimated there were 920,531 hospital beds across the United States in 2022, representing 2.76 beds per 1000 people (AHA 2022; Census Bureau 2022). Lack of health insurance is also common in Native American communities (Arambula Solomon et al. 2022; Whitney 2017). Lack of trust may be another reason for

[12] While the San Juan Mine and the coal-powered San Juan Generating Station recently shut down in 2022 (Moses 2022; Robinson-Avila 2022), the APS Four Corners power plant continues to operate, albeit at a reduced rate (Randazzo 2021).

the underreporting of health problems, as several studies have cited lower levels of trust in healthcare providers among Native Americans compared to other populations (Guadagnolo et al. 2009; Hunt et al. 2005).

Key takeaways:

- Coal mining has historically been important to the Navajo economy.
- Available studies show high levels of residential coal use in the Navajo Nation.
- There is a high public health burden in the Navajo Nation related to coal use and coal mining.

7 CONCLUSION

This literature review was conducted to answer the research question "What is the current state of knowledge on black lung disease, particularly as it relates to coal mining, residential coal use, Appalachian populations, and Navajo Nation residents?" Table 4 summarizes the key takeaways from each section of this literature review.

Table 4: Literature review key takeaways

Literature review section	Key takeaways
Black lung disease overview (Section 2)	• The narrowest definition of black lung disease describes diagnoses of coal workers' pneumoconiosis (CWP), but a broader set of illnesses and health impacts are associated with coal mining and use. • Because the symptoms and respiratory illnesses associated with coal dust can often resemble other illnesses, a well-documented history of exposure or an autopsy is the only conclusive way to determine the cause. • Undercounts in the caseload of black lung disease in the United States are attributed to factors including low uptake of screenings from the Coal Workers' Health Surveillance Program (CWHSP) and low compensation approval rates.
Coal mining and black lung disease (Section 3)	• The link between coal dust and CWP is well established and accepted by the medical community, though no definitive scientific explanation for this connection has been identified. • CWP prevalence has been increasing in the United States since the 1990s.
Black lung incidence related to residential coal use (Section 4)	• Residential coal burning poses a significant risk to public health. • Indoor air pollution from residential coal use has been shown to increase the risk of lung cancer and respiratory illness, particularly among women and children.
Black lung incidence in Appalachia (Section 5)	• Central Appalachia is experiencing a sharp rise in CWP cases after the late 1990s, as shown in a prevalence study of radiographs collected from 1970 to 2017; one in five long-tenured central Appalachian coal miners has evidence of CWP. • Appalachian communities in close proximity to coal mines experience higher rates of mortality and morbidity from a range of respiratory and other illnesses.
Black lung incidence among Navajo Nation residents (Section 6)	• Coal mining has historically been important to the Navajo economy. • Available studies show high levels of residential coal use in the Navajo Nation. • There is a high public health burden in the Navajo Nation related to coal use and coal mining.

The literature reviewed for this report found that unsafe practices in coal mining and residential coal burning continue to put people at risk of black lung disease and other negative health impacts. The prevalence of black lung disease has been rising since the 1990s and undercounts due to undiagnosed cases may mean the true nationwide caseload is higher than known. In particular, the public health burden of mining and burning coal is high in areas of Appalachia and the Navajo Nation. However, the published literature on black lung disease in the Navajo Nation is limited, highlighting the need for further research on black lung disease (and other respiratory illnesses associated with coal exposure) within the Navajo Nation. The information from this literature review can support MSHA's efforts to address the rise in black lung prevalence by shedding light on where this challenge exists and reasons why some communities have higher rates of black lung disease.

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Appendix B LITERATURE REVIEW METHODOLOGY

Summit followed a rigorous methodology and documentation process. This methodology included (1) developing key search terms, (2) identifying inclusion and exclusion criteria, (3) conducting the initial literature search, (4) performing analysis, and (5) completing additional literature searches as needed.

The key search terms (with variations shown in parentheses) are shown in Table 5. Relevant search terms were identified based on each study research question. For example, search terms around the Navajo Nation and Appalachia were defined to inform RQ3. Searches were conducted via Google Scholar using combinations of these terms. For example, the team searched for "Navajo Nation" and "home coal burning," rather than simply searching "Navajo Nation."

Table 5: List of search terms

- **Appalachia** (Appalachian)
- **Coal mining communities**
- **Household cooking** (searched in combination with "coal")
- **Black lung** (pneumoconiosis, coal workers' pneumoconiosis, emphysema, silicosis, bronchitis, respiratory illness, respiratory disease, lung cancer)
- **Coal workers' pneumoconiosis definition** (coal workers' pneumoconiosis medical codes)
- **Indoor air pollution**
- **Black lung definition** (black lung medical diagnosis codes)
- **Home coal burning** (residential coal burning, residential coal combustion)
- **Navajo Nation**

In addition to searching on the terms in the table above, Summit also solicited relevant sources from the project subject matter expert, Dr. Robert Finkelman.[13]

Summit then developed inclusion and exclusion criteria to further focus the search. The inclusion criteria are requirements that must be met for a source to be considered for analysis. The exclusion criteria are characteristics that lead to the omission of a source for analysis.

Table 6: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria

• Source is relevant to one of the following:
  ○ Black lung disease resulting from residential coal burning
  ○ Black lung disease resulting from a coal-related occupation
  ○ Contributes to black lung disease definition or medical code discussion
	• Source is older than 20 years (2002 or earlier); this exclusion criterion did not apply to federal legislation

[13] Dr. Finkelman is a research professor at the University of Texas at Dallas Department of Geosciences. His research focuses on the health impacts of coal (including residential coal use), with particular focus on the social and health impacts of coal and black lung disease. Dr. Finkelman provided feedback on draft search terms, suggested additional sources for inclusion, and reviewed the paper outline and draft.

Following the search, 124 sources were saved for inclusion in the review. Summit reviewed all sources for relevant information and synthesized findings to focus on the topics of interest. The full list of all sources reviewed is included in Appendix C. The list of sources cited within this literature review is included in Appendix A.

Appendix C SUMMARY OF REVIEWED SOURCES

Table 7 summarizes all sources that Summit reviewed for this literature review and indicates the relevant topics within each source. Relevant topics include Appalachia, the Navajo Nation, residential coal burning, coal mining communities, outdoor air pollution from coal, coal miners, black lung illnesses, black lung diagnosis, black lung medical codes, and federal legislation.

Table 7: List of all reviewed sources

Source title	Full citation	Relevant topics
Fast Facts on U.S. Hospitals, 2022	AHA (American Hospital Association). 2022. "Fast Facts on U.S. Hospitals, 2022." AHA.org (website). Last Modified January 2022. https://www.aha.org/statistics/fast-facts-us-hospitals.	*(American hospital bed availability)*
Domestic Mixed-Dust Pneumoconiosis: A Case Report and Literature Review	Al Badri, Faisal Mubarak, and Shahieda Adams. 2020. "Domestic mixed-dust pneumoconiosis: A case report and literature review." *Respiratory Medicine Case Reports* 29 (January 1, 2020): 100985. https://doi.org/10.1016/j.rmcr.2019.100985.	Residential coal burning, black lung diagnosis, black lung illnesses
The Generational Impact of Racism on Health: Voices from American Indian Communities	Arambula Solomon, Teshia G., Rachel Rose Bobelu Starks, Agnes Attakai, Fatima Molina, Felina Cordova-Marks, Michelle Kahn-John, Chester L. Antone, Miguel Flores, and Francisco Garcia. 2022. "The Generational Impact Of Racism On Health: Voices From American Indian Communities." *Health Affairs* 41, no.2 (February). https://doi.org/10.1377/hlthaff.2021.01419.	The Navajo Nation
Estimating the Prevalence and Spatial Clusters of Coal Workers' Pneumoconiosis Cases Using Medicare Claims Data	Arif, Ahmed A., Rajib Paul, Eric Delmelle, Claudio Owusu, and Oluwaseun Adeyemi. 2020. "Estimating the prevalence and spatial clusters of coal workers' pneumoconiosis cases using medicare claims data, 2011-2014." *American Journal of Industrial Medicine* 63, no. 6 (March 9, 2020): 478–83. https://doi.org/10.1002/ajim.23104.	Black lung illnesses, black lung medical codes, coal miners, Appalachia
A Scourge Returns: Black Lung in Appalachia	Arnold, Carrie. 2016. "A Scourge Returns: Black Lung in Appalachia." *Environmental Health Perspectives* 124, no. 1 (January): A13–18. https://doi.org/10.1289/ehp.124-A13.	Coal miners, Appalachia, black lung illnesses, black lung diagnosis

Source title	Full citation	Relevant topics
Coal Home Heating and Environmental Tobacco Smoke in Relation to Lower Respiratory Illness in Czech Children, from Birth to 3 Years of Age	Baker, (posthumous) Rebecca J., Irva Hertz-Picciotto, Miroslav Dostál, Jean A. Keller, Jiři Nožička, František Kotìšovec, Jan Dejmek (posthumous), Dana Loomis, and Radim J. Šrám. 2006. "Coal Home Heating and Environmental Tobacco Smoke in Relation to Lower Respiratory Illness in Czech Children, from Birth to 3 Years of Age." *Environmental Health Perspectives* 114, no. 7 (July 1, 2006): 1126–32. https://doi.org/10.1289/ehp.8501.	Residential coal burning, black lung illnesses
Risk of Lung Cancer Associated with Domestic Use of Coal in Xuanwei, China: Retrospective Cohort Study	Barone-Adesi, Francesco, Robert S. Chapman, Debra T. Silverman, Xinghzhou He, Wei Hu, Roel Vermeulen, Bofu Ning, Joseph F. Fraumeni Jr., Nathaniel Rothman, and Qing Lan. 2012. "Risk of lung cancer associated with domestic use of coal in Xuanwei, China: retrospective cohort study." *BMJ* 345 (August 30, 2012): e5414. https://doi.org/10.1136/bmj.e5414.	Residential coal burning, black lung illnesses
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Source title	Full citation	Relevant topics
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Source title	Full citation	Relevant topics
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Source title	Full citation	Relevant topics
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Source title	Full citation	Relevant topics
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Source title	Full citation	Relevant topics
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Source title	Full citation	Relevant topics
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Source title	Full citation	Relevant topics
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Source title	Full citation	Relevant topics
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Coal Home Heating Is Associated with Increased Rates of Lower Respiratory Illness during the First Three Years of Life in the Czech Republic	James, R., I. Hertz-Picciotto, M. Dostál, J. Keller, J. F. Nozicka, F. Kotesovec, J. Dejmek, and R. Srám. 2003. "Coal Home Heating Is Associated with Increased Rates of Lower Respiratory Illness during the First Three Years of Life in the Czech Republic." *Epidemiology* 14, no. 5 (September 2003): S109.	Black lung illnesses, residential coal burning
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Prevalence of Respiratory Disease in the Population of Queensland Communities in Proximity to Coal Mines and Coal Mining Activities	Karatela, Shamshad, Samantha Caruana, and Gunther Paul. 2022. "Prevalence of Respiratory Disease in the Population of Queensland Communities in Proximity to Coal Mines and Coal Mining Activities." *International Journal of Community Medicine and Public Health* 9, no. 7 (July 1, 2022): 3014–22. https://doi.org/10.18203/2394-6040.ijcmph20221776.	Coal mining communities, black lung illnesses, outdoor air pollution from coal, coal miners

Source title	Full citation	Relevant topics
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Pulmonary Inflammation and Crystalline Silica in Respirable Coal Mine Dust: Dose Response	Kuempel, E. D., M. D. Attfield, V. Vallyathan, N. L. Lapp, J. M. Hale, R. J. Smith, and V. Castranova. 2003. "Pulmonary inflammation and crystalline silica in respirable coal mine dust: Dose response." *Journal of Biosciences* 28, no. 1 (February 1, 2003): 61–69. https://doi.org/10.1007/BF02970133.	Coal miners, black lung illnesses
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