COAL MINER HEALTH ALERT: PROGRESSIVE MASSIVE FIBROSIS ("PMF")

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> *"It's more dangerous for miners now than it was 10-15 years ago. They're getting sick. They're getting lung transplants and dying from black lung."*
>
> - *Edward Petsonk, M.D., Pulmonary and Critical Care, West Virginia University Hospitals.*[1]

I. Introduction.

Over the past decade, there has been an alarming increase in the prevalence of respiratory diseases caused by excessive inhalation of coal, rock, and silica dust. "Black lung is a general legal term used to refer to coal worker's pneumoconiosis ("CWP"), bronchitis, emphysema, and silicosis when they are found in association with employment history in coal mines."[2] The most severe form of CWP, progressive massive fibrosis ("PMF"), now affects almost ten times the number of miners it affected in the late 1990s.[3]

PMF is "an advanced, debilitating, and lethal form of coal workers' pneumoconiosis with limited, primarily palliative treatment options and no cure."[4] The typical identifying symptoms of

[1] Conaway, Danielle. *Why Is Black Lung Back?* WVUHealth Magazine. 1 Jan. 2013. Web. 13 Oct. 2014. <http://wvuhealth.hsc.wvu.edu/issues/fall-2013/why-is-black-lung-back/>.

[2] V. Castranova, V. Vallyathan, *Silicosis and Coal Workers' Pneumoconiosis.* Environmental Health Perspectives. 108:4, 2000.

[3] Ward Jr., Ken. *Worst Form of Black Lung Is Roaring Back*. The Charleston Gazette. 15 Sept. 2014. Web. 9 Oct. 2014. <http://www.wvgazette.com/article/20140915/GZ01/140919507>.

[4] D. Blackley, C. Halldin, A. Laney, *Resurgence of a Debilitating and Entirely Preventable Respiratory Disease among Working Coal Miners. American Journal of Respiratory and Critical Care Medicine* 190:6, 2014.

PMF are shortness of breath, bronchitis, various chest ailments, and heart failure.[5] Although PMF is often associated with other pulmonary infirmities, it is an independent disease with increased rates of mortality.[6] CWP diagnoses, and consequently PMF diagnoses, saw a notable decrease following Congress' enactment of the 1969 Federal Coal Mine Safety and Health Act ("FCMSHA").[7] FCMSHA was far reaching in nature and established explicit exposure limits for coal dust in mines. However, in the past decade, the national prevalence of PMF, as identified through the National Institute for Occupational Safety and Health ("NIOSH") Coal Workers' Health Surveillance Program, has dramatically increased.[8] Disturbingly, the resurgence of this disease has been especially pronounced in the Appalachian coalfields of West Virginia, Virginia, and Kentucky.[9] Interagency studies attribute this rise to regional differences in coal content and have measured the overall prevalence of PMF in U.S. coal miners to be 2.5%.[10] Further, these studies have determined that as many as 16% of U.S. coal miners can progress to interstitial fibrosis.[11]

This paper will discuss PMF as a disease, examine possible explanations for its exponential growth, and analyze the recent burgeoning of PMF in Appalachia.

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[5] D. Scott, R. Grayson, E. Metz, *Disease and Illness in U.S. Mining, 1983-2001*. NIOSH.

[6] *Id*.

[7] Graber JM, Stayner LT, Cohen RA, et al. Occup Environ Med., 71:30-39, 2014.

[8] D. Blackley, C. Halldin, A. Laney, *Resurgence of a Debilitating and Entirely Preventable Respiratory Disease among Working Coal Miners. American Journal of Respiratory and Critical Care Medicine* 190:6, 2014.

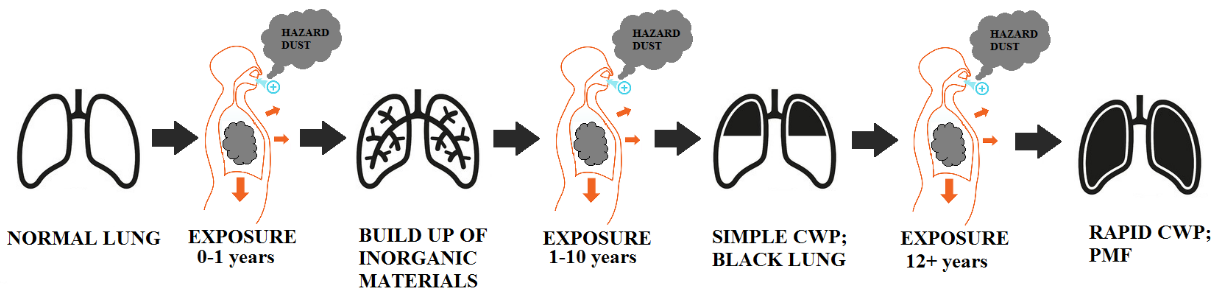
[9] *Id*.

[10] Morgan WK, Seaton A. *Occupational Lung Diseases*. Philadelphia, Pa: WB Saunders; 1975:149-210.

[11] Baum GL, Crapo JD, Celli BR. *Textbook of Pulmonary Diseases*. Vol 1. Philadelphia, Pa: Lippincott-Raven; 1998:683-92.

II. Progressive Massive Fibrosis (PMF): Disease Overview.

A. Coal Worker's Pneumoconiosis and Progressive Massive Fibrosis.



In the general sense, a pneumoconiosis is an accumulation of dust in the lungs, which eventually causes severe scarring of lung tissue.[12] CWP results where coal dust exposures are so excessive that the lungs' clearance mechanisms are overwhelmed, causing dust particles to build up and limit airflow.[13] When the severity of CWP advances to a lethal level, it is referred to as complicated CWP or PMF.[14] As PMF worsens, lung tissue retracts toward the areas of scarring in the upper lung, resulting in distorted airways and destruction of blood vessels.[15] Currently, there are no known cures and very few treatment options for PMF.[16]

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[12] Wade WA, Petsonk EL, Young B, Mogri I. *Severe occupational pneumoconiosis among West Virginian coal miners: one hundred thirty-eight cases of progressive massive fibrosis compensated between 2000 and 2009*. Chest Journal. Jun 2011;139(6):1458-62.

[13] *Id.*

[14] D. Blackley, C. Halldin, A. Laney, *Resurgence of a Debilitating and Entirely Preventable Respiratory Disease among Working Coal Miners. American Journal of Respiratory and Critical Care Medicine* 190:6, 2014.

[15] Wade WA, Petsonk EL, Young B, Mogri I. Severe occupational pneumoconiosis among West Virginian coal miners: one hundred thirty-eight cases of progressive massive fibrosis compensated between 2000 and 2009. Chest Journal. Jun 2011;139(6):1458-62.

[16] *Id.*

Several biochemical mechanisms have been identified as potential causes of the pulmonary damage and scarring indicative of PMF.[17] One potential cause is where the "[c]hemical features of silica or coal dust [react] with lung cells, leading to peroxidation of membrane lipids and damage to cell membranes."[18] Another PMF catalyst exists where silica or coal dust exposure causes the body to make reactive oxygen cells which interfere with lung antioxidants and cause a breakdown of cell membrane lipids, resulting in lung scarring.[19] Additionally, PMF can occur where coal dust exposure causes an increase in "the secretion of inflammatory cytokines and chemokines" which cause additional oxidants to be generated, resulting in tissue damage and scarring.[20] Finally, PMF has occurred where coal dust exposure stimulates "secretion of fibrogenic factors" which induce "fibroblast proliferation and/or the stimulation of collagen synthesis, leading to fibrosis."[21]

There are two forms of pneumoconiosis that coal miners develop: simple CWP and PMF. "With chronic exposure, the mild form of CWP may become complicated CWP, with enlargement and profusion of lesions in the lung."[22] "Progression of simple CWP to the more aggressive form of PMF is thought to be associated with severe cumulative dust exposure, concentration of inorganic minerals and silica, impaired clearance, infections, and immunologic factors."[23] PMF

[17] V. Castranova, V. Vallyathan, *Silicosis and Coal Workers' Pneumoconiosis.* Environmental Health Perspectives. 108:4, 2000.

[18] *Id*.

[19] *Id*.

[20] *Id*.

[21] *Id*.

[22] *Id*.

[23] *Id*.

lesions tend to develop “on the upper lobes of the right lung. However, in advanced cases, lesions are bilateral, [developing on both lungs.]”[24]

B. Cancer Implications of CWP and PMF.

Lungs that have developed CWP (left) and PMF (right).

[25] Exposure to coal mine dust has also been closely associated with an elevated risk of various cancers. Inhalation of coal, crystalline silica, and quartz dust have all shown statistically significant correlations with lung cancer mortality.[26] The International Agency for Research on Cancer has conclusively determined that crystalline silica dust is a Group I carcinogen.[27] Additionally, studies have shown that exposure to airborne quartz is associated with an increased risk of lung cancer.[28] A 2008 Czech study found a significantly higher lung cancer risk in underground miners with pneumoconiosis when compared with the general population.[29] Furthermore, ingested coal mine dust has been shown to react with the acidic environment in the

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[24] *Id*.

[25] Khan, Farhan. *Coal Worker's Pneumoconiosis*. Medscape. Web. 14 Oct. 2014. <http://emedicine.medscape.com/article/297887-overview#a0101>.

[26] Miller B, MacCalman L, *Cause- specific mortality in British coal workers and exposure to respirable dust and quartz*. Occup Environ Med 67:270–276, 2010.

[27] Attfield, Michael et al., *Coal Mine Dust Exposures and Associated Health Outcomes*. NIOSH. 2011. http://www.cdc.gov/niosh/docs/2011-172/pdfs/2011-172.pdf. (Group I carcinogens are defined as carcinogenic to humans.).

[28] Miller B, MacCalman L, *Cause- specific mortality in British coal workers and exposure to respirable dust and quartz*. Occup Environ Med 67:270–276, 2010.

[29] Tomaskova H, Jirak, Z, Splichalova, A, et al., *Lung Cancer Risk in Black-coal Miners with Pneumoconiosis in the Czech Republic*. Epidemiology 19:172-173, 2008.

stomach, potentially causing an elevated risk of stomach cancer.[30]

In addition to lung and stomach cancer, skin cancer has also been shown to manifest in correlation with pneumoconiosis. Patients who have developed fibrosis should be closely monitored for progression to peripheral squamous cell carcinoma ("SCC"), a form of melanoma that grows on the skin tissue of the lung. Studies have found that diffuse interstitial fibrosis is a potent accelerator of SCC.[31] Further, these studies have demonstrated that a "positive causal relationship between pneumoconiosis and peripheral-type SCCs of the lung" exists.[32]

While the data available is limited, a significant correlation between pneumoconiosis and an increased risk of cancer death is apparent. As recent as 2010, a study discovered four new cases of cancer in Minnesota miners, bringing the state's total number of mine-related cancer cases to 63.[33] Even in a state with lower rank coal and fewer career miners, the causal link between dust related respiratory disorders and cancer development is strong. Clearly, Appalachian miners are at an increased risk of developing cancer in relation to CWP or PMF.

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[30] Morfeld P, Lampert K, Siegler C, et al., *Overall Mortality and Cancer Mortality of Coal Miners*. Ann. Occup. Hyg 41:346-351, 1997.

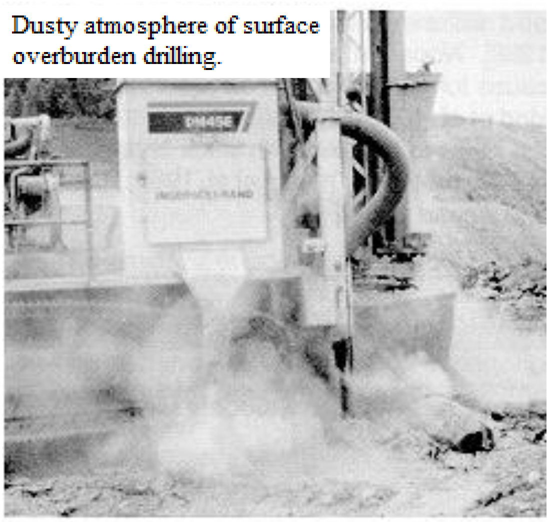
[31] Katabami M, Dosaka-Akita H, Honma K, et al. *Pneumoconiosis-related lung cancers: preferential occurrence from diffuse interstitial fibrosis-type pneumoconiosis*. Am J Respir Crit Care Med. Jul 2000;162 (1) : 295-300.

[32] *Id*.

[33] Hemphill, Stephanie. *4 New Cases of Cancer Found Among Former Mine Workers*. Minnesota Public Radio News, 30 Mar. 2010. Web. 14 Oct. 2014.

III. Exposure Sources and Causes of CWP and PMF.

A. Coal, Crystalline Silica, and Quartz Dust Exposure in Mining Operations



Dusty atmosphere of surface overburden drilling.

[34] Underground mining operations are the most significant source of coal, rock, and silica dust exposure.[35] While the exposure risks inherent in surface mining operations are significant, underground mining remains the most prominent threat due to poorly ventilated work areas with little natural airflow.[36] West Virginia currently has more underground coal miners than any other state.[37] In 2012, the Energy Information Administration reported that there were 22,786 miners in the state, more than 17,000 of which were underground.[38] For these underground miners, the highest exposure levels are experienced in continuous mining operations.[39] Their surface mining counterparts, however, experience the most exposure when drilling rock overburden.[40]

[34] Image procured from: *Preventing Silicosis and Deaths in Rock Drillers*. Centers for Disease Control and Prevention, 6 June 2014. Web. 13 Oct. 2014. <http://www.cdc.gov/niosh/docs/92-107/>.

[35] V. Castranova, V. Vallyathan, *Silicosis and Coal Workers' Pneumoconiosis.* Environmental Health Perspectives. 108:4, 2000.

[36] *Id*.

[37] *U.S. Energy Information Administration Annual Coal Report 2012.* U.S. Energy Information Administration. 1 Jan. 2012. Web. 14 Oct. 2014. <http://www.eia.gov/coal/annual/pdf/table21.pdf>.

[38] *Id*.

[39] V. Castranova, V. Vallyathan, *Silicosis and Coal Workers' Pneumoconiosis.* Environmental Health Perspectives. 108:4, 2000.

[40] JA Organiscak, SJ Page, RA Jankowski. *Sources and Characteristics of Quartz Dust in Coal Mines*. U.S. Dept. of the Interior, Bureau of Mines, 1990.

Surface miners typically work in the open air, which dilutes the amount of respirable coal, silica, and quartz dust.[41] Despite this dilution, surface miners remain at significant risk for developing PMF and other similar pulmonary disorders. In particular, surface miners tasked with drilling rock overburden are routinely exposed to high levels of airborne coal, silica, and quartz dust.[42] These miners are assigned the duty of removing the initial layers of topsoil and other overburden materials, including sandstone, shale, limestone, and unconsolidated soils.[43] This process consists of drilling holes into the rock formations for insertion of explosive charges, blasting the surrounding rock, and clearing the debris with equipment such as drag line cranes, end loaders, or power shovels.[44] Accordingly, many of the 5,701 surface coal miners in West Virginia are left susceptible to CWP and PMF.[45] Obviously, "[t]he current approach to dust control and provision of safe work conditions for central Appalachian underground coal miners is not adequate to protect them from adverse respiratory health effects."[46]

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[41] *Id*. ("Underground coal miners are at greater risk of developing CWP than strip or surface miners because of the higher dust levels in the underground environment[; whereas] in surface mining, generated coal dust is diluted by outdoor air.").

[42] *Id*.

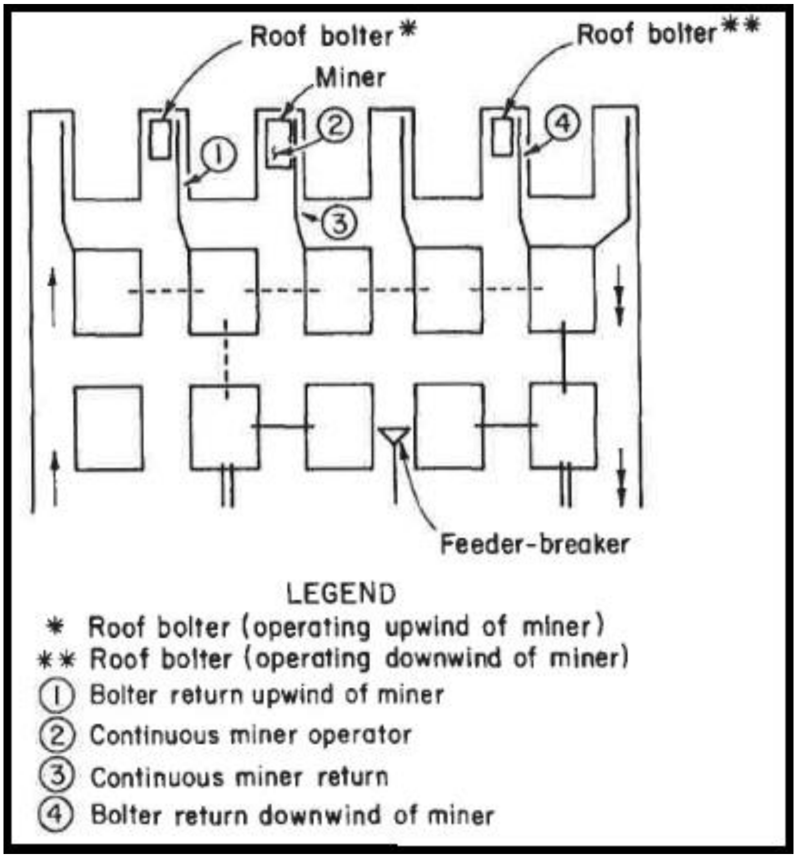
[43] *Preventing Silicosis and Deaths in Rock Drillers*. *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 6 June 2014. Web. 13 Oct. 2014. <http://www.cdc.gov/niosh/docs/92-107/>.

[44] *Id*.

[45] Surface miner employee data taken from: *U.S. Energy Information Administration Annual Coal Report 2012*. U.S. Energy Information Administration. 1 Jan. 2012. Web. 14 Oct. 2014. <http://www.eia.gov/coal/annual/pdf/table21.pdf>.

[46] Blackley DJ, Halldin CN, Wang ML, et al. *Small mine size is associated with lung function abnormality and pneumoconiosis among underground coal miners in Kentucky, Virginia and West Virginia*. Occup Environ Med 2014; 71:690-694.

B. Increased Correlation between Quartz Dust and Pulmonary Disorders



[47]

TABLE 1: Illustrates the locations of different mining jobs on a typical single-split return face ventilation system. In particular, the roof bolter positions are susceptible to exposure to quartz dust and increased risk of rapidly progressive CWP.

Recently, quartz dust exposure has seen a more prominent correlation with CWP and PMF diagnoses. Quartz is a silica-based mineral, and crystalline silica has long been recognized as a cause of "rapid disease progression and severe pneumoconiosis in coal miners."[48] NIOSH has recommended that the respirable quartz dust levels be enforced at 0.05 milligrams per cubic meter of air.[49] While there has been no consistent relationship between the percentage of respirable quartz and the severity of pneumoconiosis, coal mines containing high quartz contents have shown "a high rate of progressive massive fibrosis (PMF) and an unusually rapid development of pneumoconiosis."[50] Multiple studies of rock

[47] JA Organiscak, SJ Page, RA Jankowski. *Sources and Characteristics of Quartz Dust in Coal Mines*. U.S. Dept. of the Interior, Bureau of Mines, 1990.

[48] A Laney, E Petsonk, M Attfield. *Pneumoconiosis among underground bituminous coal miners in the United States: is silicosis becoming more frequent?* Occup. Environ. Med., 2009.

[49] *Id*.

[50] Morgan WK, Seaton A. *Occupational Lung Diseases*. 3d Edition. Pg. 140, 1995.

samples have determined that the primary sources of quartz in coal mines are roof rock and floor rock.[51] An analysis of quartz dust from two different mines utilizing conventional and continuous mining operations illustrated that "the most significant source of quartz dust in underground mines [is] the continuous miner when cutting rock[.]"[52] Furthermore, the highest quartz dust concentrations in continuous miner sections of mines were seen at the return of the continuous miner, at the continuous miner, and downwind at the roof bolters' position.[53]

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[51] JA Organiscak, SJ Page, RA Jankowski. *Sources and Characteristics of Quartz Dust in Coal Mines*. U.S. Dept. of the Interior, Bureau of Mines, 1990.

[52] *Id*.

[53] *Id*.

C. Coal and Silica Dust Exposure in Underground Mining Operations.

Although national average coal dust exposure levels have consistently been less than federal exposure limits, PMF diagnoses have been increasing in underground coal miner communities. These cases have been severe, rapidly progressive versions of PMF, heavily clustered in Appalachia.[54] "One potential explanation is that the toxicity of the dust generated during coal mining has changed, resulting in an increased inflammatory response and more potent induction of pneumoconiosis."[55] An increased proportion of crystalline silica in coal mine dust "provides [another] plausible explanation for an increase in dust toxicity."[56] Additionally, "rapid progression and progressive massive fibrosis are more likely with silicosis than with CWP."[57]

Furthermore, one of the touchstone indicators of PMF, the presence of r-type opacity patterns on chest images, is heavily correlated with silica dust exposure. Although there has been a national increase in r-type opacities, the data "suggests that a substantial portion of the effect observed at the national level is driven by the regional contribution of Kentucky, Virginia, and West Virginia."[58] In this region, the percentage of r-type opacities observed between 2000 and 2008 increased 7.6 times compared to the percentage observed in the 1980s.[59] It comes as no surprise that this substantial increase in silica induced r-type opacities has been paralleled by the substantial increase in PMF diagnoses in Appalachia.

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[54] A Laney, E Petsonk, M Attfield. *Pneumoconiosis among underground bituminous coal miners in the United States: is silicosis becoming more frequent?* Occup. Environ. Med., 2009.

[55] *Id*.

[56] *Id*.

[57] *Id*.

[58] *Id*.

[59] *Id*.

"Changes in coal demand, accessibility, and mining technology [over the last 40 years] could potentially explain increasing respirable silica exposure in coal mines."[60] There is greater demand, the coal mined is in thinner seams, and these seams are "almost exclusively in the Appalachian bituminous coal fields."[61] The concern with thin seam mining is that crystalline silica tends to be present in higher concentrations in the rock surrounding thin seam coal than in the coal seams themselves. Therefore, "the risk of breaching the coal/rock interface is greater in thin coal seams and is likely associated with greater waste rock mined."[62] In short, more waste rock is being mined; waste rock tends to have higher concentrations of respirable silica dust than coal; breathing silica dust over time causes silicosis, which causes PMF to progress more rapidly than PMF caused by coal dust exposure alone; silicosis induced PMF is identified by the presence of r-type opacities in chest images; and the identification of r-type opacities has markedly increased in Appalachia over the last 15 years.[63]

D. Exposure to High Rank Coal Dust and Development of PMF.

The primary component of coal is carbon; however, different types of coal can additionally contain "hydrogen, oxygen, nitrogen, trace metals,[64] inorganic minerals, and crystalline silica."[65] These different types of coal are distinguished by rank, which is "a measure of the age and hardness

[60] *Id*.

[61] *Id*.

[62] *Id*.

[63] *See* Blackley DJ, Halldin CN, Wang ML, et al. *Small mine size is associated with lung function abnormality and pneumoconiosis among underground coal miners in Kentucky, Virginia and West Virginia.* Occup Environ Med 2014; 71:690-694.

[64] Trace metals include boron, cadmium, copper, nickel, iron, antimony, lead, and zinc.

[65] V. Castranova, V. Vallyathan, *Silicosis and Coal Workers' Pneumoconiosis.* Environmental Health Perspectives. 108:4, 2000.

of coal."[66] As rank increases, the ratio of carbon to other chemicals and mineral contaminants increases."[67] Consequently, the level of contaminants in airborne coal dust increases with rank as well.

In general, mines where higher rank coal is mined show a stronger correlation with higher dust exposures than underground mines where lower rank coal is mined. Studies have demonstrated that "levels of pneumoconiosis are lower in [mines with] low-rank coals . . ., and that workers exposed to high-rank coals accumulate dust [in their lungs] faster than those mining low-rank coals."[68] Furthermore, coal rank tends to be higher in the East than in the West, indicating that Appalachian miners are likely exposed to more coal dust on a regular basis.[69] Accordingly, eastern Appalachian high rank mines present a higher risk for the development of CWP or PMF.[70]

E. Threat Acknowledged, Not Addressed: MSHA Exposure Level Reductions.

Several government regulations have recently been revised in an attempt to control coal dust exposure in underground and surface mining operations. For example, the current MSHA regulations allow up to 2.0 milligrams per cubic meter of air. However, on August 1, 2016, new regulations will go into effect that limit allowable coal dust exposure rates to 1.5 milligrams per cubic meter of air.[71] While this is an improvement, the new MSHA regulation still fails to reduce

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[66] V C dos S Antao, EL Petsonk, L Z Sokolow, et al. Occup Environ Med 2005; 62:670-674.

[67] V. Castranova, V. Vallyathan, *Silicosis and Coal Workers' Pneumoconiosis.* Environmental Health Perspectives. 108:4, 2000.

[68] Morgan WK, Seaton A. *Occupational Lung Diseases*. 3d Edition. Pg. 139, 1995.

[69] *Id*.

[70] *Id*.

[71] *Sampling and Compliance Overview MSHA's Final Rule to Lower Miners' Exposure to Respirable Coal Mine Dust.* MSHA. Mine Safety and Health Administration, U.S. Department of Labor, 1 Jan. 2013. Web. 9 Oct. 2014. <http://www.msha.gov/endblacklung/docs/samplingandcompliance.pdf>.

exposure rates to an acceptable level. The most recent regulation reduces the exposure limit by 50%; however, even as far back as 1995, NIOSH recommended that those same exposure rates be lowered by 100% to 1.0 milligrams per cubic meter of air.[72] Under the new exposure limit, MSHA estimates that there could still be as many as 197 cases of PMF per 1,000 miners over a 45-year work period in high exposure mining jobs.[73] These estimates are a solemn reminder that PMF "remains an important public health problem more than four decades after enforceable dust limits were implemented," and "the burden of debilitating respiratory disease is currently higher than national and regional levels from 10, 20 or even 30 years ago."[74]

IV. Complicated CWP and PMF Devastate the Appalachian Region.

> *"It was worse than I thought we would ever see. I almost fell off of my chair. I really was that shocked."*
>
> - *Edward Petsonk, M.D., Pulmonary and Critical Care, West Virginia University Hospitals, discussing his thoughts upon seeing recent CWP and PMF rates.*[75]

An American miner's current risk of developing rapidly progressive CWP or PMF during his/her working lifetime of 40 years is estimated at a 2% chance.[76] This risk factor significantly

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[72] W. Wade, E. Petsonk, B. Young, et al. *Chest Journal: Severe Occupational Pneumoconiosis Among West Virginia Coal Miners*, (In 1995, NIOSH "recommended that the permissible limit for respirable coal mine dust exposure be decreased to 1 mg/m3, but this recommendation [was never] implemented.").

[73] *Quantitative Risk Assessment in Support of the Final Respirable Coal Mine Dust Rule Statistical Methods and Analysis*. MSHA. Mine Safety and Health Administration, U.S. Department of Labor, 1 Dec. 2013. Web. 9 Oct. 2014. <http://www.msha.gov/endblacklung/docs/Quantitativeanalysis.pdf>.

[74] Blackley DJ, Halldin CN, Wang ML, et al. *Small mine size is associated with lung function abnormality and pneumoconiosis among underground coal miners in Kentucky, Virginia and West Virginia.* Occup Environ Med 2014; 71:690-694.

[75] Conaway, Danielle. *Why Is Black Lung Back?* WVUHealth Magazine. 1 Jan. 2013. Web. 13 Oct. 2014. <http://wvuhealth.hsc.wvu.edu/issues/fall-2013/why-is-black-lung-back/>.

[76] V C dos S Antao, EL Petsonk, L Z Sokolow, et al. Occup Environ Med 2005; 62:670-674.

exceeds the previously predicted national rate.[77] However, what is most troubling is the pronounced burgeoning of PMF cases seen across the Appalachian region.

"The prevalence of progressive massive fibrosis . . . has *more than quadrupled* since the 1980s among central Appalachian underground coal miners."[78] Most Appalachian miners diagnosed with PMF during this time frame have been working under the purportedly safe exposure standards implemented by FCMSHA in 1969.[79] A 2005 study examined PMF diagnoses in Appalachia and noted that the "results . . . suggest geographic clustering."[80] The Coal Workers' X-Ray Surveillance Program ("CWXSP") and Mine Safety and Health Administration's ("MSHA") Miners' Choice Program have jointly identified these "geographic clusters" of rapidly progressive CWP in underground miners, stating that "cases of rapidly progressive CWP appear to cluster along the eastern edge of the Appalachian coal fields [in Kentucky, Virginia, and West Virginia.]"[81] In 2014, Blackley et al published a review of over 3,800 chest radiographs taken of Appalachian coal miners from 2005 to 2012, and determined that CWP and PMF rates were alarmingly high.[82] In small mines with less than 50 miners, 10.8% of miners reviewed had CWP

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[77] *Id*. *Citing* Jacobsen M., *Progression of coal workers' pneumoconiosis in Britain in relation to environmental conditions underground*. *Proceedings of the Conference on Technical Measures of Dust Prevention and Suppression in Mines.* Luxembourg: Commission of the European Communities, 1972:77-93.

[78] Blackley DJ, Halldin CN, Wang ML, et al. *Small mine size is associated with lung function abnormality and pneumoconiosis among underground coal miners in Kentucky, Virginia and West Virginia*. Occup Environ Med 2014; 71:690-694. (emphasis added).

[79] *Id*.

[80] V C dos S Antao, EL Petsonk, L Z Sokolow, et al. Occup Environ Med 2005; 62:670-674. (emphasis added).

[81] *Id*.

[82] Blackley DJ, Halldin CN, Wang ML, et al. *Small mine size is associated with lung function abnormality and pneumoconiosis among underground coal miners in Kentucky, Virginia and West Virginia*. Occup Environ Med 2014; 71:690-694.

and 2.4% had PMF. [83] In larger mines, 5.2% of miners reviewed had CWP and 1.1% had PMF.[84]

West Virginia in particular has endured a grossly disproportionate rise in rapidly progressive forms of pneumoconiosis. In 2011, Wade et al reviewed records of 138 West Virginia coal miners from 2000 to 2009 and found that the number of miners with PMF, at a mean age of 52.6 years, increased substantially after 2001.[85] On average, these miners developed PMF within 12 years of their last healthy chest radiograph, after 30 years of occupational exposure.[86]

As alluded to earlier, the high rank coal in eastern Appalachian mines may partially explain this clustering. The aggressiveness of PMF is ultimately tied to the type of coal dust a miner inhales and is therefore more prevalent in Appalachian high rank mines. However, this phenomenon "does not appear to fully explain the observed geographic distribution of rapidly progressive cases. Differences in mining technique, approaches to dust control, or enforcement of permissible exposure limits may also play a role."[87] Moreover, the high amount of respirable silica in Appalachian mines serves to explain the exponential growth of PMF diagnoses.[88] This potent combination of high rank coal dust, poor work practices, and increased silica exposure presents a

[83] *Id*.

[84] *Id*.

[85] Wade WA, Petsonk EL, Young B, Mogri I. *Severe occupational pneumoconiosis among West Virginian coal miners: one hundred thirty-eight cases of progressive massive fibrosis compensated between 2000 and 2009*. Chest Journal. Jun 2011;139(6):1458-62; *Cf.* Petsonk EL, Rose C, Cohen R. *Coal mine dust lung disease. New lessons from old exposure*. Am J Respir Crit Care Med. Jun 1 2013;187(11):1178-85.

[86] *Id*.

[87] Blackley DJ, Halldin CN, Wang ML, et al. *Small mine size is associated with lung function abnormality and pneumoconiosis among underground coal miners in Kentucky, Virginia and West Virginia*. Occup Environ Med 2014; 71:690-694.

[88] Laney AS, Petsonk EL, Attfield MD. *The Changing Epidemiology of Coal Workers' Pneumoconiosis in Appalachia - Investigating the Role of Silica Exposure*. D42. *OUTCOMES FROM OCCUPATIONAL FIBERS AND DUSTS 2009: A5900, 10.1164/ajrccm-conference.2009.179.1_MeetingAbstracts.A5900*. ("The changing epidemiological patterns of coal workers pneumoconiosis in the Appalachian region of the United States attributes the increased exposure to respirable silica, as suggested by radiographic abnormalities consistent with silicosis.").

serious threat to the well-being of miners in this region.

In several Appalachian mining counties, "over two thirds of working miners with pneumoconiosis showed rapid progression."[89] Furthermore, "[r]apid progression was also significantly associated with work in smaller mines (less than 50 employees) and with longer tenure in jobs at the face of the mine."[90] Perhaps most concerning is the fact that "miners with rapidly progressive CWP were *significantly younger* than other miners with CWP, *strongly implicating recent mining conditions*."[91] These studies seem to suggest that smaller mines across Appalachia, due to their more modest resources, are experiencing lax supervision of exposure levels. Consequently, there has been an increase of miners who are developing severe, rapidly progressive forms of CWP at younger ages.

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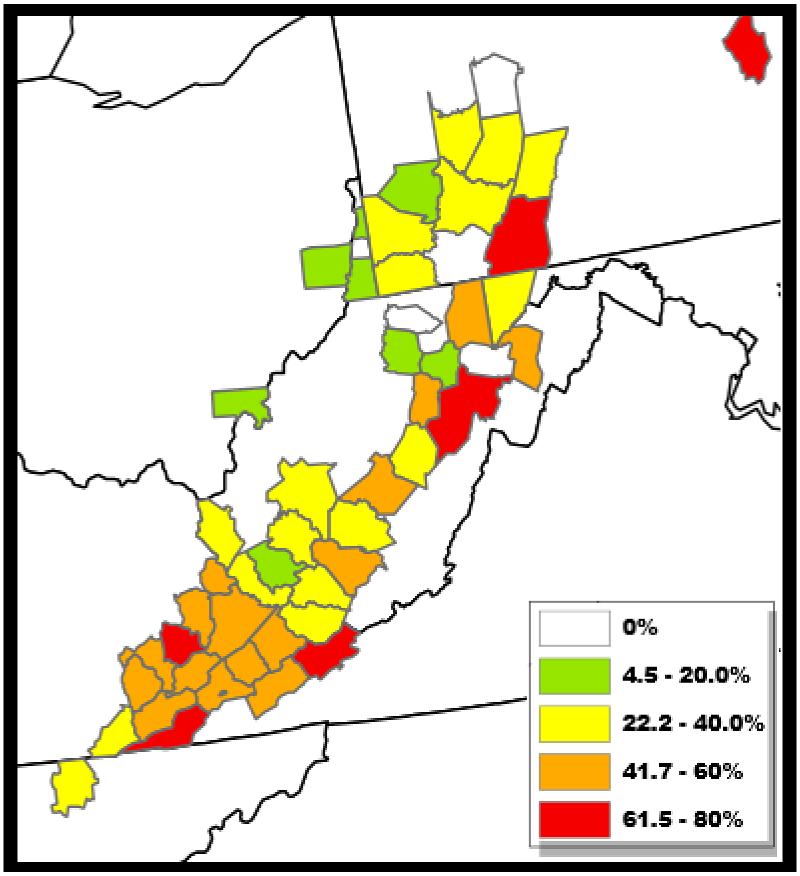
[89] *Id*.

[90] Blackley DJ, Halldin CN, Wang ML, et al. *Small mine size is associated with lung function abnormality and pneumoconiosis among underground coal miners in Kentucky, Virginia and West Virginia.* Occup Environ Med 2014; 71:690-694.

[91] V C dos S Antao, EL Petsonk, L Z Sokolow, et al. Occup Environ Med 2005; 62:670-674. (emphasis added).

V. Breakdown of PMF Rates Across Appalachian Region by County and State.



[92]

TABLE 2: This image illustrates the "hotspots" of rapidly progressing CWP in the Appalachian Region. According to Coal Worker's X-Ray Surveillance Program regulations, every underground miner is eligible to have a chest radiograph once every five years. In 2005, scientists from the Center for Disease Control conducted a study of these archived chest radiographs in order to evaluate the severity of PMF. In order to be used for the study, the radiographs had to come from a miner who was evaluated at least twice from 1996-2002. Each county where at least 5 miners had been evaluated twice is charted in the map to the left. This image shows the percentage of miners evaluated who were determined to have a rapidly progressing from of CWP. **Specific statistics in counties showing rapid CWP rates over 40% are listed below in table form.**

In **West Virginia**, the counties of Randolph, Grant, Upshur, Raleigh, Nicholas, and Preston have seen the most pronounced rise in PMF occurrences.

TABLE 3: 1996 – 2002 Study: West Virginia Coal Miners with Rapidly Progressing Coal Worker's Pneumoconiosis[93]

County, State (Highest rate counties listed)	**Miners Evaluated** (at least two examinations pre-1996 through 2002)	**Miners with Rapid Progression**	**Proportion of Evaluated Miners with Rapid Progression**
Randolph, West Virginia	8	5	62.5%
Grant, West Virginia	7	4	57.1%
Preston, West Virginia	16	8	50%
Upshur, West Virginia	13	6	46.2%
Nicholas, West Virginia	11	5	45.5%
Raleigh, West Virginia	51	22	43.1%

[92] Colinet J, *Health Consequences of Overexposure to Respirable Coal and Silica Dust*, NIOSH Office of Mine Safety and Health Research, June 2, 2010.

[93] V C dos S Antao, EL Petsonk, L Z Sokolow, et al. Occup Environ Med 2005; 62:670-674.

In **Kentucky**, the counties of Knott, Leslie, Martin, Pike, Floyd, Perry, Letcher, and Harlan have seen the most pronounced rise in PMF occurrences.

TABLE 4: 1996 – 2002 Study: Kentucky Coal Miners with Rapidly Progressing Coal Worker's Pneumoconiosis[94]			
County, State (Highest rate counties listed)	**Miners Evaluated** (at least two examinations pre-1996 through 2002)	**Miners with Rapid Progression**	**Proportion of Evaluated Miners with Rapid Progression**
Knott, Kentucky	9	6	66.7%
Leslie, Kentucky	5	3	60%
Martin, Kentucky	10	6	60%
Pike, Kentucky	73	39	53.4%
Floyd, Kentucky	6	3	50%
Perry, Kentucky	9	4	44.4%
Letcher, Kentucky	23	10	43.5
Harlan Kentucky	24	10	41.7

In **Virginia**, the counties of Lee, Tazewell, Wise, Dickenson, Buchanan, and Russell have seen the most pronounced rise in PMF occurrences.

TABLE 5: 1996 – 2002 Study: Virginia Coal Miners with Rapidly Progressing Coal Worker's Pneumoconiosis[95]			
County, State (Highest rate counties listed)	**Miners Evaluated (at least two examinations pre-1996 through 2002)**	**Miners with Rapid Progression**	**Proportion of Evaluated Miners with Rapid Progression**
Lee, Virginia	5	4	80%
Tazewell, Virginia	26	16	61.5%
Wise, Virginia	63	37	58.7%
Dickenson, Virginia	31	16	51.6%
Buchanan, Virginia	122	60	49.2%
Russell, Virginia	13	6	46.2%

[94] *Id*.

[95] *Id*.

In **Pennsylvania**, the counties of Columbia and Somerset have seen the most pronounced rise in PMF occurrences.

TABLE 6: 1996 – 2002 Study: Pennsylvania Coal Miners with Rapidly Progressing Coal Worker's Pneumoconiosis[96]			
County, State (Highest rate counties listed)	**Miners Evaluated** (at least two examinations pre-1996 through 2002)	**Miners with Rapid Progression**	**Proportion of Evaluated Miners with Rapid Progression**
Columbia, Pennsylvania	5	4	80%
Somerset, Pennsylvania	14	9	64.3%

VI. Conclusion.

Despite government regulation of the coal mining industry, PMF diagnoses are increasing in the United States, particularly the geographic region comprising Kentucky, Virginia, and West Virginia. PMF is an entirely preventable disease that's sole cause in miners is overexposure to occupational dusts, including coal, rock, and silica. The most probable explanations for this regional epidemic are: (1) the high rank coal composition in the region; (2) collateral drilling of rock in the region's thin coal seams; (3) higher silica dust content in the region; (4) poor work practices, especially in smaller mines; and (5) inadequate MSHA exposure limits. Medical monitoring and other early detection methods combined with operator dust control efforts and use of personal protective equipment are the best ways to help decrease PMF among Appalachian coal miners. Notwithstanding these initiatives, miners will likely continue to suffer from PMF's crippling effects due to the dangers associated with chronic occupational dust exposure.

[96] *Id*.

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