Journal of Clinical Toxicology

Gamble et al. J Clinic Toxicol 2011, S:1
DOI: 10.4172/2161-0495.S1-003

Research Article | Open Access

Rapidly Progressing Coal Workers Pneumoconiosis as a Confounding Risk Factor in Assessing Coal Mine Dust Safe Exposure Levels

John F Gamble*, **Robert B Reger and Robert E Glenn**

Consultant, Somerset, NJ, USA

Abstract

The US coal mine dust ("CMD") standard is among the lowest in the world. Lowering exposures to 2 mg/m³ markedly reduced prevalence of coal workers pneumoconiosis ("CWP"). Lowering the standard to 1 mg/m³ is proposed because of a recent increase in rapidly progressive coal workers pneumoconiosis.

The purpose of this report is to evaluate the characteristics of the reported rapidly progressive CWP to evaluate these findings with regard to classical characteristics of CWP and to establish whether these rapidly progressive cases call for a lowering of the CMD standard.

We conclude that rapidly progressing CWP appears to be silicosis based on rapid progression of disease, the characteristics of the radiological changes observed, and the high quartz exposures experienced by these cases.

Keywords: Coal Mine Dust (CMD); Coal Rank; Coal workers pneumoconiosis (CWP); Progressive massive fibrosis (PMF); Radiographic category ; Rapidly progressive CWP ; Silicosis

Abbreviations: BOM: Bureau of Mines; CMD: Coal Mine Dust; CWP: Coal Workers Pneumoconiosis; ILO: International Labour Office; MSHA: Mine Safety and Health Administration; NCB: British National Coal Board; NIOSH: National Institute of Occupational Safety and Health; NSCWP: National Study of Coal Workers' Pneumoconiosis; SAR: Southern Appalachian Region of eastern Kentucky, western Virginia and southern West Virginia; UG: Underground

Introduction

The Mine Safety and Health Administration (MSHA) in the U.S. has proposed lowering the coal mine dust (CMD) from 2.0 mg/m³ to 1.0 mg/m³. This would be the lowest exposure standard in the world. Standards in other countries include Finland and the Netherlands at 2 mg/m³; Australia, Italy and the UK at 3, 3.3 and 3.8 mg/m³; and Yugoslavia at 4 mg/m³. Important potential confounding factors include potential roles of quartz and coal rank with respect to rapidly progressive CWP. The majority of coal[1] miners is from the UK and US and provides the weight of evidence for determining whether or not an exposure limit of 2.0 mg/m³ prevents category 2 CWP.

The basis for setting the US CMD Standard was that a miner exposed at 2.0 mg/m³ over a working lifetime of 35 years would have zero risk of developing Category 2 simple CWP. Since passage of the 1969 Mine Act, measured dust exposures in US coal mines have been reduced to a considerable degree, with a large majority of coal mines being in compliance with the 2.0 mg/m³ dust standard. However, as can be expected, occasional periodic excursions can occur above the PEL. The reported prevalence of CWP in the Nation's coal mines has decreased from around 30 % to about 3%.

In the past decade, there have been reports of a slight increase in the prevalence of CWP. The increase is coupled with reports of rapidly progressive CWP in younger miners often exposed for a relatively short time period and producing steeper exposure-response estimates for predicting the occurrence of CWP. These three points, [1] increased prevalence, [2] rapid progression, and [3] new exposure-response estimates, are mainly the stimuli for the proposal to lower the current US CMD standard to 1.0 mg/m³. This report will focus on the issue of rapidly progressing CWP to determine its relevance for inclusion into consideration for a new CMD standard, or whether the rapid progression and increased prevalence are due to confounders, and not to CMD exposure. Coal rank is another potential confounding risk factor in assessing safe exposure limits, and will be treated elsewhere.

Studies on Rapidly Progressive CWP

Summary of studies on rapidly progressive CWP

In the US, after the implementation of the interim CMD standard of 3.0 mg/m³ in 1970, and the final standard of 2.0 mg/m³ in 1972, the prevalence of CWP and concentrations of CMD began a steady decline. Beginning in the mid-1990s, an apparent increase was observed in what was at first thought to be more severe and rapidly progressive CWP despite the apparent stability in CMD exposure levels. The change in the pattern of CWP occurrence was identified as a "sentinel health" event and commonly occurred in the southern Appalachian region ("SAR") of eastern Kentucky, western Virginia and southern West Virginia.

Several potential causal factors have been investigated in an attempt to explain these changes in CWP severity and progression, as well as why it is more common in the SAR. According to NIOSH, the greater

[1]Coal rank defines the carbon content with higher ranks having more carbon (and lower rank number). Coal ranks go from 100 to 900 in the UK and 1 to 5 in the US. Number 1 is the highest ranking coal, anthracite with 93-95% carbon, and number 5 is the lowest ranked high volatile Western coal with <85% carbon.

***Corresponding author:** John F Gamble, Consultant, Somerset, NJ, USA, E-mail: john.f.gamble@comcast.net

Received November 12, 2011; **Accepted** December 06, 2011; **Published** December 10, 2011

Citation: Gamble JF, Reger RB, Glenn RE (2011) Rapidly Progressing Coal Workers Pneumoconiosis as a Confounding Risk Factor in Assessing Coal Mine Dust Safe Exposure Levels. J Clinic Toxicol S1:003. doi:10.4172/2161-0495.S1-003

Citation: Gamble JF, Reger RB, Glenn RE (2011) Rapidly Progressing Coal Workers Pneumoconiosis as a Confounding Risk Factor in Assessing Coal Mine Dust Safe Exposure Levels. J Clinic Toxicol S1:003. doi:10.4172/2161-0495.S1-003

severity and rapid progression of CWP are more characteristic of silicosis than CWP and are associated with r-type opacities on the chest radiograph. Smaller mines (which often experience higher exposures than larger mines) and thinner seams of coal (with more cutting of sandstone and quartz-containing rock) are almost uniquely a feature of the SAR. Rapidly progressive CWP may also be associated with higher coal rank.

These factors have been investigated in US studies [1-5]. Potential confounding risk factors examined include quartz exposure, increased length of shifts and rank of coal. A similar pattern of changes in exposure and severity of CWP has been observed in the UK including a Scottish coal mine where there was a period of extensive cutting through quartz-containing rock that produced increased adverse health effects that did not appear to be due to coal dust [6-8].

In the US rapidly progressive cases of CWP have been identified nationwide [1] and locally in two counties in Virginia [2]. The nation-wide analysis showed that despite "excellent progress in reducing dust exposure" severe cases of rapidly progressive CWP and PMF continued to occur "among relatively young US coal miners" [1]. The geographic locations of rapidly progressing CWP were largely in 25 counties in the SAR. Overall reported prevalence of CWP >1/0 ranged from 0.8% to 17.6%, while the proportion of evaluated miners with rapidly progressive CWP ranged from 41.7% to 80%. Nearly 30,000 miners were evaluated, and the reported prevalence (% of total 29,521) of different categories of CWP was as follows [1]:

● All CWP = 866 cases (2.9% CWP > 1/0)

+ 783 (2.65%) cases had 2 radiographs so progression could be assessed.

+ 277 (35%) of these783 case with CWP had rapidly progressive CWP or 0.94 % overall;

+ 41 had rapidly progressive PMF (14.8%) or 0.14% overall;

+ 8 (2.9%) had progression of one subcategory or 0.03% overall;

+ 156 (56.3%) had progression of 2-3 subcategories over 5-years or 0.53% overall;

+ 72 (26%) had a progression of more than 3 subcategories over 5-years or 0.24% overall.

● 73% of rapidly progressive cases (n = 202) had rounded opacities as the primary shape/size profusion, and 13% of these (n=26) of these were r-type;

● 50% of non-rapidly progressive cases (n=392) had rounded opacities, and 4% of these were r-type (n = 16).

● Based on r-type markings (n=42) the reported prevalence of silica-related CWP (42/29,521) appears to be about 0.14%. Based on the rapid progression characteristic of silicosis the reported prevalence of silica-related CWP appears to be about 0.94% (277/ 29,521).

Another study produced results showing r-type opacities (silicosis) are associated with rapidly progressing CWP, which the evidence suggests is due at least in part to quartz [4]. These authors reported an overall prevalence of 0.22% primary r-type opacities, 0.21% had secondary r-type opacities, or a total of 0.35% (n = 321) showing r-type opacities. These data are from miners participating in the NIOSH-administered CWXSP. The reported prevalence of coal-related CWP International Labour Office ("ILO") Category 1 has been reduced since 1980 and CWP ILO Category >2 has remained relatively stable. Silica-related reported prevalence of CWP (based on r-type opacities) has risen steadily for all categories including PMF (Figure 1).

Another feature of CWP needs to be considered for interpreting these data. That is the question of background prevalence of radiological opacities that are read as pneumoconiosis and are found in non-exposed subjects. Unpublished data from 218 blue-collar workers not occupationally exposed to dust with a mean age of 56 years showed a reported prevalence of 1.4% (standard error (SE) =0.8) category 1/0 and greater [9], referring to unpublished data from Castellan, et al. [10]. It may the older age of this group of men that is the reason prevalence is different than the 0.21% prevalence of rounded opacities reported in the published study. Attfield and Seixas [9] suggested there was a 5% or greater prevalence of small irregular opacities 0/1 or greater (90% 1/0 or greater) for men 60 years old with zero dust exposure (interpolated from [11]. Attfield and Seixas also reported that the prevalence of small opacities among non-exposed older workers (from [11]) would naturally rise above the 5% rate. The lowest estimate of 1.4% with an upper bound of 2 (SE = 3%) is greater than the observed prevalence of radiographic CWP (Figure 1).

If r-type opacities are a reliable marker (or radiologic pattern) for silica-related pneumoconiosis (or silicosis) among coal miners, then the data displayed in Figure 1 indicate:

- The overall reported prevalence of coal-attributable CWP since 1980 declines over time with no upturn at any time;
- The reported prevalence of CWP is below the 3% background level for >1/0, and is well below the predicted background prevalence of 5%;

The recent increase in reported prevalence of CWP and PMF [3] appears to be due to silica-related pneumoconiosis. Both categories

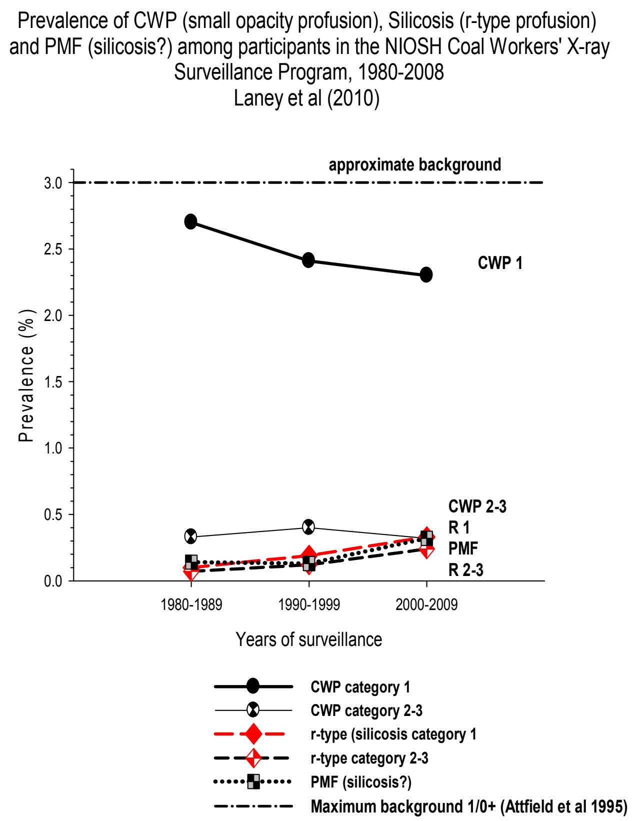


Figure 1:

1 and 2 doubled in reported prevalence in the 1990s and were three times greater in the 2000s compared to the 1980s. PMF remained stable through the 1990s and then more than doubled in the 2000s (Figure 1). PMF is presumed to largely be due to quartz exposure rather than coal dust.

The geological characteristics of coal from the SAR and the character of the mines provide indirect evidence that quartz is a likely contributor to rapidly progressing CWP [5]. These include small seams requiring large amounts of cutting stone to recover the coal, small mines where small seams and higher exposure are not uncommon, and very high proportions of quartz in the dust. These factors are highly correlated in the SAR and provide circumstantial evidence supporting quartz as an etiological agent in the development of rapidly progressing CWP.

An example of rapidly progressing CWP related to quartz exposure in a Scottish colliery [6,7] will be discussed later.

In sum, these studies provide strong evidence that the quartz in CMD is producing rapidly progressive silicosis that has been misdiagnosed as CWP. The evidence supports the belief that there has been no increase in the reported prevalence of CWP and that the prevalence of CWP may well be below background levels. The recent increase in CWP prevalence is due to the increasing prevalence of r-type opacities suggestive of the effects of silica exposure. Increases in prevalence are due to rapidly progressive silicosis associated with quartz concentration; and, in fact, there is no association with CMD and CWP.

The basis for the conclusion that rapidly progressive CWP is, in fact, rapidly progressive silicosis caused by high quartz levels is from the evidence in the studies summarized in section 2 below.

Summary and comments on studies of rapidly progressing CWP [1]

Summary and comments: The authors Antao, et al. [1] note that about 3.2% of approximately 35,000 current coal miners (1996-2002) show evidence of CWP. This reported prevalence is down from about 33% prevalence found in 1970. According to the authors, despite the progress in decreasing dust levels and the prevalence of CWP, severe cases of CWP (including PMF) continue to occur among younger miners. This report attempts to identify rapidly progressive cases of CWP (including PMF) and investigates some factors that contribute to this disease.

This is a nation-wide study of 29,521 miners in the CWXSP for the years 1996-2002 and includes miners with at least 2 chest radiographs with the most recent showing at least 1/1 pneumoconiosis. Rapid progression is defined as progression of more than 1 ILO subcategory over 5-years after 1985 and/or the development or progression of PMF after 1985.[2]

The ILO has developed classification systems for determining if radiographic lung opacities are consistent with pneumoconiosis for use in epidemiology studies. Concentration of small opacities are graded on a 12-point scale of four major categories each with 3 subcategories and progressively increasing profusion:

Major Categories	Subcategories	Characteristics
Category 0	0/-, 0/0, 0/1	No opacities or less than the lowest category 2(<1/0
Category 1	1/0, 1/1, ½	Continuation of concentrations between categories 0 and 2
Category 2	2/1, 2/2, 2/3	Profusion concentrations between categories 1 and 3
Category 3	3/2, 3/3, 3+	Profusion concentrations between categories 2 and PMF

PMF (progressive massive fibrosis), subcategories A,B,C indicating increasing larger opacities >10 mm.

A crude prevalence of 3% (866 CWP cases) was identified for the years 1996 -2002. Among these 866 cases there were 783 cases with 2 or more radiographs so progression could be evaluated; of these, 277 (35%) were rapidly progressive CWP. This is the study group of interest, and among this group were 41 (14.8%) with rapidly progressing PMF. The extent of progression in less than 5 years included 8 (2.9 %) with progression of 1 subcategory (at variance with the authors definition of rapid progression), 156 (56 %) with progression of 2-3 subcategories, and 72 (26%) with progression of more than three subcategories.

Rapidly progressing cases were compared to non-rapidly progressing cases on several characteristics. The study group is thus finally reduced to 277 workers. It seems that the manner in which the higher percentages are quoted gives rise to a suggestion that the progression is more serious than it really is.

	N	Age	Tenure	Work in smaller mines (<50)	Tenure at face
Rapid progression	277	48(6)yrs	27 (6) yrs	OR = 1.55 (1.2-2.0)	19 (10) yrs
Non-rapid	506	51(6) yrs	26(8) yrs	OR = 1.0	17(10) yrs

The data indicate occurrence of rapid progression to be associated with several factors:

- Geographical clustering is in eastern Kentucky, southern West Virginia and western Virginia. Overall there were 277 cases of rapidly progressive CWP in 14 different states and 137 different counties. There were 295 rapidly progressive cases in 25 counties, and comprised over 40% of all rapidly progressive cases of CWP. [Note: The 277 rapidly progressive cases are from the text and abstract and presumably included all rapidly progressive cases. Table 1 shows 295 rapidly progressive cases and excludes counties with <5 miners evaluated and with <40% of evaluated miners with rapid progression. This discrepancy raises the question of how many actual cases (i.e. >295) there are of rapidly progressive CWP. Cases tended to cluster along the eastern edge of the Appalachian coal field and may in part be explained by rank of coal and other factors such as silica exposure. An earlier study demonstrated rapid progression to have been previously observed more often in West Virginia and Pennsylvania than in western states where there was negligible progression [12].
- Work in smaller mines (<50 employees) is where respirable CMD exposures are higher [13].
- Longer tenure at face jobs is where exposure is typically greatest and face workers have previously been shown to experience more rapid progression of CWP [14, 15];
- Younger age is "strongly implicating recent mining conditions." The authors characterize cases with rapidly progressive CWP as "sentinel health events" indicating inadequate prevention in those situations where they occur. Such sentinel health events should prompt investigation to identify the causal agents that lead to preventive actions.

Critique of Antao VS, et al. [1]: The authors themselves suggest several limitations. These include:

- Inter-reading variability occurred because of independent readings

Citation: Gamble JF, Reger RB, Glenn RE (2011) Rapidly Progressing Coal Workers Pneumoconiosis as a Confounding Risk Factor in Assessing Coal Mine Dust Safe Exposure Levels. J Clinic Toxicol S1:003. doi:10.4172/2161-0495.S1-003

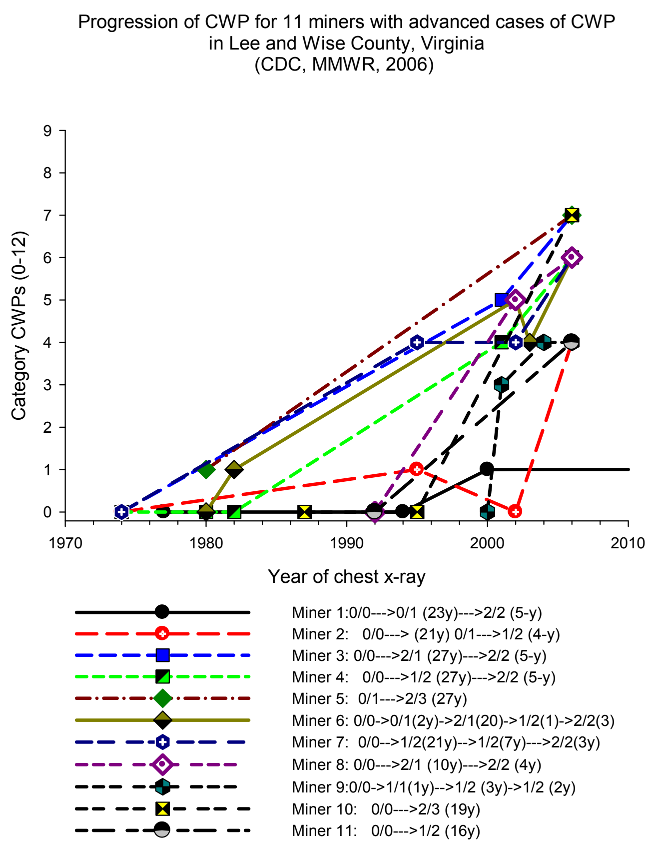


Figure 2:

by different readers at different times (separated by 5+ years). Variability is somewhat limited as at least two subcategories are necessary for a diagnosis of rapid progression. Regression can also occur, and it is not too infrequent as some classifications "improve" due to reader variability and film quality. This phenomenon was found in Miner 6 as shown in Figure 2. While minor regression did occur at a point in time, overall progression did occur. On inter-reader variance, the authors indicated there was good reliability of case definition when they selected a subset of 211 films and had them reviewed side by side. The side-by-side readings were compared with the independent assessments and "good" agreement was reached. It was never stated what "good" meant.

- Selection bias may be occurring. The participation rate was about 31%. It is not clear how this is a limitation if the cases with rapid progression are more likely to participate. However, it becomes a limitation if cases do not participate so there are no "sentinel" events to observe. Since the authors did not investigate why miners were more, or less, likely to choose to participate it is pure speculation as to which way this might bias the study. Low participation is a substantial limitation for estimating prevalence, but less so for sentinel events where about 3% is a high enough prevalence to identify a potential health concern and need for investigation.

It is important to be mindful of this limitation when considering exposure-response studies of radiographic CWP, as it is here that selection bias because of low participation becomes important. *See* [16] for more about prevalence rates.

Other comments: There are no exposure estimates in this paper. Without estimates of CMD, it is impossible to develop safe exposure levels based on science. Since these are "sentinel events" the lack of exposure estimates are not necessarily important. "Sentinel events" indicate a need for further investigation to determine cause(s). However, sentinel events cannot be used for setting quantitative exposure standards.

Coal rank declines going east to west in the US and CWP risks are greater among high rank coals even at similar dust levels. So this explains in part the lower prevalence of CWP in western mines. But rank does not fully explain either the clustering, or other factors such as quartz, mining techniques, mine size, dust control, and enforcement of exposure limits, all of which should be considered.

A case of rapidly progressive CWP was defined as "the development of PMF and/or an increase in small opacity profusion greater than one subcategory over five years." Further on, it is noted that the 1996-2002 time period is the period when the terminal x-ray was taken, and earlier films from the same period (1996-2002) or pre-1996 films are used to assess progression. The terminal film must be at least category 1/1. If all earlier ILO classifications were zero, the final determination had to be at least category 1/2. This is unclear and was an attempt to minimize false-positive conditions, but terminal films that were classified lower than 1/2 (viz. 1/1) may also have had previous film readings which were normal.

The case example given is pertinent -- the final determination of category 2/1 small opacities with PMF (large opacity size B) is clearly within the time frame designated, i.e. it occurred in the year 2000 or between 1996 and 2002. The miner's previous x-ray was from 1992 and showed category 1/2. He was young when the last x-ray was taken at 40 years. This progression, as did all of the attack rates, indicated it could have been from a multitude of factors; e.g. past exposures (for this particular person) for 18 years at the face, quartz content, residence time of dust in the lungs, mining methods, mine size, area where high grade metallurgical coal is taken, individual susceptibility, and inter-reader variance.

	Mean age yrs	Yrs UG mining	Yrs at face
Examined Miners	47 (21-63)	23 (0-41) yrs	66% worked at face
Advanced CWP	51 (39-62)	31 (17-43) yrs	100% at face=29 yrs (17-33)

The authors also stated that the younger men were progressing. On average, the ones progressing were 48 years old and those not progressing were 51. That is a three year difference on average, with clearly overlapping distributions. This is hardly a noteworthy age differentiation justifying a conclusion that younger miners were progressing.

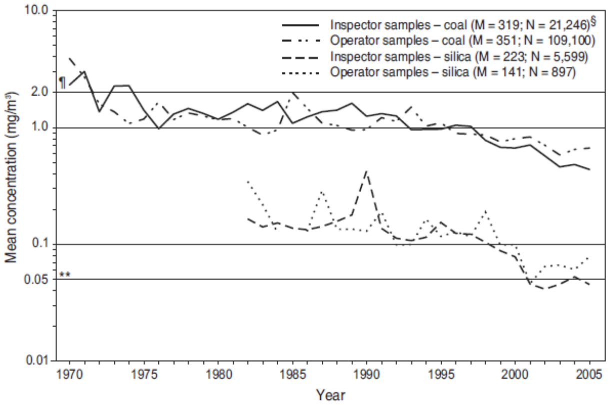
Summary and comments [2]

This CDC [2] report describes some of the characteristics of 11 miners with advanced cases of CWP. In 2006, 31% (328) of the estimated 1,055 underground coal miners in Lee and Wise counties, Virginia were administered questionnaires, spirometry, and chest radiographs. Statistics on the examined miners and the 11 miners with advanced CWP are as follows:

The editors make several comments. Nine of the 11 miners had not worked in coal mines prior to 1969. Based on statistical modeling using average dust exposure at the face in these counties and coal rank, the number of expected cases of CWP would be 12 if coal mine dust exposures had been 4.0 mg/m^3.

Citation: Gamble JF, Reger RB, Glenn RE (2011) Rapidly Progressing Coal Workers Pneumoconiosis as a Confounding Risk Factor in Assessing Coal Mine Dust Safe Exposure Levels. J Clinic Toxicol S1:003. doi:10.4172/2161-0495.S1-003

FIGURE. Mean concentrations of respirable coal mine dust and crystalline silica in coal mine dust* for underground workers at the coal face† — Lee and Wise counties, Virginia, 1970–2005



* Data from Mine Safety and Health Administration (MSHA) coal mine inspector and mine operator samples.
† The cutting surface where coal is sheared from the wall and dust levels typically are greatest.
§ M = number of mines sampled; N = number of samples taken.
¶ MSHA permissible exposure limit for coal mine dust with <5% silica content.
** National Institute for Occupational Safety and Health recommended exposure limit for crystalline silica in coal mine dust.

Figure 3:

The editors propose several hypotheses to explain these cases of advanced CWP:

- The current standard of 2.0 mg/m³ might be too high. This inference is not consistent with the data presented in their Figure 1 (shown in our Figure 3).
- CMD levels in these two counties were below the standard from 1970 to 2005, and were below the NIOSH Recommended Exposure Limit ("REL") of 1.0 mg/m³ since 1995.
- Sampling for silica began in the early-1980s and remained above the standard of 0.1 mg/m³ until about 1998. About 65% of silica samples collected in 1982-2000 exceeded the NIOSH REL for silica of 0.05 mg/m³; only since 2001 have mean county levels been below the NIOSH REL for silica (Figure 3).
- Actual dust levels might be above the standard. From 1970-2005 about 2.5% of individual samples were greater than 2.0 mg/m³ but compliance samples may be biased and underestimate exposure levels [17,18].
- Silica might be a contributing factor as mean silica levels were above the NIOSH REL of 0.05 mg/m³ before 2001, and 65% of MSHA samples were above the REL during 1982-2000.[3]
- Higher rank of coal may be more fibrogenic in the lung, although the rank of coal in these two Virginia counties has not been previously associated with increased fibrogenicity.

Limitations to these data include participation was very low (31%) and the miners worked for only a limited time in these mines (8 of 11 had worked in current mines for less than 5-years).

Critique of CDC [2,19]: The silica and CMD levels may not be relevant for eight of the 11 miners as they were not working in these two counties at the time these samples were collected. If dust levels were known for the mines in which these eight miners were working, these data might support the hypothesis that excessive exposures to silica and/or CMD were etiological agents, and which agent was primarily responsible for the disease endpoint observed.

Progression can occur in a few years if these X-ray readings are reliable. For example, the 'latency' for change was six years from 0/1 to 2/2; five years from 2/1 to 2/3 and 1/2 to 2/2; four years from 0/0 to 1/2, 1/2 to 2/2 and 2/1 to 2/2; and three years from 1/2 to 2/2 (Figure 2).

The data suggest that the rapidity of progression in some cases is caused by a fairly short-term high exposure. For Miner 1 there are 23 years for progression of one sub-category (0/0 to >0/1) compared to five years for a full category (0/1 to >2/2). Similar changes are seen in Miners 2, 4, 7. In other instances there may be decades for sub-category progression as seen in Miners 2, 4, 7, and 11. In Miner 6 there was a regression from 2/1 to 1/2 (likely reader variability) and then progression to 2/2 in three years.

Thus, it appears there are about four miners who show rapid (<6-years) and substantial progression (a whole category or more). Moreover, two of these four miners developed PMF. These miners show the strongest pattern for progression of their condition, which is consistent with silicosis. These patterns require confirmation using additional data, including assessment of r-type opacities on the radiographs.

As the editors note, these are sentinel health events and largely confirm results of Antao, et al. [1]. Their hypotheses remain speculative without individual rather than group analysis. This individual analysis might involve a case-control study assessing individual dust exposure, silica exposure, mine size, rank of coal, height of roof, and mining practices.

High rank coal (anthracite) tends to be in the east, but high grade bituminous coals are located in the SAR. Thus, as the SAR contains high grade bituminous coals, rank probably also contributed to these cases of rapid progression.

The group of studies following provides indirect or circumstantial evidence about some of the hypotheses regarding the etiology of so-called rapidly progressive CWP. Rapidly progressive CWP may be a misnomer as it appears to be rapidly progressive silicosis. The predominant opacities seen on the X-ray are r-type opacities associated with silica; and there are high concentrations of quartz in the coal being mined which produces high exposures to silica, and there is rapid progression of the cases, all of which are characteristic of silicosis but not CWP.

Summary and comments [5]

The objective of Pollock D, et al. [5] study was to identify mining conditions and exposures that might explain the occurrence of sentinel events showing advanced and rapidly progressing cases which were considered to be CWP in the SAR [1].

Of immediate concern in this area of the country is the fact that around half of the mines in these MSHA districts are on a reduced dust standard due to the high percentage of quartz in the CMD. Thus, silica exposure is a major concern.

[3]A NIOSH Recommended Exposure Limit or "REL" is an exposure level for toxic agents that are health-based and are considered safe for various periods of employment, including but not limited to the exposures at which no worker will suffer diminished health, functional capacity, or life expectancy as a result of his or her work experience. NIOSH RELs are recommendations, not mandatory standards, but they can be adopted as such by MSHA, following rulemaking in accordance with Mine Act requirements.

The "hot spots" investigated were located in MSHA Districts 4 (southern WV), 5 (Virginia), 6 (eastern Kentucky), and 7 (central Kentucky and states of NC, SC and Tennessee). MSHA compliance data from 2000-2005 were extracted to analyze exposure in all occupations, continuous miner occupation, number of samples > 2.0 mg/m^3 and the number exceeding the reduced dust standard after adjustment for high quartz. These data were then used to target specific active mines exceeding these standards more than 5% of the time and mines cited >2 times for excessive dust the previous year under MSHA's Respirable Dust Emphasis Program initiative. MSHA reports of these mines were also examined for equipment, mine conditions, etc.

The results are summarized by the topic identified in analysis of these data:

●Small mines < 50 employees and compliance with standards: Most mines are small and the proportion in compliance varied between 43% and 80% depending on the MSHA district.

Characteristics of small underground mines (<50 workers) in SAR

District	N small (% total)	% not meeting standards >5% of time	% RDEP (2+ times excessive dust	% in Compliance
4	85/148 =57%	43%	57%	43%
5	39/53 = 73.6%	90%	50%	50%
6	88/105 = 84%	83%	50%	75%
7	50/70 = 71%	66%	33%	80%
Total	262/373 = 70%			

RDEP = Respirable Dust Emphasis Program

● Mining conditions in the SAR:

All of these operations mined through substantial rock layers to maintain roof height. Thickness of rock in five mines ranged from 6-12 inches. One mine was cutting through three feet of rock. A large amount (20-30%) of quartz-containing rock was being cut in these mines.

Further dust surveys were conducted at six mines. Results from four of these mines indicated median dust levels were all below 2.0 mg/m^3 for continuous miner operators, shuttle car operators and roof bolters (intake and return air). However, all jobs had area sample levels greater than the standard with maximum levels between 8 and 10 mg/m^3. Quartz content of the dust in these jobs had median levels between 20-30% and maximum levels between 40-50% quartz. For levels to be that high suggests they must have been cutting through a sandstone formation. Therefore, quartz percentages ranging from 20-50% in the personal samples and area samples measures ranging from 8-10 mg/m^3 would result in area quartz exposures ranging from 1.6 to 5.0 mg/m^3. Since the MSHA standard for quartz is 0.1 mg/m^3, quartz exposures were a factor of 16 to 50 times greater than the standard.

Cutting through rock drastically reduces life of the cutting bit. As the bits wear, more CMD is generated, often in quantities that prevent sprays and scrubbers from keeping up with the dust generated. In some instances every time the cutter is relocated, bits must be replaced and clogged water sprays and scrubbers have to be cleared.

Often roof bolters were working downwind of the continuous miner and bolter faces were inadequately ventilated. These conditions are demonstrated in similar median and maximum dust and percentage of quartz levels in the intake and return air of roof bolter samples.

Critique of Pollock, et al. [5]: Dust problems in the SAR relate to the fact that around half of the mines in these MSHA districts (4, 5, 6, 7) are on a reduced dust standard per 30 C.F.R. §70.101 because of quartz which is, thus, a major concern. Such high ratios (20 to 30 percent) of rock to roof height are astounding. To cut through this much silica-laden material can surely cause a marked change in the exposure contribution to disease outcomes and produces constant maintenance and ventilation problems that must be of concern just to keep producing coal in addition to health concerns.

This article [5] gives good guidance for a select area of the country's coal fields where most of the recent increases in the reported prevalence of CWP and PMF are occurring. It gives considerable weight to the importance of equipment maintenance and work practices as well as geological conditions. The circumstantial evidence of Pollock, et al. [5] that characterizes mining conditions in the SAR is consistent with other articles where rapidly progressive silicosis appears when conditions are similar to those in the SAR in that quartz exposure as well as rank and mine size are also important. For example, the quartz exposure experienced in a Scottish colliery [6] produced similar cases of silicosis due to geological conditions requiring cutting through quartz-rich faults, which is similar to the descriptions of some mines in the SAR.

Moreover, 70% of the mines in these MSHA districts are small mines that are more likely to have thin seams of coal and therefore more quartz-bearing rock being cut, thereby producing higher exposure to both coal dust and silica. Since small mines are more common in the SAR than elsewhere in the US, it is not necessarily unexpected that a high proportion of rapidly progressive cases of silicosis occur in this area. Also, these small mines are more often out of compliance than large mines, especially when quartz levels are excessive.

This investigation revealed that a majority of underground small coal mines in this "hot spot" area of the SAR are out of compliance, have high CMD and quartz levels, and have difficult mining conditions that can produce rapidly progressive cases (likely silicosis, misdiagnosed as CWP).

It appears there is no more "easy coal" left to mine in this area. All mines have high proportions of rock through which miners must cut. This fact results in increased silica exposure that requires more preventive maintenance. In the absence of adequate ventilation the roof bolter and cutting machine operators face excessively high coal dust and silica exposure levels.

These adverse mining conditions are described over a five-year period at the beginning of the 21st Century, which appears to be long enough for progression to higher ILO sub-categories, and in some instances to PMF. It appears likely that some of these conditions existed before 2000 and therefore could explain a portion of cases showing early signs of CWP in the 1990s or before given the short latency for silicosis progression [2].

These results are suggestive that having to mine excessive amounts of quartz-bearing rock means that to stop increases in CWP, there must be continuous maintenance of dust control systems, replacement of worn bits, continual scrubber maintenance, continual surveillance to insure proper ventilation and reduction of down-wind operations. The large amount of rock through which cutting must be carried out and high quartz levels provide a strong case that silica is more likely than not the major factor producing these sentinel events of highly progressive CWP.

What is needed is for NIOSH to do a reanalysis of the data in the Pollock, et al. study to determine if these general characteristics of mines in the SAR, and specifically quartz concentrations, can be correlated with the SAR miners identified in the study as developing rapidly progressive CWP, to determine whether the disease is actually silicosis.

Summary and comments [3]

The purpose of Laney A, et al. [3] study was to assess whether "CWP prevalence and severity are associated with mine size" among participants in the NIOSH-administered CWXSP.

Diagnosis and severity of CWP was determined from the last radiograph with agreement from two readers. All 145,512 miners with X-rays taken 1970-2009 with size and location of the mine were included in the analysis.

The reported prevalence of CWP has consistently dropped in the 1970s, 1980s and the first half of the 1990s, and began to rise in the late 1990s in mines employing less than 50 workers. For example, the reported prevalences through the decades were about 4%, 1.9%, 0.5% and 1% for mines with more than 500 employees. For small mines (less than 50 workers), the reported prevalences were 6%, 3%, 5% and 7.5% respectively. For small mines CWP reported prevalence dropped by 50% in the 1980s compared to the 1970s, but subsequently nearly doubled relative to the lowest small mines' prevalence in the 1980s. In general, mines intermediate in size between large and small showed intermediate trends in CWP reported prevalence.

The prevalence of PMF was higher among large mines in the 1970s and 1980s, but changed dramatically in the 1990s and 2000s when PMF became increasingly higher in small mines for the next two decades. Adjusting for age, miners from small mines in the 1990s were three times more likely to have PMF than miners from large mines and five times more likely in the 2000s (Figure 4).

Critique of Laney A and M Attfield [3]: Increases in reported prevalence and severity of PMF since 2000 is well documented (Figure 4), but the reason for these changes is less clear. This study [3] clearly shows that the increasing reported prevalence of PMF beginning around the 1990s is due in large part to PMF in small mines. Reasons for this dramatic shift of prevalence from large to small mines is unknown and cannot be assessed in this study.

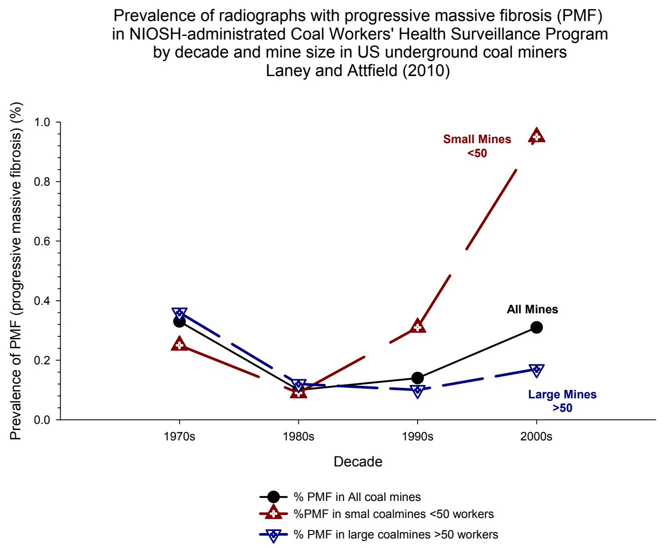


Figure 4:

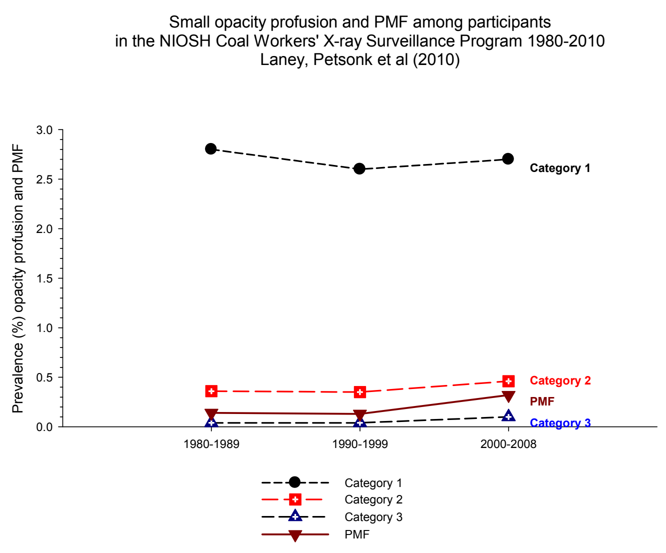


Figure 5a:

The authors [3] indicate several adverse effects occurring more commonly in small mines. One is that non-fatal disabling injuries and fatalities are more common in small mines [20,21]. A reason may be a younger, less experienced workforce [21]. This is not a plausible reason for size-related PMF effects in this study because differences were modest in absolute terms and because of adjustments for age differences.

Excessive quartz and mixed mine-dust exposures have been suggested as potential causes of severe CWP. Small mines work thinner seams of coal and cut more rock than larger mines. This study does not support this reason as thin-seams are primarily in Kentucky, Virginia and West Virginia while the small mine-effect was observed nationwide. However, the vast majority of thin seam coal being mined is in small mines in the SAR.

Small mines may have higher actual CMD levels than operator-sampled levels indicate. A study was conducted to sample CMD levels at the face and compare them to operator-based samples. At large mines the results were comparable. As the size of the mine decreased, the operator-based sample results tended to become smaller than inspector samples as mine size became smaller. The maximum difference shown was when MSHA samples were about two-fold greater than operator samples [22].

These results suggest CMD and quartz levels in small mines may be (more-or-less) two-fold higher than operator samples for equal percentages of quartz in the CMD. This phenomenon produces biased underestimates of exposure, which in turn produces biased overestimates of the potential to produce fibrogenicity in the lung.

Summary and comments [4]

The possible role of silica in the increasing occurrence of reports since 2000 of rapidly progressing CWP led to this investigation. Since 1980, mean CMD levels have been consistently below mandatory standards. This apparent contradiction suggested further explanation was needed. Silica seemed a plausible possibility as dust generated during coal mining now contains a higher proportion of crystalline silica, which produces "an increased inflammatory response and potent induction of pneumoconiosis." Lesions typical of silicosis have been

Citation: Gamble JF, Reger RB, Glenn RE (2011) Rapidly Progressing Coal Workers Pneumoconiosis as a Confounding Risk Factor in Assessing Coal Mine Dust Safe Exposure Levels. J Clinic Toxicol S1:003. doi:10.4172/2161-0495.S1-003

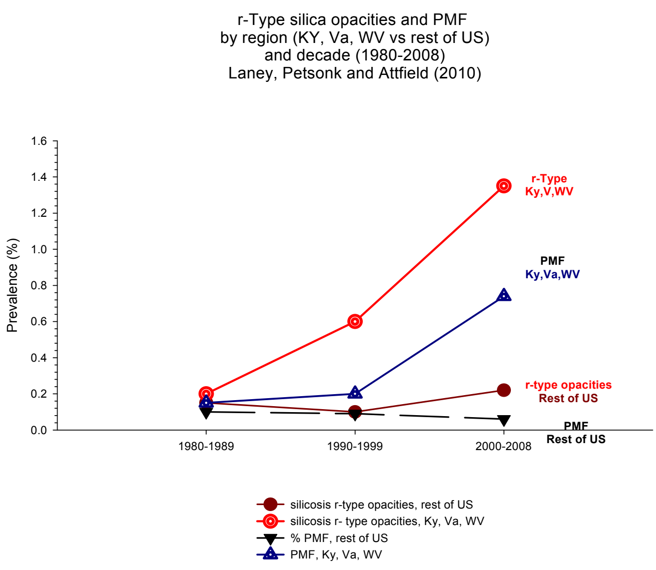


Figure 5b:

observed in some miners [14,23,24]. Also, rapid progression and PMF are more characteristic of silicosis than CWP [14,23,25].

To test the quartz hypothesis, chest radiographs collected by NIOSH from 1980-2008 were examined for rounded opacities greater than 3 mm= r-type opacities. Silicosis can also be characterized by "p" and "q" type opacities. Like simple CWP, silicosis is characterized primarily by rounded opacities occurring mostly in the upper lung zones and sometimes with hilar involvement and calcifications. Thus, it is often difficult to distinguish silicosis from ordinary CWP on the chest radiograph.

There were 2868 radiographs (3.2%) showing category > 1. Between 1980 and 2008 the proportion of categories 0 and 1 showed little change. Since 1990, there has been an increase in category 2 and 2.5-fold increases in category 3 and PMF respectively (Figure 6).

There were 321 (0.35%) X-ray readings showing r-type opacities (primary and secondary) overall during 1980-2008. For the SAR, prevalence of both r-type opacities and PMF increased each decade with a 7.6-fold increase in r-type lesions in 2000-2008 compared to the 1980s. For the rest of the US there was no trend for r-type opacities to increase, and slight downward trends for PMF (Figure 5a,b).

Critique of Laney et al. [4]: The authors [4] conclude the increasing reported prevalence of r-type opacities, rapid progression and more severe disease (PMF) in the Appalachian coal fields is consistent with an increased exposure to crystalline silica (quartz) and silicosis etiology.

The increase in reported prevalence does not appear to be caused by changes in the readings over this 30-year period as tested in a subset of B readers' employed over this entire time period. R-type opacities are plausible indicators of excessive quartz exposure based on autopsy findings of classical silicotic nodules and high levels of non-combustible ash consistent with silica [26]. CWP commonly does not progress rapidly, and requires a long latency period. On the other hand, silicosis has these characteristics, particularly at high concentrations well above the quartz standard.

Quartz is not necessarily the only cause of rapidly progressing CWP. Coal production has increased nearly 70% since the 1980s. There has been a trend toward increasing hours worked per shift that leads to higher CMD deposition. Increased reported prevalence could also be due to several other factors, e.g. different miners studied at different times, different x-ray readers interpreting films, and different ILO standards being utilized.

Several factors emphasize quartz as a plausible explanation for the SAR being a "hot-spot" geographic area. Increased mining has reduced available coal in the most easily accessible coal seams. The high demand for coal, its increasing price and increasingly productive equipment for extracting and cleaning coal has led to mining thinner and thinner seams. Silica-containing rock commonly surrounds coal seams. The thinner the seam the greater the proportion of rock and quartz that has to be cut relative to coal. Almost all (96%) of thin coal seams (less than 43 inches) are located in Kentucky, Virginia, and West Virginia.

Under these mining conditions one would expect elevated quartz levels in personal samples taken to enforce the CMD standard. Such an increase has not been noted in compliance samples, but this has been explained as not happening because quartz measurement is indirect and complicated.

This study is one of several implicating quartz rather than CMD and suggesting that the increased reported prevalence of CWP and rapidly progressive pneumoconiosis observed over the last 20-years may actually be rapidly progressive silicosis. While not known for sure, this study (like others) strongly points towards a serious quartz effect. As the study authors note, further evaluation of quartz exposures and control strategies is necessary in all underground coal mines, but the SAR should be a primary target.

Summary and comments [6]

The purpose of Miller B [6] study was to describe radiographic changes and their relationships to dust exposure among Scottish coal miners exposed to unusual concentrations of respirable quartz.

Chest radiographs were available on 547 coal miners who had worked at one Scottish colliery during the 1970s. The colliery participated in six medical surveys of the British Pneumoconiosis Field Research ("PFR") conducted from 1954 to 1978. At the sixth survey there were 21/623 (3.4%) coal miners who showed unusually rapid progression of pneumoconiosis compared to radiographs taken four years earlier. A small case-control study of the 21 cases [14,15] showed clear exposure-response relations with respirable coal dust, and an even stronger relationship with the respirable quartz exposures in the 1970s. The radiographic changes resembled silicosis. Normally there is <10% quartz in CMD. In this colliery there were two seams of coal being mined in the 1970s. In seam A mean exposures were less than 1.0 mg/m^3 and the proportion of quartz never exceeded 15%. In seam B more than 10% of samples were >1.0 mg/m^3, two work groups had means (>10 samples) that were > 10 mg/m^3, and in some instances there were proportions of quartz up to 60%. In all the surveys the mean percentage of quartz in environmental samples was 4.8%, 7.7%, 8.6%, 9.1% and 7.3 %; maximum % quartz in these samples was 7.6%, 17.5%, 29.4%, 26.6%, and 16.1% respectively. During the 1970s both quartz and coal dust exposures were high.

These data show a clear and strong exposure-response relationship between CWP ≥ ILO Category 2 small opacities (CWP 2+) and respirable quartz from mining in this particular colliery. This clear trend is seen in a categorical analysis (Figure 6). The best logistic regression models were with quartz exposures from surveys 3-6 either with or without non-quartz dust in the model. Non-quartz CMD showed no association with CWP 2+ at any concentration and a slightly negative association in the model with respirable quartz (Figure 6). The authors summarize this association as: "with quartz exposure in the model, non-quartz dust gave no significant improvement, whereas the inclusion of quartz after dust was highly significant. This is strong support for the conclusion that the abnormalities found are the result of the exposure to respirable quartz, rather than to the non-quartz content of the dust."

Critique of Miller et al. [6]: These data do not support an association of CWP 2+ with CMD up to cumulative exposure around 10 gh/m^3 (5.7 mg/m^3) (Figure 6). A reason for suspecting quartz exposure is because much higher risks than expected were produced for low CMD levels with the typical composition according to the authors. The rapid progression occurred after the high quartz exposures were diminished, which is atypical for CWP but typical of silicosis.

The best predictor of risk for category 2/1+ was quartz exposure particularly during 1964-78 when concentrations were high. During this inter-survey period of about 15-years, the model predicted that an average quartz exposure of 0.1 mg/m^3 or cumulative exposure of 1.5 mg/m^3-years produced a risk of about 5%. About 20% of the miners had exposures greater than 3.25 mg/m^3-yrs and risks of about 10% of category 2/1+. These data suggest that coal miners with quartz exposures at these levels may be showing increased risk of silicosis, not CWP. To avoid this misclassification, exposure estimates should include both quartz and CMD, radiographs should be carefully examined for the appearance of silicosis and the relationship between progression of disease with and without quartz should be analyzed.

The logistic regression results indicated no risk from non-quartz CMD at any exposure level in this mine (Figure 6).

A limitation of this study is that exposure to quartz and non-quartz CMD were determined for the miners as "data are differentiated by seam" and miners worked in different seams at different times. There is a clear difference between the strong association quartz with 2/1+ and no association with CMD or non-quartz dust. The use of gh/m^3 units is confusing as it was not clear when the units were for average and when for cumulative exposure. The estimated risk at average or cumulative exposure to quartz is unclear because the distinction between average and cumulative exposure is not made by the authors.

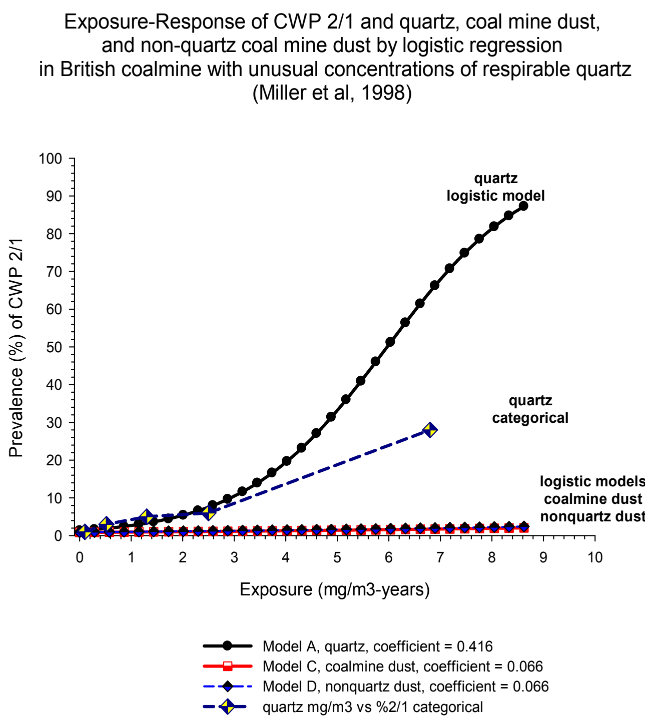


Figure 6:

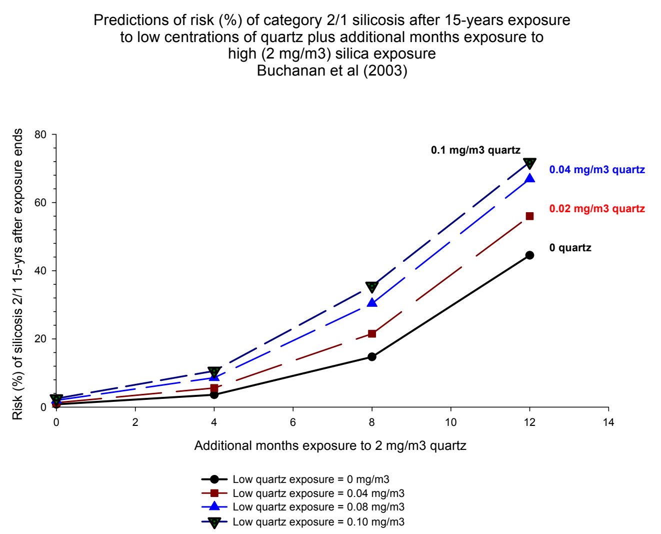


Figure 7:

This is a well-done but small study. It clearly demonstrates the importance of quartz content in CMD exposures. Rapid progression of pneumoconiosis was very likely silicosis, and the predicted risk of 2/1+ at follow-up provides good evidence for exposure-response to respirable quartz.

Summary and comments [7]

The study of Buchanan et al. [7] is a re-analysis of the exposure-response data from the Scottish colliery [6] and considered alternative quartz indices taking into account variable intensities and time elapsed since those exposures.

Risks of CWP 2+ were evaluated by cumulative exposures to CMD and quartz for all periods and for pre- and post-1964. For CMD there was no association with CWP, with an odds ratio ("OR") = 1.03 (1.02-1.04) for all time periods. For quartz, there were clear associations with pneumoconiosis with ORs of 1.70 (1.46-1.99) for all time periods and 1.81 (1.54-2.14) for the post-1964 time period. There were no increased risks of CWP associated with age, smoking or CMD.

The risk of category 2/1 silicosis with long exposure to low concentrations of quartz combined with high short-term exposures (2.0 mg/m^3 in this example) shows a dramatic increase in silicosis risk with relatively short periods of high quartz exposure (Figure 7).

Critique of Buchanan et al [7]: This paper shows a dramatic effect of short but high exposures to quartz in CMD that is not associated with CWP. Using data from the Scottish colliery cohort [6] the regression models predict the occurrence of silicosis after 15 years CMD exposure with variable (0-0.10 mg/m^3) quartz exposure, and added months of high quartz exposure (2.0 mg/m^3) (Figure 7). The effect of cumulative CMD exposure is negligible, while cumulative quartz exposure produces a substantial increase in silicosis prevalence.

The model then predicts the effect of high quartz exposures of 2.0 mg/m^3 occurring over a year. The 2.0 mg/m^3 concentration is representative as maximum concentrations were 3.0 mg/m^3. Four months exposure to 0.04 mg/m^3 quartz increases 4.4 fold the occurrence of CWP 2+ from background prevalence (zero months quartz exposures) (Figure 7). The NIOSH REL for quartz is 0.05 mg/ m^3 and the American Conference of Governmental Industrial Hygienist Threshold Limit Value is now 0.25 mg/m^3. For 1-year high quartz exposure the risk of CWP 2+ increases 56-fold. Coal mined from Seam B greatly increased quartz exposure and is the period when quartz effects are greatest. The high quartz exposures essentially drown out other exposure effects from low quartz and CMD.

This analysis suggests that coal miners without radiographic indications of CWP and exposed for even a short time (months), may show unexpectedly large increases in radiographic indications of silicosis. These progressive changes appear to be silicosis, not CWP, and are consistent with the recent and unexpected increase in rapidly progressive silicosis [27-29] observed in the SAR.

Summary and Conclusions

There is a natural progression of thought based in the epidemiological literature that leads to the current situation. Since the 1970s, when an X-ray surveillance program for coal workers in the US began, and CMD standards were initiated, there was a rapid decline in the reported prevalence of CWP from around 30% to 3%, and this decline was coupled with decreasing CMD levels. However, from around 1970 to the 1990s, CMD appeared to stabilize at around 1 mg/m^3 and then decrease slightly. In the 1990s or later, there were reports that CWP prevalence was increasing slightly without concomitant increases in CMD exposure.

In the 2000s, NIOSH reported cases of rapidly progressive CWP. Some miners were described as developing dust-induced disease of high severity over short time periods, and some cases were among relatively young men. While the frequency of these sentinel events was low in absolute numbers, they were nonetheless a serious health concern calling for a determination of their cause and how to prevent their occurrence.

Unlike studies of prevalence in CWP in cohort studies of coal workers, sentinel health events such as cases of rapidly progressing disease are unaffected by limitations in participation rates or unreliable exposure estimates. They are events indicating a problem requiring investigation to determine causes and how such events can be prevented.

Our examination of these reports indicates the rapidly progressing cases of pneumoconiosis are likely silicosis being misdiagnosed as CWP. This conclusion is based largely on a number of factors in the SAR region including: extremely high quartz exposures (two to three times the quartz standard on average); low coal seams with high percentages of quartz admixed in the coal; small mines with historically high dust exposures; and longer shifts resulting in higher cumulative exposures of CMD and quartz.

No studies have been conducted to identify specific etiological agents or factors associated with rapidly progressing cases such as a case-control study. The evidence that this reported outbreak of CWP is indeed CWP, and not silicosis, has not been adequately examined.

A properly designed case-control study should be conducted to produce more definitive conclusions as to the etiologic agent and exposure-response relationships. Such a study would be useful to determine etiology (or test the quartz hypothesis) and assess exposure-response so needed prevention controls can be instituted where necessary.

Acknowledgements

This paper is revised from comments submitted to MSHA regarding the adequacy of the current federal coalmine dust standard. It was partly funded by coal operators.

References

1. Antao VS, Petsonk EL, Sokolow LZ, Wolfe AL, Pinheiro GA, et al. (2005) Rapidly progressive coal workers' pneumoconiosis in the United States: geographic clustering and other factors. Occup Environ Med 62: 670-674.
2. CDC (2006) Advanced cases of coal worker's pneumoconiosis--two counties, Virginia, 2006. MMWR Morb Mortal Wkly I Rep 55: 909-913.
3. Laney A, Attfield M (2010) Coal workers' pneumoconiosis and progressive massive fibrosis are increasingly more prevalent among workers in small underground coal mines in the United States. Occup Environ Med 67: 428-431.
4. Laney A, Petsonk EL, Attfield M (2010) Pneumoconiosis among underground bituminous coal miners in the United States: Is silicosis becoming more frequent?. Occup Environ Med 67: 652-656.
5. Pollock D, Potts J, Joy G (2010) Investigation into dust exposures and mining practices in mines in the Southern Appalachian Region. Mining Engineering 62: 44-49.
6. Miller B, Hagen S, Love RG, Soutar CA, Cowie HA, et al. (1998) Risks of silicosis in coalworkers exposed to unusual concentrations of respirable quartz. Occup Environ Med 55: 52-58.
7. Buchanan D, Miller B, Soutar C (2003) Quantitative relations between exposure to respirable quartz and risk of silicosis. Occup Environ Med 60: 159-164.
8. Hurley J, Copland L, Dodgson J (1979) Simple pneumoconiosis and exposure to respirable dust: relationships from twenty-five years' research at ten British coalmines, in Report TM/79/13. Institute of Occupational Medicine: Edinburgh, Scotland.
9. Attfield M, Seixas N (1995) Prevalence of pneumoconiosis and its relationship to dust exposure in a cohort of U.S. bituminous coal miners and ex-miners. Am J Ind Med 27: 137-151.
10. Castellan R, Sanderson W, M Peterson (1985) Prevalence of radiographic appearance of Pneumoconiosis in an unexposed blue collar population. Am Rev Respir Dis 131: 684-686.
11. Collins H, Dick JA, Bennett JG, Pern PO, Rickards MA, et al. (1988) Irregularly shaped small shadows on chest radiographs, dust exposure, and lung function in coalworkers' pneumoconiosis. Brit J Ind Med 45: 43-55.
12. Amandus H, Reger RB, Pendergrass EP, Dennis JM, Morgan WKC, et al. (1973) The pneumoconioses: methods of measuring progression. Chest 63: 736-743.
13. Force T (1993) Report of the Statistical Task Team of the coal mine respirable dust task group. US Department of Labor, MSHA: Washington, DC.
14. Seaton A, M Dodgson , J A Dick, M Jacobsen (1981) Quartz and pneumoconiosis in coal miners. Lancet 2: 1272-1275.
15. Seaton A (1982) Quartz and pneumoconiosis in coal miners (letter). Lancet 1: 45-46.
16. CDC (2003) Pneumoconiosis prevalence among working coal miners examined in federal chest radiograph surveillance programs-United States, 1996-2002. MMWR Morb Mortal Wkly Rep, 52: 336-340.
17. Boden L, Gold M (1984) The accuracy of self-reported regulatory data: the case of coal mine dust. Am J Ind Med 6: 427-440.
18. Weeks J (2003) The fox guarding the chicken coop: monitoring exposure to respirable coal mine dust, 1969-2000. Am J Public Health 93: 1236-1244.
19. CDC (2007) Advanced pneumoconiosis among working underground coal miners--Eastern Kentucky and Southwestern Virginia. MMWR Morb Mortal Wkly lRep 55: 909-913.
20. NIOSH (2006) Number and rate of fatalities by employment size of mining operation. CDC: Atlanta, Ga.

21. Hunting K, Weeks J (1993) Transport injuries in small coal mines: an exploratory analysis. Am J Ind Med 23: 391-406.

22. MSHA (1993) Report of the Statistical task team of the coal mine respirable dust task group. U.S. Department of Labor Mine Safety and Health Administration.

23. Jacobsen M, Maclaren W (1982) Unusual pulmonary observations and exposure to coalmine dust: a case-control study. Ann Occup Hyg 26: 753-765.

24. Castranova V, Vallyathan V (2000) Silicosis and coal workers' pneumoconiosis. Env Health Perspect 108: 675-684.

25. Hurley J, Burns J, Copland L, Dodgson J, Jacobsen M, et al. (1982) Coalworkers' simple pneumoconiosis and exposure to dust at 10 British coal mines. Brit J Ind Med 39: 120-127.

26. Soutar C and H Collins (1984) Classification of progressive massive fibrosis off coalminers by type of radiographic appearance. Brit J Ind Med 41: 334-339.

27. Antao VS, Petsonk EL, Sokolow LZ, Wolfe AL, Pinheiro GA, et al (2006) Rapidly progressive coal workers' pneumoconiosis in the United States: geographic clustering and other factors. Occup Environ Med 62: 670-674.

28. Antao VS (2006) Advanced cases of coal workers' Pneumoconiosis--two counties, Virginia, 2006. MMWR, Morbidity and mortality weekly report 55: 909-913.

29. Scarisbrick D, Quinlan T (2002) Health surveillance for coal workers' pneumoconiosis in the United Kingdom 1988-2000. Ann Occup Hyg 46: 254-256.

This article was originally published in a special issue, **Epidemiology of Poisoning** handled by Editor(s). Dr. John F Gamble, Consultant, Somerset, New Jersey, USA; Dr. Monath Sanjaya Kuruppu, Monash University, Australia