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PNEUMOCONIOSIS TRENDS IN THE US CONSTRUCTION INDUSTRY: A COMPARISON BETWEEN THE COAL MINING AND CONSTRUCTION INDUSTRIES

Syed M. AHMED[1] and Yimin ZHU[2]

Department of Construction Management, College of Engineering, Florida International University, Miami, FL 33174.
[1] Phone 305/348 2730; FAX 305/348-6255;Email: ahmeds@fiu.edu
[2] Phone 305/348 3517; FAX 305/348-6255;Email: zhuy@fiu.edu

Abstract
This paper presents a comparison between the construction and the coal mining industries in the USA relating to the different types of pneumoconiosis (i.e. silicosis, asbestosis, Coal Worker's Pneumoconiosis (CWP), and byssinosis) in order to determine the relationships between each type of pneumoconiosis and the occupations in both industries that are mostly affected by the disease. In this study, regression models have been developed to determine the patterns of fatalities and Years of Potential Life Lost (YPLL) due to each type of pneumoconiosis after 1968, and to identify the relationship between fatalities and potential life losses.

The objective of the study is to provide construction researchers and relevant government agencies with information regarding the current state of the construction industry in fighting the disease and the outlook for the future. Many previous studies have focused on the details of treating and managing pneumoconiosis. This study provides a different and complementary perspective to those previous studies.

The data was obtained from The National Occupational Respiratory Mortality System (NORMS). Based on the data analysis, the authors concluded that the impact of pneumoconiosis on the construction industry was distributed across several types of workers including insulation workers, construction laborers, plumbers and pipe fitters, and carpenters. Among them the insulation workers were affected most, especially by asbestosis. Existing measures for preventing pneumoconiosis might only be successful in delaying the occurrence of deaths once workers had been exposed but would not necessarily maintain normal life expectancy. In addition, it was observed that the rate of loss of life for people aged under 65 was constant, regardless of the advance of modern medical technology and stringent prevention measures.

Keywords
Pneumoconiosis, Construction Industry, Regression Model, Safety, Health

INTRODUCTION

Pneumoconiosis is a general term for specific respiratory diseases that develop after prolonged exposure to harmful forms of dust in industrial work places. The main industries associated with pneumoconiosis are mining, construction, and manufacturing. The specific respiratory diseases are silicosis, asbestosis, coal worker's pneumoconiosis (CWP), and byssinosis according to the Encarta Encyclopedia, 2000 edition, which also gives definitions for each type.

Silicosis: *This disease occurs because of prolonged inhalation of silica dust (silicon dioxide SiO2). This dust is found in substances such as concrete, masonry, and rocks. People involved in mining, rock-cutting, sand blasting, metal grinding and other industries are at risk.*

Asbestosis: *lung disease resulting form inhalation of dust from asbestos, a fibrous substance made of minerals and silicates that has wide application in the construction industry.*

Byssinosis: *lung disease resulting from inhalation of organic dust such as cotton. Usually occurs in textile-related occupations.*

CWP: *lung disease due to inhalation of coal dust found predominantly in mining industry and occupations.*

Pneumoconiosis is a preventable disease as long as proper precautions are taken by employers, and exposure limits set by the Occupational Safety and Health Administration (OSHA) are properly observed. However, no cure exists once the disease is acquired and no effective treatment exists (Becklace and Cowie 2000). In its early stage, the disease is asymptomatic but its development causes pulmonary fibrosis and can cause premature death (Attfield and Costello 2004). According to the Work-Related Lung Disease Surveillance Report published National Institute of Occupational Safety and Health (NIOSH), approximately 300,000 years of potential life have been lost and 31,000 deaths have occurred in the period 1990 to 1999 due to pneumoconiosis (NIOSH 2003). These statistics show the necessity of continuing prevention strategies. Overall, the mortality rates for all types of pneumoconiosis have been declining since 1972 but deaths due to asbestosis itself have been gradually increasing since 1968 according to the World Health Organization report. The CWP decline can be attributed to the Federal Coal Mine Health and Safety Act of 1969 that calls for lower dust limits in the mining environment. Decline in Silicosis rates can also be attributed to continuous efforts by OSHA/NIOSH to restrict dust levels. Another factor is the reduction in the number of jobs in heavy industry. NIOSH also implements two types of surveillance programs, the SENSOR (Sentinel Event Notification System for Occupational Risks) Silicosis program which is a state-based reporting system and is limited to a few states, and the Coal Workers' Health Surveillance Program which is a consequence of the 1969 Act.

Due to the fact that construction jobsites tend to be dusty, construction work has long been known to be hazardous to workers' lungs. Many factors may contribute to the hazardous environment such as opened cement bags, cutting wood products and masonry, the operation of heavy equipment, and the inhalation of fumes generated by painting, gluing, cleaning with solvents, welding and so on.

A study of death certificates of 20 states from 1991 to 1993 by the Center to Protect Worker's Rights (CPWR) suggests that members of some construction trades in those states have about a 25% higher risk of death from "pneumoconiosis and other respiratory diseases" than does the general U.S. population (matched for age, race, and sex). In addition, from 1996 to 2002, a study supported by the Center to Protect Worker's Rights (CPWR) performed 2,602 pulmonary (lung) function tests and chest X-rays on current and former construction workers at the Department of Energy nuclear weapons facilities. The study found that an average of 45% of the pulmonary function tests were abnormal compared with tests for men of the same age and height without any known lung disease. Chest X-ray abnormalities, compared to what was expected among workers with no known lung disease, ranged from 19 to 44%, depending on the trade. These statistics, as well as the results of many other studies, suggested that pneumoconiosis is still a major hazard causing lung problems among construction workers.

However, conclusive studies on work-related exposure diseases are difficult to obtain because symptoms of these diseases may take years or decades to develop. Consequently, the deaths caused by particular hazards may be under-reported. The same must apply to other dust hazard industries such as the coal mining industry. Therefore, a comparison between the construction and coal mining industries will provide valuable information on where the construction industry stands since the coal mining industry is usually considered as the industry most severely affected by pneumoconiosis.

The objective of this study is two-fold. First, the study seeks to understand how the different forms of pneumoconiosis vary between occupations and industries through an observational study of the types of pneumoconiosis found in the coal mining and construction industries which are the two major industries most affected by this disease. The results will reveal which occupations are high risk and what forms of pneumoconiosis are more likely to occur. The outcome of the study will lead to the development of measures that can be used to provide increased protection for high risk workers. Secondly, an exploratory study that examines the trends of pneumoconiosis in the United States will help researchers, policy makers, and practitioners in the identification of issues that are likely to be faced in the future and to assist in the development of plans for dealing with such issues.

Although the construction industry has a long history of fighting against asbestosis, asbestosis is still one of the major forms of pneumoconiosis diseases. In addition, this study also discusses other forms of pneumoconiosis diseases besides asbestosis.

In the first part of the study the coal mining industry was selected because it is the worst case among industries subject to severe pneumoconiosis diseases. The study uses the coal mining industry only as a baseline to see how close the construction industry is, not intending to draw lessons from it, because the two industries are very much different. On the other hand, despite the differences between the two industries, a comparison between them in terms of the number of death and the Years of Potential Life Lost (YPLL) due to pneumoconiosis, will provide some valuable information about the existing status of pneumoconiosis in the construction industry.

METHODOLOGY

Data was collected from the National Occupational Respiratory Mortality System (NORMS). This database was located at the Centers for Disease Control website in its National Institute for Occupational Safety and Health (NIOSH) subdivision. NORMS is a database system developed and maintained by NIOSH. NORMS data is obtained from the causes of death outlined in the death records in the National Center for Health Statistics for several types of respiratory complications including pneumoconiosis. NORMS provides two databases: a national database and an Industry/Occupation database.

Data was first drawn from the Industry/Occupation database. This database provides the number of deaths and Proportionate Mortality Ratios (PMRs) for different occupations/industries from the time period 1985-1999 for selected states (NORMS). PMR is a statistic calculated as the ratio of the number of observed deaths due to a given cause and the number of expected deaths for that given cause. Therefore a PMR over 1 indicates that more people have died than expected from a particular cause.

Occupational data was collected for the coal mining and construction industries for workers between the ages of 15 and 64, for both sexes combined, and for all races. The top five occupations for each industry with the highest number of deaths for the period 1985-2000 were tabulated, including the PMR for that occupation and the corresponding percentage of deaths within the industry.

For the second part of the study, data was drawn from the NORMS. This database was used to generate different types of statistics such as deaths, mortality ratios, and Years of Potential Life Lost (YPLL) by categories such as age, sex, time period, and race. YPLL values are calculated using the method described by the Centers for Disease Control (CDC) (MMWR, 1986). YPLL values related to age 65 may be considered as lost years from a traditional working life, while YPLL values related to life expectancy may be considered as lost years from the overall life span.

Data was drawn from this database for the period 1968 to 2000 for those who died between the ages of 15 and 64, since 65 is the retirement age. Data collected for those who died before that age provides information potentially relevant for economists.

Experimentation was done to determine the best regression models to be used for forecast. Linear, logarithmic, exponential, and power models were tested for appropriateness. Only the linear, exponential, and power models were used for modeling after the experimentation.

A general form for the exponential model can be expressed as

$$y = a \times b^{x} \quad (1)$$

where x is the number of years after 1968, and y is either the number of death for a given year or the years of potential life lost prior to age 65. The NORM database includes this variable as a data search category.

A linear model can be expressed as

$$y = m \times x + b \quad (2)$$

where x and y have the same meaning as defined above in (1).

A power model is expressed as

$$y = a \times xb \quad (3)$$

where x and y have the same meaning as defined above in (1).

In order to compute the exponential models, the general form (1) was transformed into the form

$$\ln y = \ln b \times x + \ln a \quad (4)$$

From there, the general least-squares regression model was applied to the variables $\ln y$ and x. In addition, linear correlations and r^2 values were calculated to test the strength of the models.

A similar process was used to compute power models where the general form (3) was changed into

$$\ln y = \ln a + b \times \ln x \qquad (5)$$

Least-squares linear regression was applied to the variables ln*y* and ln*x*. When a linear model had to be computed, the least-squares regression model was applied to the variables *y* and *x*. The variables *y* and *x* also have the same meaning as defined above in (1).

Different time periods were used when developing the models based on an observable trend analysis. For the pneumoconiosis models, the time period 1972-2000 was used because there was a clear, observable, and continuous trend for that period. Data for the time period 1968-72 was not used for the pneumoconiosis models because it contradicted that continuous trend. For the asbestosis models, two different time periods, 1968-1985 and 1986-2000, were analyzed. This was done because there were two different observable trends for these time periods. For CWP, the same time period was used as was used for all types of pneumoconiosis and for the same reason. he silicosis model was the only one that incorporated the whole time period for which the data was available, namely 1968-2000. Other/unspecified pneumoconiosis was also considered and the same time period was used as was used for all forms of pneumoconiosis.

The total number of fatalities was used as an explanatory variable and the years of potential life lost was used as a response variable. Models were constructed for each type of pneumoconiosis to determine the relationship between these two variables. Scatter plots were then developed to show the actual versus predicted values produced by the models. The slope of these models indicate years of potential life being lost per death and it is a very useful statistic to show on average when people are dying.

Scatter plots were also developed to compare the affects of the different types of pneumoconiosis. The first set of scatter plots show the percentage of deaths attributable to the different types of pneumoconiosis versus the number of years after 1968. The percentage of deaths was calculated by taking the ratio of the number of deaths for a particular form of pneumoconiosis to the total number of deaths. The second set of scatter plots show the YPLL attributable to the different types of pneumoconiosis versus the number of years after 1968. The YPLL attributable to the different types of pneumoconiosis was calculated by taking the ratio of the YPLL for a particular form of pneumoconiosis to the total number of years lost due to all forms of pneumoconiosis.

For simplicity, Microsoft Excel was used to create the charts, and tables, and to compute models.

DISCUSSION

In the following sections, the statistics presented in Tables 1 through 9 comparing the construction and coal mining industries are discussed followed by an analysis of the regression models representing the trends of pneumoconiosis related fatalities in the United States.

Basic Statistics

Although the coal mining industry had a larger number of fatalities between 1985 and 1999 due to pneumoconiosis for all age groups, the construction industry experienced a higher percentage of fatalities for the age group of 15 to 64 years old. Historically, the coal mining industry is by far the most affected by pneumoconiosis. A total of 711 people died in that industry between 1985 and 1999 for the selected states included in the Industry/Occupation database and for the given age group i.e. 15 to 64 years old (Table 6). However, 5,964 people died in the age group for 65 and older according to the National Occupational Respiratory Mortality System (http://webappa.cdc.gov/ords/norms.html). It seems that in the coal mining industry most people die of complications due to pneumoconiosis after the retirement age of 65. This is because it takes many years for pneumoconiosis to develop after initial exposure. The construction industry lags far behind with 275 deaths for the same time period, age group, and selected states (Table 1).

One the other hand, in the coal mining industry, the age group of 15 to 64 years old accounts for 10.7% of the deaths (i.e. 711/6675; 711 is the number of deaths in the age group 15-64, and 6675 is total number of deaths for 15 years or older, according to NORMS) while in the construction industry, this age group accounts for 18.7% of the deaths (i.e. 275/1471; 275 is the number of deaths in the age group 15-64, and 1471 is total number of deaths for 15 years or older according to NORMS).

This difference could be caused by the fact that different types of pneumoconiosis occur at different times after initial exposure and different forms of pneumoconiosis constitute different make-ups for each industry. For example, in the construction industry, asbestosis accounts for 63% of the deaths while in the coal mining industry, 83% of the deaths are due to CWP. However, according to some researchers, asbestosis is the one that takes 40 to 45 years to form while other forms take considerably less implying that victims of asbestosis usually have a longer living period than victims of other forms of pneumoconiosis (Attfield and Costello 2004).

The severity of pneumoconiosis varies by occupation within each industry. In the coal mining industry, there seems to be one occupation that is affected the most by pneumoconiosis. The mining machine operators account for 88.2% of the deaths in that industry with 627 deaths (Table 6). These operators also have the highest PMR of about 46.13 (Table 6). The second most affected occupation in the coal industry is truck drivers. While truck drivers only accounted for 16 deaths, these workers have a very high PMR of 40.56 (Table 6). Other affected occupations are supervisors of extractive occupations, managers, and administrators. In the construction industry, there is a more visible and equal distribution of deaths among the occupations unlike the mining industry. Insulation workers in the construction industry rank number one in deaths with 57 deaths accounting for 20.7% of the deaths within this industry (Table 1). These workers also have a very high PMR value of 49.36 which is even higher than mining machine operators. Other affected occupations in the construction industry include construction laborers, plumbers and pipe fitters, and carpenters. Except for mining machine operators, the top recorded occupations affected in the coal mining industry have fewer deaths recorded than their same-ranked counterparts in the construction industry yet they all had a higher recorded PMR than the ones in the construction industry. This shows that there were more unexpected deaths in occupations of the coal mining industry than there were for occupations in the construction industry.

Table 1 All Pneumoconiosis in construction

OCCUPATION	Deaths	Percent	PMR
Insulation Workers	57	20.73	49.36
Constr uction Laborers	41	14.91	1.06
Plumbers, pipe fitters, and steamfitters	30	10.91	2.60
Carpenters	25	9.09	0.69
Painters, construction and maintenance	20	7.27	1.36
Total of all Occupations	**275**	**100**	-

Table 2 Asbestosis in construction

OCCUPATION	Deaths	Percent	PMR
Insulation Workers	57	32.95	180.62
Plumbers, pipe fitters, and steamfitters	27	15.61	8.55
Carpenters	16	9.25	1.64
Construction Laborers	16	9.25	1.62
Electricians	10	5.78	3.35
Total of All occupations	**173**	**100**	-

Table 3 Coal Workers Pneumoconiosis in construction

OCCUPATION	Deaths	Percent	PMR
Construction laborers	4	11.76	n/a
Managers and administrators	3	8.82	n/a
Brickmasons and stonemasons	3	8.82	n/a
Carpenters	3	8.82	n/a
Painters, construction and maintenance	3	8.82	n/a
Total of All Occupations	**34**	**100**	

Table 4 Silicosis in construction

OCCUPATION	Deaths	Percent	PMR
Painters, construction and maintenance	15	30.61	6.59
Construction laborers	12	24.49	1.61
Construction trades, e.g., Sandblasters	8	16.33	21.15
Carpenters	3	6.12	n/a
Operating engineers	3	6.12	n/a
Total of All occupations	**49**	**100**	

Table 5 Other/unspecified forms of Pneumoconiosis in construction

OCCUPATION	Deaths	Percent	PMR
Construction laborers	9	47.37	1.72
Carpenters	4	21.05	-
All other occupations	6	31.58	-
Total of All Occupations	**19**	**100**	-

Table 6 All Pneumoconiosis in coal mining

OCCUPATION	Deaths	Percent	PMR
Mining machine operators	627	88.19	46.13
Truck Drivers	16	2.25	40.56
Supervisors, extractive occupations	9	1.27	28.70
Managers and administrators	8	1.13	27.93
Laborers, except construction	5	0.70	19.49
Total of All occupations	**711**	**100**	-

Asbestosis accounted for 63% of the deaths in the construction industry (Figure 1) with 173 deaths (Table 2) while there were fewer than three recorded cases according to NORMS for asbestosis in the coal mining industry. This must be due to the lack of asbestos use in the coal mining industry. However asbestos is very widely used in the construction industry. In fact, 57 out of 173 of the deaths recorded for insulation workers happened due to asbestosis and the re-calculated PMR for insulation workers for asbestosis is surprisingly large at 180.62 (Table 2). Insulation workers are most prone to asbestosis out of all the forms of pneumoconiosis probably because asbestos is used widely in insulation materials. For plumbers, pipe fitters, and steamfitters, 27 out of 30 deaths were due to asbestosis (173 is total number of deaths due to asbestosis in the construction industry for the respective time period, 30 is the total number of deaths plumbers suffered due to all forms of pneumoconiosis for the respective time period, 27 were due to asbestosis). The PMR value was 8.55 (Table 2) for these workers. These results show that insulation workers and plumbers, pipe fitters, and steam fitters have a high risk to asbestosis in the construction industry. In addition, electricians have the least fatality due to asbestosis; however, the PMR is higher than expected. Construction labourers and carpenters have less fatality due to asbestosis and the fatality rate is close to what would be expected (Table 2).

In the coal mining industry, 577 (81%) of deaths were due to CWP (Table 8). In the construction industry, CWP only accounted for 34 (12%) of the deaths due to all pneumoconiosis (Table 3). Again, the mining machine operators accounted for 88.7% of the deaths from CWP with 514 deaths (Table 8). The recalculated PMR for mining machine operators for this industry is 83.2 which is greater than their PMR for all forms of pneumoconiosis. Other occupations affected include truck drivers, managers and administrators, and supervisors related to extractive operations. In construction, the most notable of the occupations were the construction laborers with four deaths (Table 3).

Silicosis had the second highest occurrence in the construction industry with 49 deaths (Table 4) which accounts for 18% of all deaths (Figure 1). In the coal mining industry, silicosis accounts for 23 deaths (Table 7) which is only 3% of the deaths in that industry (Figure 2). Again in the coal mining industry, 19 of those deaths were attributable to coal mining operators. The PMR for coal mining operators for this type of pneumoconiosis was also considerably lower than for other forms of the disease. Construction and maintenance painters were most affected by silicosis in the construction industry followed closely by construction laborers. Occupations that come under construction trades, such as sandblasters, had the highest PMR of 21.15 but were third in ranking for deaths (Table 4). This is not in accordance with other reports and researches that say sandblasting is at the highest risk of silicosis (Shaman 1983, NIOSH 1992).

Other/unspecified forms of pneumoconiosis formed a significant part in the coal mining industry where there were 78 deaths (16%) (Table 9). In the construction industry, it constituted 7% or 19 deaths (Table 5). Construction laborers were most affected in the construction industry while the mining machine operators were still ranked highest in the coal mining industry. Truck drivers in the coal mining industry were also affected and had an unusually high PMR.

Table 7: Silicosis in coal mining

OCCUPATION	Deaths	Percent	PMR
Mining machine operators	19	82.61	10.67
All other occupations	4	30	.
Total of All Occupations	**23**	**100**	-

Table 8 CWP in coal mining

OCCUPATION	Deaths	Percent	PMR
Mining machine operators	514	88.70	83.20
Truck drivers	10	1.73	39.46
Managers and administrators	8	1.39	61.12
Supervisors, extractive occupations	7	1.21	69.46
Laborers, except construction	5	0.87	43.64
Total of All occupations	**577**	**100**	-

Table 9 Other/unspecified Pneumoconiosis in coal mining

OCCUPATION	Deaths	Percent	PMR
Mining machine operators	93	83.78	51.45
Truck drivers	5	4.50	80.93
Operating engineers	3	2.7	-
All other occupations	10	9.01	-
Total of All occupations	**78**	**100**	-

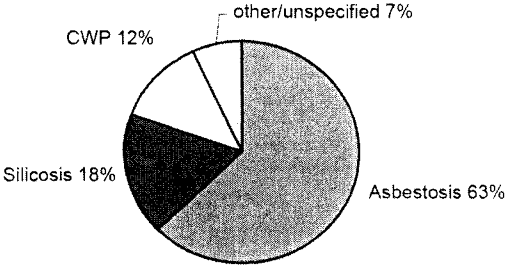

Figure 1 Percentages of deaths due to different forms of pneumoconiosis in Construction

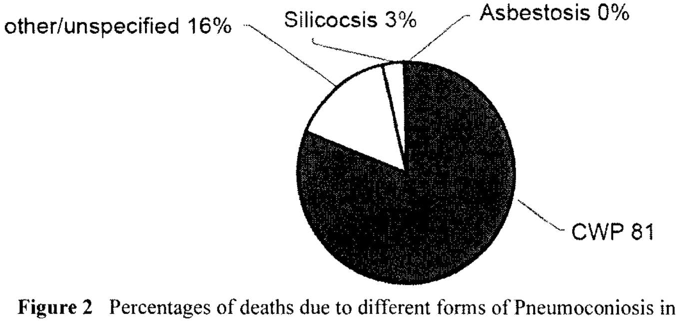

Figure 2 Percentages of deaths due to different forms of Pneumoconiosis in Coal Mining

REGRESSION MODELS

Several models have been developed to evaluate a cause-response relationship between exposures and mortality. For example, Bang *et al.* (1999) applied linear regression models to age-specific mortality rates between for the time period 1985-1996 for three different age groups. That study showed that pneumoconiosis surveillance is useful in identifying recent mortality patterns. This study differed from previous studies in that it applied different types of regression models for a longer time period and for one age group to find patterns in mortality and years of potential life lost to age 65.

For all forms of pneumoconiosis, two trends were observed in this study. First, an increase in deaths and years of potential life lost from 1968 to 1972 was observed. Secondly, a steady decline in deaths and years of potential life lost was observed between 1972 and 2000. The shape of the scatter plots for the period 1972-2000 showed an exponentially declining relationship between years and deaths so an exponential regression model was applied for that time period (Figure 3). The r^2 value was found to be 0.9876, indicating a very strong exponential relationship (Table 10). The scatter plot for years of potential life lost showed a similar shape to the scatter plot for deaths (Figure 4). The r^2 value was calculated to be 0.9682 (Table 10). These strong exponentially decreasing trends show how death should decrease in the future if things continue the way they are. Furthermore, the model predicts that by 2011, there will be fewer than 100 deaths due to pneumoconiosis for this age group nationwide. In addition, it is interesting to compare this exponential trend with a very constant trend that exists for the age group of 65 and above. From 1972-2000 there was a 31.5% decline (e.g., 2632 deaths in 2000, 3840 deaths in 1972, (3840-2632)/32840 = .3146, according to NORMS) in deaths for the age group of 65 and above, while for the age 15 to 64 there was an 85.4% (e.g., 232 deaths in 2000 and 1590 deaths in 1972, (1590-232)/1590 = .8540, according to NORMS) decline in death.

Table 10 Regression Models for Pneumoconiosis

All Pneumoconiosis	Model	Time period used by models	Correlation	r2
Deaths	$y = 1919.901 \times (0.93286)^x$	1972-2000	-0.9938	0.9876
Years of potential life lost	$y = 13508.366 \times (0.936334)^x$	1972-2000	-0.984	0.9683

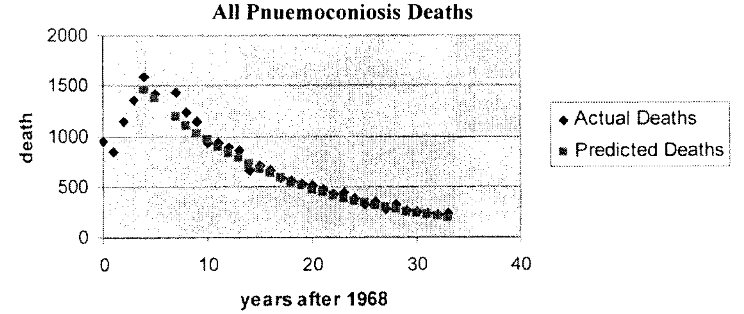

Figure 3 All Pneumoconiosis deaths under age 65

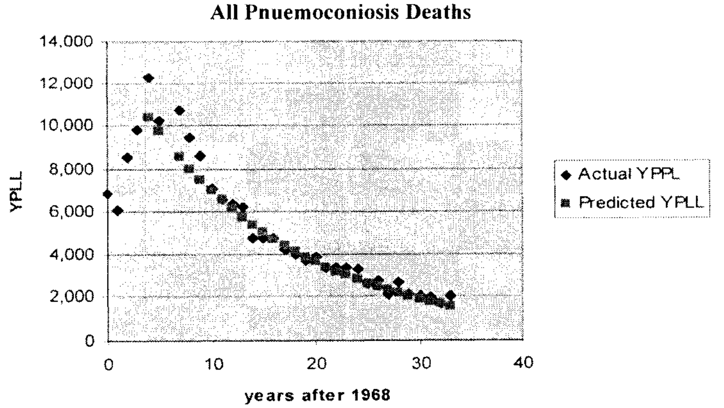

Figure 4 Potential years of life lost to age 65

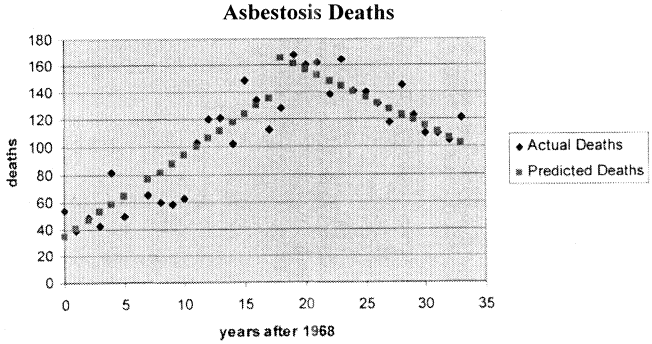

Figure 5 Deaths due to asbestosis

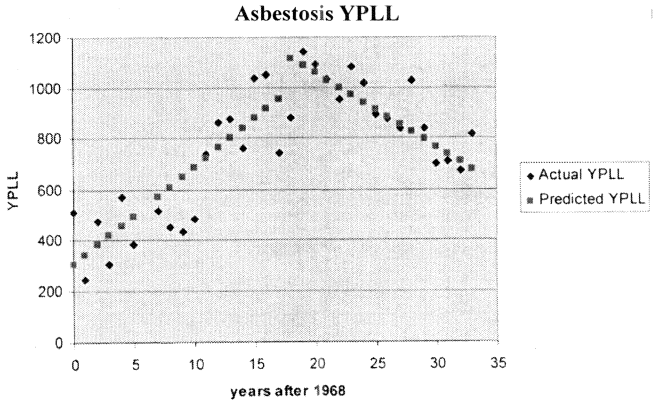

Figure 6 Years of potential life lost due to asbestosis to age 65

The patterns observed in the asbestosis case were not as straightforward as that of pneumoconiosis. There were two observable trends for deaths by year and by years of potential life lost. The first was a linear increase from 1968 to 1985 and the second was a decrease from 1985 to 2000 (Figures 5 and 6). This pattern is probably caused by regulations and/or measures implemented around the early 1980s to prevent or limit workers' exposure to asbestosis. For this reason, two linear models were applied for these respective time periods. The two models for deaths showed a linear correlation of 0.87 and -0.8819 respectively (Table 11). These values indicate a moderately strong linear relationship. For years of potential life lost, there was also a similar pattern of rise and fall corresponding to the patterns of deaths. The linear correlation values, 0.8325 and -0.865 respectively for the different time periods, indicate a moderately strong relationship with time but not as strong as the deaths with time (Table 11). These trends contrast significantly with the trends observed for the age group of 65 years and older where we observe an exponential increase in death and years of potential life lost to life expectancy between 1968 to 2000 (Figure 21 and 22).

It was found that CWP followed the same trends as observed for all pneumoconiosis, namely that deaths seem to be increasing from 1968 to 1972 and then on declining exponentially between 1972 and 2000 (Figure 7 and 8). This makes sense because CWP is a major contributor to deaths from all forms of pneumoconiosis. For the time period 1972-2000, the r^2 values calculated from the exponential models are 0.9795 and 0.9712 for the number of deaths versus time and years of potential life lost versus time (Table 12). These values also imply a very strong exponential relationship between the response variable and time. Compared with

Table 11 Regression Models for Asbestosis

ABESTOSIS	Model	Time period used by models	Correlation	r2
Deaths	y = 5.8926 x +35.0233,	1968-1985,	0.87, -	0.7569,
	y = - 4.196 x +240.510	1986-2000	0.8819	0.7777
Years of potential life lost	y = 38.215 x+ 302.95,	1968-1985,	0.8325, -	0.6931,
	y= - 29.16 x + 1639	1986-2000	0.865	0.7482

Table 12 Regression Models for Coal Worker's Pneumoconiosis

CWP	Model	Time period used by models	Correlation	r2
Deaths	$y = 1371.76 \times (0.908937)^x$	1972-2000	-0.9897	0.9795
Years of potential life lost	$y = 8386.32 \times (0.919247)^x$	1972-2000	-0.9855	0.9712

Table 13 Regression Models for Silicosis

Silicois	Model	Time period used by models	Correlation	r2
Deaths	$y = 293.594 \times (0.925526)^x$	1968-2000	-0.9753	0.9512
Years of potential life lost	$y = 2260.07 \times (0.933229)^x$	1968-2000	-0.9715	0.9438

Table 14 Regression Model for Other/Unspecified

Other/unspecified	Model	Time period used by models	Correlation	r2
Deaths	$y = 7838.2 \times x^{-1.7089}$	1972-2000	0.964365	0.93
Years of potential life lost	$y = 56710 \times x^{-1.6799}$	1972-2000	0.95734	0.9165

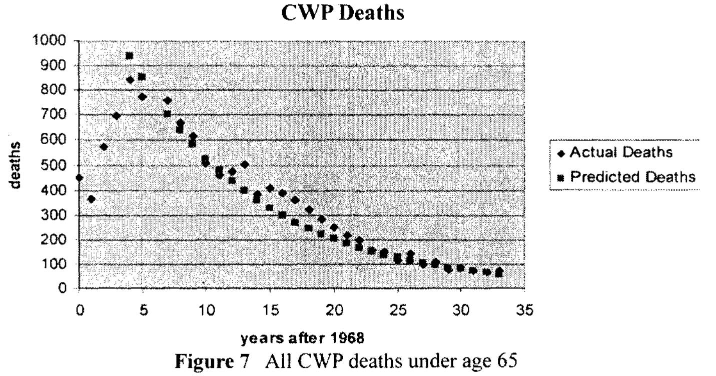

Figure 7 All CWP deaths under age 65

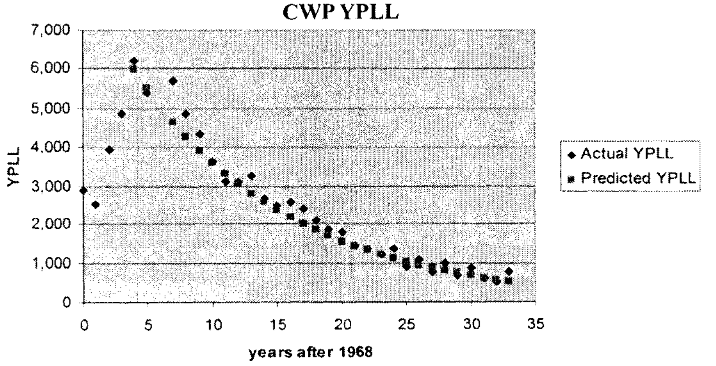

Figure 8 Years of potential life lost due to CWP to age 65

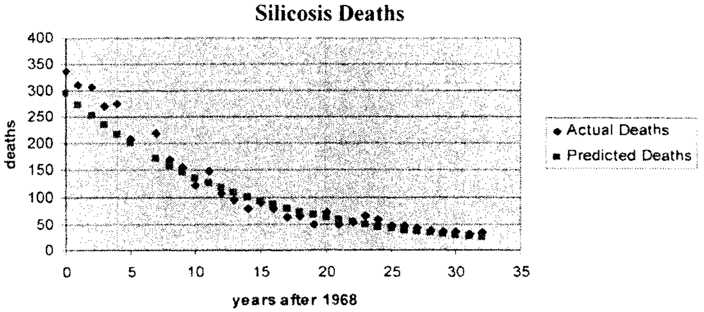

Figure 9 Deaths due to silicosis

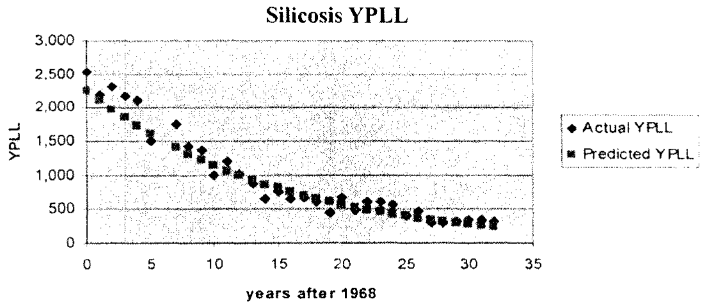

Figure 10 Years of potential life lost due to Silicosis to age 65

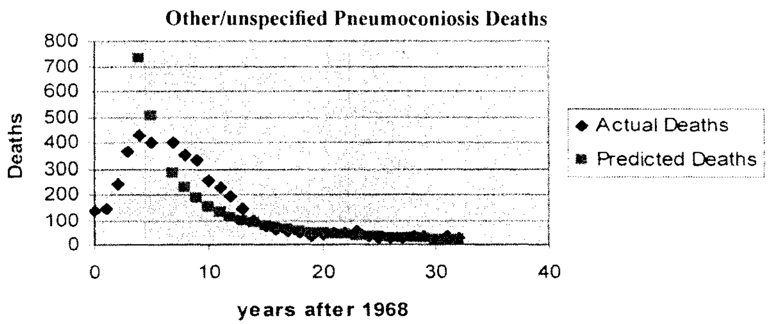

Figure 11 Deaths due to other/unspecified forms of pneumoconiosis

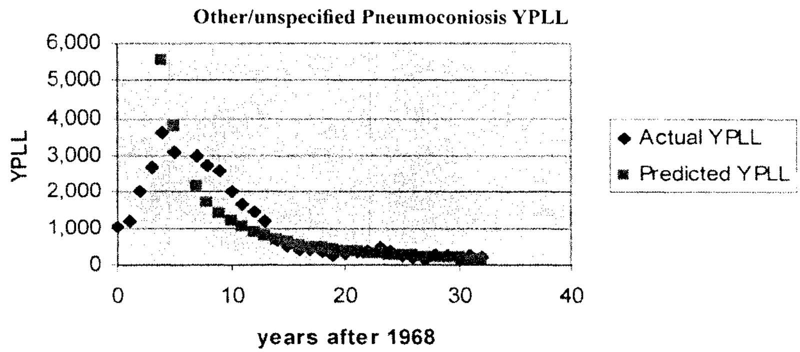

Figure 12 Years of potential life lost due to other/unspecified forms of Pneumoconiosis to age 65

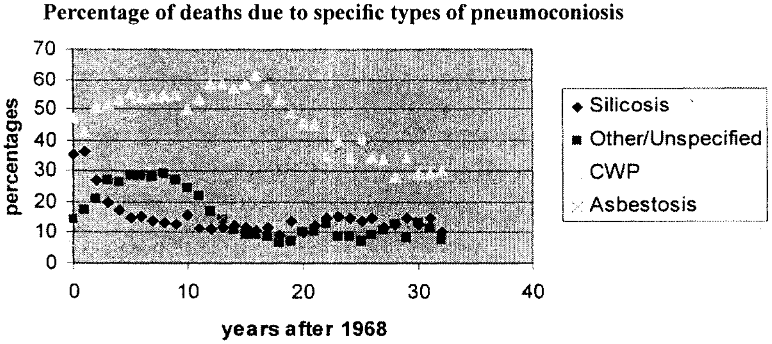

Figure 13 Percentage of deaths due to specific types of pneumoconiosis

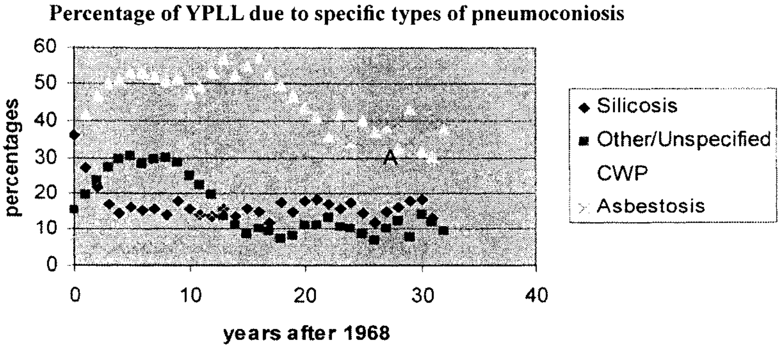

Figure 14 Percentages of years of potential life lost due to specific types of pneumoconiosis to age 65

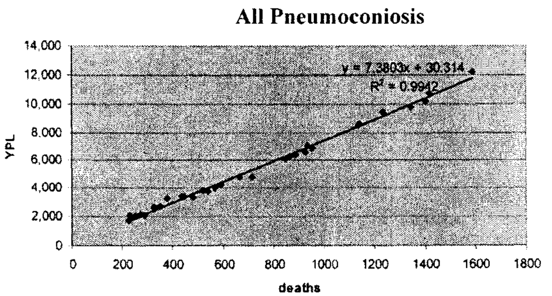

Figure 15 Years of potential life lost to age 65 versus deaths plots – All pneumoconiosis

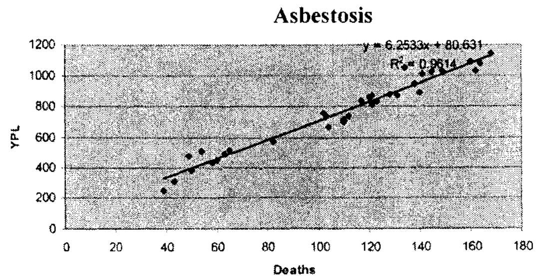

Figure 16 Years of potential life lost to age 65 versus deaths plots – Asbestosis

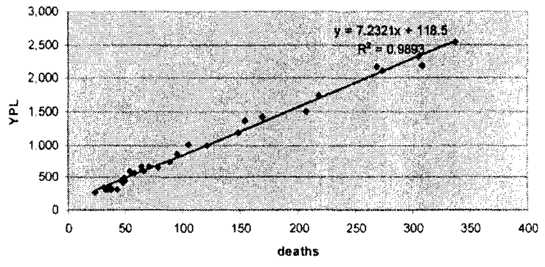

Figure 17 Years of potential life lost to age 65 versus deaths plots – Silicosis

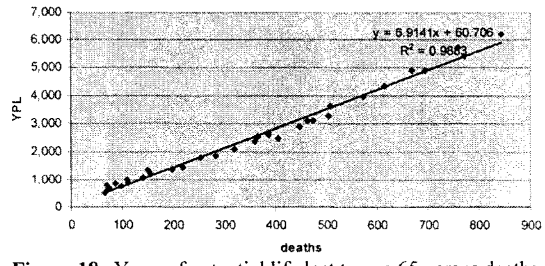

Figure 18 Years of potential life lost to age 65 versus deaths plots – CWP

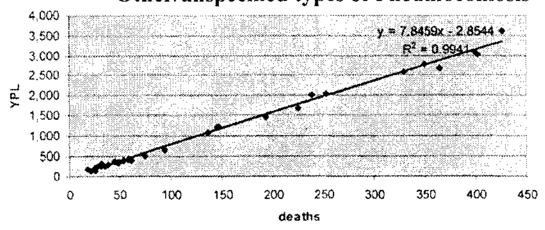

Figure 19 Years of potential life lost to age 65 versus deaths plots – Other/unspecified types of Pneumoconiosis

trends for the age group of 65 and older, an increase in deaths and years of potential life lost occurs from 1968 to 1984 and then a linear decline is observed (Figure 23 and 24). Even though the CWP trends are similar in shape to all pneumoconiosis trends for the age groups 15 to 64, CWP trends for 65 and older is dissimilar to all forms of pneumoconiosis trends for that age group. In fact, the CWP trend for 65 and older resembles the asbestosis trends that occurred for the age group 15 to 65, where there is a linear increase from 1968 to 1985 and then a linear decline till 2000. This could mean that CWP is not a major a cause of death for the age 65 and older group when compared with other forms of pneumoconiosis as it is for the ages 15 to 65 since its distribution would have had more of an effect on the all pneumoconiosis distribution. However, CWP accounts for 56.9% of deaths for the ages 65 and older for the time period of 1968 to 2000 and accounts for 50.2% for ages 15 to 64 and the same time period. According to the 2004 WORLD report, CWP contribution to death compared to other forms of pneumoconiosis has declined from 1968 to 2000. Consequently, it could be said that CWP played a major role earlier and lost its bulk more sharply for the ages 65 and older than it did for 15 to 64 nearing 2000, an observation of the trends indicate.

Silicosis trends showed an exponential decline from the very start of 1968 unlike all pneumoconiosis trends, asbestosis trends, and other/unspecified pneumoconiosis trends (Figure 9 and 10). The r^2 values for the exponential regression model was 0.9512 for deaths

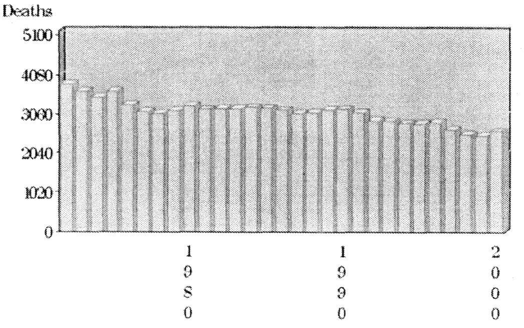

Figure 20 All pneumoconiosis deaths 1972-2000, age group - 65 years+(NORMS)

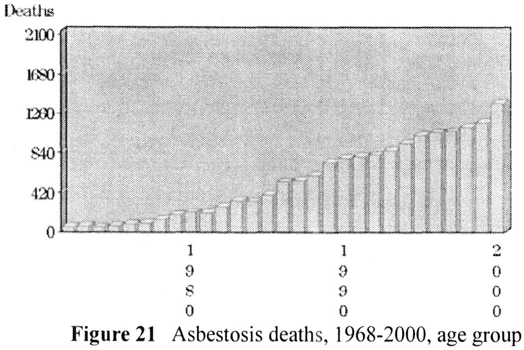

Figure 21 Asbestosis deaths, 1968-2000, age group 65 +

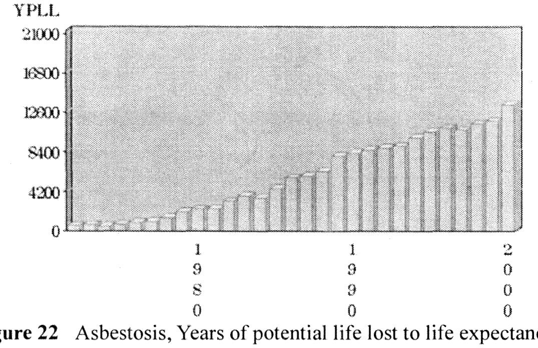

Figure 22 Asbestosis, Years of potential life lost to life expectancy, age group 65+

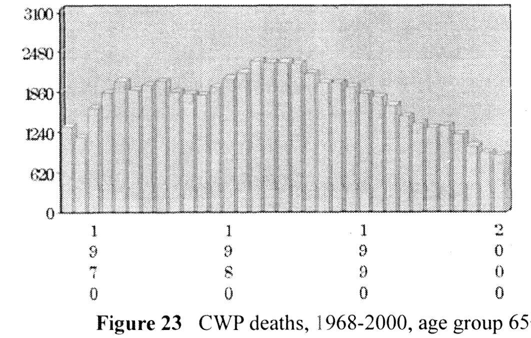

Figure 23 CWP deaths, 1968-2000, age group 65+

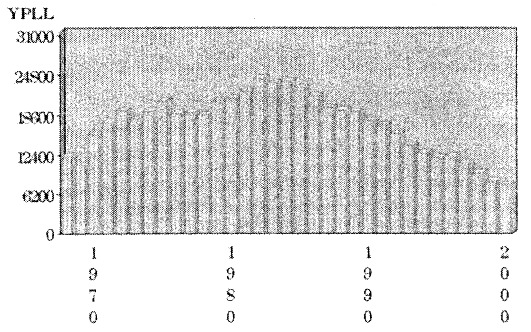

Figure 24 CWP years of potential life lost to life expectancy, 1968-2000, age group 65+

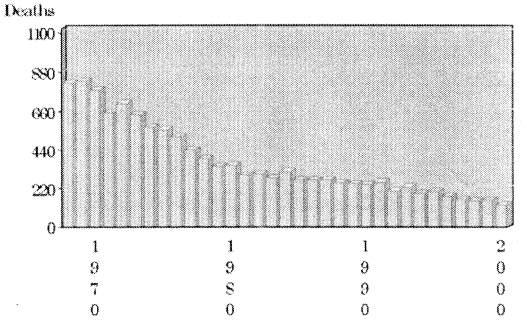

Figure 25 Silicosis deaths, 1968-2000, age group 65+

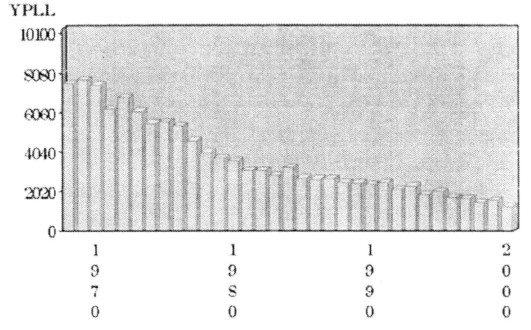

Figure 26 Silicosis years of potential life lost to life expectancy, 1968-2000, age group 65+

versus time and 0.9438 for years of potential life lost to age 65 versus time (Table 13). These models were strong but not as strong as the CWP and all types of pneumoconiosis models. There was also a similarity in trends when compared to the age group of 65 and above. For both deaths and years of potential life lost, both time periods showed an exponential decline after 1968 (Figures 25 and 26).

Other/unspecified forms of pneumoconiosis constituted 19.2% of the recorded deaths from pneumoconiosis (4443 deaths due to other/unspecified forms of pneumoconiosis for age group 15-64, period 1968-2000 and 23182 deaths due to all forms of pneumoconiosis for age group 15-64, period 1968-2000, 4443/23182 = 0.1916 (NORMS). Due to the large percentage of deaths, this type of pneumoconiosis cannot be ignored. The power model was found to be the most applicable for the observed trends (Figure 11 and 12). Just like in the case of all

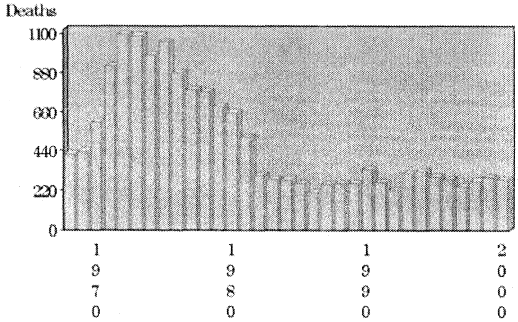

Figure 27 Other/unspecified forms of pneumoconiosis deaths, 1968-2000, age group 65+

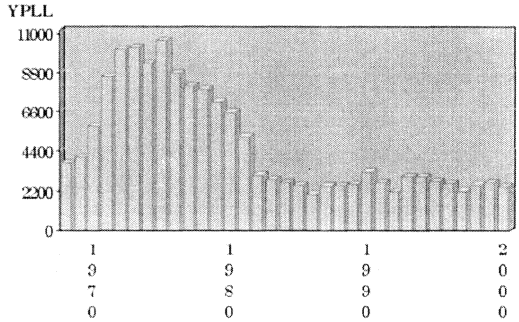

Figure 28 Other/unspecified forms of pneumoconiosis years of potential life lost to life expectancy, 1968-2000,

pneumoconiosis trends and CWP trends, the time period 1972 to 2000 was used in calculating the models. The r^2 values were calculated to be 0.93 for deaths versus time and 0.9165 for years of potential life lost due to age 65 versus time (Table 14). These models failed to accurately predict the number of deaths and years of potential life lost prior to the year 1981, however, tjeu were found to be very accurate after 1981. Other/unspecified pneumoconiosis recorded deaths for the age group of ages 15 to 64 was approximately ¼ of recorded deaths for the same cause for the age group 65 and above (4443 deaths for age group 15-64, 16147 deaths for age group 65+ (NORMS)). The trends for that age group also resembled the trends observed in ages 15 to 64, namely an increase till 1972, and then a decrease till 2000 (Figure 27 and 28) .

Plotting years of potential life lost versus deaths for the different forms of pneumoconiosis revealed a very strong linear relationship between the two (Figure 15 to 19). It is interesting to see that even though deaths have been decreasing due to enforced standards, years of potential life lost has been decreasing only linearly with the deaths. One explanation for this could be that medical treatments have not been very effective in prolonging the ages of victims. This is in accordance with Becklace's points (Becklace and Cowie 2002). The slopes of the linear models applied for each form reveals the average years of potential life lost to age 65 per death. This slope is lowest for asbestosis with 6.2533 Years of Potential Life Lost (YPLL) per death, CWP with 6.9141 YPLL per death, Silicosis with 7.232 YPLL per death, and other/unspecified forms with a high 7.8459 YPLL per death. Overall, all forms had a slope of 7.3803 meaning that on average, people died around 57.61 years old.

LIMITATIONS OF THIS STUDY

A major limitation to this study is that the industry/occupation database provided by NIOSH only records data for a certain group of states in the USA. In addition, certain states among the selected states did not meet the quality criteria set by the National Center for Health Statistics each year for industry and occupation codes from death certificates. The death certificates, the primary source where the database derives its data, record the occupation of the person when he died. This doesn't necessarily mean that that was the occupation or industry that led to the initial exposures. It is also very possible that since the original source of the data is death certificates, physicians could have misclassified or misdiagnosed certain diseases. Also, certain political events can change the reporting of these types of diseases. For example, after the Federal Coal Mine Health and Safety Act of 1969, combined with the Farmington, West Virginia mine disaster of 1968, recording and diagnosis of CWP could have dramatically increased (Attfield and Wood 2004). Some researches developed methods for determining cases of Silicosis and there results were greater than those reported by the current surveillance programs (Rosenman *et al* 2003), therefore, it is possible that other forms could have also been under-reported. However data from the national database is national in scope and provides a good insight into future trends. And hence this research paper can be used to improve disease-management programs and be useful for policy-makers to appropriate resources more effectively to the right domains. Economists can estimate more accurately how much life will be lost before retirement age and develop ways for determining potential economic loss from knowing potential life that will be lost in the future. The models can even be used to better estimate the expected deaths and thus improve PMR values.

This research does not include an analysis of exposure rates. Research has been done involving models using exposure rates; however these models are restricted to certain regions and are not national in scope (Attfield and Kuempel 2003, Attfield and Costello 2004). Future research incorporating exposure rates and other factors for a nationwide and even worldwide analysis is needed. It would also be useful to be able to analyze and predict trends in other countries, especially third-world countries so organizations such as the International Labor Organization and the World Health Organization can take appropriate measures.

CONCLUSIONS

It was found in this study that the distribution patterns of pneumoconiosis vary between the coal mining and construction industries. For example, a majority of deaths (88.2%) in the coal mining industry occur in a single occupation (mining machine operating) while in construction, there is a more equal distribution among the various occupations. Even so, in the construction industry, insulation workers seem to have the most risky occupation in terms of being affected by all forms of pneumoconiosis and asbestosis in particular. In addition, although the coal mining industry has about 2.6 times as many deaths as those in the construction industry, the construction industry has a higher percentage of deaths due to pneumoconiosis diseases. Yet the high PMR in the construction industry indicates that many people are not expected or prepared to protect against these illnesses.

Regression models revealed that overall fatalities and YPLL due to pneumoconiosis under age 65 are declining for both industries. The fatalities and YPLL caused by some types of pneumoconiosis under age 65 are declining exponentially. However, it is interesting to see that the patterns are different for people over 65. First, there is a much flatter decrease in overall fatalities after age 65. Second, the fatalities and YPLL caused by asbestosis are increasing. Third, all other patterns, except for that of asbestosis, show a decreasing trend. Such observations suggest that asbestosis is the major cause for deaths and YPLL and also indicate that existing measures for preventing asbestosis may only be able to delay the cause of death.

The cross-analysis of YPLL under age of 65 versus the number of deaths also revealed very interesting results. The linear relationships in all cases clearly suggest that even though fatalities caused by pneumoconiosis are declining overall; the rate of work life lost due to pneumoconiosis is constant. It is likely that the rate of work life lost will continue to decrease due to developments in modern medical technology and stringent prevention measures. It would be interesting to further investigate the reasons why such linear relationships are observed in all pneumoconiosis types.

It is also interesting to see how different forms of pneumoconiosis contributed to deaths and years of potential life lost as a whole. Earlier in 1968, CWP was the most recorded of all types of pneumoconiosis, accounting for 47% of all deaths recorded due to pneumoconiosis. In 1984, it peaked by contributing to 61.2 % of all recorded deaths due to pneumoconiosis. By 2000, however its percentage had dropped down to about 30%, becoming the second highest contributor. Meanwhile, asbestosis has been on a continuous linear rise since 1968, starting at 5.4% of all deaths in 1968 to 52% of all deaths in 2000. Silicosis, on the other hand, showed a sharp decline from 1968 where it accounted for 32% of the deaths ranking as the second highest contributor to 13% in 1977. From then on it stayed relatively constant, composing on an average, 11% of pneumoconiosis deaths becoming the second lowest contributor. From 1970 to 1980, other/unspecified forms of pneumoconiosis had been the second highest contributor recorded for pneumoconiosis deaths. The peak came in 1974 when it was recorded to have contributed to 28.9% of pneumoconiosis deaths. By 2000, it accounted for 7.8% of recorded pneumoconiosis deaths ranking last just after silicosis, which accounted for 10.3% of the deaths. The respective distributions of years of potential life lost were also similar in shape to the death distributions.

ACRONYMS

CWP - Coal Worker's Pneumoconiosis
OSHA - the Occupational Safety and Health Administration
NIOSH - the National Institute of Occupational Safety and Health
SENSOR - the Sentinel Event Notification System for Occupational Risks
NORMS - the National Occupational Respiratory Mortality System
PMR - Proportionate Mortality Ratios
YPLL - Years of Potential Life Lost
CDC - the Centers for Disease Control

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