

PREVALENCES, INCIDENCE DENSITIES AND CUMULATIVE INCIDENCES OF PNEUMOCONIOTIC CHANGES FOR TWO GROUPS OF MINERS OF A MINE IN WESTERN GERMAN COAL MINING

H.J. VAUTRIN* • P. Morfeld† • B. KAMPMANN†

*Bergwerk Walsum, Ruhrkohle AG, Duisburg, F.R.Germany

†Institut für Arbeitswissenschaften der Ruhrkohle AG, Dortmund, F.R.Germany

INTRODUCTION

There is a discussion in the Federal Republic of Germany that the average level of respirable dust in the underground coal mine atmosphere has to be reduced for minimizing the risk of coalworkers' pneumoconiosis (CWP). Now it was offered a level of 2 mg/m^3 , a value having been in force in the U.S. since December 1972.¹ To determine an adequate level, extensive studies according to the problem of CWP caused by respirable coal mine dust in dependence on various stratigraphic horizons have been started. This relation between coal rank and frequency of CWP—sometimes described as a geographical or "mine effect"—was often mentioned in the last twenty years.^{11,14,18,19,20,21,22} In German research on pneumoconiosis cytotoxicity of dust and the outcome of dust exposure on animals was extensively studied. The development of pneumoconiotic abnormalities in chest radiographs of miners has not been investigated to the same extent. Therefore it seems to be expedient to study the data collected by the physicians carrying out regular medical surveys of all miners in Germany to estimate the risk of developing pneumoconiotic abnormalities in chest radiographs in relation to time underground.

MATERIAL

The totality of miners who left the mine as workers in 1980 (group 1) or 1985 (group 2) took part in this longitudinal study. Group 1 and group 2 were pooled to form a third study group (group 3). The study avoids further selection bias since all miners who turned off were included in the investigation. Table I gives information on the study groups. The number of the retired gives workers in the whole study group (group 3) amounts to 952 persons. 548 miners left in 1980, 404 turned off in 1985.

Table I

Information on Study Groups: — group 1: all miners who retired as workers in 1980; group 2: all miners who retired as workers in 1985; group 3: group 1 and group 2 pooled

		Number of persons	Cumulative observation time / yr	Mean time of observation per person / yr	Number of chest radiographs	Mean number of chest radiographs per person
group 1 (1980)	a	548	3767	6.9	2214	4.0
	b	115	2456	21.4	1692	14.7
group 2 (1985)	a	404	4789	11.9	2047	5.1
	b	174	4841	28.2	3095	17.8
group 3 (1980;1985)	a	952	7556	7.9	4261	4.5
	b	289	7017	24.3	3187	11.0

a: all miners

b: subset of miners who worked at least five years underground

The miners enter the study with the beginning of their time underground. Time of investigation ends with the last medical survey. In Table I cumulative observation time and mean time of observation per person by study group are presented. Observation time includes time underground and subsequent time on surface. In the whole study group (group 3) 41 miners were examined in medical surveys after they finished work underground. They contribute 403 years of observation time during their subsequent time on surface to the total cumulative observation time of 7556 years. 663 miners turned off with an individual time underground less than five years. Their contribution to total cumulative observation time of the whole study group amounts to 539 years. Therefore the average observation time per person who turned off with an individual time underground less than five years was just 0.81 years. The subgroup of miners who worked at least five years underground (group 3b) comprises 289 persons and covers 92.9% of the total cumulative observation time (group 3a). On average every miner of this subgroup is observed for 24.3 years.

As a whole 5261 full size posterior anterior chest radiographs comprising 5.5 radiographs on average per person are taken into account. 3187 radiographs are concerned with those working at least 5 years underground at an average value of 11.0 radiographs per person (Table I). First valuation of the radiographs took place during medical survey, a further one by a second physician ("side-by-side method") at sole knowledge of underground time, both according to ILO-classification of 1980,¹⁰ supplemented by the 'supplying set of standard films to ILO 80 of Hauptverband der gewerblichen Berufsgenossenschaften e.V.' Final valuation was determined by joint examination, partly with a third physician in case of disagreement. For seven cases the first radiograph was valued >0/0. These persons were kept in the study and the grading linearly interpolated. The results on hand show neither jumps nor regressions.

According to the stress-strain-model both parameters must be defined as precisely as possible. The strain part is exactly determined by a great number of double-examined radiographs with respect to categorization. Stress is partly described rather precisely in the references with information about dust quantity, concentration, influence and retention time. Further on exposure periods are referred to.^{2,8,9,11} The data of this study do not give exact information on dust quantities (respirable dust concentration) and actual number of shifts. In the information of underground years these variables are implied, if not precisely defined.

The study was designed as a cohort study. In a classical design of a prospective study the study groups are defined as cohorts fixed in respect to calendar time or age.⁶ This design was not practicable with regard to our data basis. The forming of a fixed cohort requires a survey of all employees of one or two years between 1950 and 1955 in order to answer the questions about the development of pneumoconioses. Complete data from this period were not available. Therefore the study groups were formed as dynamic cohorts in respect to calendar time and age.¹² Admissibility criterion was retirement in a fixed calendar year (1980 or 1985). No further selection was made. All retiring workers have had no symptoms and preliminary stress at the beginning of the study.

The two turning-off groups (1980/1985) are showing differences in regard to calendar time and age. Figure 1 informs about time at risk in dependence on age. Time is classified into intervals of two years according to the mean interval of medical survey. The curves do not only distinguish in the maximum but also in the distribution. The curves reflect the dynamic of the cohort in respect to age. In Figure 2 the time at risk is also displayed but in dependence on calendar time. The 'three elephants' show a break at the same time in 1973, the period of the 'oil crises' (additional employment). Here as well, the curves show the effect of the dynamic cohort in respect to calendar time. The differences between group 1 and group 2 are not examined in this study further on.

The study groups are transformed into cohorts fixed in respect to observation time.¹² The miners enter with the beginning of their work underground. In the main study terminus is the last medical survey until they finished mining underground.

Prevalences and incidence densities¹⁵ of all categories of CWP are computed for each study group and for each two-year interval of time underground. Intervals are closed on the left side and open on the right. Confidence intervals for the prevalence proportions (binomial distribution) are determined.⁵ The median (with upper 95% confidence limit²³) and the 95th centile of coalworkers' simple pneumoconiotic (CWSP) are computed in relation to time underground. Calculation of cumulative observation time, candidate time,¹⁵ and rates are done by PERSON-YEARS 1.2, a FORTRAN program for cohort study analysis.⁴ For estimation of risk associated with varying time underground cumulative incidences are computed using the density method.¹² In most figures time underground is limited to a period of 0 to 32 years to present reliable data only.

RESULTS

Prevalence of CWSP

Figure 3 shows the relation between prevalence proportions of category 0/1 or more, 1/0 or more and 1/1 or more CWSP and time underground for the whole study group (group 3). In the interval of 28 to 30 years underground the prevalence of CWSP \geq 1/1 is 15.5%. The 95% confidence interval for this value spans from 9.7% to 22.7% and is based on the data of 129 persons. The curves are ranked systematically with abnormality level and increase progressively with time underground ignoring smaller fluctuations.

Figure 4 shows the median with its upper 95% confidence limit and the 95th centile of CWSP (prevalent cases) for the whole group (study group 3) in relation to time underground. The median is 0/0 for the whole time period presented and never statistically different from 0/0 on the 5% level during the total time of observation. The upper confidence limit of the median is 0/0 for the period from 0 to 30 years underground. In the last

presented interval from 30 to 32 years underground the upper confidence limit reaches 0/1. The 95th centile of CWSP is 0/0 in the period from 0 to 14 years underground and changes profusion category after that point every 3.5 years on the average. The .95 fractile reaches profusion category 2/1 in the interval from 28 to 30 years underground.

Incidence of CWSP

Cumulative observation time and candidate time for profusion categories of CWSP in relation to time underground are presented in Figure 5. The curves refer to all miners in the whole group (study group 3) who worked underground for at least 5 years. Therefore the curves are censored at the left. The omitted values are: 1020 years (673 years) of cumulative observation time in the interval from 0 to 2 years (2 to 4 years) underground. The top curve shows the decline of cumulative observation time due to loss of cases in respect to time underground. The lower curves (top down) represent candidate time for profusion category 1/1, 1/0 and 0/1 of CWSP respectively. The curves rank inverse with abnormality level. The top curve showing cumulative observation time is equivalent to the curve of candidate time for profusion category 3/+ because no incidence of 3/+ happened during time underground. Candidate time as proportion of cumulative observation time decreases monotonously for the three presented categories of CWSP in the interval from 0 to 32 years underground. Moreover the decline of relative candidate time is ranked with category of CWSP.

Figure 6 presents the incidence density (number of incident cases per 100,000 years of candidate time) of CWSP category 0/1, 1/0, 1/1 and 2/2 respectively related to time underground. The data concern the whole group (study group 3). Although there is a lot of fluctuation increasing trends of incidence densities of CWSP are shown generally. The rate of profusion category 2/2 amounts to 500/(100,000 years) after about 30 years mining underground.

For assessment of risk cumulative incidences are given in Figure 7 for the whole group (study group 3). The risk of developing category 0/1, 1/0, 1/1, or 2/2 (starting category 0/0) increases with time underground. Moreover the incline of the curves is increasing with time underground in general. The curves rank clearly with CWSP category. The risk of developing category 2/2 after 28 to 30 years working underground amounts to 2.7%. The cumulative incidence of CWSP category 1/1 is 16.6% for the interval from 28 to 30 years underground. The prevalence proportion of category \geq 1/1 for the same interval of time underground was found to be 15.5% (95% confidence interval spans from 9.6% to 22.7%). Similar relations between cumulative incidences and corresponding prevalences were determined for other categories of CWSP. Therefore the estimation of risk given by the cumulative incidences seem to be reliable.

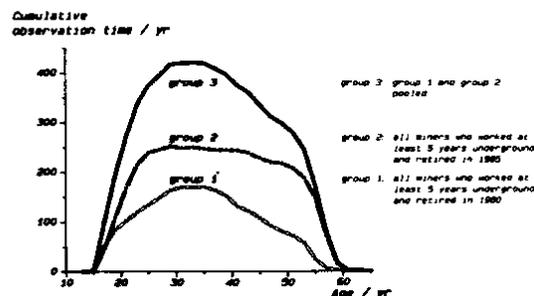


Figure 1. Cumulative observation time by two-year intervals of age.

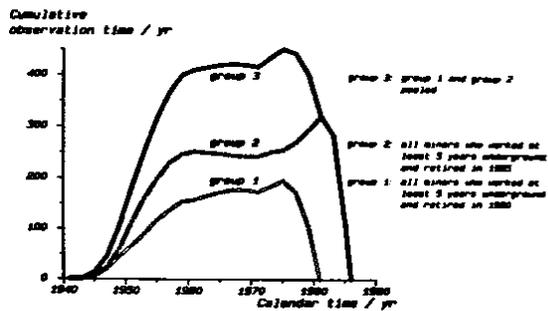


Figure 2. Cumulative observation time by two-year intervals of calendar time.

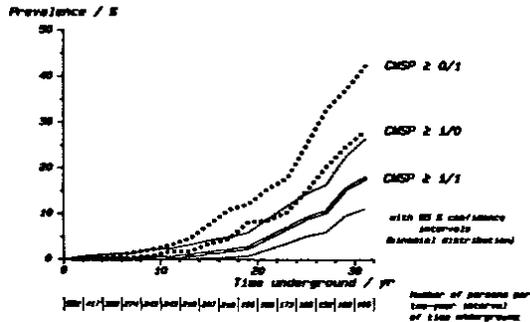


Figure 3. Prevalence proportion of CWSP (profusion) in two pooled groups of miners (all miners who retired as workers in 1980 or 1985) by two-year intervals of time underground.

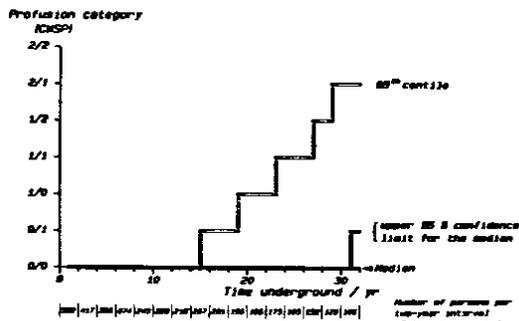


Figure 4. Median with upper 95% confidence limit and 95th centile of CWSP (profusion) in two pooled groups of miners (all miners who left the mine as workers in 1980 or 1985) by two-year intervals of time underground.

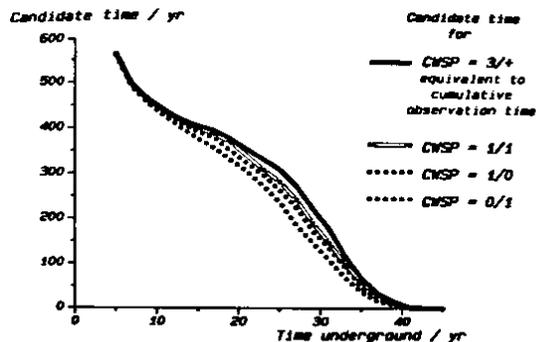


Figure 5. Cumulative observation time and candidate time for CWSP (profusion) in two pooled groups of miners (all miners who retired as workers in 1980 or 1985) by two-year intervals of time underground.

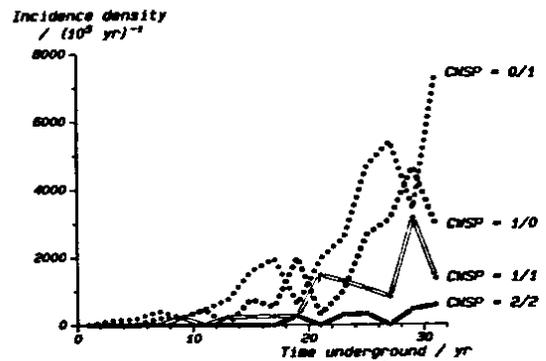


Figure 6. Incidence density of CWSP (profusion) in two pooled groups of miners (all miners who retired as workers in 1980 or 1985) by two-year intervals of time underground.

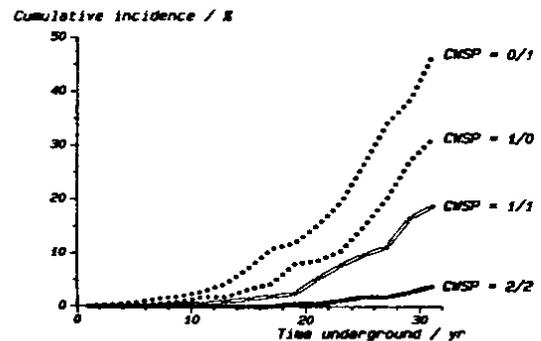


Figure 7. Cumulative incidence of CWSP (profusion) in two pooled groups of miners (all miners who left the mine as workers in 1980 or 1985) by two-year intervals of time underground.

DISCUSSION

Prevalence of CWSP

The prevalence proportions found in our study agree with results given in reports of British and American studies in general. Hurley et al.⁹ found a prevalence for category $\geq 2/1$ CWSP of 1.2% (1.3% respectively) in an investigation of 465 (456) British miners who worked 25 (30) years underground. From the study's data corresponding prevalences of 1.8% (5.4%) are yielded. For a comparison of the results it is necessary to take into account that the selection procedure used in sampling the British study group "may have led to a preferential inclusion of healthier man."⁹ Attfield et al.¹ determined a prevalence proportion of 3.0% (1.4%) for category CWSP $\geq 1/1$ (CWSP $\geq 2/1$ respectively) after about 20 years underground in an investigation of a not systematically sampled group of 1252 U.S. miners.

Recent German studies on prevalence of CWP performed by Ulmer et al.^{7,24,25,26,27,30} presented results not corresponding to those of this study. Ulmer et al. described the development of CWP in terms of "averaged categories" in relation to age taken as an indirect measure of time underground. They reported an "averaged category" of 1/2 or 2/1 CWSP after about 30 years mining underground. The median of CWSP in this study is 0/0 after 30 years underground and is significantly less than 0/1. Whether these differences may be due to selection bias or e.g., "mine effects" is still under discussion. Ophoff¹⁷ in a study based on 218 selected German miners re-

ported an "averaged category" of about 0/1 after 20 years underground. Reisner et al.^{18,19,21} also performed several studies more than ten years ago. The authors¹⁸ presented a prevalence of about 9% for CWSP $\geq 2/1$ after 20 years underground. It is, however, very difficult to compare these results with the findings of this study, because the chest radiographs were not classified according to the ILO-standard, while Reisner et al. tried to overcome this problem by a translation from the former classification into ILO-standards, a procedure which leaves a lot of uncertainty.

Incidence of CWP

The risk of British coal miners to develop CWSP was described by Jacobsen et al.^{9,11,28} The given estimates of risk vary substantially due to a "mine effect." For a mean dust concentration between 2.5 and 4.5 mg/m³ the average risk of developing CWSP $\geq 0/1$ in ten years working underground was found to be in the range of 2 to 10%. Attfield et al.¹ studied U.S. coal miners. An estimate of risk of developing category 0/1 or more in about ten years of 1.9% was found here. The mean dust concentration was reported as 2.5 mg/m³ or less. Our assessment of risk by cumulative incidences agree with the findings in this study. For the whole study group (group 3) a cumulative incidence for developing category 0/1 after 10 years underground of 1.9% was computed.

Reisner et al.¹⁸ calculated estimates of risk of developing CWSP $\geq 1/0$ ("translated" category, cf. 3.1) in 35 years underground of 5 to 50%. The variation is due to a "mine effect." The corresponding cumulative incidence found in our study is 27% (group 3).

In our study we observed just one case of progressive massive fibrosis (PMF): one miner developed a large opacity of type A during time underground. Large opacities of type B or C did not occur. The one incident case corresponds to an incidence density of 14/(100,000 a). Hurley et al.⁸ described a mean rate of PMF in British miners of 180/(100,000 a). The rate was 0 in one mine.

Implications

This study shows that the study design chosen produced valid results comparable to those of other authors. The portion of miners working more than 30 years underground is too small to estimate exact risk of development of CWP yet. Therefore a study is planned about all miners having worked more than 20 years underground selected from the totality of miners who turned off in 1973, 1974, 1975, 1976, 1977, 1980, and 1985. Moreover, calendar time will be taken into account as a covariable. In the future, analysis will be extended to the development of shape-size. Later the aspect of stress shall be determined more precisely to estimate the risk in relation to the respirable dust concentration in order to attribute to the discussion on dust level. We hope to estimate the risk of CWP by using this method more adequately and by this help to minimize that risk in the future.

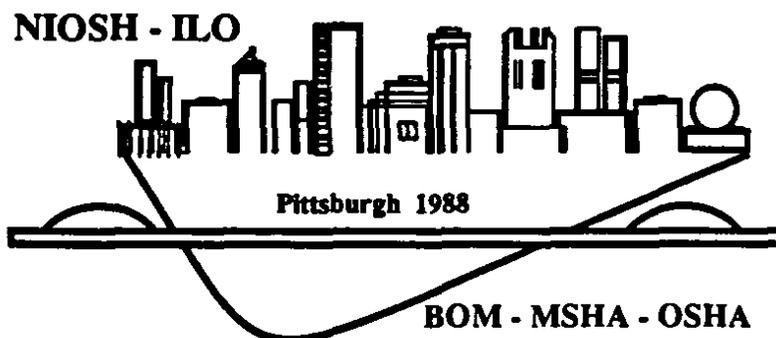
REFERENCES

- Attfield, M., Reger, R., Glenn, R.: The Incidence and Progression of Pneumoconiosis Over Nine Years in U.S. Coal Miners: I. Principal Findings. *Am. J. Indust. Med.* 6:407-415 (1984).
- Attfield, M., Reger, R., Glenn, R.: The Incidence and Progression of Pneumoconiosis Over Nine Years in U.S. Coal Miners: II. Relationship with Dust Exposure and Other Potential Causative Factors. *Am. J. Indust. Med.* 6:417-425 (1984).
- Breuer, H., Reisner, M.T.R.: Die Beziehung zwischen der Staubexposition und dem Auftreten der einfachen Pneumokoniose und der Einfluss des Beurteilungszeitraumes auf das Überschreiten von Staubgrenzwerten. *Silikosebericht Nordrhein-Westfalen* 15:433-444 (1985).
- Coleman, M., Douglas, A., Hermon, C., Peio, J.: Cohort Study Analysis with a FORTRAN Computer Program. *Int. J. Epidemiol.* 15:134-137 (1986).

- Documenta Geigy. Wissenschaftliche Tabellen.* 7th Ed., K. Diem and C. Lentner, Eds. Georg Thieme Verlag, Stuttgart (1975).
- Frentzel-Beyme, R.: *Einführung in die Epidemiologie.* Wissenschaftliche Buchgesellschaft, Darmstadt (1985).
- Hanzlik, J.A., Tomaszewski, J.J., Barud, W., Ostrowski, S., Ulmer, W.T.: Gesundheitszustand von Bergleuten in Lublin/Polen. *Arbeitsmed. Sozialmed. Präventivmed.* 22:238-242 (1987).
- Hurley, J.F., Alexander, W.P., Hazledine, D.J., Jacobsen, M., Maclaren, W.M.: Exposure to respirable coalmine dust and incidence of progressive massive fibrosis. *Br. J. Ind. Med.* 44:661-672 (1987).
- Hurley, J.F., Burns, J., Copland, L., Dodgson, J., Jacobsen, M.: Coalworkers' simple pneumoconiosis and exposure to dust at 10 British coalminers. *Br. J. Ind. Med.* 39:120-127 (1982).
- Internationales Arbeitsamt (IAA) *Richtlinien für die Anwendung der Internationalen Klassifikation des IAA von Pneumoconiosen-Röntgenfilmen.* Internationales Arbeitsamt, Genf (1980).
- Jacobsen, M., Rae, S., Walton, W.H., Rogan, J.M.: The Relation between Pneumoconiosis and Dust-Exposure in British Coal Mines. In: *Inhaled Particles III*, pp. 903-920. W.H. Walton, Ed., Pergamon Press, Oxford (1971).
- Kleinbaum, D.G., Kupper, L.L., Morgenstern, H.: *Epidemiologic Research. Principles and Quantitative Methods.* Van Nostrand Reinhold Company, New York (1982).
- Lauffhütte, D.W., Robock, K., Klosterkötter, W.: Untersuchungen über die cytotoxische Wirkung von Grubensstäuben aus dem Saarkarbon. *Silikosebericht Nordrhein-Westfalen* 8:131-138 (1971).
- Miller, B.G., Jacobsen, M.: Dust exposure, pneumoconiosis, and mortality of coalminers. *Br. J. Ind. Med.* 42:723-733 (1985).
- Miettinen, O.S.: *Theoretical Epidemiology. Principles of Occurrence Research in Medicine.* John Wiley & Sons, New York (1985).
- Morfeld, P., Vautrin, H.J., Kampmann, B.: Expositionszeit-spezifische Prävalenzen der Silikose für zwei Abkehrjahrgänge eines Bergwerkes im deutschen Steinkohlenbergbau. *Verh. d. Dtsch. Ges. f. Arb.-Med.* 28 (1988) (to appear).
- Ophoff, B.: *Pneumokoniosehäufigkeit und -ausprägungsgrad in Abhängigkeit von der Staubbelastung in unterschiedlichen Flözhorizonten des Steinkohlenbergbaus.* Hamburg (1985).
- Reisner, M.T.R.: Pneumokoniose und Staubexposition—Epidemiologische Untersuchungen im Ruhrbergbau über einen Zeitraum von 14 Jahren. *Silikosebericht Nordrhein-Westfalen* 10:209-231 (1975).
- Reisner, M.T.R.: Ergebnisse epidemiologischer Untersuchungen zum Fortschreiten von Staublungenveränderungen. *Silikosebericht Nordrhein-Westfalen* 11:209-223 (1977).
- Reisner, M.T.R.: Program zur Untersuchung der spezifischen Schädlichkeit von Feinstäuben im Steinkohlenbergbau. *Silikosebericht Nordrhein-Westfalen* 12:167-172 (1979).
- Reisner, M.T.R., Kotischke, G., Niesert, E.: Pneumokoniose und Staubexposition—Epidemiologische Untersuchungen im Steinkohlenbergbau an der Ruhr über einen Zeitraum von 20 Jahren. *Silikosebericht Nordrhein-Westfalen* 15:445-492 (1985).
- Reisner, M.T.R., Robock, K.: Untersuchungen über die spezifische Schädlichkeit von Feinstäuben aus dem Ruhrbergbau. *Silikosebericht Nordrhein-Westfalen* 10:145-154 (1975).
- Sachs, L.: *Angewandte Statistik. Anwendung statistischer Methoden.* 6th Ed., Springer-Verlag, Berlin (1984).
- Ulmer, W.T., Bengtsson, U., Reischig, H.L., Speckmann, B., Vautrin, H.J., Zimmermann, I.: Neue Ergebnisse der Silikoseforschung. *Verh. d. Dtsch. Ges. f. Arb.-Med.* 27:93-96 (1987).
- Ulmer, W.T., Bengtsson, U., Reischig, H.L., Speckmann, B., Vautrin, H.J., Zimmermann, I.: Silikoseentwicklung und Lungenfunktion bei Bergleuten. *Silikosebericht Nordrhein-Westfalen* 16:387-393 (1987).
- Ulmer, W.T., Bengtsson, U., Vautrin, H.-J., Reischig, H.L., Zimmermann, I.: Die Entwicklung der Bergarbeiter-Pneumokoniose während und nach der Untertage-tätigkeit. *Arbeitsmed. Sozialmed. Präventivmed.* 22:91-94 (1987).
- Ulmer, W.T., Zimmermann, I., Bengtsson, U., Lindke, M., Mocker, U., Reischig, H.L.: Ergebnisse zur röntgenologischen Entwicklung der Silikose nach gemeinsamen Röntgenlesen auf 4 Zechen. *Silikosebericht Nordrhein-Westfalen* 15:409-432 (1985).
- Walton, W.H., Dodgson, J., Hadden, G.G., Jacobsen, M.: The Effect of Quartz and other Non-Coal Dusts in Coalworkers Pneumoconiosis. Part I: Epidemiological Studies. In: *Inhaled Particles IV*, pp. 669-690. W.H. Walton, Ed., Pergamon Press, Oxford (1977).
- Zimmermann, I., Rahlf, V.W.: *Methoden der Auswertung von Ordinaldaten mit wenigen Ausprägungen und ihre Berechnung mit Standardpaketen.* Vortrag anlässlich der 3. Konferenz über die wissenschaftliche Anwendung von Statistik-Software, Gesellschaft für Strahlen- und Umweltforschung, Neuherberg (1985).
- Zimmermann, I., Ulmer, W.T., Chimombe, A.E., Lindke, M., Bengtsson, U., Mocker, U.: Untersuchungen von Röntgenresultaten bei Überwachungsuntersuchungen von 4 Ruhrgebietsbetrieben. *Silikosebericht Nordrhein-Westfalen* 14:385-398 (1983).

Proceedings of the VIIth International Pneumoconioses Conference
Transactions de la VIIe Conférence Internationale sur les Pneumoconioses
Transacciones de la VIIa Conferencia Internacional sobre las Neumoconiosis

Part **I**
Tome
Parte



Pittsburgh, Pennsylvania, USA—August 23–26, 1988
Pittsburgh, Pennsylvanie, Etats-Unis—23–26 août 1988
Pittsburgh, Pennsylvania EE. UU—23–26 de agosto de 1988



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health



Sponsors

International Labour Office (ILO)
National Institute for Occupational Safety and Health (NIOSH)
Mine Safety and Health Administration (MSHA)
Occupational Safety and Health Administration (OSHA)
Bureau of Mines (BOM)

September 1990

DISCLAIMER

Sponsorship of this conference and these proceedings by the sponsoring organizations does not constitute endorsement of the views expressed or recommendation for the use of any commercial product, commodity, or service mentioned.

The opinions and conclusions expressed herein are those of the authors and not the sponsoring organizations.

DHHS (NIOSH) Publication No. 90-108 Part I