COMMISSION OF THE EUROPEAN COMMUNITIES

industrial health and safety

Seminar

Epidemiology and technical and medical prevention of coal miner's pneumoconiosis

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OPENING ADDRESS

by Dr P. RECHT, Advisor hors classe
Health and Safety Directorate
Directorate-General for Employment and Social Affairs
Commission of the European Communities

Ladies and Gentlemen,

We are very pleased to welcome you to Luxembourg to discuss a subject which concerns medical circles, health authorities and both sides of industry. I should like to extend a particular welcome to the guests we have invited from the United States and whose avowed interest in our work and research projects will no doubt emerge during the discussion.

The seminar focuses on two main themes : epidemiology and prevention. The reports we have received indicate the state of the art of Community research and emphasize a number of points relating to the improvement of the protection and safety of miners. There are still a large number of unknown factors and problems that have not been solved. The objective manner in which they have been presented indicates the authors' concern with the practical consequences of their studies.

The first problem is that of basic research, whose aim is to gain a better understanding of the way in which dust affects the lungs, and outstanding reports have been drawn up on this topic. Free silica is no longer considered the only cause; dust hazards in mines differ considerably, depending on the geographical situation and the composition of the dust. It seems that certain components of these dusts have contradictory or additive effects - a familiar problem in other medical fields and in occupational hygiene. You may be called upon to suggest more precise guidelines for future studies which could lead to positive results within a reasonable time. I think that particular attention should be paid to the pulmonary clearance mechanisms, which are well known in radiobiology and in respect of which a precise respiratory model has been in existence for 15 years.

The second problem is that of epidemiology. The number of pneumoconiosis cases in the Member States of the Community is still high; in France, for example, almost 60 000 miners suffer from the disease at present and the figures are similar in Belgium. Thus the number of workers who have this disease and receive benefits under the special compensation systems runs into tens of thousands. Pneumoconiosis is still the most serious occupational disease, as regards both its incidence and its consequences. It thus poses a serious social and economic problem and everything should be done to improve prevention.

There is no doubt that medical progress has led to improvements and to a notable increase in miners' life expectancy. I remember my frequent visits thirty years ago to the mining villages in the Pays Noir and the Charleroi area, where pneumoconiosis was a widespread and serious disease. Like other countries, Belgium set up rehabilitation centres but unfortunately treatment proved exceedingly difficult and the results were unsatisfactory. Epidemiology should help us to improve our understanding of the relationships between the composition of mine dusts and the frequency of the disease, no matter now great the difficulties involved in such research work.

There is a need for closer links between your studies and the work being carried out by Mr LEMOINE in the field of dust measurement. One of the tasks of the European Community is to harmonize techniques and standards in this area. Scientific research is indispensable but it should be seen in the context of a policy of standardization, prevention and protection. Research work should be as practically oriented as possible. Coordination with the Mines Safety and Health Commission should be improved, this being the body which draws up the Community recommendations to promote the protection of miners. Perhaps you might also consider studying other varieties of pneumoconiosis. Silicosis exists in foundries and respiratory diseases in coking plants. You have the ability to initiate such work; moreover, there is a need to study other types of pulmonary diseases.

The sums made available each year via the levy and which are earmaked for social research provide the Commission with a powerful lever for the promotion of science and technology, whereas in other research fields considerable difficulties remain.

I would like to stress the vital role of the occupational physician in the implementation of effective medical prevention.

Technical prevention and medical prevention are the two cornerstones of overall prevention aimed at ensuring the health protection of workers.

Although technical prevention must step in first, medical prevention is indispensable with a view to detecting the very first signs of health impairment or preventing it altogether. One important topic we will be discussing during this meeting is how to improve cooperation between medical and technical prevention.

In June 1978 the Commission set up a general action programme on health and safety at work which comprises a series of fourteen broad projects which we hope to complete by 1982. In certain fields satisfactory progress is being made. In connection with this programme, a proposal for a framework Directive has been prepared defining the rules and principles which should guide legislation on the exposure of workers to physical, chemical or biological toxic agents, including atmospheric pollutants, at workplaces.

The joint principles will provide a framework for standard setting activity in the Member States, in all fields relating to the protection of workers, including miners and steel workers.

One of the principles that has been put forward is the determination of limit values for exposure. The activities of the Mines Safety and Health Commission and the social research work carried out by the ECSC may be considered as models of scientific rigour and rule-making procedures. With your help we should be able to establish acceptable exposure levels for miners and stellworkers in respect of the different pollutants which they are liable to encounter at the workplace. There is also a need for more precise assessment of the hazards connected with different stages in the use of coal as a fuel. More and more attemps are being made to compare the hazards connected with specific energy cycles. The coal cycle is considered to be more damaging to the health of the workers and the general public than the oil or the uranium cycle.

It would be useful if you would also examine this new aspect of the assessment of "detriment" and the real meaning of statistics of accidents and diseases.

After your meeting it should be possible for our departments to prepare a new research programme to commence in 1981.

Your work is of considerable importance as we are now reaching a critical moment in the development of Community research. Both the workers and the Commission will be making increasing demands as regards research output and the production of practical and concrete results. It will be necessary to modify the themes of the future programme and to change its title and content in the light of the guidelines which will emerge from your discussions.

I wish you success in your work and hope that, under the direction of the various chairmen of the meetings, you will considerably facilitate our task of drawing up within the next few months new research themes contributing to the community-wide harmonization and standardization which are mandatory if we are to improve the safety and health of the important occupational group in which you have taken such competent and enthysiastic interest for 25 years.

2. THE IMPORTANCE OF EPIDEMIOLOGY IN RESEARCH ON PNEUMOCONIOSIS

M. JACOBSEN - United Kingdom

SUMMARY

Events leading to the start of the Pneumoconiosis Field Research in 1953 are reviewed. Research methods are outlined, progress is described, and the main results are summarised.

Three medical surveys were conducted at approximately five-year intervals at 24 coal mines. A further two quinquennial surveys took place at 10 of them, thus completing 20 years' observations. Individual miners' exposures to dust have been measured throughout the periods of study and earlier exposures have been estimated.

The dust exposures have been expressed as cumulative time-weighted mass concentrations of dust in the respirable range. Correlations have been demonstrated between this index of exposure and (a) risks of developing various degrees of simple pneumoconiosis, (b) the occurrence of chronic bronchitic symptoms, (c) level of breathing capacity, and (d) among miners with no pneumoconiosis, mortality attributed to respiratory diseases generally, chronic bronchitis and emphysema in particular, and to cancers of the digestive organs.

Exposures to quartz amounting to less than about 10 per cent of mixed coalmine dust do not generally affect the probability of developing simple pneumoconiosis. But there is evidence that some miners may show unusual radiological changes over ten years when exposed to dust with a relatively high quartz content.

Current work includes continuation of mortality studies and follow-up surveys of miners no longer working at the research collieris. The inter-disciplinary nature of the research team is emphasised and there are suggestions for further work on unresolved problems.

INTRODUCTION

Epidemiology is the study of disease profiles in groups of people. The essence of the science is the search for associations and relationships with factors influencing the occurrence of disease so that preventive measures may be taken. The importance of the epidemiological approach in British research on coalworkers' lung diseases has been that it has repeatedly led to social and political action during the past 40 years. How effective that action has been in preventing the disease will be discussed in later sessions of this seminar. The present paper reviews the background to the National Coal Board's long-term epidemiological research on pneumoconiosis; outlines the design and methods used; traces progress over 26 years; summarises the major results; and concludes with suggestions for future research.

THE MEDICAL RESEARCH COUNCIL'S STUDIES IN SOUTH WALES

An early application of the epidemiological approach to the study of coalminers' lung diseases was reported by Dr. E.M. Williams in 1933 (55). She examined and documented the health of 100 old Welsh coalminers, and concluded that "Pneumoconiosis appeared to be more generally distributed throughout the occupational groups of coal miners than had hitherto been thought the case". Thus Dr. Williams anticipated the Parliamentary debate in 1936 which stimulated the Medical Research Council (MRC) to undertake large scale surveys of miners in the Welsh valleys. The results from these medical studies were published in 1942 (21). But it was realised at the outset that on its own a description of the prevalence and natural history of disease was insufficient. If effective preventive measures were to be taken then it was necessary also to attempt to characterise quantitatively the environmental conditions which had led to the observed disease prevalence. No reliable records were available for this purpose, but approximations were made using results from measurements of dust concentrations at the collieris at the time of the medical surveys, and information on the work histories of the miners studied (2).

The results from these investigations had far-reaching consequences both on subsequent social measures regarding pneumoconiosis and on the orientation of later research. Two aspects were particularly important. The first was the conclusion that abnormalities in the chest radiographs of the South Wales coalminers were often of a type which did not conform to criteria generally accepted as indicating silicosis. This newly defined condition, now known universally as coalworkers' simple pneumoconiosis, was found to be associated "not infrequently" with some degree of respiratory disability, and it occurred among men who were unlikely to have had any substantial exposure to silica dust. This opened a new chapter in research on relationships between radiological signs and respiratory function, and it indicated that the most important aetiological factor might be exposure to mixed coalmine dusts, rather than just the silica content of such dusts as had been assumed previously.

The second major result from the MRC research was the demonstration by Briscoe and his colleagues (2) of a correlation between the prevalence (standardised by length of employment) of the more serious radiological abnormalities and the average mixed coalmine dust concentrations at the collieries at the time that the medical surveys were conducted. It was on the basis of this and associated evidence that soon after nationalisation the National Coal Board (NCB) instituted airborne dust standards ("Approved Conditions") for British coal mines (42). This was an example of the application of epidemiological research results for preventive purposes, but there were a number of difficulties.

The results on which the standards were based came from the South Wales coalfield only. The radiological abnormalities used in the MRC correlaction studies were so-called "consolidations", that is, advanced stages of the disease which would now be recognised as complicated rather than simple pneumoconiosis. No similar relation had been demonstrated between dust exposure and simple pneumoconiosis ("reticulation" in the nomenclature of Hart and Aslett (21)). There were difficulties also in relating medical findings, which reflected conditions of many preceding years, to dust measurements made at the time of the surveys. Although the suggestion was that dust standards should be based on mass concentrations of dust not exceeding five microns in size, no suitable measuring instruments were available at that time for use underground. Recommendations on standards were therefore expressed in terms of the number of particles in the respirable range per unit volume of sampled air, using limited data on the correlation between such measures and the corresponding mass concentrations. This was recognised as, at best, an approximation to the desired standard. The recommendations were designated as provisional, and it was emphasised by the MRC scientists that they should not be considered as definitions of "safe working conditions".

THE PNEUMOCONIOSIS FIELD RESEARCH

Aims

It was against this background of uncertainty that the NCB began a nation-wide longitudinal study in 1953. A primary aim of the Pneumoconiosis Field Research (PFR) was to obtain information that would permit the formulation of new dust standards ("to establish what environmental conditions should be maintained if mineworkers are not to be disabled by the dust they breathe"). The immediate research objective was to determine "how much and what kinds of dust cause pneumoconiosis".

Design and methods

The design of the study was first described in detail in 1957 (18). Subsequent publications have emphasised both the continuity and development of the methods used as the work progressed. In summary, the plan was to obtain full-size chest radiographs at five-year intervals of all miners employed at 25 collieries. The collieries were selected from all the British coalfields to provide a representative range of environmental conditions that might prove to be important in the causation of pneumoconiosis. Teams of investigators, stationed full-time at the collieris, carried out a statistically designed programme of full-shift dust sampling close to randomly selected members of a group of men working together in an essentially common environment. Records were accumulated of the time spent by each miner in these "occupational groups", and earlier occupational histories were compiled by interview with the men surveyed.

Progress and development

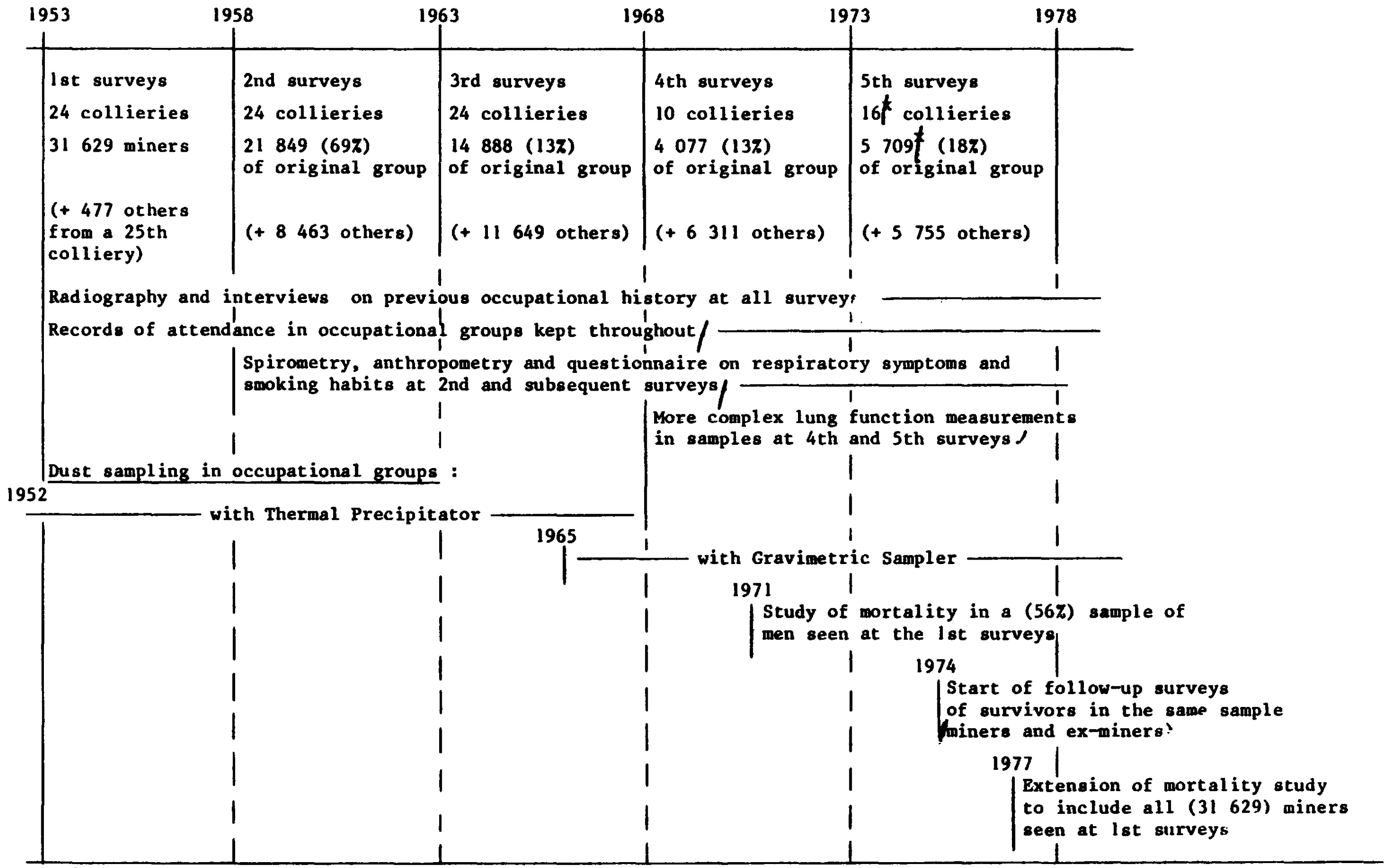
The Figure illustrates how the project has progressed and developed. One of the collieries closed soon after the initial survey. Twenty-four were visited on three consecutive occasions by the medical survey teams. The men seen at the third surveys included 47 percent of those surveyed initially, thus providing data referring to a 10-year period of observation for nearly 15 000 miners. Several of the collieries had closed by 1968 and others were expected to close soon after. The fourth and fifth surveys took place at 10 of the original collieries. The last of the fifth surveys, completing 20-year periods of study, occurred in the spring of 1978.

An investigation of mortality in a sample of all miners seen at the first surveys began in 1971. This was followed, in 1974, by the start of a series of medical surveys of survivors in the same sample, many of whom were no longer working in the coal industry. These "follow-up" surveys are continuing, as is an extension of the mortality study to include all the miners seen at the first surveys.

The regular radiography was supplemented at the second and subsequent surveys by simple measurements of lung function, anthropometry, and the application of a questionnaire on respiratory symptoms and smoking habits. More complex measures of lung function were made at the fourth and fifth surveys on samples of the men seen.

During the first 15 years of the project measurements of airborne dust concentrations were made with the Thermal Precipitator. Underground trials of the MRE Gravimetric Sampler began at the collieries in 1965/66, and this instrument was used routinely either immediately before or shortly

FIGURE : Progress and development of the pneumoconiosis Field Research



(*) Including some ex-miners seen in the PFR "Follow-up" surveys. Complete radiological and dust exposure data available for 2 600 (8%) of the original group at 10 collieries.

after the completion of the third surveys at collieries where the research continued. As before, all measurements of dust concentrations were made close to the men, from their arrival at pit bottom to their return there at the end of the shift.

RESULTS

Cross-sectional studies (1953-58)

During the course of the first PFR surveys several independent reports appeared confirming that the pneumoconiosis problem was not confined to South Wales. Studies in the Durham coalfield (in North-East England) showed that the disease was common among underground and surface workers at four collieries (35). Subsequent surveys at three collieries a little further North in the adjoining Northumbrian coalfield, showed much lower prevalence of pneumoconiosis than in Durham (36). The MRC work in South Wales was continued and extended to include four English collieries (10). At one of the latter the overall prevalence of pneumoconiosis among underground workers was as high as 60 percent, with about 14 percent showing Progressive Massive Fibrosis (PMF).

The completion of the initial surveys at PFR collieries provided further data on the distribution and prevalence of the disease (50). Wide variations between collieries were demonstrated both between and within coalfields, with the prevalence of category 1 or more (on the ILO, 1953 scale) ranging from about five to 41 percent. The results were documented in detail in terms of sub-groups defined by the miners' ages, previous occupational histories, and regional and geological factors (23).

These cross-sectional descriptions from the first PFR surveys supplemented usefully the information available at that time. But the main purpose of course was to characterise the radiological status of the miners involved at the start of the longitudinal study envisaged.

The value of these statistics as epidemiological indicators of the national picture in the 1950s was overshadowed in the ensuing five years by the inception, in 1959, of the NCB Medical Service's Periodic X-ray Scheme. Radiological surveys were scheduled at all British collieries. By 1963, a total of 463 000 miners employed at 652 collieries had been studied in this way. This represented more than 90 percent of the aggregate colliery populations at the time (43). The results provided a comprehensive epidemiological description of pneumoconiosis in Britain in terms of age-specific period prevalence rates. The picture has been up-dated annually since then (45).

The first longitudinal analyses of PFR data

The completion of the second round of PFR medical surveys, in 1963, provided data on radiological changes among more than 21 000 miners over periods ranging from 4.0 to 6.2 years, and averaging 5.1 years. Attempts were made to correlate numerical indices of these changes with averages of measured dust concentrations at the collieries. The correlation was poor (52). Methodological problems which might have contributed to this result were discussed, and the work then in progress on these matters was described.

The 1967 review of the stage reached by the PFR (52) drew attention also to the development in Britain and Germany of new sampling instruments suitable for measuring the mass concentration of respirable coal mine dust underground (4, 20, 56). It was anticipated that gravimetric samplers would soon be introduced for routine monitoring of dust conditions at all British collieries. New dust standards, expressed in gravimetric units, would therefore be required. Moreover, there was some evidence indicating that conversion of the accumulated PFR particle-count dust concentration data into mass concentration units (using experimentally determined factors) would lead to a closer correlation between the radiological and the dust exposure results.

The interim study (10-year periods of observation)

The imminent need to give guidance on suitable dust standards in mass concentration units determined that an interim analysis of 10-year periods of observation was begun in 1967. At that time the third medical surveys had been completed at only 20 of the 24 collieries.

Results from this work were first reported briefly in 1970 (31) and in more detail a year later (32). On this occasion a statistically significant correlation was demonstrated between the standardised aggregates of radiological changes observed among coalface workers at the 20 collieries and the averages of dust concentrations at the coalfaces sampled. The longer periods of observation (10 rather than five years) and the more sophisticated radiological scale used in the study (the 12-point NCB elaboration (34) of the four-point ILO scale (25)) are both likely to have contributed to this result. But perhaps most important was the application of averages of conversion factors ("Mass/Number Indices") to the particle-count dust measurements. This permitted the results of 14 years' dust sampling to be expressed in mass concentration units (14). Only a weak correlation had been detectable between the radiological results and the colliery-mean particle count concentrations ($r = 0.44$). The estimates of corresponding mass concentrations transformed the picture ($r = 0.80$), and separate consideration of results from men whose first-survey radiographs showed no signs of pneumoconiosis (category 0/0 or 0/- on the 12-point scale) improved the correlation further ($r = 0.87$).

The results were used to estimate long-term risks of developing various degrees of simple pneumoconiosis during a working-life at the coalface. The environmental field investigators had also made studies of how the method used for measuring dust concentrations in the PFR (for epidemiological research purposes) related to the type of measurements made routinely in British collieries for monitoring compliance with the standard (44). This information, and the application of results from the probability calculations to estimate the likely incidence of simple pneumoconiosis under different conditions (26), provided the scientific background to decisions on new dust standards. The gravimetric standard was introduced in 1970 (45).

Continuation of the research after the third surveys (1968-78)

The analysis of material used for the interim study was extended while the field research continued at ten of the collieries. The basic correlations reported originally were confirmed using time-weighted exposures experienced by individual miners (as distinct from averages of coalface dust concentrations) during ten years (27). Effects of assumptions and approximations made in the statistical modelling of the data were explored (28, 29, 30). The methods used were shown to have been reasonably robust, and it appeared that the dust-dose-specific probability estimates made in 1969 were unlikely to have been seriously misleading. The later work (30) also emphasised the need to supplement the 1970 dust standard with additional measures for the protection of miners with early or more advanced signs of pneumoconiosis. (The standard had been formulated on the basis of estimated long-term risks for new entrants to the industry.)

The intensified programme of gravimetric dust sampling following the third medical surveys also provided opportunities for new investigations of factors influencing the generation of respirable coalmine dust (3), of the distribution of dust concentrations underground and of the effectiveness of methods used for monitoring the underground environment (19). Such work is of general interest to those concerned with the suppression and surveillance of airborne dust in all countries where coal is mined. The results were particularly important in the British context because they provided, inter alia, information which was needed to verify the reasoning that had linked the research data to predictions of the likely effect of the 1970 British dust standard.

The possible importance of the composition of mixed airborne dust, particularly its silica content, was studied further. The interim analysis had not shown any clear correlation between the average quartz content of the dusts at the 20 collieries and the radiological results. But it was noted then that quartz levels had been very variable. If an additional effect due to quartz did exist then it was likely to have been obscured when considering only the average results from 20 collieries (32).

Later analyses of the same data, using information on individual miners' exposures, indicated conflicting patterns of radiological response to the non-coal components of the dust, depending apparently on the type of coal (the "coal rank") at the collieries where the exposures had been experienced (54). No generalisations were possible from these data about the effect of quartz in mixed coalmine dust on the chances of developing coalworkers' simple pneumoconiosis. (About 90 percent of the men studied had less than 7.5 percent quartz in their measured exposures to dust during ten years.) A preliminary investigation of the attack rate of complicated pneumoconiosis (PMF) in the same group of miners had also failed to show a relation with the quartz content of the dust to which the men had been exposed (37).

The "rank" of the coal refers to a complex of mineralogical and physicochemical properties. Earlier observations from the PFR of an association between this classification system and pneumoconiosis prevalence (23) had been overshadowed by the findings from the interim study. The varying aerodynamic characteristics of coals of different rank were associated with the experimentally determined Mass/Number Indices which had been used to convert the particle-count dust concentration measurements into gravimetric units. Correlations of radiological results with the estimates of average mass concentrations of dust at the collieries were not improved by adjustments for differences in coal rank as measured by the carbon content of the coal (32). But the indecisive results from the subsequent studies of the importance of dust composition (54), and the large differences between collieries in radiological results even after adjustment for varying individually experienced exposures, has directed attention back to the search for quantifiable colliery-specific factors.

By 1975 remarkably similar broad conclusions had emerged from the parallel longitudinal studies of coalminers in Britain (54) and in Germany (47, 49).

(i) The most important single factor influencing the development of coalworkers' pneumoconiosis was the mass of the respirable fractions of the mixed coalmine dust to which the miners had been exposed.

(ii) The quartz content of the dust, in the ranges studied, did not appear to affect the results generally.

(iii) There were large and as yet unexplained differences between collieries in effects of apparently similar exposures to mixed respirable coalmine dust.

These concordant findings stimulated a series of new and continuing research projects in countries of the European Community. They are aimed at identifying and characterising factors which are important in determining the variable noxiousness of different coalmine dusts.

Twenty-year periods of observation

The equivocal results concerning the effect of quartz from the interim, 10-year data placed this question high on the agenda for study when the fifth round of PFR surveys (at 10 collieries) was completed in 1978. Twenty-year periods of observation were now available, with gravimetric sampling over 10 years and greatly improved information about the quartz content of the dust (15, 16). Recent analyses of the new results (24) have again failed to establish any general pattern which can be interpreted as indicating that the quartz content of the dust to which men were exposed (generally less than 10 percent, with a median less than five percent) influenced the probability of developing simple pneumoconiosis. However, there is now evidence associating unusual radiological changes over ten years among some miners with exposures to dust containing relatively high proportions of quartz. These clues are being pursued both at PFR collieries and in wider studies involving all British collieries.

The new results, referring in part to 20-year periods of observation, were examined also to test the reliability of the previously estimated dust-dose-specific probabilities of developing category 2 or more simple pneumoconiosis. The general shape of the relationships described earlier, using only 10-years' data, was confirmed, as was the existence of still unexplained differences between collieries. On average, estimates of pneumoconiosis risks over about 35-years work at the coalface appeared to have understated the real situation by one to two percentage probability units. In practical terms this prediction error was more than compensated by (a) the reduced long-term risks for British miners in consequence of the more stringent dust standard that was introduced in

1977; and (b) the lowered retirement age for British miners, which also effectively reduced the maximum possible life-time exposure to coalmine dust (24).

The analyses confirmed that cumulative dust exposures, expressed as the summed products of time and concentration, correlated well with various formulations of the radiological data. It was clear however that the effect of a given cumulative exposure depended not only on its magnitude but also on the length of the time period during which it was accumulated. This result too is consistent with reports from the German research (48).

Respiratory symptoms and lung function

The word "pneumoconiosis" is usually interpreted as a reference to radiologically identifiable lung-dust disease, and it has been used in this sense here. But as indicated above the "Pneumoconiosis Field Research" had wider terms of reference. The aim was to establish what environmental conditions should be maintained if miners are not to be disabled by the dust they breathe.

The chances of developing the disabling complicated form of pneumoconiosis (PMF) is known to be far greater in the presence of the more severe categories of simple pneumoconiosis (7, 37). The introduction of gravimetric dust standards in Britain necessitated intensified engineering measures for dust suppression. The anticipated result, further reductions in the prevalence of simple pneumoconiosis, are clearly evident in the latest report from the NCB's Medical Service (45). In this sense therefore the epidemiological research results have certainly contributed to a reduction in disablement and premature mortality associated with PMF. Whether or not the radiological signs of simple pneumoconiosis are themselves associated with disability has been the subject of controversy for many years, and the debate continues (9, 13, 29, 38, 41). In this area too the results from the PFR have made important contributions.

A preliminary investigation was made in 1961 using results from the second surveys at eight PFR collieries (51). These indicated that increasing profusion of small opacities on radiographs, as reflected in the ILO (1953) radiological scale, were associated with small reductions in pulmonary function (Forced Expiratory Volume in one second, FEV_1) and with an increase in prevalence of respiratory symptoms characteristic of bronchitis. The results were not adjusted for differences in exposures to dust of men with varying degrees of pneumoconiosis, and they were not confirmed by other cross-sectional studies of respiratory symptoms and lung function among British coalminers (5, 9, 11).

However, results from young miners attending the third PFR surveys showed correlations between estimates of their cumulative exposures to respirable dust and the prevalence and incidence of the most common symptoms of bronchitis (persistent cough and phlegm) (46). Soon afterwards the same data were used to demonstrate that levels of FEV_1 among young and older miners were related inversely to the men's cumulative exposures to respirable dust (53). Both these effects were detectable among smokers and non-smokers, and the dust-associated reductions in lung funtion occurred both among men with and without radiological signs of simple pneumoconiosis. Moreover, it was shown that once the effect of dust exposure on FEV_1 had been taken into account then there was no detectable residual effect which could be attributed to radiologically defined simple pneumoconiosis _per se_. The implication was that in general exposure to airborne coalmine dust might cause _either_ simple pneumoconiosis, _or_ some other respiratory disease (or diseases) reflected in respiratory symptoms and reduced FEV_1, _or_ in some cases exposure to dust might result in all these conditions. A model of this kind had been postulated in 1961 (51) as an explanation of the earlier PFR results.

Selection effects, "Follow-up" surveys and mortality

A major difficulty in interpreting PFR results arises from the fact that all the relationships described were derived from examinations of working miners who remained at the research collieries for at least 10 and in some cases 20 years. To what extent have the estimates of dust effects been understated because of failure to include miners who left the collieries between surveys (53) ? Or could it be that exclusion of ex-miners from the surveys has exagerated the effects attributed to dust exposure (9) ?

The on-going follow-up surveys of a sample of men who attended the first PFR surveys, but who subsequently left the collieris, is expected to provide new information on this question. Preliminary results (40) suggest that miners from PFR collieries who left the industry were less rather than more fit than those who remained. Moreover, the estimated effect of exposure to dust on FEV_1 among all the men studied so far (miners and ex-miners) was more rather than less severe than that found in the selected group of coalface workers who stayed at the collieries during the first ten-year phase of the project (53).

A study of mortality among the miners and ex-miners who attended the first PFR surveys is complementing the medical follow-up surveys. The first phase of this work was in a sample drawn from all the PFR collieries (29). Results were consistent with earlier findings from cross-sectional investigations (22, 33) which suggested that as a group, British coalminers have no higher death rates than other men in Britain. A 20-year follow-up of Welsh miners surveyed by the MRC (8, 12) showed that survival rates of miners and ex-miners were independent of radiographic category of pneumoconiosis except for the two more severe categories of PFM where the survival rates were much reduced. The average results from the first phase of the PFR mortality study also confirmed this finding. However, the PFR data suggested that there was an increased risk of death attributed to cancers of the digestive organs, and to chronic bronchitis and emphysema, among miners who had experienced high dust exposures but who had no pneumoconiosis. The continuing work, among a larger group and over longer follow-up periods, will investigate these trends in greater detail.

CONCLUSIONS

The large-scale epidemiological research among British coalminers during the past 26 years has provided quantitative information about relationships between exposure to coalmine dust and various measures of miners' lung diseases. Particularly valuable has been the provision of estimates of dust-dose-related probabilities of developing radiological signs of simple pneumoconiosis. Equally important has been the fact that it was possible to express these results in a form relevant to decision-making on hygiene standards for coalmines.

The work has provided new insights into the complex relationships between exposure to dust, radiological signs, respiratory symptoms, and measures of lung function which may reflect impairment of health attributable in part to work underground. Further efforts are required on these and other questions if the increasing demand for energy from coal is to be satisfied without unacceptable health risks for the men who mine the coal. The major unresolved research topics are

(i) clarification of the role of quartz in the causation of coalworkers' lung disease;

(ii) the aetiology of complicated pneumoconiosis (PMF) and investigation of factors that may predispose individuals to succumb to this disease;

(iii) studies on why similar dust exposures at different collieries lead to disparate radiological outcomes;

(iv) further elucidation of the degree to which respiratory disease described as bronchitis and emphysema among coalminers is attributable to their work environment, as distinct from personal, social, geographical, and familial factors.

The British research has been carried out by an inter-disciplinary team combining medical, environmental and statistical expertise. Britain's entry in the European Community, and the closer contact that this has engendered with colleagues in other countries, has provided additional impetus to the work. The continuing epidemiological research will be assisted if the inter-disciplinary and international character of the effort is maintained and extended.

ACKNOWLEDGEMENTS

This has been a personal review of the role played by the PFR in epidemiological research on pneumoconiosis. I wish to thank the organisors of the seminar for the invitation to present it, and the National Coal Board, Dr. J.S. McLintock, and Dr. A. Seaton for encouraging me to accept the invitation.

The review, and the international setting in which it is being presented, is an appropriate occasion to acknowledge the leading role played in the work by Dr. John Rogan. He directed the PFR for 20 years, from its inception to 1973.

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2. THE IMPORTANCE OF EPIDEMIOLOGY IN RESEARCH ON PNEUMOCONIOSIS

M. REISNER - Germany

Epidemiological studies are often limited to determining the distribution and development of a disease without showing a direct relationship between it and a particular harmful substance. Equally, their objective may be solely to identify and measure known harmful agents in the environment without considering the effect of these on human health. Comparison of the results of these separate types of study may provide valuable insight into the health effects of the harmful substance.

However, as is the case in Britain, epidemiological studies in the West German coalmining industry have always aimed to combine the two approaches to examine the exposure-effect relationship between dust and coalminer's pneumoconiosis (6).

Basis, aim and development of the studies over time

The foundation for the studies was laid in the early 1950s. This included three basis elements.

1. The establishment and expansion of occupational health services in conjunction with medical surveillance of the entire workforce by means of pre-employment and follow-up examinations at one to three-year intervals.
2. The development and introduction of a dust measurement and evaluation procedure accompanied by systematic surveillance of dust in the workplace especially in regard to concentration and mineral content of respirable dust (1).

3. The creation of a personal file for each miner - dating back to 1954 in some cases - containing monthly data on type, location and duration of work and on dust exposure at the workplace (17).

From 1960 on, in connection with the first research programme on Technical Measures of Dust prevention and Suppression in Mines, organized by the European Coal and Steel Community, the filed data on individual dust exposure was evaluated along with the lung X-ray findings recorded in the health certificates. The aim here was to determine the dust threshold values and other relevant criteria to avoid conditions and circunstances conducive to the development of pneumoconiotic changes in susceptible workers. A further objective was to establish conditions under which miners with initial symptoms of pneumoconiotic changes could continue to be employed without significant health risks.

Figure 1 provides a simplified picture of the various factors which cause pneumoconiosis and influence its development. The causal factor is dust exposure. Given the specific harmfulness of the dust, development of the disease depends on the respirable dust concentration and the duration of exposure. The intensity and type of breathing in turn affects the deposition of respirable dust in the alveoli - the actual dose.

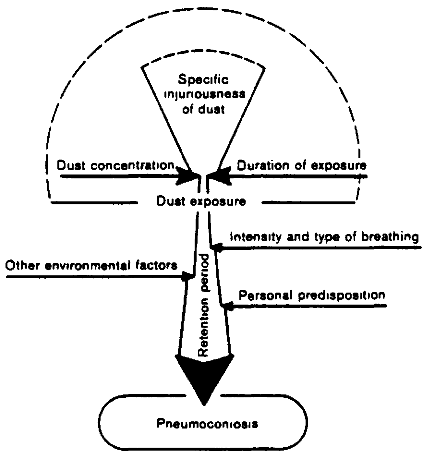

Figure 1 : Factors contributing to pneumoconiosis

If the respirable dust cannot be eliminated via the bronchial system it reaches the lung tissue and the lymph channels and, depending on how long it remains there, leads to the fibrotic tissue changes. Personal predisposition, which varies with individual airways structure and the reaction capacity of the organism, dictates when pneumoconiotic changes will be accelerated or delayed. It is also possible that other environmental factors, such as general air pollution caused by gases, fumes and fog, and individual living habits, play a role.

Initially, particular attention was paid to the effect of dust exposure. The indicator chosen was the cumulative dust exposure index $\sum (c \cdot S)$. This is the sum of the products of the respirable dust concentration (c) at the workplace, recorded on a monthly basis, and the number of shifts (S) worked there over a particular period. This gives an indication of the total amount of dust, and thus the dose, eventually retained in the lungs. As a result of the large number of comparative measurements, it is possible to convert the respirable dust concentration - initially measured tyndallometrically - into volumetric concentrations expressed in mg/m^3, allowing comparison with corresponding results in other countries (3,9,10,12).

During the studies, which took place in several stages (8,9,13-15), the influence of other factors was also investigated. The fourth and current stage of the epidemiological studies comprises periods of up to 20 years of known individual dust exposure in the Ruhr area and has been expanded to include collieries in the Saarland, which constitute an important addition because of their specific geological features and the composition of the respirable dusts.

Results are available for the third stage of these studies (13-15). Data relating to over 18 000 miners in 13 collieries have been compiled, and periods of up to 14 years of known dust exposure have been evaluated. Here can only brieffly survey the findings on the occurrence and development of simple pneumoconiosis.

Occurrence of simple pneumoconiosis

One of the most important results is the finding that the occurrence of simple pneumoconiosis can be explained largely by the dose-effect relationship. Particularly important is the cumulative value of dust exposure, corresponding to the quantity of dust retained in the lungs. The clearest findings emerged from the evaluation of data relating to over 4500 miners, whose total cumulative dust exposure index from the time they started to work in coalmines could be established for up to 18 years; only in some cases was it necessary to estimate unknown previous exposure to dust over a brief period (maximum four years).

As figure 2 shows, the frequency of pulmonary changes of varying degrees of severity depends very clearly on the cumulative dust exposure index +) over three to 18 years.

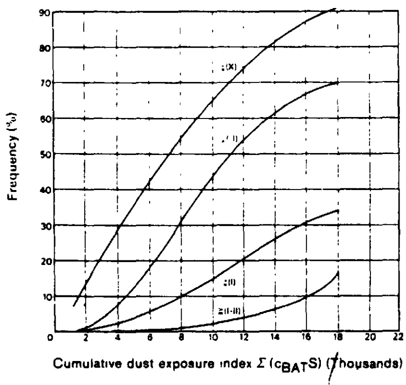

Figure 2 : Pulmonary changes of varying degrees of severity over a 3 to 8 year period as a function of the cumulative dust exposure index.

+) The gravimetric cumulative dust exposure indices in the figures are based on the respirable dust concentrations recorded by the sampling apparatus BAT I. To compare these data with the measurement values provided by sampling apparatus which collect respirable dust on the basis of the 1959 Johannesburg recommendation - on which the MAC value is based - the cumulative dust exposure indices should be multiplied by a factor of approximately 4.5 (3,12).

The lung X-ray findings at the end of the exposure period are based on the expanded three-phase classification in line with the 1930 Johannesburg Recommendation. Up to now this breakdown has been retained for reasons of continuity, although for a number of years the X-ray films used by occupational physicians have also been classified in accordance with the international 1958/68 Geneva Classification. A simplified comparison of both schemes is given in the following table.

Table : X-ray film assessment

Expanded three-stage classification Johannesburg 1930		International classification Geneva 1958-68
0	none	0
X	doubtful	Z
Definite pneumoconiotic changes		1 (p,m,n)
-I	very slight	
I	slight	
I - II	slight to average	2 (p,m,n)
II	average	3 (p,m,n)
II - III	average to severe	A
III	severe	B, C

The fact that pneumoconiotic changes vary with the cumulative dust exposure index indicates that the average respirable dust concentration during a specific exposure period is the decisive factor. There was no indication that periods of high dust exposure which exceeded average monthly exposure by a factor of up to five and over were associated with increased risk provided that these peak exposure periods were compensated for by corresponding periods of low dust exposure. It follows from this that what mattes about employing people in dusty environments; is not so much the upper limit for permissible dust concentrations, as the possibilities of compensating periods of employment in dust-free environments.

Another important factor is the better effect of the accumulated dust. The risk of pneumoconiosis increases significantly with the length of time the dust remains in the lungs. Figure 3 expresses, as the result of a regression analysis, the relationships between the cumulative dust exposure index and the occurrence of simple pneumoconiosis that is, the occurrence of definite pneumoconiotic changes (-I), as a function of the average retention time of dust in the lungs (weighted by monthly dust exposure) in a high-risk colliery.

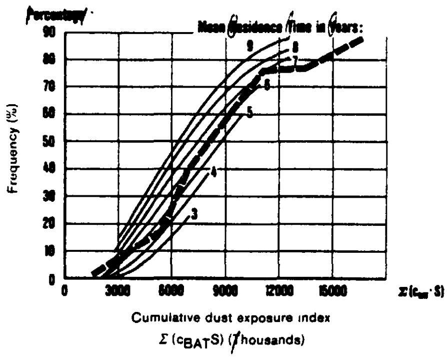

Figure 3 : Occurrence of simple pneumoconiosis as a function of the cumulative dust exposure index and the average retention period of dust in the lungs in Colliery A, as the result of a regression analysis (ash content 10%, age at first exposure 23 years; the dotted line shows the frequencies actually recorded without reference to the other parameters)/

Given the same cumulative dust exposure index, pneumoconiotic changes will be more frequent the longer the retention period. In the lower frequency range a doubling of the retention period increases the risk by a factor of two.

These findings enable us to estimate the risk of pneumoconiotic changes as a function of the average volumetric respirable dust concentration to which miners are exposed for 35 working years (fig. 4). It was on the basis of these findings that the Injurious Materials Testing Board of the German Research Association (Deutsche Forschungsgemeinschaft) laid down a MAC value of 4 mg/m^3 for siliceous respirable dust (2).

In 1974 this value was defined as a long-term value for dust exposure over five years. This was a unique step as hitherto no MAC value had been laid down for the long term. Today, all MAC values for fibrogenous and inert dusts are long-term values. The purpose of the five-year limit is to ensure that long-term exposure to high concentrations of dust at a particularly early stage is not compensated for too late because of the effects of dust retained in the lungs.

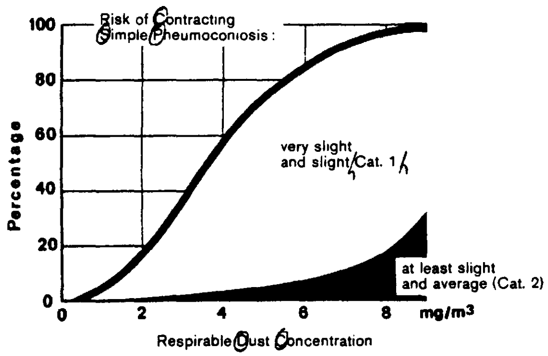

Figure 4 : Estimated pneumoconiosis risk after 35 working years as a function of respirable dust concentration in accordance with the MAC definition

In fig. 4 the respirable dust concentration c_{MAC} relates to average exposure over an eight-hour shift. It was calculated as a mean value on the basis of the cumulative dust exposure index for 35 working years at 200 shifts per year, bearing in mind the average lung dust retention period of about 18 years. In the region of the MAC value for siliceous respirable dust (4 mg/m^3) the slope in the risk function is still very flat for at least slight to average pneumoconiotic changes, corresponding to category 2 in the International Classification. The risk here is still less than 5% and only from 6 mg/m^3 on does it begin to increase rapidly. This agrees quite closely with the result of studies carried out in the British coalmining industry (5).

Knowledge of the pneumoconiosis risk explains the success of dust control measures over the past 25 years. The first dust measurements in the mid 1950s showed average respirable dust exposure amounting to approximately 14 mg/m^3 (over an eight-hour period) for personnel working at the return end of the face. A miner who worked in these dust conditions for 35 years thus had a 100% risk of contracting's light to average pneumoconiotic changes (category 2). This emerges from the extrapolation of the curve shown in fig. 4. By the mid 1960s it became possible to halve the respirable dust concentration at these workplaces with the aid of intensified dust control measures. However, 7 mg/m^3 still involved a risk of approximately 10%.

Although mechanization and winning capacity have been increased, thanks to more effective dust control and organizational measures after the introduction of gravimetric dust measurement and evaluation procedures, the average dust exposure of miners at these workplaces is at present approximately 5 mg/m^3. This still corresponds to a risk of approximately 5%. Thus, by lowering respirable dust concentrations to about one-third of previous levels, the risk of slight to average pneumoconiotic changes has been reduced by a factor of twenty.

It should be mentioned in this connection that the reduction of working time to five shifts a week has lowered the risk significantly, because of the cumulative effect of dust exposure. The wide dispersion of risk curves for categories 1 and 2 indicates a slow development of pneumoconiotic changes after initial detection, to category 2. This should make it possible successfully to redeploy miners with slight changes that have been diagnosed at an early stage.

It is clear, however, that, as long as respirable dust exposure is present, there is no such thing as a zero risk. Even with 1 mg/m^3 definite pneumoconiotic changes are likely to arise, even if very rarely. The sigmoid shape of the curves suggests that not all miners react identically. It is among the susceptible miners that changes develop even in the case of relatively low dust exposures. If it were possible to identify this small proportion of susceptible miners at a sufficiently early stage, they could be protected from lung damage by means of adequate occupational health surveillance and allocation to suitable workplaces. As long as it is not possible to create an overall dust-free environment using dust control measures special protection of susceptible individuals is called for as an auxiliary measure.

Accordingly, a focal point of future research work will be to investigate differences in predisposition to pneumoconiosis. Data on individual dust exposure over many years enable us to identify individuals who, despite undoubtedly low dust exposure for a relatively short period, have nevertheless undergone pneumoconiotic changes, and to compare them with those whose lungs have remained undamaged despite clear evidence of high dust exposure over many years. Contrasting groups selected in this way are at present being examined for significant characteristic differences, with a view to identifying individual factors which indicate a particular predisposition to pneumoconiosis.

As long as it remains impossible to achieve acceptable respirable dust concentrations at all workplaces, it is useful to allocate workplaces in mines on the basis of a cumulative dust exposure index. In the Saarland, the employment of miners in underground workings is already based on such an index. In North Rhine-Westphalia since 1965, the duration of exposure has been taken into consideration along with the respirable dust concentration, by limiting the number of shifts involving high dust exposure levels. However, the new regulation laying down a dust exposure level which came into effect on 1 October 1979 comes very close to the concept of cumulative dust exposure index. Dr zur Nieden, will speak about this later on (18).

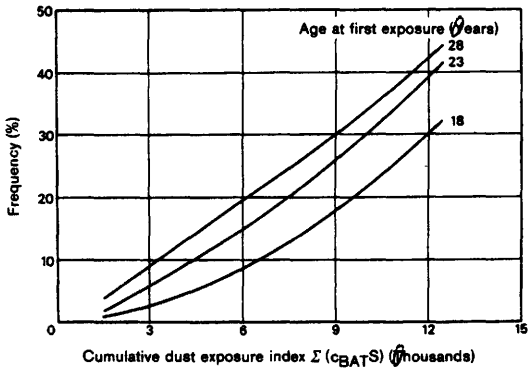

Figure 5 : Occurence of simple pneumoconiosis as a function of cumulative dust exposure index and age at first exposure in a low-risk colliery, as the result of a regression analysis (ash content 20%, retention period seven years)

It also emerged that, despite identical dust exposure levels, miners who started work before the age of 21 years experienced pneumoconiotic changes less frequently than those who started at a later age (fig 5), probably because they had a better chance through health protection schemes and training facilities, of developing defence mechanisms. This does not mean, of course, that young miners may be exposed to higher dust levels, as their initial advantage would be cancelled out by the inevitably longer lung dust retention period. Thus, the retention effect justifies special protection of persons under 21 years against high dust exposure.

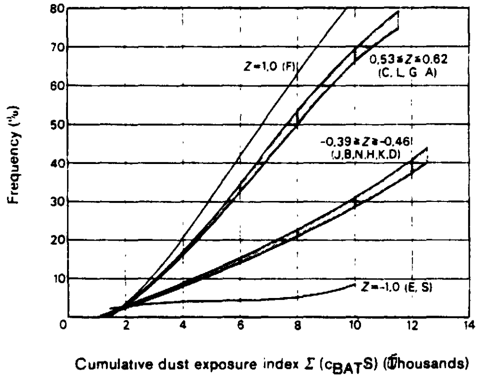

Figure 6 : Occurrence of simple pneumoconiosis as a function of cumulative dust exposure index at 13 collieries with different risk factors Z, as the result of a regression analysis (ash content 20%, retention period seven years, age at first exposure 23 years)

Despite identical dust exposure the risk of pneumoconiosis differs from one colliery to another, as shown in fig. 6. This is in line with findings which have also been made in other coalmining countries. Colliery factors which indicate these differences on a standardized scale from + 1 to - 1 have been determined. They depend on the geological stratum the carbonization degree of the deposits or both. Indeed, there is a negative correlation in respect of the quartz and mineral content : the risk of pneumoconiosis increases with the age of the working seams, but the quartz and mineral content of the respirable dusts decreases (11).

Moreover, X-rays show that the nature of pneumoconiosis has changed since 1950. The typical silicotic nodular (that is, coarse grained) lung shadows have become rare. These used to be very frequent among stone-cutters, who, because of the lack of suitable dust control techniques, were exposed to high concentrations of respirable dusts with a high quartz content. The increasing mechanization of winning workings led to a concentration of dust hazards in these areas. The composition fo typical airborne dust has also changed with a decrease in the mineral and quartz content. Today, pneumoconiotic lung X-rays mainly show up point-shaped or micronodular (that is, fine-grained) shadows (4).

In recent years, pneumoconiosis research has concentrated in particular on the specific harmfulness of dusts, using biological and physical methods of examination. So far, cell tests with genuine colliery respirable dusts confirm the findings made in epidemiological studies (16).

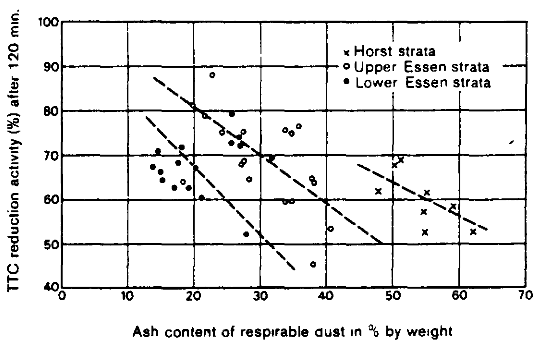

Figure 7 : Cell damage by respirable dusts from different strata as a function of ash content

Tests with isolated cells from the lungs or abdominal cavity of animals can be carried out relatively rapidly and give an indication of the damage caused by dust to the alveolar cells - the alveolar macrophages - during the primary stage. As part of the defence mechanism, these form a barrier against the entry or penetration of particles into the lung tissue. The dust particles which are absorbed and metabolized by these cells can be eliminated via the cleaning mechanism of the bronchi. However, the more rapidly a dust type is able to destroy these cells, the more thoroughlyly it penetrates the lung tissue and the lymph nodes, where it finally leads to fibrotic changes.

The TTC reduction activity-value shown on the ordinate of fig. 7 indicates the activity of dust-affected cells in reducing triphenyl-tetrazolium-chloride measured after 120 min, as compared to dust-free cell cultures. This compound is reduced to formazan by an enzyme which arises in the metabolism of the living cells.

The decrease in this reduction activity therefore indicates the degree of cell damage. Thus, the lower the TTC-RA value, the greater the damage. These tests indicate that respirable dusts from more recent seams with comparable mineral content do less damage to macrophages than dusts from older seams. A higher mineral content leads to an increase in cell damage only in the case of respirable dusts from the same seam horizon. These relationships have also been established for the quartz content, as approximately one-tenth of the minerals consists of quartz.

We still know very little about the reasons for the differences in the specific harmfulness of dusts. Certainly, it is not possible to explain the biological effects as being caused solely by the minerals in the mixed dusts. Rather, it must be assumed that there is an interdependence between the individual minerals and the organic components of the coal, which affects changes in the biological environment both in the long and in the short term. As all biological changes caused by dust particles originate in the dust surface, examinations of the dust surface are of particular importance.

The study of the specific harmfulness of respirable dusts will thus remain a focal point of future research work. At present - in cooperation with several institutes +) - the biological effect of 120 respirable dust samples from workings which are representative of seams worked in the Ruhr and Saarland mining areas, is being examined in cell and animal tests and is being compared with the mineral, chemical, and physical properties of these dusts.

In connection with the epidemiological findings, the aim is ultimately to determine the best means of identifying and evaluating the different toxic potentials of respirable dust in coalmining.

As the result of an initiative by the Commission of the European Communities, these studies are also being carried out in the context of a Community research project in Belgian, British and French coalmining areas. The project includes plans to exchange standard samples, so that the findings can be confirmed internationally. Mr Le Bouffant will give a detailed report on this subject (7).

As it is clear that the quartz content of respirable dust is not in itself a sufficient criterion of the specific harmfulness of coalmining dusts, the 1956 list of MAC values permits a modified application of the MAC value for quartz (respirable dust) - laid down at 0.15 mg/m^3 - for production areas in coal mines.

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- Medical Department, Silicosis Research Institute, Bergbau-Berufsgenossenschaft, Bochum (Professor Ulmer);
- Medical Institute for Air Hygiene and Silicosis Research, University of Düsseldorf (Professor Schlipköter);
- Institute of Hygiene and Occupational Health, University Hospital, University of Essen (Gesamthochschule) (Professor Bruch);
- I. Physical Institute of the Justus Liebig University, Giessen (Professor Scharmann);
- Institute of Hygiene, Ecology Centre, Justus Liebig University, Giessen (Professor Beck);
- Institute of Mineralogy and Petrology, Justus Liebig University, Giessen (Professor Strübel)

The development of pneumoconiotic changes

The influence of dust exposure can be shown not only in connection with the occurrence of pneumoconiotic changes but also with their development (14,15). Initial findings indicate that both doubtful, and slight changes are clearly dependent on further dust exposure, particularly when they have developed over a short period of time (fig. 8). It can be assumed that in most cases especially susceptible miners are involved and their reactions in the case of further dust exposure are clearly dose dependent. The preventive limitation of dust exposure required by the Mines Inspectorate in the case of miners with definite and in particular early pneumoconiotic changes is based on these findings.

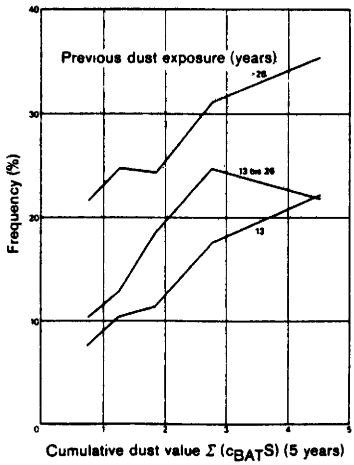

Figure 8 : The development from "very slight" and "slight" pneumoconiotic changes (category 1) to "slight to average" (category 2) as a function of cumulative dust exposure index over five years and previous dust exposure in years

However, the development of pneumoconiotic changes is also influenced by the after-effects of dust absorbed during earlier periods. This cas be shown both from the duration of previous exposure together with the associated cumulative dust exposure index, and from the retention period of the respirable dust deposited in the lungs. This after-effect means that the development of pneumoconiosis cannot be avoided completely even when dust exposure stops. The likelihood of further development generally decreases as the pneumoconiotic changes become more pronounced. This may point to a deceleration of pneumoconiosis development with increasing severity. However, the more severe the degree of simple pneumoconiosis and the longer the previous dust exposure, the less clear are the dose-effect relationships. This may be connected with the fact that miners who show pneumoconiotic changes at a relatively late stage are more resistant and continue to react less strongly to the dose.

These relationships are further differenced by the previous cumulative dust exposures, the levels of which are unknown, but which differ greatly and have after-effects of varying intensity. The fact that the duration of the previous exposure has absolutely no effect on the development of pneumoconiosis in category 2 would seem to indicate that in the development of more severe forms of the disease, dose-independent and possibly endogenous factors play an ever-increasing role. Studies of the individual factor in pneumoconiosis should cast more light on this problem. The continuation of the epidemiological studies covering a period of at least 20 years of known individual dust exposure will make it possible to provide further confirmation of the relationships which have been discovered so far, to place the findings on a sound basis, and to introduce further parameters into the evaluations.

Conclusion

Although epidemiological studies of pneumoconiosis cannot clarify the biological mechanism, findings up to now do provide valuable indications for further pneumoconiosis research and for operational measures to prevent pneumoconiosis. A decade ago dust control and workplace allocation were determined mainly by technical considerations. Today, thanks to epidemiological findings, the acceptable pneumoconiosis risk largely determines the nature of the preventive measures to be taken. As regards the adoption of an acceptable risk, we conclude by referring to the finding of the well-known occupational physician, Paracelsus, which, after more than 400 years, has also been shown to hold for dust :

> "What is not poison ? all things are poison and nothing is poison; the dose alone makes a thing not poisonous".
> from the third Treatise (August 1538).

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2. THE IMPORTANCE OF EPIDEMIOLOGY IN RESEARCH ON PNEUMOCONIOSIS

G. PORTAL - France

History and Basic purpose

Traditionally, epidemiology is the discipline which studies the influence of various factors (including environmental ones) on the incidence, prevalence and aetiology of a disease in a given population. These factors therefore have to be identified, quantified, and then linked to medical indicators. Colliery medical services have for a long time been conducting epidemiological studies of pneumoconiosis, its complications (such a tuberculosis), changes in respiratory function in relation to length of service, and so on. However, they are especially concerned with the relationship between dust and endemic pneumoconiosis firstly, from a medical point of view in order to increase our knowledge of this disease, and secondly, from the point of view of industrial hygiene in order to arrive at reference values for dust levels so that the endemic forms of the disease may be virtually eliminated.

The initial stage consisted in establishing a causal relationship. Since the beginning of the 1950s, it had been assumed that endemic pneumoconiosis was the result of prolonged inhalation of respirable (between 0.5 and 5 μ) and quartz dust. But after effective technical dust control measures had been taken in traverse headings, silicosis as such disappeared and a large amount of residual disease was revealed, despite the low quartz content of the mine dusts. It was thus necessary to conclude that the harmful agent was dust in working spaces.

The subsequent stage - the present one - is devoted to establishing the dose-effect relationship and deciding on an approach to maximum acceptable concentrations by the use of epidemiological techniques.

In France, this approach was first tried in the Bassin du Nord and Pas-de-Calais coalfields (work by Quinot and Amoudru) and subsequently extended to the other two coalfields by Ganier (CERCHAR).

The basic idea is to try to foresee how endemic pneumoconiosis will develop. Calculations are made to establish a reference dust level, E_o, which is such that subjects who are originally in good health and work in this environment for 30 years would not contract the disease. In fact, since the phenomenon is a random one, a residual risk, R%, has to be allowed for.

Work completed

The representative parameters chosen are the radiograph - to determine the harmful effects suffered by personnel - and the amount of dust and the length of exposure to the hazard in order to assess technical factors.

The medical criterion selected is the radiograph, classified in accordance with the International Classification of Radiographs of the Pneumoconioses drawn up by the ILO (1968 - 1971). It has the advantage of not being affected by legislation or court decisions on compensation.

Since pneumoconiosis is a "cumulative" disease which manifests itself only at a late stage, the length of exposure to dust in working spaces has to be taken into account.

The amount of respirable dust with particle sizes of between 0.5 μ and 5 μ was at first expressed in terms of the number of respirable particles per cubic centimetre. However, it was found that there was no single relationship between the number of particles per cubic centimetre and endemic pneumoconiosis. This lack of correlation was attributed to the method chosen for counting the particles since it persisted after the counting method had been improved and standardized.

Some United Kingdom studies then showed that there was a high correlation between the extent of endemic pneumoconiosis and the weight of the dust retained in the lungs. As a result, it was decided to use the weight of respirable dust as a technical indicator. Once again, a lack of correlation was found. Where the weight and the quartz content of dust are similar, there are always wide variations in the incidence and prevalence of the disease : depending on the colliery concerned, incidence ranges between 0 and 1% and prevalence between 0 and 17%. This led to formulation of the theory that dusts have a specific degree of harmfulness related to the vein being worked and that certain cofactors in the biosphere such as infections, way of life and soon, may also reinforce the effects of dust.

There is as yet no clear explanation for these differences in harmfulness between the various coalfields. However, to take them into account, the number of reference values for dust levels which are drawn up is equal to the number of homogeneous mines.

We wish now show how the reference dust level, E_o, is calculated in terms of the known mean annual dust level, E_n (that of the year "n"), by using epidemiological curves and allowing for a residual risk, R%, which is determined in advance. The epidemiological model used is that developed by Quinot from the 1960s onwards. It is derived from the theory of reliability; it dispenses with identifying the risk cofactors for the homogeneous mine under consideration and defines the latter's degree of harmfulness in terms of a threshold value or, if one prefers, a reference dust level E_o.

Epidemiological curve for the year "n" (Fig. 1)

At the end of each year, a curve is produced which shows the prevalence of form 1 (or higher) disease in radiographs of the lung per unit of exposure to dust hazards, the latter being equal to three years.

To be more precise, the personnel is divided into three-year groups : (0, < 3), (3, < 6), (6, < 9), ... (27, < 30), (30 and over). The prevalence of pneumoconiosis is calculated for each group; this prevalence is marked on the y-axis and plotted against the average length of service of the group on the x-axis (1.5; 4.5; 7.5; etc.).

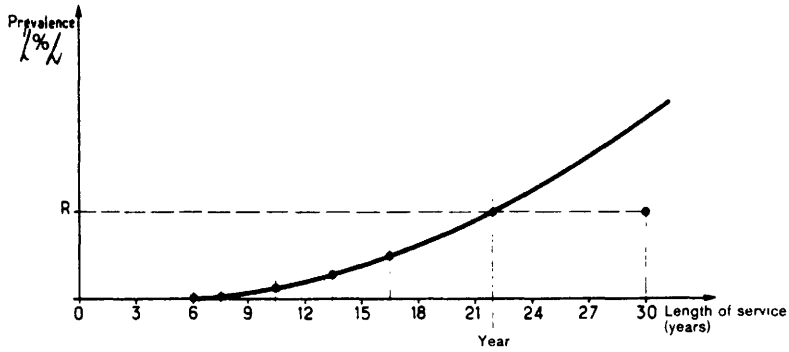

Figure 1 : Epidemiological curve for the year "n"/

If one has several epidemiological curves relating to different years but for the same mine, one can immediately see the direction in which endemic pneumoconiosis is developing (fig. 2), that is the situation is improving if the curve for year "n" + 1 is below that for year "n", and deteriorating if the opposite is the case.

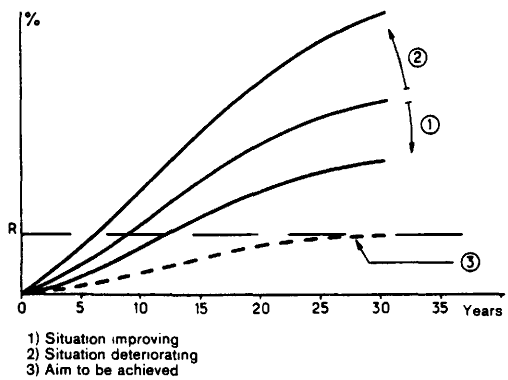

Figure 2 : Variation in epidemiological curves

Figure 3 shows how epidemiological curves relating to a French coalfield have evolved over the years 1970 - 1973 - 1976 - 1977 - 1978.

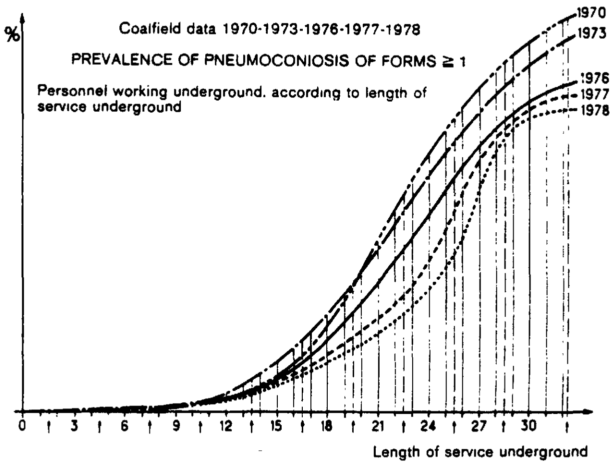

Figure 3

Using the epidemiological curve for the year "n"

On this curve are determined :

$\boxed{A_n}$ The length of service (in years) corresponding to a prevalence equal to the predetermined residual risk, R%, and

$\boxed{K_n}$ a coefficient defined by $K_n = \left[\frac{30}{A_n}\right]^2$.

For each given division of length of service, A, the indidence during year "n" is proportional to the total dust inhaled during the years preceding year "n". One can therefore assumè that the incidence in a division of length of service (A) for the year "n" is proportional to the product of the average annual dust level during the years of exposure multiplied by the length of exposure. This average dust level is called the "historical dust level" $\boxed{E_n}$.

Prevalence in calculated by integrating incidence over time and is a function of the product of historical dust level multiplied by the square of the length of exposure, thus

$$\text{Prevalence} = \mathcal{f}(E_h \times A^2)$$

In other words, if the dust level is divided by K, one obtains the same figure for endemic pneumoconiosis as that existing after a length of exposure equal to $A \times \sqrt{K}$.

On the epidemiological curve for the year "n", the prevalence corresponding to the residual risk R% is obtained after a certain length of exposure, A_n. The same prevalence value, R%, could have been obtained after 30 years of exposure that is, after $A_n \times \frac{30}{An}$ years if it had been possible to divide the historical dust level E_h by $\left[\frac{30}{An}\right]^2$, that is, by K_n.

For that reason, the value $\frac{E_h}{K_n}$ is called the reference dust level E_o

$$\boxed{E_o = \frac{E_n}{K_n}}$$

Calculating reference dust level E_o for year "n" in a given mine

If the historical dust level E_h remained constant during the years preceding year "n", the calculation would be straightforward since K_n is known from the epidemiological curve for the year "n". However, E_h is not known and, in order to estimate it, it is assumed that the coefficients K have remained proportional to the dust levels in the corresponding year, thus :

$$\frac{E_n}{K_n} = \frac{E_{n-1}}{K_{n-1}} = \dots \frac{E_i}{K_i} = \dots = \frac{E}{K} = \frac{E_h}{K_h}$$

hence $\quad E_h = E_n \frac{K_h}{K_n} \quad$ and $\quad \boxed{E_o = E_n \frac{K_h}{K_n{}^2}}$

E_n and K_n are known. All that remains is to determine K_h, which is the average of the coefficients K of the epidemiological curve for the year preceding year "n". For each epidemiological curve, a coefficient K can be calculated. It is assumed that all the coefficients K (known and unknown) are on a straight line which is constructed by linear extrapolation from between known points (fig. 4).

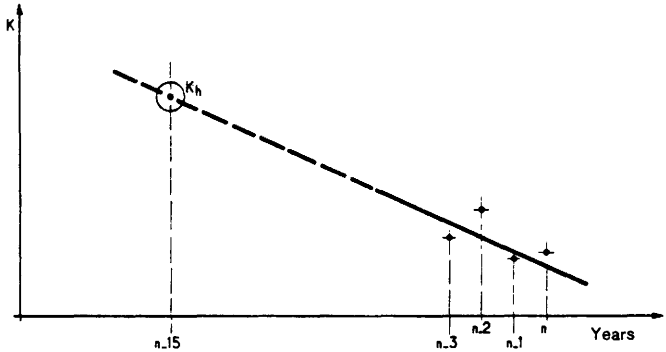

Figure 4 : Average straight line of different K values extrapolated over 30 years/

The middle point on this straight line gives the average coefficient K_h. Thus for 30 years of exposure K_h is the ordinate for point n - 15 on the abscissa. The reference dust level is usually expressed in terms of mg/m^3.

When applied to the mines considered to be homogeneous, this method produced the data shown in the following table which show that results vary from one mine to another.

Mine	Reference dust level (in mg/m^3)
A	2
B	7.2
C	9.5
D	5
E	7
F	3.5
G	8
H	4

Regular updating of E_o

Certain hypotheses may be disputed (proportionality between the average annual dust levels and the corresponding coefficient K, linearity of K over time, and so on). Moreover, dust levels may vary both in time and in space. Hence the value calculated for E_o is approximate but it is updated regularly (every year). Since more and more epidemiological curves are being produced, it will presumably become more and more precise. At all events, this reference dust level, even though approximate, provides the mine operator with a target and enables him to take appropriate technical dust control measures.

Difficulties

These can be divided into two categories, those of a methodological nature and those concerning the actual collection of data.

Methodological difficulties

Reference has already been made to possible anomalies in the mathematical theory. Nevertheless, calculating E_o by means of successive approximations should reduce these anomalies.

On the other hand, this method is based on the average dust levels in working spaces and not on the dust burdens of individuals, which correspond much more closely to the actual risk. Moreover, cases of pneumoconiosis occur among retired individuals no longer exposed to risk. As a result, the reference values, E_o, derived solely from the working population are influenced by a certain coefficient of error by default, particularly since the average age at which pneumoconiosis appears is getting closer and closer to the age of retirement. On the other hand, this method enables target dust levels to be set without knowing either the cofactors or their respective roles in the appearance and development of the disease. Therefore, for the mine operator, there is no more suitable method on which to base his technical dust control measures than obtaining a value for minimum dust level.

Finally, epidemiology puts forward hypotheses. Since covariations do not necessarily imply cause-effect relationships, it must therefore be supplemented by experiments involving the variation of one parameter only in order to verify the validity of the hypotheses.

Data collection difficulties

These difficulties lie in the collection of medical and technical data. The epidemiological studies in question rely on radiographs. Efforts have therefore had to be made to standardize the quality of the pictures, to ensure consistency and to standardize the way in which they are read by committees of doctors trained for the purpose. On the technical side, sampling apparatus and measuring methods have changed in the last 30 years. In chronological order, the methods used were : the discontinuous counting of particles on a diaphragm, continuous counting at a workplace by means of the Turbocapteur, and the weighing of dust by the CERCHAR CPM_3 mine dust sampler. Many more samples are now taken. However, although present dust levels are reasonably well known, the dust levels of previous years which are required for calculating the historical dust level are less so.

Conclusion

These epidemiological studies have involved a great deal of work. The errors which have been detected have produced improvement at every stage. The method described above, although not perfect, is very suitable for largescale and homogeneous mines. It has the advantage of being operational, of setting objectives for the mine operator, and of enabling him to plan his preventive measures. It has led to increased knowledge of pneumoconiosis and of dust and should smooth the path which has still to be covered before a fully effective system of technical dust control is achieved.

2. THE IMPORTANCE OF EPIDEMIOLOGY IN RESEARCH ON PNEUMOCONIOSIS

A. MINETTE - Belgium

INTRODUCTION

Epidemiology, which was restricted at first to the investigation of epidemics of infectious diseases, has gradually broadened its scope in recent decades. Today Sartwell's (8) broad description of it as the science of the dynamics of health processes in populations is appropriate. It has a number of fields of application. These range from a simple description of diseases to the establishment of bills of health for various purposes : primary and secondary preventive medicine, treatment, planning of health policy.

Epidemiological procedure is not intended to define the causes of the diseases, except in special cases. Generally speaking, it simply provides us with information from which the relationship between the frequency of diseases in populations and the frequency of the phenomena recognized as likely to be responsible for them can be established. It is however obvious that epidemiology may in this way become a remarkable tool for preventive medicine (6) in that it is a means of studying the way in which a disease recedes according to the methods used to prevent its causes.

Clearly, this is possible only if health experts are using both sufficiently sensitive surveillance criteria applicable to specific diseases, and reliable and reproducible methods for the identification and measurement of harmful factors in the environment.

SURVEILLANCE CRITERIA

1. Routine X-ray examination

Since the 1930s a considerable amount of medical research into the diagnosis of coalminer's pneumoconiosis has established that the only reasonable means of diagnosing the existence of the disease at the workplace during the lifetime of the individuals concerned is very careful radiological examination (4).Specialists all agree that neither clinical examination nor respiratory function tests are adequate for diagnosis.

Certainly the results of some research work would seem to indicate the existence of statistical links in large groups between certain clinical signs of bronchitis, certain functional disorders and fairly lengthy stays in the atmospheres of underground workings, in particular dusty atmospheres.

In the diagnosis of individual cases, however, these clinical and functional means of investigation can only provide additional information. They do not enable the physician to make a fundamental distinction between those subjects who are affected by dust and those who are not. Even today, these problems are still a matter for research.

At present only radiology provides valid criteria which are sufficiently sensitive and specific for the purposes of preventive measures. A high degree of standardization in the taking and reading of X-ray pictures is also found to be necessary for the following reasons : (1) for diagnosis of the initial stages of the disease; (2) to facilitate valid comparison of the state of health of workers exposed in a variety of ways in different undertakings, coalfields, or countries; (3) to follow the course of the disease in the subjects themselves over the years.

The merits of the ILO international classification of pneumoconiosis are well known. It was drawn up in 1959 and has since been subject to regular revision (some recent) to provide greater scope for the classification of subjects into graduated categories based on severity. We know that this classification provides two alternatives a short version and a complete version which allows for further subgroups and more complex classification. The latter form is used in our Hasselt and Lanaken Institutes. This classification is accompanied by a series of reference X-ray pictures to improve the precision of diagnosis.

2. Dust level monitoring

Prolonged inhalation of dust in underground workings has been universally recognized for many years as the main factor responsible for pneumoconiosis in coalminers. Numerous radiological, anatomical, and clinical studies combined with dust level measurements and chemical and physical analyses of dusts inhaled by the miners affected have established that for pneumoconiosis to occur, free silica must be present in the air inhaled. Health experts have come to the conclusion that preventive work should be conducted on the assumption that the presence of silica is enough to produce the disease. In practice, the quantitative and qualitative analysis of dust levels is now the basic parameter for the epidemiological surveillance of pneumoconiosis.

Of course, many research workers now think that the dusts associated with silica, particularly the dusts of coal and types of silicate, could have another effect and increase or slow down the toxic action of silica, according to circumstance (5). However, in practice, industrial health workers involved in the prevention of pneumoconiosis are now concentrating on the silica content of the dusts and on particle size measurement.

Mr Degueldre will deal later with the way in which these technical problems are tackled in Belgium. Although I do not want to anticipate his paper, I think we should be clear in our minds that, for coalminer's pneumoconiosis to arise, it is generally accepted that the silica dust in the inhaled air must fulfil precise particle size standards.

The margin of risk in this respect is narrow. To be toxic, the particle size must correspond to that of the dust, known as respirable dust, which entails maximum retention by the pulmonary alveoli. Figure 1 illustrates this well. These curves were drawn up by research workers operating independently in two coalfields in the Community and are based on careful microscopic studies of the lungs of dead miners. They show that maximum alveolar retention is found with particles of a diameter of about 1 micron (μ).

The reference generally accepted is the curve established in 1950 by Hatch and Gross (2). This is no 1 in figure 2. The same figure also shows the particle size distribution of dust collected in various sampling devices used today in the West. As can be seen they do not entirely tally. Some separators are stricter than others in relation to Hatch's ideal curve.

As a result, the Community research workers realized that a comparative study of the various devices was required in order to draw up a conversion table of the results and thus create a common basis. A valid comparison of the epidemiological data of all the countries would then be possible. A comparative study of this kind is now being carried out in the Belgian coal field of Campine under the engineers of the Hasselt Institute, in cooperation with German, French, and British colleagues.

EPIDEMIOLOGICAL METHODS

There are various ways of organizing epidemiological studies. Basically, they are all geared to frequency studies carried out on as broadly based groups of subjects as possible. The size of these groups depends of course on the frequency of the disease and the time it takes to appear and develop. Taking into account all these requirements and the decrease in endemic disease, one may say that in practice, as a result of the recession and the reduction in staff in the European coal industry, the size of the groups needed for these frequency studies is near the lower acceptable limit in many coalfields. Moreover, for epidemiological purposes, a clear distinction must be made between two types of frequency, prevalence and incidence (7).

1. Prevalence

Prevalence represents the frequency of cases in a population at a given time. It is a static concept which gives a spot check on the health situation. It is of course the method chosen when the effects of a disease on a group of persons are to be assessed. In Belgium, for example, the statistics of the Occupational Disease Fund show that, at the end of August 1979, 50 344 miners or ex-mineurs were receiving compensation for pneumoconiosis. At the same time, pensions were being paid to 10 696 widows. The conclusion is that, since 1 January 1964, when the legislation on compensation for pneumoconiosis was brought into force in our country, 61 040 workers were recognized to be suffering from this disease. This represents about six thousandths of the population of Belgium. This figure should of course be corrected by a factor representing movements within the population in the intervening period.Information of this kind is useful for the management of social security benefits, but it is only of limited use to the epidemiologist whose aim is to prevent disease.

The risk associated with the work of a miner immediately seems much greater when the number of subjects affected is compared with the number of workers exposed to the risk before the period in question. The table shows that there were 108 677 underground workers in 1950 and 114 452 in 1955. The figure went down to 77 333 in 1960. By the end of 1978, there were 17 422. However, although comparing these figures with the 61 040 workers recognized as having been affected over 16 years is enough to establish the idea that there was a high risk of pneumoconiosis in the past, it does not give a precise risk level for the past and cannot therefore help us to improve the situation in the future.

2. Incidence

For epidemiologists it is much more useful to know the frequency of new cases in a group exposed for a given time, in relation, for example, to the application of preventive measures. This is known as the incidence among subjects at risk. It is clearly a much more dynamic notion than that of prevalence and more suitable for following the effects of changes in the environment on the health. The advantage of incidence studies is particularly evident in the case of coalminer's pneumoconiosis.

It is clear that the two parameters, prevalence and incidence, are related. The relationship is shown by the following formula :

$$\text{Immediate prev. } t_x = \text{Immediate prev. }_{to} + I \,\Delta t\ (o.x) - I_{em} + I_{im}$$

The frequency at a given time - that is, immediate prevalence - clearly results from previous prevalence to which new cases which have appeared within the group or cases which have come in from the outside must be added and from which cases which have since left the group must be substracted.

It is thus easy to see that the effects of preventive work, designed to affect the incidence within the original group, cannot be studied solely on the basis of prevalence at time X which is influenced by the past and by the turnover of working populations in coalfields. In practice, the arrival of miners from other undertakings, coalfields, or countries and the regular departure of others from the same groups for various reasons - often, incidentally, for reasons of health connected with the state of their lungs - considerably complicate the interpretation of results based on prevalence measurements alone.

APPLICATION TO EPIDEMIOLOGICAL SURVEILLANCE OF MINERS

All this helps us to understand the need for a strict approach based on regular research into the incidence of pneumoconiosis in stable groups of workers who are, for known periods of time, subject to dust levels the harmfulness of which can be monitored regularly.

This consideration has led various specialists to design plans for surveillance on the basis of frequency studies of successive radiological stages (3). The instigators of these methods have already discussed the technicalities.

In our country, an approach of this kind is impractical at the moment. The enormous turnover in staff in the past 15 years in our coalmines the gradual reduction in underground staff (see table), and the progress made in preventive work have led to complicated epidemiological situations resulting from numerous variables. It is impossible to assess the relative importance of each one of these and the possibility of indroducing surveillance methods based on studies of successive radiological stages in stable groups is therefore excluded.

Over the past 20 years or so it has, however, been possible to develop an approach which is reasonably acceptable in the Mines Health Institute in Hasselt. The results have been published periodically in the Annales des Mines de Belgique by Degueldre and his coworkers and they will be given in a general report in the near future (1).

For the reasons already discussed this approach is not based on the surveillance of well-defined stable groups. The aim is to compare the numbers of workers suffering from the various stages of pneumoconiosis defined in the international classification, for all categories of length of service underground surveyed each year in each coalfield or undertaking, and for average dust levels established consistently.

The method will provide a clear picture of the health improvements achieved in our coalfields. It will also enable us to define our aims as regards an maximum acceptable dust level. Mr Lavenne will comment on the figures obtained in his paper. This general preliminary paper will consider only, as an example, the phenomena observed over the past 20 years in the only coalfield which has maintained almost the same level of activity throughout that period - the Campine coalfield.

The various curves given in figure 3 show us that in this coalfield, in 1959-60, 48 % of workers with 30 years' service had reached or exceeded stage m2 and that this percentage fell to only 12 % in 1976. For a working life of 25 years underground (the maximum allowed today over the normal career of a miner in Belgium), this percentage was 9 % in 1976 and 44 % in 1959.

Similar curves have been established for lower levels such as m1 or p1 but, because of the problems of radiological diagnosis in these initial stages and the range of variation between observers, it was considered reasonable, for this paper on techninal methods, to take stage m2 as the criterion for assessing the effects of dust control.

These curves help considerably with research into the allowable threshold level for dust, which in this coalfield, for example, would be aimed at a maximum percentage of 5 % subjects with no more than stage m2 at the end of 25 years service underground.

In this connection, reference can be made to the development of methods for calculating the maximum allowable dust level, the principles of which have been described by one of the previous speakers. It is then easy to estimate the value which the maximum dust level should not exceed in our coalfield if the point of intersection of this curve with the ordinate of 5 % is to be moved to the right and to brought up "25 years" on the abscissa, representing the end of a normal career underground today. Once an assessment of the dust exposure experienced by the 5 % of workers who in 1976 had reached m2 after 18 years has been made, it is possible to calculate how far this dust level will have to be reduced in future to achieve the same result after 25 years. In fact, the general formula used to calculate this reduction put forward in work by Ganier, shows that it is linked to the square of the desired extension of the underground exposure period. This procedure makes it possible to achieve a reasonable calculation of the reduction in dust levels to be made in order to attain fixed aims of radiological improvement.

CONCLUSIONS

Our analysis shows that, by the gradual introduction and extension of preventive work, considerable progress has been made in Belgian coalfields. Much work remains to be done and efforts cannot be reduced but the aim of a complete career of 25 years underground with a minimum acceptable risk of incipient pneumoconiosis appears to be within reach.

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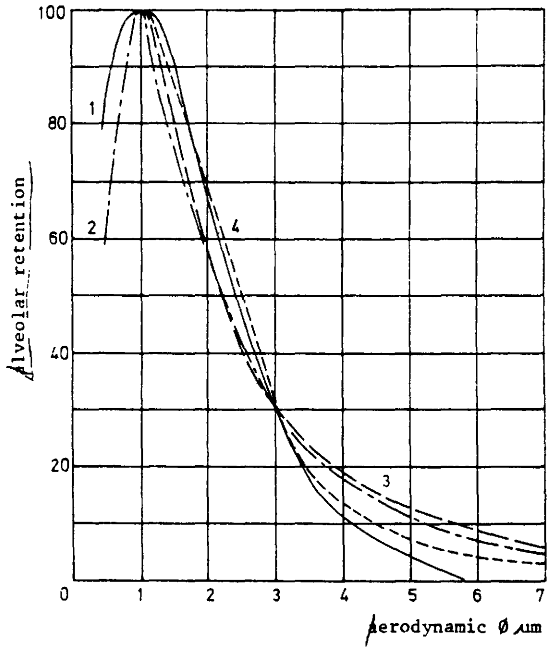
Figure 1

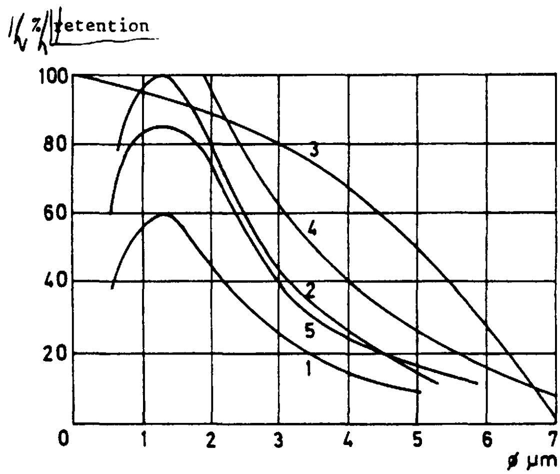
Alveolar retention (measures made on deceased miners)



1. J. Cartwright and G. Nagelschmidt
2. C.N. Davies
3. and 4. Hauptstelle für Staub- und Silikosebekämpfung

Figure 2

Comparison of alveolar retention curves for dust



1. T.F. Hatch and co-workers (1950)
2. Affine curve 1.
3. Curve accepted for the MRE separator
4. Curve accepted for the AEC separator
5. Curve accepted for the CPM_3 separator

Figure 3

Prevalence of pneumoconiosis of type m2 and m2+ in the Campine coalfield (% of the number of workers with the same length of service in 1959-60, 1969-70, 1974 and 1976)

Epidemiological curves RX : m2 - m2+

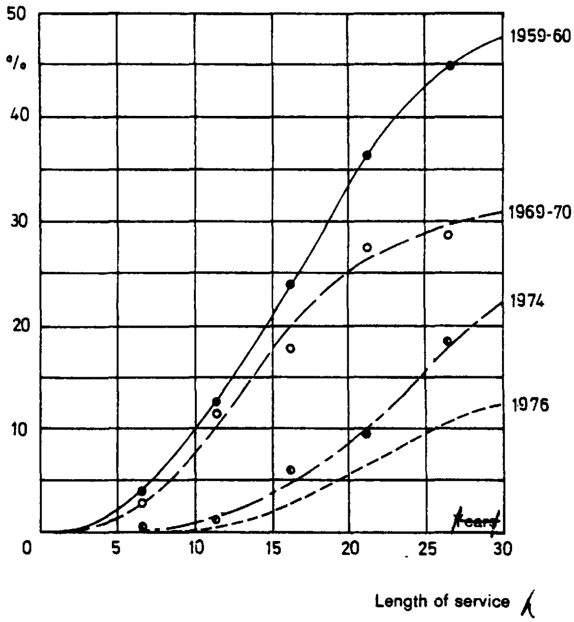


Table - Reduction in underground staff in Belgian coalfields between 1950 and 1978

	Campine	Southern coalfield	Whole country
1950	27.594	81.083	108.677
1955	29.678	84.774	114.452
1960	27.936	49.397	77.333
1965	24.578	32.889	57.467
1970	15.189	12.531	27.720
1975	14.911	5.635	20.546
1976	14.895	4.259	19.154
1977	14.747	2.934	17.681
1978	14.975	2.447	17.422

2. THE IMPORTANCE OF EPIDEMIOLOGY IN RESEARCH ON PNEUMOCONIOSIS

M. BRANCOLI - Italy

The choice of theme for this seminar stems from the need to make a technical contribution to a specific industrial sector, coalmining, to which the oil crisis, the constantly spiralling prices and the search for alternative sources of energy - which together constitute one of the most acute problems of our troubled times - have given a new lease of life. The end of the age of "cheap" energy and of unlimited and blind faith in unbounded technological progress has sparked off a complex and critical reappraisal of the underlying methods and principles on which our industrialized society is founded. I need not dwell on how different the general pattern of events is today, or on how the expansionist Keynesian approach to economic growth has given way to a gloomier and less confident outlook.

Coal has therefore suddenly returned to the limelight and with it all the attendant problems of extraction and processing ant their often serious effects on worker safety. Particularly important are those hazards which do not lead to sudden tragedy, but which slowly and inevitably ruin the health and lives of many people.

In Italy, the situation has special features of its own, and does not lend itself easily to study and analysis owing to the lack of adequate documentary information.

Although there were fairly substantial deposits of coal in Italy - particularly in the Sulcis coalfield in Sardinia, the Monte Amiata region in Tuscany, and Val d'Aosta - nearly all coal winning operations were brought to a standstill in the 1960s because the cost at the time, in purely monetary terms, was absolutely uncompetitive compared with that of oil.

Technology has in the meantime continued to advance and extraction methods have radically changed. The need to have miners at the working face has been greatly reduced and the risk of sudded and serious disasters minimized. Such developments have completely changed the nature of mining, and this will no doubt te reflected in the data collected during the coming years in the impact of new technology on health now that fresh interest in the use of coal has led to the reopening of workings.

Against this background, what contribution can I make to today's debate in which the other delegates will be dealing with quite different problems, particularly those representing countries where coal has never ceased to play a major role ? Although I shall give some statistical material, I feel it will be easier and more agreeable if I try to outline the most effective approach for minimizing the risk of silicosis in miners. The subject matter dealt with by the first working party - comprising national experts entrusted with the task of reporting on the role of epidemiology in pneumoconiosis research - has widespread validity, for the application of epidemiology is not specific or exclusive to coalmining, but meets a need which is apparent in all industrial sectors where there is a risk of silicosis or pneumoconiosis and, more broadly speaking, in all studies of the causes of industrial accidents or diseases.

Moreover, the problem as regards work in coalmines is, in my opinion, the same as that encountered in the study of all other industrial activities, that is, the need to develop a systematic technique for determining causes and contributory factors and to show the critical areas on specially-drawn "risk maps" which serve as the starting point for all measures taken in situ. This is the fundamental task of epidemiology considered as a science which studies the causes and laws of illnesses and diseases in general, and which plots their history and evolution.

By "risk maps", I do not mean a mere superficial indication of risk factors, but an in-depth analysis, carried out systematically and in great detail, of the most diverse aspects of incidence at various levels, for example, factory, department, work schedule and methods, and direct and indirect causes.

This complex analysis should be pursued along two lines which, far from being divergent, are complementary and equally necessary to a proper understanding of the real inherent hazards.

The first is the study of the objective conditions in which the worker has to perform his duties and involves a whole panoply of values, levels, dust concentration thresholds, and safeguards. In Italy, this issue has in the past few years been the focus of considerable attention thanks to constant trade union pressure and to the gradual rejection of the passive approach which left the risk factor intact and which has now become obsolete.

The second is the analysis of subjects exposed to risk. Apart from certain rheumatoid-type complaints associated with work in coalmines, the type of pneumoconiosis most frequently encountered in miners is silicosis. An effort should be made in this context to improve the system of regular checkups carried out not only on confirmed cases of silicosis but on all subjects exposed to this risk. This can be done by incorporating the elements whereby preventive measures can be introduced which are effective, timely and backed by the results of environmental analyses. Due attention should also be paid to the frequency of such checkups in order to reconcile prevention techniques with protection from other, possibly more dangerous risks arising from the examination itself (this applies mainly to X-ray examinations).

There is nothing new in what I have said up to now, since it is fairly common practice to organize prevention along these lines. Nor is this approach to the problem of health safeguards for miners in any way exceptional, for this approach is valid in this as in all other contexts.

What I would like to stress, and this obviously has more to do with statistical analysis, is that the data collected must be utilized properly. Collecting data is one thing, but exploiting them to the full when it comes to preventive action is an entirely different matter.

I have already mentioned the data which can be collected at the workplace on dust generation, concentrations of certain substances, and general environmental information. I have also mentioned the regular general checkups on exposed subjects today required by law in Italy. If these data remain idle in the archives of individual enterprises, hospitals, occupational medicine faculties and the like, or if, after being entered in personal health record or risk books, they are not forwarded to a central body equipped with computer facilities capable of determining statistical distribution and incidence and of providing pointers for preventive action, we shall most certainly fall far short of achieving what could be achieved, both qualitatively and quantitatively.

I for one have always been somewhat sceptical as to the real value of personal record books left in the possession of the subjects themselves to become increasingly dog-eared or forgotten at the bottom of a drawer. In any case, they are not popular with medical staff, who often regard them as the material symbol of the bureaucracy which threatens their profession. Admittedly, they may provide medical staff with indications useful for prescribing treatment, or serve as an aid to diagnosis; nevertheless, if data are to be used according to sound statistical principles such record sheets should not be their final resting place.

What is needed, on the contrary, is a central body with prompt and flexible means of cooperating with the individual unit. A system (known as the CIDI) for collecting and processing data on occupational accidents and diseases in general, and managed by the INAIL (National Institute for Insurance against Industrial Accidents) has been operational for some time in Italy. Information on preventive measures is available at very detailed sectoral and territorial levels. The same is not true of occupational diseases, for which information continues to be scanty.

On 1 January 1980, however, a systematic plan for detailed information on occupational diseases will be implemented in conjunction with other bodies so that the nosological classifications adopted can be harmonized in the interests of comparisons at national level, which can then also be used for the purposes of international comparisons in specific areas.

Unfortunately, as I said earlier, and despite the increased coverage, upstream information on silicosis continues to be scanty, that is, data on the subjects exposed to this risk. In a word, such information as is available is fragmentary and cannot easily be utilized. Although subjects exposed to the risk of silicosis are required to undergo regular X-ray examinations, no provision has been made for centralized data collection and processing. As things stand, each employer may choose freely from among the recognized centres the one he prefers to carry out health checks on his employees, with the inevitable consequence of arbitrariness and superficiality.

It ought at least to be compulsory for recognized centres to forward to a central body all the data collected so that these can be coded, stored in a data bank and, most important of all, processed according to sound statistical principles which will enable them to be studied and analysed for patterns. Interest in the issue would then go far beyond the purely personal level of the worker required to undergo a checkup and would extend to the organization of work in general.

Admittedly, certain obstacles would have to be overcome in the initial stages, for example, coding systems which are still inadequate and incomplete. Nevertheless, proven international codes which represent years of research and experience are now available, and satisfactory results are possible.

The cost involved would not be excessive, particularly if the task were to be entrusted to a body with suitable practical experience in the field of data processing for industry, which would give it the advantage of a wider perspective of the problem of occupational diseases and, in addition, the possibility to link advantageously insurance considerations and preventive measures. This would be in line with the idea that this is the correct way to reduce the inherent cost of risk as well as the risk itself, as widely advocated at the ILO's meeting on prevention problems, held in February 1979 in Geneva.

Some of you may be under the impression that this concern for the statistical and information side of the problem may have blinded me to the real issue. In fact, as I have already mentioned, the working basis as far as figures are concerned is very flimsy, and such data as are available cannot readily be broken down.

A brief review of the situation in Italy may, however, be useful. Accident insurance in Italy is subject to a tariff structure which is differentiated according to risk category. One of these categories covers coalmines, although not exclusively.

In this category, the number of subjects exposed to risk, expressed in terms of workers/year, went down during the 1972-77 five-year period by approximately 25%, falling from approximately 12 000 to just over 9000. The number of contracts - that is, companies insured against this risk - shows a corresponding decline.

An anlysis of the amount of compensation paid out in respect of silicosis under the tariff category just mentioned shows that the number of cases has fallen appreciably over the years from 949 in 1972 to 395 in 1976. Furthermore, deaths from silicosis have all but ceased. It may therefore be considered that the fall in the number of compensation payments is not only the result of the decline of activity in this sector, but also perhaps of more conscientious and more energetic preventive action.

The distribution in time of compensation for permanent disability is fairly steady, with roughly two-thirds of cases in the under-25% disability bracket and 2-3% in the over-60% bracket.

One last point is of considerable interest. Distinguishing cases of silicosis ending in permanent disability from terminal cases reveals a considerable and almost constant difference between the average compensation figures for the two groups, with the lower figures usually being paid out in respect of fatal cases. Why should this be so ? Probably because the most serious cases generally affect the workers who perform the more menial jobs and are consequently pais less. Morever, the scanty information and the flimsy statistical evidence available mean that this type of analysis leaves many questions unanswered.

This and the need for reliable data is precisely why I feel I must once again stress the need for the checkup-based approach I have advocated throughout this brief address.

The solution to this specific problem, to the wider problem of the types of silicosis encountered throughout industry, and to all prevention problems lies in a reliable information system based on a central data bank suitably equipped technically to avoid wastage, duplication of effort and processing incompatibilities, and which will provide rapid information broken down by sector so that the specific problems can be identified and acted upon appropriately.

3. QUALITATIVE AND QUANTITATIVE ASPECTS OF DUST AND THEIR ROLE IN THE DEVELOPMENT OF COALMINER'S PNEUMOCONIOSIS

L. Le BOUFFANT - Creil

INTRODUCTION

The existence of a dose-effect relationship is a very familiar concept in the field of toxicology. The effect of inhaled dust is no exception to this rule. However, although the quantitative element represented by the dust burden seems to be an important factor in coal-miner's pneumoconiosis, certain findings exclude the idea of a simple relationship which would suffice to define the pathological effects quite generally, solely as a function of the quantity of dust deposited in the lungs. The reason for this is the extreme complexity of coalmine dusts, which are made up of different minerals present in variable quantities and which have different toxic effects. If one adds to this the fact that certain interactions are liable to take place between these constituent substances, it becomes clear that the qualitative characteristics of the dusts, along the quantitative factors, inevitably play an important role in the development of coalminer's pneumoconiosis.

In attempting to assess the role of the different factors which are thought to be involved, one encounters the difficulty of isolating their effects, in the presence of these complex interrelationships, of gathering sufficiently precise information on all the epidemiological factors, and of finding experimental methods which are sufficiently accurate and representative. These difficulties are so considerale that it has not yet been possible to throw full light on the problem. However, by combining the data derived from autopsy studies of miners' lungs with the results of animal experiments involving mine dusts from various sources or their components, it is possible today to point to a certain number of substantiated findings and to specify the areas where additional research is needed.

Role of the lung dust burden

A lot of research has been done with a view to determining a relationship between the severity of pneumoconiosis and the quantity of dust present in the lungs. The first study was carried out by King and Nagelschmidt (1945) on the lungs of 54 Welsh miners divided into three pathological groups (reticulation, nodules, confluent fibrosis). Only a very gradual increase, in coal or quartz concentration was established from one group to another. In a later study of 71 coalminers' lungs, King et al (1956) recorded a certain relationship between the pathological data and the dust quantity, but they again qualified their interpretation because the relationship was not very marked, and since then they have stressed the necessity of falling back on a second explanatory factor. A further study by Rivers et al (1960) of 45 lungs of coalminers with simple pneumoconiosis concludes, on the basis of a comparison of the radiological, histological, and analytical data, that a relationship exists between the average weight of total dust in the lungs and the radiological category of the lesion (table 1).

Table 1 : Relationship between average weight of dust in lungs and radiological category of lesion (from Rivers et al 1960)

Category	Average weight of dust in the right lung (g)
0	4.3
1	10.5
2	14.5
3	26.7

Worth et al (1967) in turn examined the lungs of 52 coalminers from the Ruhr. Their findings (table 2) reveal a wide dispersion in the quantities of dusts found in the lungs within each category. If the average dust content in category 0 is clearly lower, there is on the other hand no correlation between the degree of silicosis and total dust concentration in the other classes. However, the average quantity of mineral dusts increases from one class to another. Casswell et al (1971), in an analysis of the lungs of 145 miners, concluded that there is a correlation between the X-ray image and the quantity of dust, and more particularly the quantity of mineral dusts.

Table 2 : Summary of findings in the lungs of 52 coalminers (from Worth et al 1967)

Degree of silicosis	Total dust (g/100 g dry weight)	Mineral dust
0	5.67 (2.18 - 11.15)	1.63 (0.64 - 2.56)
I	10.45 (2.08 - 32.93)	2.55 (0.55 - 5.94)
II	12.52 (5.31 - 40.00)	2.97 (0.97 - 7.12)
III	10.20 (5.05 - 23.12)	3.34 (1.76 - 5.54)

It goes without saying that there is a certain relationship between the quantity of dust found in the lungs and the quantity of dust inhaled, although pulmonary clearance capacity can vary to a significant extent from one individual to another. Walton et al (1977) have compared X-ray data relating to 3154 underground miners who were not affected initially by pneumoconiosis, and the quantities of inhalable dusts to which these subjects were exposed. They conclude that the total quantity of inhalable dusts is the most significant variable in pneumoconiosis.

Although there is no doubt about the relationship between the lung dust burden and the intensity of pneumoconiotic lesions, it would nonetheless seem that considerable qualifications are called for, as pointed out by Davies et al (1979) in a very recent study carried out in the context of the ECSC.

The study carried out by these authors relates to the lungs of 500 coalminers in 25 mines spread out over all the mining sectors in the United Kingdom. The lesions observed have been classified into three categories corresponding to the following pathological types : simple coniotic masses (M), lesions involving one or several fibrous nodules (F), lesions consisting of nodules exceeding 1 cm (PMF). From one pathological type to another the average dust weight in the lungs does indeed increase, but there are considerable variations and, in practice, the categories overlap. Thus it would appear that the quantity of lung dust is not the only factor to be considered in assessing the pneumoconiosis risk and that, along with the dust burden, attention must also be paid to other data, relating to the nature of the dust components.

Composition of lungs dusts

Quite a substantial amount of data is available on the composition of dusts contained in miners' lungs and certain comparisons can be drawn between this material and the dusts in the inhaled air.

In the course of the above-mentioned study of the lungs of anthracite miners, carried out by King and Nagelschmidt in 1945, the authors established the composition of the siliceous minerals found in the lungs and compared it to that of airborne dusts discharged at the cutting face in mines of this type. They recorded average values which were very similar in both cases (table 3), indicating that these minerals neither dissolved nor developed selectively in the lungs.

Table 3 : Composition of siliceous minerals in lungs of anthracite mines and in airborne dust on the cutting face (from King and Nagelschmidt 1945)

	Quartz	Mica	Kaolin
Dusts in the lungs	15 %	35 %	50 %
Airborne dusts	12 %	35 %	53 %

Leiterits et al (1967) carried out the same type of research on 26 lungs of miners in the Ruhr and Saarland, measuring also the proportions of coal in the dust. Like the preceding authors, they also found that there was little difference in the values of respirable dust levels in the air and in the lungs (table 4).

However, this similarity between the composition of airborne dusts and that of dusts found in the lungs should not be considered an absolute rule. Deposits containing calcareous minerals - calcite, gypsum and anhydride - constitute an important exception. These are particularly to be found in the coalmine dusts in the Bassin de Provence (France), where the proportion of calcareous minerals can amount to 60 % of the mineral material.

Table 4 : Composition of dust in the lungs of 26 miners (from Leiterits et al 1967) and in the air

		Airborne dust (BAT II)		Lung dust	
Quartz			4 %		5%
Other minerals	) illite-sericite	18)	32 %	20)	37 %
	) kaolinite	11)		15)	
	) various	3)		2)	
Coal			64 %		58 %

Despite this high level in the airborne dusts, the analysis of seven miners' lungs - the only ones available in this mining region, where there are no silicosis cases - show that the pulmonary tissues were completely free of these calcareous minerals and that the main mineral substances they contained were quartz, kaolin, and mica.

Similar differences are also referred to by Davis et al (1979) who indicate, in the case of low-grade coals, a higher proportion of quartz, kaolin, and mica in the lung dust than in the mine dust. This proportion grows with increasing severity of the lesions and the proportion of quartz in PMF lungs may be up to threee times as high as in the mine dust.

Variations in lung dust distribution

Whatever conclusions may eventually be drawn as regards the average composition of lung dust, they do not exclude the possibility of topographical variations within the lungs, whether with respect to the concentration or the composition as such.

Nagelschmidt et al (1963) have analysed the dusts contained in massive lesions and in the rest of the lungs of 18 miners in the PMF category and have found that the dust concentration in the PMF was approximately twice as high as in the rest of the lung. The percentage of quartz was identical in both cases, so much so that the quantity of quartz in the PMF was finally double that contained in the same mass of the rest of the lung. This lead Pratt (1968) to conclude that quartz is probably responsible for the development of PMF.

Apart from local concentrations, selective migrations of the dust components also occur. In the course of the same study, Nagelschmidt et al (1963) discovered that the dust isolated from certain lymph glands of miners suffering from simple pneumoconiosis had a considerably higher quartz level than the dust from the corresponding lung. In the course of research work at present being carried out on rats, we ourselves have found that the quartz contained in mine dust, whether it is present in the dust in its natural state or whether it has been added artificially, tends to concentrate in the tracheobronchial glands during the months after inhalation (table 5).

Table 5 : Concentration of quartz-containing dust in lungs and glands

	Concentration in lungs and glands 22 months after inhalation	
	Lungs	Glands
Mine dust containing 8.4% quartz	7.2 %	13.2 %
Artificial mixture containing 16% free silica	19.8 %	58.6 %

Apart from this selective migration of quartz vis à vis the other mine dust components, this mineral also has a very marked, effect on the migration of all dusts, the result of which is diffusion of particles in the interstitium and, in particular, in the direction of the pleura, in proportions which depend on the concentration of quartz in the dust. This very evident phenomenon has already been shown experimentally in the case of rats by intratracheal injection of quartz- free coal (Ste Fontaine) or to which 13% to 28% quartz has been added : coal dust migration is indicated by a blackening of the pleura, which is the more marked the higher the quartz level.

Role of dust components in the formation of lesions

Should one in fact agree with Walton et al (1977) that the total mass of inhalable dust is the most important parameter in the risk of pneumoconiosis, irrespective of composition ? It should be noted that these authors nevertheless find a better correlation if mineral substances or quartz are introduced into the analysis. Moreover, they have found that the probability of developing the disease declines with an increase in the concentration of minerals, and - as the highest proportion of mineral substances is found in low-grade coals - they ask whether this result may be due to lower toxicity of low-grade coals rather than to the minerals themselves.

The recent study by Davis et al (1979), referred to above, provides a number of interesting indications in this respect. It shows that the presence of PMF in the lungs in connection with low-grade coals in associated with a high percentage of quartz, kaolin, and mica - a higher percentage than in the case of M-and F-type lesions. Moreover, the PMF cases contain less total dust in the case of low-grade coals than in the case of high-grade coals. These results indicate the possible role of the mineral components, considered from the point of view both of their concentration in the dusts and of their specific properties.

These studies of human lungs constitute an essential chapter in the examination of the role of different mine dust components in the development of pneumoconiotic lesions. However, given the impossibility of analysing the different variables separately, it would appear necessary to carry out parallel experiments on the toxicity of the main components of mine dust and the factors capable of modifying them.

Considerable differences have been found in the occurrence of pneumoconiosis between mining areas, such as Nord-Pas-de-Calais and Provence, which differ not in respect of the concentrations of airborne dusts or their particle size characteristics but in the composition and physicochemical characteristics of these dusts. This suggests the need for research in the form of analytical studies and animal or cell experiments with a view to explaining these differences and the mechanisms at work.

An initial question which must be answered is whether it is possible to make valid distinctions, based on experiments, between the toxicity of coalmine dusts from different sources. The difficulty here is mainly caused by the fact that the dusts in question ore of relatively low toxicity and that the results of available tests, whether carried out in vivo or in vitro, show significant dispersion. Nonetheless a limited test has shown (Le Bouffant et al, 1973) that coals from different mining regions have different fibrotic effects and that the results would seem to tally with the rate of pneumoconiosis. A Community campaign was started recently to compare the harmfulness of 23 dust samples taken from coalmines in the Federal Republic of Germany, Belgium, France, and the United Kingdom, by means of animal and celle tests. The aim of this campaign is to investigate the relationship between the toxicity of dusts as determined in laboratory conditions and the epidemiological data.

However, this study of overall toxicity is only one stage in the research that has been undertaken with a view to casting light on the harmfulness of various types of mine dusts. The main problem is to determine the contribution of to the different dust components : quartz, other minerals, coal.

As emerges from the work referred to above, it has not yet been possible to explain the role of quartz fully. Quartz, which in its pure state has an exceptional fibrotic effect, is still very harmful even in concentrations of the order of 5% (Le Bouffant et al, 1976). However, certain types of quartz (various sands) are only mildly harmful in the first few months after entering the lungs, because of the presence of protective substances of argillaceous origin at the particle surface. The elimination by the organism this protective films restores its normal toxicity to the quartz (Le Bouffant et al 1977). In the case of quartz present in mine dusts, the problem is thus to determine its real toxicity, which can differ from that of pure quartz either because of differences in the real level of toxicity or because of the presence at the surface of a protective layer whose stability must then be established. Recent work - not yet published - carried out on quartz samples taken from coalmining dusts from different sources seems to indicate that the real toxicity of quartz is more or less the same, irrespective of its origin. However, it has not yet been possible to determine whether there is a protective layer at the particle surface, or, consequently, to determine its stability over time.

Apart from the protective film which may cover the particle surface, other inhibiting elements may be present in the mine dust. Thus when highly toxic quartz dust is incorporated into coal dust, the noxiousness of the latter increases but remains lower than that of the same quantity of quartz not mixed with mine dust. Accordingly, mine dust has a protective effect in respect of quartz. This protection is not permanent : the lower the quartz content the longer it lasts. It has been shown that protection, where it exists, is caused by the presence in the mine dust of mineral substances whose dissolution products attach themselves to the quartz surface.

The other mineral components in mine dust can themselves cause fibrosis. This is true of clays (kaolin, illite), micas, and possibly of feldspars. Although they are decidedly less toxic than quartz, the fact that they are highly concentrated in most mine dusts means that their capacity for causing fibrosis may well be equal to or greater than that of the quartz present in these dusts.

As opposed to this toxic effect, the protective effect mentioned above would appear totally or partly caused by the argillaceous minerals. This effect varies with the type of clay (illite has a significant inhibiting effect, whereas in the case of kaolin it is negligible) and seems to be connected with the capacity of clays to release aluminium in the environment.

Finally, the role of coal itself has never been explained clearly, although it is one of the most common components of mine dust. It is generally agreed that noxiousness increases with the coal grade that is, its degree of carbonization. However, it is difficult to separate the effect of the coal itself from that of the mineral substances present, the quantity of which in the coal varies with the grade. In TTC tests on in vitro cells, Reisner and Robock (1977) have noted that, given the same proportion of mineral substances, high-grade coals are more toxic than low-grade ones. This result does not agree with the study made by Davies et al (1979) and they recognize the lack of correspondance between epidemiology, animal tests, and cytotoxic studies. Walton et al (1977) conclude that the effect of grade in the case of high-grade coals (anthracites) is equivalent to that of minerals, and that in the case of low-grade coals it plays no role at all.

It should be added that apart from these somewhat contradictory assertions on the specific toxicity of coal, no data exist on the possible surface interactions between coal and the various minerals present, in particular quartz, although thus has been shown to be capable of attaching itself to many types of organic molecules.

CONCLUSION

This analysis of the qualitative and quantitative aspects of dusts and their role in coal miner's pneumoconiosis may be summarized by saying that both parameters seem to be important. There is no doubt that the quantity of dust present in the lungs is an essential element : without dust in the lungs there would be no such thing as pneumoconiosis. Moreover, everything toxicology teaches us about the dose-effect relationship leads us to assume that the pneumoconiotic risk increases with the quantity of dusts inhaled that is, with the dust exposure which the individual has experiences during his working life.

However, although this is a necessary condition, there is nothing to prove that it is sufficient. In effect, the decisive role attributed to quantitative dust exposure is based exclusively on the correlation which exists between this factor and X-ray data. But it is also recognized that in the case of simple pneumoconiosis, the X-ray picture, which is simply a result of the X-ray absorption properties of the lung and its content, evidences a clear relationship with lung dust - a relationship which may be complicated by the ferruginous reaction, which is known to vary from one individual to another. Thus, radiography may be to a large extent a representation of lung dust and its typical distribution. One should also mention the difficulties that sometimes arise in correlating X-ray findings with the results of functional tests. In these circumstances it is not at all surprising that there is a relationship between the X-ray data for an individual and the dust exposure the individual has experienced.

But the real problem is to determine to what extent there also exists a relationship between dust exposure and lesions identified post-mortem. This is a far more complex matter and - as we have seen - categories of lesions tend to overlap considerably. Thus, it would seem that one cannot whotly disregard the qualitative aspect of dusts. Because of the complexity and variety of the mineralogical characteristics of coalmining dusts, very little is known about their toxicity and possible interactions. Their surface states - the importance of which is obvious, because it is via their external layer that the particles enter into contact with the cells and tissues - and their development in biological environments are concepts which have hardly been touched on - a situation which is partly explained by the fact that testing techniques suitable for the study of surface states have only recently been developed.

This situation has led to the establishment of a Community research programme, the aims of which are to determine the caracteristics of the components of coal dusts which contribute to lung damage, to study the factors relating to the nature of the dusts themselves and their environment which are capable of influencing harmfulness, and to analyse the surface phenomena and their development over time. Particular attention will be paid to quartz, the specific toxicity of which in the case of mine dust is still unclear, as is the significance of its concentration. The research programme will involve a range of physical analysis techniques, in particular recent methods for the study of surface layers and elementary or structural analysis at microscopic level, chemical methods of preparation, extraction and analysis, and biological methods to determine the harmfulness of the dusts at the cell and tissue levels. These investigations will be supplemented by autopsy examinations of the lungs of pneumoconiosis victims, with a view to determining the correlation between the lesions observed in man and the characteristics of the dust present in the lungs.

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4. DUST MEASUREMENT TECHNIQUES

H. BREUER - Essen

The measures to be taken to prevent penumoconiosis in miners present a number of challenges in terms of dust measurement.

In technical terms the causes of dust generation must first be established and methods of dust control then adapted to them. Their success must then be determined. Particularly suitable for these purposes are measuring devices with which rapid changes in dust concentration can be detected and registered. For medical measures, and for decisions on the deployment of miners, dust exposure levels must be established over a prolonged observation period. To this end gravimetric long-term sampling equipment is generally used.

To tackle these problems a variety of dust measurement techniques and measurement programmes have been developed in Community countries over the past 30 years. This was covered in detail in the Synthesis Report on the Third Programme on Health in Mines, 1971-1976.

Today I should like to report on the main developments in measurement techniques and on the results of recent research.

In the past few years dust exposure limits have been lowered and revised in certain countries, thus placing higher demands on dust measuring techniques. Successful application of technical and medical measures, - that is, elimination of dust hazards - calls for measurement and analysis of this pollutant as regards particle size distribution, concentration and specific harmfulness, in order to determine the possible effect of these factors on the occurrence of pneumoconiosis.

Definition of "respirable dust"

Only that part of suspended particulate which is deposited in the alveolar region of the lungs is of importance in the development of pneumoconiosis. When routine dust measurements were begun it was not possible to produce sufficiently accurate data on this point. It was therefore decided to use either the measurement of the particle size from 1 or 0.5 to 5 µm (konimeter, thermal precipitator, turbocaptor sampler), or gravimetric measurements of total dust in mg/m^3 (Staser device), or measurement of the diffused light intensity of the respirable dust under 10 µm (Tyndalloscope). These values cannot, however, be compared with one another when the particle size distribution of dust is different, as was illustrated by the first comparative measurements at the beginning of the 1960s. It was decided at the time to develop gravimetric sampling devices which could collect and separate the dust responsible for pneumoconiosis from the coarse dust during sampling (figure 1). To trap the coarse particles, parallel plate elutriators in line with the BMRC separation curve or cyclones in accordance with the "Los Alamos" curve are used.

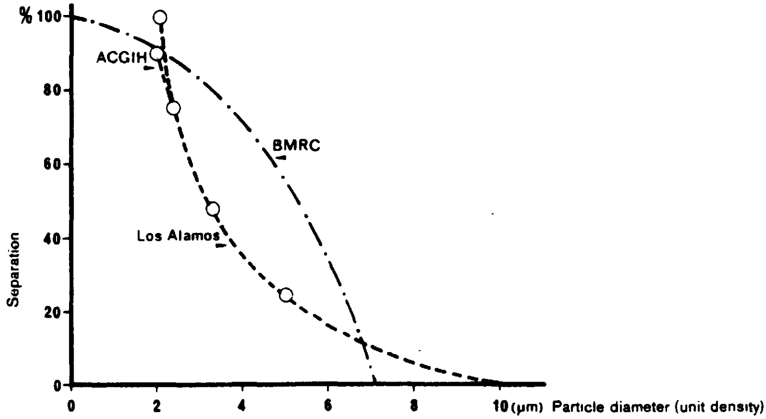


Figure 1 : BRMC, Los Alamos and ACGIH separation curves for respirable dust

The MRE gravimetric dust sampler and the MP device (SFI, Bochum) were developed on the basis of the BMRC curve. The CPM device (Cerchar) and the TBF device (BF) use similar cyclones for preliminary separation.

A sponge, which also acts as a ventilator, is used in the CPM device to filter the respirable dust, whereas in the TBF device a further cyclone is used. The respirable dust is collected in this sponge or cyclone in accordance with the deposition curve of Hatch et al for dust in the alveolar region. Comparative tests just completed show that the measurements produced by these gravimetric devices can be converted from one to the other with far greater certainty than the measurements produced by devices used in the 1960s.

With a view to obtaining experimentally substantiated data on the inhalation and regional deposits of dust in the respiratory tract, research projects are currently being carried out at the Institute of Occupational Medicine (Edinburgh), and by the Bergbau-Forschung (Essen) in conjunction with the Gesellschaft für Strahlen- und Umweltforschung (Frankfurt). Figure 2 shows the result of the German research on oral breathing during light work (respiratory volume 20 l/min, 20 breaths per minute).

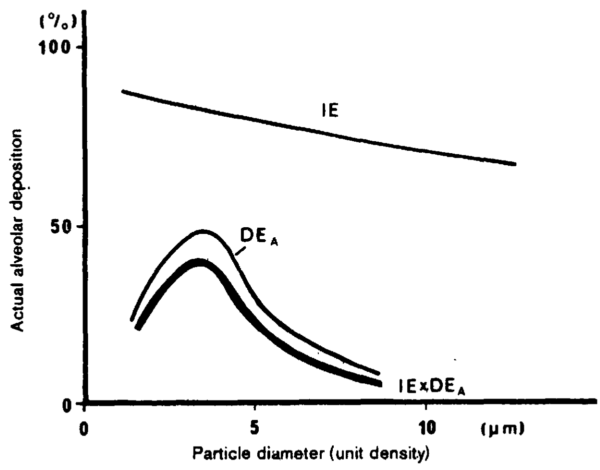


Figure 2 : Actual alveolar deposition, calculated from the average inhalation speed for various head positions (IE) and the alveolar deposition DE_A/

The upper curve (IE) shows the mean probability of inhalation of particles at an air velocity of 1 to 8 m/s and head positions of 0°, 90°, and 180° to the wind direction. Because of these differences in air flow round the head, the individual values vary greatly, especially in the particle size range above 10 μm. Of the regional depositions established at the Frankfurt Institute with the help of manodisperse radioactive particles, only the values for alveolar deposition DE_A are given. These are at a maximum between 3 and 4 μm; below 2 μm they are the same as the total deposition with a minimum of 0.6 μm. These two curves were used to calculate the "actual alveolar deposition" - IE x DE_A.

The practical significance of these experiments depends on the particle size distribution of the dust, especially in the range below 10 um. Determination of this parameter, however, has still not been satisfactorily solved. Devices are currently being developed, especially impactors, with which the particle size distribution can be determined with certainty in accordance with the aerodynamic diameter of the particles. Subject to the familiar limitations, earlier tests using sedimentation analysis of the samples give an idea of the expected spread of particle size distribution (figure 3).

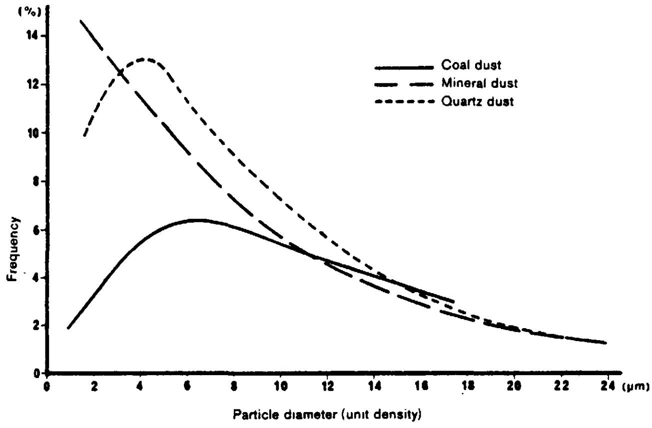


Figure 3 : Particle size distribution of coal, mineral and quartz dust

Downwind of mine workings the maximum particle size distribution of coal dust was generally between 4 and 8 μm, of quartz dust between 1 and 6 um,and of the other rock particles, consisting primarily of clay minerals, below 2 μm. It follows that the particle size distribution of the suspended dust is determined largely by the content of respirable rock dust. Dusts of this king are overestimated, sometimes excessively so, when measured by equipment which covers practically 100% of the particle content below 2 μm. This is perhaps a reason for the lower risk of pneumoconiosis presented by dusts with high rock content, as was clearly visible from the analysis of measurements with the Tyndalloscope, which produces an even higher average assessment of these respirable dust particles. Epidemiological and biological research should therefore take into account the particle size distribution of the supended dust.

Determination and assessment of dust exposure at work

Epidemiological research projects in the Second and Third Programmes on Health in Mines have shown that the total dust exposure - the product of the respirable dust concentration and the duration of employment at the given workplaces - has a decisive influence on the occurrence of simple pneumoconiosis. This finding induced the Deutsche Forschungsgemeinschaft, for example, to fix the respirable dust limit at 4 mg/m^3 for an observation period of five years.

This value now forms the basis for new regulations issued by the mines inspectorates in the Federal Republic of Germany on permissible dust exposure levels for miners without (B1) and with dust-induced lung changes (B2 : categories 1 to 3), including persons under 21 years of age. These dust exposure limits in North Rhine-Westphalia are shown in figure 4 as possible frequency distributions of concentrations of respirable dust with less than 5 % quartz content. Distributions of this king are based

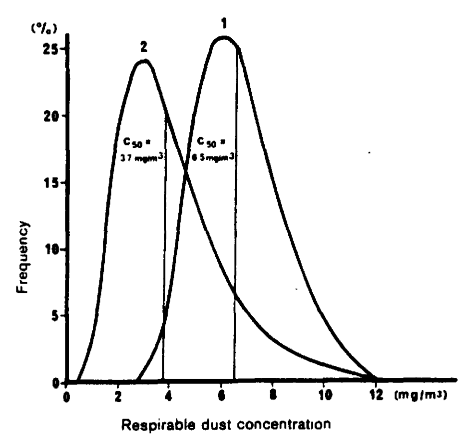


Figure 4 : Permissible levels of exposure to respirable dust for miners in fitness grades 1 and 2 at a quartz content of less than 5% (North Rhine-Westphalia)'

on at least 60 measurements taken during coal winning within a period of five years. In calculating the distributions it was assumed that values would be below the maximum permissible level of 12 mg/m^3 with 99% certainty and that a miner would work 1100 shifts in five years.

For miners without pneumoconiosis (B1) 95% of the individual values are spread between 3 and 12 mg/m^3, around an average of C_{50} = 6.5 mg/m^3; the average for miners requiring particular protection is C_{50} = 3.7 mg/m^3, the spread being between 1 and 12 mg/m^3.

Given a quartz content of 5 or more per cent, jobs in North Rhine-Westphalia are graded solely in accordance with the respirable quartz dust concentration, the permissible maximum value of which is 0.6 mg/m^3. There is thus a downward shift in the curves shown in figure 4 - for example, with a quartz content of 10% from an average of 6.5 to 3.2 mg/m^3 for B1 miners and from 3.7 to 1.8 mg/m^3 for B2 miners.

In Community countries dust exposure in specific kinds of work and classified areas is measured at fixed points for as long as the miners are at work. These areas generally comprise an entire colliery or, as in the Federal Republic of Germany, only parts thereof, depending on the dust concentration. Figure 5 shows a diagram of a working with highly variable respirable dust concentrations ranging from 1 to 10 mg/m^3 at workplaces at the face and in the ajacent roadways.

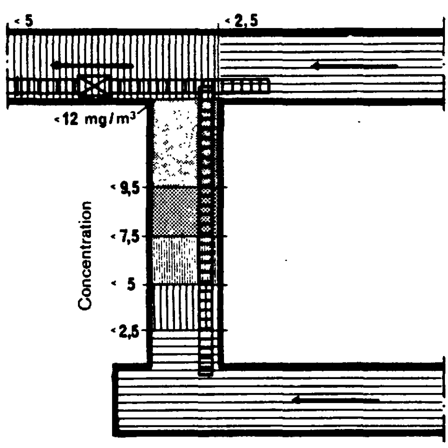
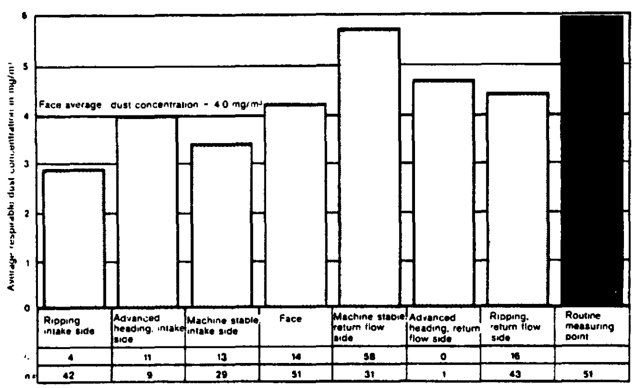


Figure 5 : Respirable dust concentration in a working

For an accurate measurement of the dust exposure of individual groups of miners, several areas can be determined - for example, the measurement classification in North Rhine-Westphalia with its five grades of respirable dust concentration and upper limits of 2.5, 5.0, 7.5, 9.5, and 12 mg/m^3. A different system is used in the British mining industry, where the routine measuring point is set up some 70 m downwind of the face, five measurements generally being taken on consecutive working days. Their average value should not exceed 7 mg/m^3. A good number of tests have shown that the value found at the routine measuring point produces a dust concentration 1.4 to 1.6 times higher than the average of all measurements at the face. By way of example, figure 6 shows the average respirable dust concentration at different workplaces taken from measurements at 51 faces in 1974. The average for persons employed at the face was 4 mg/m^3 whereas the average at the routine measuring point was around 6 mg/m^3. Jobs on the return air side near the end of the face, such as in the machine stable, show higher dust concentrations.



<u>Figure 6</u> : Change in respirable dust concentration along a face up to the routine measuring point

Determination of the dust exposure to miners by means of a measuring point in the return flow assumes that differences in dust concentration at the face with miners deployed at all workplaces are cancelled out over a prolonged period of time.

Since the methods of measuring dust exposure in Community countries vary, limits cannot be compared directly. The only basic value can be used to compare limits is the desired or permissible average dust exposure which still entails a certain risk of pneumoconiosis. This problem is now being examined in the two Community research projects "Comparative measurements in mine workings" and "Specific harmfulness of dust".

Measurement and analysis of the quartz content or specific harmfulness of dust

In the past, as now, the quartz content - in Belgium the ash content of respirable dust - has been used as an indication of the specific harmfulness of dust. The X-ray diffraction or infrared methods used to determine quartz content were improved considerably by an active exchange of experience and comparison of methods, with the result that readily comparable figures are now produced. To this end a standard for quartz was established.

There are, however, still considerable differences in the determination of quartz. Epidemiological and biological studies on the significance of quartz in the occurrence of pneumoconiosis have not provided any definite conclusions which could prompt authorities to call for a radical change in the method established some years ago. Figure 7, for example, shows that the quartz content is not taken into account in

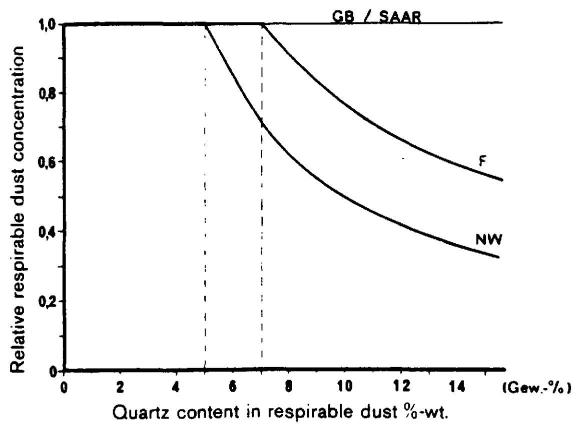


Figure 7 : Effect of the quartz content on respirable dust concentration limits in mine workings (Great Britain, Saarland, France, and North Rhine-Westphalia)

France limits above 7% quartz and in North Rhine-Westphalia above as little as 5% quartz are reduced to different extents - for example, for a quartz content of 10% by around 25% in France an by 50% in North Rhine-Westphalia.

A Community project has been set up with a view to solving this problem and its inherent effects on dust control and the deployment of miners. What can we expect in practical terms from this project ? A possible differentiation of dust exposure limits in accordance with the varying harmfulness of dust. In the French mining industry, for example, respirable dust limits are already being established in accordance with the pneumoconiosis risk in the individual districts and collieries. This procedure cannot, however, be applied to newly-worker seams where the harmfulness of the dust is either not or hardly known. A measurable parameter must therefore be fixed as a measure of the harmfulness of dust. From our current knowledge this could be achieved by determination of the biologically active surface of the quartz, an approach which, without the additional words "biologically active", was recommended at the Johannesburg Conference on pneumoconiosis in 1959.

The previous, relatively simple routine determination of the quartz content by mass would then be practically no longer applicable, unless a definite relationship between the biologically active surface and the mass of the quartz dust were established. Modern physical, microscopic, and biological methods are being studied with a view to determining the active surface of quartz. Given the current state of the art, however, these methods are still far from the stage where they could be used as standard procedures at a rate of many thowsands of samples per year. Perhaps this will not be necessary in future if it becomes possible to find a yardstick for the harmfulness of certain dusts based on a smaller number of samples, with which the respirable dust concentration can be evaluated.

Dust control measurements in work processes

The demands placed on technical measurements are far simpler and more readily met than the problems involved in the measurement and assessment of dust exposure in miners. Technical investigation is merely a question of establishing the connection between the respirable dust concentration and the different work processes in a mine, so that their significance in terms of dust exposure at a given time can be correctly assessed.

For this purpose two instruments have been developed : the TM digital by Bergbau-Forschung, Essen, and the Simslin by SMRE, Sheffield. Both instruments give a direct reading and recording of a diffused light value for the respirable dust concentration. The TM has been supplied to a number of institutes for trials.

These have shown that the diffused light value of the TM digital can be converted with sufficient accuracy into respirable dust mass. Several Simslin instruments are currently being distributed for similar studies. The following examples are designed to illustrate the potential uses of these instruments in underground workings and in testing bays :

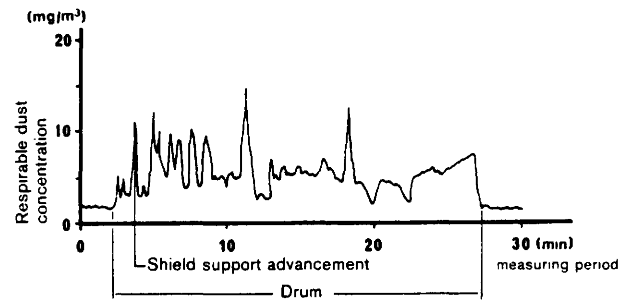


Figure 8 : Generation of respirable dust in a mine with drum loader-cutter and powered supports/

Figure 3 shows the generation of respirable dust measured with the TM digital in an area worked with a drum cutter-loader.

The superimposition on the dust generated at the drum of the high, but short dust peaks caused when the support advances can be seen quite clearly. Figure 9 shows the dust generated only by advancing the shield supports.

In the cleaned gas output from a filter dust collector (fig. 10) in the Bergbau- Forschung testing bay, the TM digital showed high values first of all when the filter bags were cleaned, because of leaks at some

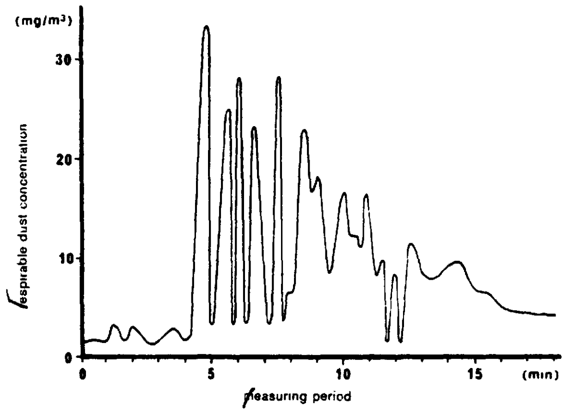


Figure 9 : Respirable dust generated by advancing the shield supports

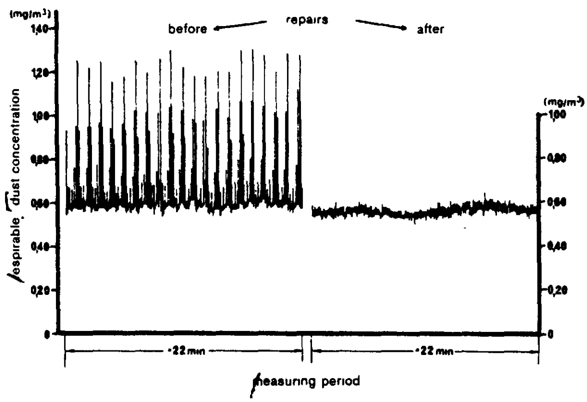


Figure 10 : Respirable dust concentration in the cleaned gas output from a dry filter before and after elimination of a leak in the filter frames

of the filter frames. Once these faults were eliminated the respirable dust concentration in the cleaned gas was more or less regular.

At another testing bay for drum loader-cutters (scale 1 : 10) the effect of the extraction ventilation air flow from the machine of the concentration at the end of the face was determined within a measuring period of 10 minutes as shown in figure 11. The concentration dropped with increasing extraction flow from around 55 mg/m^3 (D = no extraction) to around 15 mg/m^3 at an extraction air flow of 27% of the total air current (a).

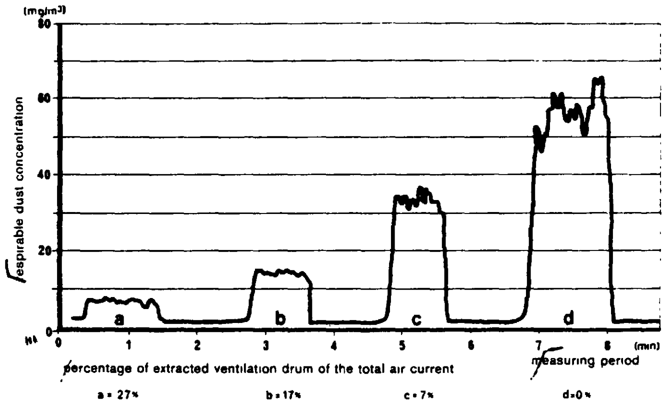


Figure 11 : Effect of the extraction ventilation air flow from a drum loader-cutter on the respirable dust concentration in the return air flow at a face

A new model of the TM digital with additional devices to keep the optical read out clean and for remote transmission of the values is now being tested. This will permit continuous monitoring and, if needed, control of mining operations and dust control measures.

4. METHODS OF DUST CONTROL

G. DEGUELDRE - Hasselt

INTRODUCTION

The importance of dust control is obvious when it is realized that, in some modern faces where there are no preventive measures of any kind, routine winning, loading out, and support operations can lead to quantities of dust between 10 and 15 times greater than the proposed limit values being suspended in the air, not to mention the sometimes enormous increases in concentration caused by roadway drivage or stable hole machines.

This importance becomes even more obvious if the rates of incidence of pneumoconiosis observed over the last 20 years or so are compared. Twenty years ago in some coalfields (and even as recently as 10 years ago in some high-tonnage pits) more than 40% of the miners with between 20 and 25 years' service underground had X-ray pictures of micronodular type m_2 and over. Nowadays, in the "good" pits in the same coalfields, 2-3% of the workers with the same length of service have the same X-ray pictures, the overall rates of incidence being less than 2% or even 1%. This unquestionable improvement in workers' state of health is due largely to technical control of dust.

Without going into details of the many methods of prevention which have been developed - notably with financial support from the Commission of the European Communities and the ECSC - it would seem sensible to start by describing briefly the "sources of dust" and by attempting to summarize the "control methods" most commonly used on an industrial scale.

Sources of dust in underground workings

Unlike the dust made during traditional or mechanical drivage of roadways (which is dealt with in a later section), the sources of dust at the face are widespread and mobile, the dust being produced and suspended in the air by the activities of the workers and above all by the operation of machines placed along the length of the same branch of the ventilation circuit (in our longwall workings). These sources act simultaneously : although the digging up, dislodging, bringing down, and loading of coal are in fact becoming more and more concentrated at one point, conveyor haulage, shifting of powered supports, stowing, roof caving, etc are spread over the whole length of the coal face.

Moreover, the basic dust made at the entrance to a coal face depends essentially on the conditions prevailing upwind of the ventilation: bringing down and transfer of the products (generally at the foot of the face), development of the end of the face (roadway, stable hole, etc), any crushing of the products, operation of conveyors placed at intervals in the roadway, reactivation of settled dust, and so on.

All these causes and sources of dust inevitably have cumulative effects. The situation is thus practically the same as it was previously (except perhaps as regards the adaptation of new ventilation systems). On the other hand, these modern faces produce average daily tonnages which are in many cases well in excess of the weekly production capacity of faces 15 or 20 years old.

As a result of increasingly rapid rates of advance, the new winning methods and machines used require an ever increasing supply of energy per unit of time to dig up, loosen, bring down, and crush on the spot increasingly greater quantities of coal and rock. In many cases this increase in output per face is liable to lead to a worsening of environmental conditions, resulting in increased quantities of dust of all grain sizes becoming suspended in the air (as well as in an increase in the dry and wet temperatures of the air, the noise level in workshops and the firedamp concentrations in the ventilation air current).

Preventive techniques most commonly used

Real prevention is only very rarely the result of applying a set formula, especially as the effectiveness of a particular method of prevention depends on the relative size of the various concurrent sources of dust emission.

In order to solve this problem (although no solution can ever be final), it is essential to adopt and combine several methods in an effort to tackle the dust at source and as early as possible.

1. Ventilation is obviously still an extremely efficient means of diluting "respirable particles". Although its main function is to dilute firedamp and its use has therefore practically doubled over the last 10 years or so, ventilation is still restricted as a result of the extension of circuits and congestion at the faces and in the roadways. Any increase in the flow of air at the face results in an increase in air speeds, local variations in which are liable to reactivate already settled particles.

2. The preventive techniques used to improve working conditions in winning areas are generally classified as "methods of control outside winning operations" and "methods of control during winning operations". It is becoming increasingly difficult in fact to make a clear distinction between these various methods, since the cyclic organization of operations has turned into a repetition of virtually continuous and simultaneous operations. Dust control outside winning operations is thus becoming of prime importance; to neglect it inevitably jeopardizes the success of face operations.

It therefore seems more appropriate to make a distinction between dust control methods which strike at the source itself and those which attempt to suppress the dust already suspended in the air, the former being regarded a priori as distinctly more effective.

A. Control at source of emission

Irrespective of the mining techniques or winning methods used to reduce dust make (eg hydraulic winning in steep seams, converted cutter-loaders, modified ventilation circuits etc), methods designed to :

a) soak the solid before winning,

b) wet the rock during winning or while it is being loosened,

c) spray the products on loading, either before or during haulage,

d) remove the dust cloud formed or being formed away from the (general) flow of air,

are in principle to be used at the sources of dust emission.

The recommended methods are therefore :

a) infusion of water in the solid or injection of water in the seam, perpendicular to the line of face at a short distance or at greater depth, infusion parallel to the line of face, long-hole preinjection, etc;

b) sprinkling of faces, wetting of winning machines, spraying during caving, etc;

c) sprinkling or spraying above conveyors, placing of discharge, transfer and crushing points in a housing with spraying or suction devices and isolation by means of air or water curtains;

d) suction devices fitted to machines, above support units, etc. followed by filtering or precipitation of the dust in dry or wet dedusters.

If, in addition, pneumatic stowing is carried out simultaneously with winning, it is necessary to select, calibrate, and wet the goaf (outside the face) and regulate its quantity as a function of the flow of compressed air, whereby the precautions to be taken at the face are designed to avoid reactivating the settled dust (at the moment of impact of the stowing material projected).

B. Control of suspended dust

Apart from personal protection equipment, the methods generally used to suppress dust particles suspended in the air, although fairly difficult to apply at the face +), are based on precipitation by spraying, with or without diversion of the air current, on filtering after localized suction.

Moreover, the consolidation of strata and the binding of dust to the walls by means of hygroscopic salts (in solution or in crystal form)

+) NB : These methods frequently require more than 50-60 litres of water a minute or several m^2 of filtering surface per m^3 to be treated.

or caking products (some of which are occasionally used as evaporation inhibitors) with a view to collecting by impact and retaining the settled dust are techniques which contribute to the general purification of the atmosphere.

3. In the case of roadway and gate road drivage, dust control methods are generally more selective. They are designed to reduce the scale of the sources and causes of dust make, which may be outlined as follows :

a) Either the drilling of shot holes, firing of explosives, charging of debris and, to a lesser extent, placing of permanent supports;

b) or the action of the mechanical heading machine, which may be of the selective or the full-face type.

Depending on circumstance, it will thus be necessary to resort to:

a) wet drilling (injection of water via the drill rod);

b) sprinkling or spraying, reversal or diversion of the ventilation, and the use of a deduster and water cartridges during shotfiring;

c) sprinkling or continuous spraying during loading;

d) the use of cutters fitted with water atomizers during any necessary trueing of walls;

e) a combination of forced and exhaust ventilation with diversion of the dust-laden air towards a battery of dust extractors.

Efficiency of dust control

All the techniques we have just examined very briefly, the underlying principles of which have been well known for a long time, have unquestionably improved working conditions in roadways and coal faces.

As a result of the unceasing research which has made it possible to widen the scope of these methods and to develop other systems from them +), it is no exaggeration to say that this improvement if reflected in a reduction of more than 60% in dust levels. The dust concentrations currently obtained at the face are on average lower than the threshold

+) The majority of these research projects were carried out with financial assistance from the CEC-ECSC.

values laid down or recommended. Compared with the values which would be measured if there were no dust control, suppression or reduction rates in excess of 90% are quite common with an astute combination of several processes. During mechanical roadway drivage the overall efficiency can be as high as 99% (all grain sizes), the suppression rate for "respirable" particles being in some cases higher than 95%.

The rates of incidence of pneumoconiosis in the past few years are proof of the real value of technical dust control.

Recent progress and trends

Although in present conditions it has been possible to achieve average dust levels which may in all honesty be regarded as "acceptable" from the point of view of industrial hygiene, it must nevertheless be admitted that there are still working conditions which require special attention.

An average value does not have any meaning unless the dispersion affecting all the measurements is known. Two average values, equal to or lower than a given limit value, do not necessarily describe the same overall situation; there may still be a certain percentage of values which exceed the threshold laid down ! Whether this be 15%, 10% or even 5%, our aim should be to bring this percentage down towards zero that is, to bring about a situation in which all the concentrations measured - and not only their average value - are below the proposed limit.

The recent summary report on the research carried under the third programme on "Health in mines" +) outlines the progress made, particularly with regard to prevention. The adaptation of these results to an increasingly greater number of specific cases will without doubt enable us to find better ways of overcoming the problems which are still arising.

We are unfortunately unable to comment on or even to list here all the research projects which have been approved by the Commission of

+) Commission of the European Communities "Industrial Safety and Health - Health in Mines", EUR 5931, 1978, catalogue n° CD - NQ - 77 - 013 FR - C, summary report (H. Breuer).

the European Communities (around a 100 in the past six years); we shall therefore merely quote some of the most salient findings and facts taken from this publication.

Release and propagation of dust

Because of the increase in unit output, it proved necessary to consider carrying out studies of a more fundamental nature in order to lay down better guidelines for prevention policies. Efforts were therefore made to establish relationships between the release of dust, its propagation in the air current, the speed and turbulence of the air current, operating conditions, geological data, and the humidity of the products (since water in still the best practical means of reinforcing the coagulation of dust particles).

If hourly output is doubled in normal operating conditions (for example, from 80 to 160 t/h), the fine dust concentration does not increase proportionately; the increase is around 20% on average in faces of the Ruhr type, irrespective of whether winning is carried out by means of ploughing or mechanical cutting. The quantity of fine dust released is usually higher, however, during cutting, although the excess can generally be suppressed by increasing the water content (for example, 4.5 - 6.5.% by weight for the fraction between 0 and 10 mm instead of 2.4 - 4.5% in plough faces). Even in low-tonnage faces, the fine dust concentration is frequently high if this low output is the result of poor geological conditions.

The water content (measured for the fraction between 0 and 10 mm) considerably influences the fine dust concentration, which is "optimal" at 5% humidity in the case of ploughing and 8% in the case of cutting. With water levels of this order, the dust concentration decreases as the speed of the air in the face increases, even up to 4.5 m/s, as a result of the dilution caused by the air flow.

When the water content is too low, the speed of the air current has a critical value; above 2.5 m/s, the amount of dust raised surpasses the amount that can be diluted. An increase in the "natural" water content by infusion into the rock mass causes an appreciable reduction in the amount of dust released, especially when the initial level is low. Steady, slow, and even infusion is vastly preferable in this respect; further addition of water during and after loosening and breaking up of the coal reduces the amount of dust released still further.

During cutting with drums with a depth of cut of between 0.2 and 0.6 m, the amount of dust produced decreases when the rate of advance of the machine is increased (for example, with a depth of cut of 0.4 m, the quantities of dust released are proportionately 9 - 5 - 3 at rates of advance of 1,2, and 3 m/min. respectively). This has led to the development of drum cutter - loaders with a small number of picks placed at wide intervals and with a great depth of cut.

During pneumatic stowing, the quantity of dust suspended in the air is less than 1% (by weight) of the total quantity of dust contained in the stowed goaf, when the water content of the fraction up to 10 mm is around 6%.

Precipitation of dust by spraying

Research in this area has been going on for over 20 years, covering in particular the number, size, and electric charge of the dust and drops of water, the trajectory of the drops of water, the temperature and humidity of the air, the water/dust contact time, and so on. Around 10 years ago it was assumed - and it still holds true today - that the efficiency of dust suppression increased in proportion to the water pressure before discharge and the quantity of water used per m^3 of air (for example 45-50% at 10 bar and 55-60% at 40 bar for 0.4 l/m^3; approximately 60% at 10 bar and 70-75% at 40 bar for 0.8 l/m^3, with stone dust as described in DIN 70, 40-45% of the particles which have a grain size of less than 3 μm). By increasing the pressure and decreasing the diameter of the head piece it is possible to obtain a greater outflow speed and a finer distribution of the drops of water; however, there is a maximum pressure beyond which no further improvement in efficiency is possible (40 bar for a head piece with a diameter of 3 mm; 20 bar for a diameter of 1.5 mm.).

Further research projects were carried out recently (some of which are still in progress) with a view to improving efficiency by reducing water consumption. To this end, a saturated atmosphere is created by atomizing the water with compressed air and steam or steam alone.

Spraying with very fine water droplets or the use of water vapour at 5.5 bar gives (in the laboratory) the same efficiency with regard to coal dust as spraying at 21 bar by conventional hollow-coned blowers consuming three times as much water. An increase in contact time leads to a further improvement in efficiency in the case of the water/steam mixture (15% improvement when the contact time is increased threefold) but to virtually none in the case of the compressed air/water mixture.

In order to prevent a worsening of atmospheric conditions as a result of the use of steam, the tests are continuing with a view to developing the process for use in confined spaces, - for example, inside a casing round the drum of a cutting machine.

Dust extraction equipment

Even if it is carried out under optimal conditions, the suppression of dust by means of drops of water is not sufficient when the fine dust concentrations are very high, as is the case during mechanical roadway drivage.

When machines of this type were first used, there was quite naturally a tendency towards dry filtering; however, this had to be discontinued shortly afterwards because of the excessive congestion caused by the installations and their unduly high repair and maintenance costs.

Studies were therefore made of wet separators which are smaller and at present can handle air flows of 2.5 - 5 m^3/s, with fine dust throughput rates of between 3 and 7% at underpressures of between 1.1. and 4 kPa (venturi scrubbers, cyclones, humidified filters, and parallel vane separators, etc); specific water consumption is still between 0.1 and 0.5 l/m^3.

Since 1976, however, there has been renewed interest in dry filters which can handle a greater flow of air with the same efficiency but with a distinctly lower energy consumption, thus giving rise to less pollution from heat and noise.

In view of the space available, installations of this type (dry or wet) cannot be used when drum cutter-loaders, stable hole machines, or rise heading machines are being used. Very encouraging tests have been carried out with an impact-mesh wet deduster incorporated in the spill-plate of a rise heading machine conveyor (efficiency up to 93%; throughput 0.6 m^3/s; specific water consumption 0.2-0.25 l/m^3; these tests are continuing.

Another way of improving dust extraction involves reducing the volume of air to be collected (and, therefore, the amount of energy consumed) by isolating the sources of dust by means of an air screen or curtain, or reducing the proportion of dust of grain size below 5 μm by pre-binding the dust collected by emitting sound waves in the air current.

The results of the air curtain experiments have still to be confirmed in underground practice, but they hold out the possibility of reducing the flow of air to be exhausted by half. Coagulation by means of sound waves - which do not have any harmful effects - requires further refinements in order to increase the effective life of these waves (as well as a more detailed study of the electric charges taken up by the dust and the drops of water).

Injection of water into the solid

This method of prevention is unanimously regarded as giving by far the best results provided that it can be applied :

Recent work in this area has been concerned mainly with : (a) the development of techniques involving constant, slow infusion, preferably at low pressure, working from the face or better still from the gate roads (devices for sealing boreholes by means of quick-acting binders or synthetic adhesives, flow regulator, drilling frames, etc); (b) study of the advance and distribution of water in the solid; (c) study of the fissuring of coal seams (and their permeability and porosity); (d) research into new measuring and control devices (measurement of the quantity of water absorbed by determining the variation in the density of coal etc); (e) consolidation and protection of roadway walls and improvement of the behaviour of the roof.

All the research carried out (parallel injection, diagonal injection, spreader injection, long-hole pre-injection, etc) widens considerably the range of possible applications in more steeply inclined or thicker seams, as well as making ploughing easier (by reducing the hardness of the seams) and causing, under certain conditions, a reduction in firedamp desorption.

In some mining districts, the efficiency of the process was improved by adding wetting agents (in very small quantities) or calcium chloride (0.2%). Further studies are necessary, however, before anything definite can be decided (ie a judicious choice of additives, based on the properties and characteristics of the coal to betreated and the water to be used).

Plough faces and cutter faces

It is essential to wet the face by sprinkling or spraying and to precipitate the dust produced during winning, especially if the solid has not been soaked with water in advance.

In plough faces, sprying from the conveyor spill-plates must be done at a sufficiently high pressure by means of water jets only and not by compressed air atomizers (which produce very fine droplets and haze if the trajectory is too short).

Local sprinkling that is, sprinkling of the section of face close to the plough is justified in thick seams. The control devices, such as magnetic switches, present tricky problems, however. A method of triggering the atomizers by means of the device for measuring the advance of the plough is being developed (the signal being transmitted to the valves electrically, electro-pneumatically, or electro-hydraulically).

In order to reduce water consumption still further, the possibility of fitting the atomizers to the plough is being studied (Gleithobel and even drag-hook type plough, fitted with an "ad hoc" arm). A consumption of 60 l/min at 15-20 bar is quoted, giving rise to a 70% reduction in the quantity of respirable dust released (the humidity of the raw smalls increasing from 2.1 to 2.9%).

In cutter faces, the coal is generally harder and not very absorbent. The machine often cuts into the surrounding rock, thus causing finer dust particles with a higher quartz content to be suspended in the air.

The main aims of the research here were : (a) to modify the design of the machines and improve their mode of operation in order to reduce dust make; (b) to prevent the emission of dust into the air current by using water, vapour, steam, foam, etc; (c) to collect and suppress the dust on the machine itself.

The results of all the tests carried out since 1976 have shown that :

it is preferable to have a small number of large picks combined with a low rotation speed (as had already been assumed previously);

it is better to fix blowers to the windings of the drum than to place sprinklers in the pick box;

suction via the hollow shaft of the drum has definite possibilities (with a view also to diluting the firedamp in the cutting area);

the most difficult problems can be solved, in principle, by hooding the cutting machine, exhausting the dust-laden air contained in the enclosure thus formed, and precipitating it into a deduster fitted to the machine.

Dust caused by powered supports

Over the last four years more than 80% of the Community coal has been produced in faces equipped with powered supports. The dust produced by caving, the advance of supports, crushing of the debris accumulated on the roof bars, lateral movement of the supports, and so on may well be released into the face air current. In some cases it was estimated that the use of powered supports was responsible for an increase of between 1 and 3 mg/m^2 in the concentration of fine dust, comprising mainly dirt, and thus automatically having a higher quartz content (concentration in proportion to the length of the shift).

The aim of the studies carried out, some of which are still in progress, was to find a way of re-covering the sections of roof exposed between roof bars, using netting, pieces of belt, metal strips, etc, and to develop sprinkling and spraying devices which are engaged when the supports are advanced or suction devices which pick up the debris between the roof bars and precipitate it backwards by means of wet blowers towards the caved goaf.

Some of these preventive techniques have resulted in the suppression of more than two-thirds of the dust produced.

CONCLUSION

This review - necessarily incomplete - of the most recent and continuing projects shows the direction being taken by dust control and what we should expect of it namely, the most effective protection possible for all underground workers, whatever their job, qualifications, or duties.

Despite the undeniable progress made overall, this aim alone is ample justification for further research in the field of technical dust control. This is a difficult task which we will not be able to bring to a successful conclusion without the help of all concerned.

5.1. DEFINITION AND LEGISLATION

J.S. McLINTOCK - United Kingdom

In Britain coal measures are present in many parts of the country, and the types of coal vary considerably. Some 230.000 men are employedat mines; on average around 1.000 per mine.

Occupational medicine in Britain places prime importance on the definition of health hazards, on developing environmental standards and on persuading engineers to alter the working environment to meet these standards. There is therefore, close cooperation between doctors in industry and scientists, occupational hygienists, ergonomists and engineers. Medical prevention is regarded as a secondary defence, not a primary one.

Because the National Coal Board is a single organisation controlling all coal mining in Britain, it is possible for NCB instructions to be issued to virtually all mines, instead of governmental regulations. Thus, although this paper is mainly concerned with the present day practices consequent upon the "The Coal Mines (Respirable Dust) Regulations, 1975" NCB directives dating back to 1949, soon after the industry was nationalised, set dust standards, maintained dust exposure records of men with pneumoconiosis, initiated a periodic X-ray scheme for all miners and began a medical surveillance system.

The policies were consolidated and extended in the governmental regulations, known colloquially ad the 1975 Dust Regulations. In essence

There are four parts to these Regulations (Fig. 1)

1) Dust sampling and evaluation

2) Dust control

3) Medical supervision

4) Provision of dust respirators.

Almost all deep-mined coal production in Britain is from long wall faces (Fig. 2) and the dust sampling point is in the return roadway (because this is in general the dustiest and most practical point). The dust level here must not exceed 7 mg/m^3 +) (seven milligrams per cubic metre of air) on average. If the worst coal face in a mine is at 7 mg/m^3 then the average exposure on coal faces in that mine is approximately 3.5 mg/m^3.

Most coal faces are well below this figure of 7 mg/m^3 (Fig. 3).

Only the mass of respirable dust is considered. Research has shown a good correlation between mass and pneumoconiosis risk, but has as yet been unable to measure the importance of dust composition, especially quartz.

In drivages, the permitted dust level is 5 mg/m^3. Here for historical rather than scientific reasons, the quartz content is measured, if the level is over 3 mg/m^3 and must not exceed 0.45 mg/m^3.

All measurements are made with the MRE Type 113A instrument giving a cut-off close to the Johannesburg curve. Dust sampling must be carried out at least once a month if the dust levels are below, or by five samples within seven days if they are above, the figure of 5 mg/m^3 for coal faces or lower elsewhere.

The objectives of the medical supervision scheme are as follows (Fig. 4) : -

1) To ensure that entrants to the industry are fit to work in the mining environment.

2) To identify as soon as possible men beginning to show early signs of pneumoconiosis and to take appropriate steps for their protection.

+) The Coal Mines (Respirable Dust) (Amendment) Regulations 1973.

3) To identify particularly susceptible individuals so that they may be protected from further significant dust exposure.

4) To monitor the success of dust control.

In practice, the medical supervision scheme operates as follows (Fig. 5) : -

1) All entrants to industry have compulsory examination including full-size chest radiograph.

2) All men working at mines are offered full-size chest radiograph every four years.

3) a) All men with Cat 2 or more pneumoconiosis
   b) or young men with Cat 1
   c) or any man showing rapid progression
   are offered a full-size chest radiograph and a lung function test every two years.

4) Full investigation is offered every two years to men at particular risk.

5)+ All men in (3) above are offered work in dust conditions below 3 mg/m^3.

Apart from the entry examination all further examinations are voluntary. The miner can refuse examination or if he wishes can neglect to follow advice on his working conditions. However in practice over 90% of men come forward for examination. The shortfall tends to be in the young age group who have just entered the industry. Incidentally virtually all British miners are of British origin; there are almost no foreign workers in UK mines.

All chest radiographs are full-size films and great emphasis is laid on

(a) the production of consistently high quality radiographs and

(b) the consistency of interpretation of the radiographs by the eight doctors involved.

+) (NCB policy - not legal requirement).

There is a need for doctors to ensure that these two factors are as comparable as possible.

The text of the 1971 ILO Classification of pneumoconiosis is used but for comparative purposes, the films from the 1968 ILO classification are used. (The 1971 radiographs are not considered to be accurate copies of the films originally selected).

It may be asked why the intervals should be 4 years and 2 years. In our dust conditions we believe that within such periods any change which we think we can detect is just as likely to be due to differences in film quality or some other factor as it is to indicate any real change in the pneumoconiosis picture.

I have tried to summarise legislation and medical practice over pneumoconiosis in the National Coal Board; later in the morning I will give you the results of our X-ray surveys.

FIGURE 1 (Dias)

THE COAL MINES (RESPIRABLE DUST) REGULATIONS 1975

A) DUST SAMPLING AND EVALUATION

(a)	Persons competent to sample to be appointed
(b)	Equipment to be approved
(c)	Evaluation to be at approved laboratory
(d)	Scheme for sampling to be approved
(e)	Manager to take action to reduce dust if dust level above specified figure
(f)	Work to stop if dust level above specified higher figure

B) DUST CONTROL

(a)	Manager to maintain a system to minimise dust production and to supress any dust produced

C) MEDICAL SUPERVISION

(a)	Owner to arrange medical supervision scheme

D) DUST RESPIRATORS

(a)	Approved dust respirators to be freely available and suitably maintained

Figure 2

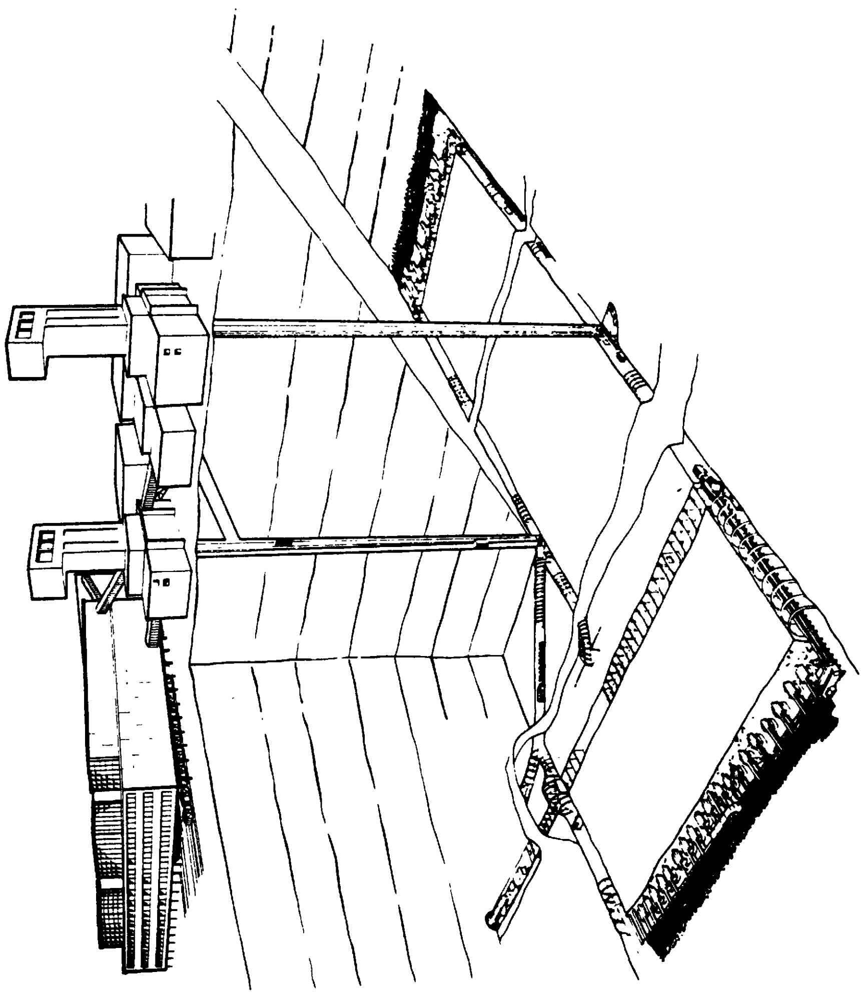


Figure 3

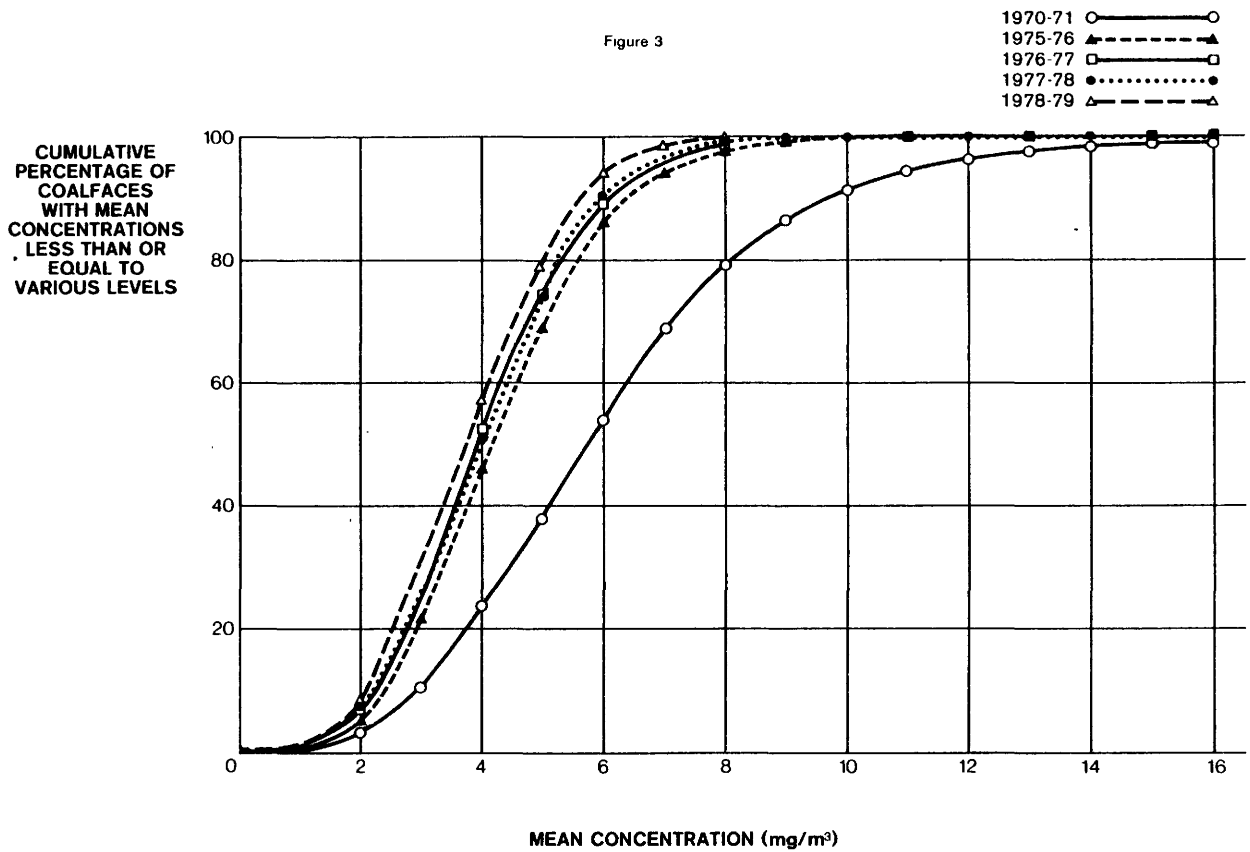

1970-71
1975-76
1976-77
1977-78
1978-79
CUMULATIVE PERCENTAGE OF COALFACES WITH MEAN CONCENTRATIONS LESS THAN OR EQUAL TO VARIOUS LEVELS
100
80
60
40
20
0
2
4
6
8
10
12
14
16
MEAN CONCENTRATION (mg/m³)

FIGURE 4 (Dias)

MEDICAL SUPERVISION

OBJECTIVES

1)	Fitness on entry
2)	Early identification of disease and protection from further risk
3)	Early identification of particularly susceptible individuals and their protection
4)	Monitor of dust control

FIGURE 5 (Dias)

MEDICAL SUPERVISION

1)		All entrants to industry have compulsory examination including full-size chest radiograph
2)		All men working at mines are offered full-size chest radiograph every four years
3)		
	(a)	All men with Cat 2 or more pneumoconiosis
	(b)	or young men with Cat 1
	(c)	or any man showing rapid progression
		are offered a full-size chest radiograph and a lung function test every two years
4)		Full investigation is offered every two years to men at particular risk
5)+		All men in (3) above are offered work in dust conditions below 3 mg/m^3

+) NCB Policy - not legal requirement

5.1. DEFINITION AND LEGISLATION

E. zur NIEDEN - Germany

In the West German coalmining industry, the development of techniques for measuring and analyzing dust, and the introduction by the mining authorities of regulations to protect underground workers have been closely dependent on both improved medical knowledge of the aetiology of pneumoconiosis, and technical possibilities for applying the regulations in practice.

In the early 1950s dust levels were first monitored and documented by means of regular and systematic dust measurements to determine the concentration of total respirable dust smaller than five microns (μ) in diameter and the rock concentration in this dust in underground workings. The results of these measurements were used to compare operations which generate dust and to determine the main sources of dust. The dust control measures then introduced were based on the findings obtained.

Industrial medical research into the development of pneumoconiosis showed that hazards for workers increase in proportion to dust concentration, quartz content, exposure period, and residence time of dust in the lungs, and that to reduce hazards for workers an individual medical assessment is required on the basis of a diagnosis. These findings lead to the introduction of the following measures.

1. Four dust exposure categories were created on the basis of dust concentrations measured.
2. On the basis of a medical examination each worker was assigned by the doctor to one category or group.

3. Limitations on employment were imposed on the basis of dust exposure categories and groups.

These measures, which the mines initially carried out voluntarily, became a modified and self-contained system after the mine authories' ruling of 1957.

From 1 January 1965 employment in dust exposure category 4 was prohibited. The following regulations were in force in North Rhine Westphalia :

Workers whose lungs were unaffected by dust, or in whom the effects of dust were questionable, could only work 500 shifts in dust exposure category 3 over five years.

Workers with radiologically confirmed, though not serious dustinduced lung changes were not permitted to work in exposure category 3. The minimum age of workers in this level was also raised from 18 to 21 years. Both groups had to undergo yearly medical examinations.

Workers with no dust-induced lung changes had to be examined every three years. The examination had to be carried out earlier if more than 100 shifts were worked in exposure category 3 in one year.

For the first time respirable quartz dust was included in the assessment of dust exposure.

In the Saar coalfield, limits on employment based on dust levels were also imposed, but they were applied to total dust values (respirable dust concentration x number of shifts) rather than to the number of shifts.

This assessment procedure made it necessary to divide the collieries up into zones and to keep a record of shifts worked in order to monitor the hours worked and to keep track of examination dates. This method has remained basically unchanged, although there have been great changes in permissible workplace levels and individual exposure levels.

In 1974, after publication of the maximum permissible workplace concentration (MAK), values for respirable dust containing quartz and respirable quartz dust, the tyndallometer was replaced for purposes of dust measurement by gravimetric devices. The concentration values k and kq were abandoned in favour of values expressed in mg/m^3.

Dust exposure categories are now determined on the basis of respirable dust containing quartz, and in the North Rhine Westphalia coalfield respirable dust is also taken into account.

Even when gravimetric analysis was first introduced it was understood that the limit values of the dust exposure categories would be reduced in time as medical and technical knowledge increased, and this has been the case.

The aim was to bringthe individual dust exposure of each worker as near as possible to the MAK values of 4 mg/m^3 for respirable dust containing quartz an 0.15 mg/m^3 for respirable quartz dust.

The mining regulations for North Rhine Westphalia did not contain any direct reference to the period for which the lungs are affected by dust.

This situation was completely changed by the new regulations dating from 1. Oktober 1979.

Basically, dust concentrations are still divided into categories, but the limit values are now as follows :

c	c_c	Category	Category factor
$\leq$ 2.5	$\leq$0.125	0	0.8
$\geq$ 2.5 - 5.0	$\geq$0.125 - 0.25	1	1.0
$>$ 5.0 - 7.5	$>$0.25 - 0.375	2	2.0
$>$ 7.5 - 9.5	$>$0.375 - 0.475	3	3.0
$>$ 9.5 - 12.0	$>$0.475 - 0.60	4	5.0
$>$12.0	$>$0.60	Non permis-sible	

Group	Maximum permissible dust exposure values / 5a
1	2.500
2	1.500
3	Prohibited
4	2.500

Dust classification for North Rhine Westphalia

If the quartz content of respirable dust is less than 5%, this determines the dust category. Each dust category has a category factor. Factors 0.8 and 5.0, which correspond to dust categories 0 (up to 2.5 mg/m^3) and 4 (9.5 - 12.0 mg/m^3), are calculated in such a way that account is taken of the hazards of high respirable dust concentrations and that temporary employment in areas of low respirable dust concentration may be guaranteed to offset this hazard.

In the case of workers with no lung changes, or with suspected lung changes, the product of number of shifts x category factor must not exceed 2500 in fixed five-yearly periods. In the case of those with clear but only slight dust-induced lung changes and of workers under 21 years, the dust exposure level must not exceed a total of 1500.

This regulation applies to the area under the supervision of the regional mining authority of North Rhine Westphalia and covers 85% of West German coal production.

In the Saar coalfield tyndallometers are still used rather than category factors to determine total dust values. Calculations cover periods of one year rather than five years.

From 1980 gravimetric values of respirable dust concentration will be used to set the limits of dust exposure categories and for total dust levels. Discussions on this are still in progress.

It is the mine authorities' responsibility to add up individual dust exposure levels regularly (that is, every month) and to adjust the miners' work to ensure that maximum individual levels are not exceeded.

The regulation described can only be controlled by means of electronic data processing. This does not present any major obstacles, as EDP has been used to protect the health of workers since 1959.

Given the present state of knowledge on penumoconiosis namely, that the hazard increases as the amount of dust accumulates, that it increases the longer the dust remains in the lungs and young workers are therefore particularly at risk, and that some people have a particular susceptibility to pneumoconiosis, the regulation described may be regarded as the optimum solution at present. Furthermore it can be adapted to future developments in science and technology which means that the existing supervision and control procedures will not be invalidated. Continuous progress and development are therefore ensured.

5.1. DEFINITION AND LEGISLATION

C. AMOUDRU - France

PRINCIPLES AND REGULATIONS

Under French law, the industrial medical officer's basic role is to prevent specific changes in health caused by occupational activities. Because of this, there are many regulations on preventive medicine in a wide variety of fields involving work with benzene, lead, ionizing radiation, and harmful dusts, but few cover the technical methods of prevention as such.

Preventive medicine in the field of silicosis and mixed dust pneumoconiosis, which are still the most common and most serious occupational diseases, is covered by Decree No 54-1277 of 24 December 1954 and various texts issued in application of this Decree, the most recent of which are Instructions DM/H No 1737 - 1739 of 15 December 1975 on preventive medicine in the field of pneumoconiosis and silicosis in coal mines. The complete texts are given in a leaflet published by the INRS, Prévention de la silicose - recueil des textes réglementaires, 1 June 1977 edition, INRS, Paris (1). These documents lay down regulations on the sampling of dusts, the conditions for their analysis, the classification of sites according to the risk involved, the procedure for medical examinations for fitness for workplaces to which people have been assigned or transferred, the recommendations to be made to the occupational medical officer, the statistics to be supplied to the Coal Board, and the methods for assessing maximum allowable concentrations in relation to the specific risk in each mine (see report by G Portal). This field is thus subject to many special

(1) Also in documents published by the French Coal Board and distributed throughout the industry.

regulations which are regularly brought up to date. Our intention here is not to go into them in great detail but to pinpoint a number of the basic principles involved, their measurable effects, and relative inadeguacies.

At a seminar on the interplay of research and preventive medicine, it is appropriate to point out that, before benefiting from the results of research in this field, the medical officers were among the instigators of the research. University and institute research workers did of course supply the basic data, often with financial aid from the Commission. But the mines medical officers contributed extensively to the planning and execution of programmes of preventive medicine, first and foremost through their specialisi knowledge of pneumoconiosis and its complications, but also through their studies of the working environment itself, and in particular, the first epidemiological surveys exploring the link between working conditions and pathology. The mines medical officers were very largely responsible for creating this kind of preventive medicine and many regulations are based on their work. A case in point is the annual occupational medical report submitted to the Mines Administration so that trends and risks can be assessed and the necessary corrections made.

There are various stages in preventive medicine. Traditionally, primary preventive medicine, which consists in avoiding the disease, is distinguished from secondary preventive medicine which consists in detecting occupational diseases and preventing the condition from becoming worse as a result of the job. Tertiary preventive medicine - namely the rehabilitation of affected individuals - is even recognized in some circles.

Primary preventive medicine

Under the French Labour Code, a pre-employment medical examination is compulsory, and Article III of the Decree of 24 December 1954 stipulates more precisely that no worker may be assigned to a site where there is a risk of pneumoconiosis unless a certificate drawn up on the basis of a special medical examination (for fitness for work in a specific workplace) states that he is fit to work there.

Article IV states that, before any worker is engaged, the employer must cause him to sign a declaration stating whether or not he has ever been in receipt of compensation for change of employment or of a pension for permanent disability caused by occupationally-induced silicosis.

Article V states that all medical examinations must include a chest teleradiograph or X-ray obtained by means of an approved procedure.

Article VI states that the above medical examinations should be carried out by the occupational medical officer.

The Decree of 18 March 1958 lays down the recommendations to be made to the medical officer responsible for preventive medical examinations. This states that contraindications for assignment of workplaces subject to risk arise mainly from the state of the bronchial tubes and lungs. Where the lungs are concerned, suspected active tuberculosis is an abolute contraindication. Other bronchopulmonary diseases, the after-effects of pleurisy or thoracic abnormalities are either absolute or relative contraindications depending on their degree and effects on function. We do not need to justify these rules as it is obvious that tuberculosis aggravates pneumoconiosis and that, if pneumoconiosis occurs on top of a pre-existing pathological condition, it is more damaging that if it occurs alone. Legislation has gone even further in making BCG vaccination compulsory in tuberculin-negative subjects under 25 years of age where there are no contraindications (Decree of 5 May 1964). Young people of under 18 years of age may be assigned to healthy workplaces only.

Is it possible to find a better selection procedure ? Lung clearance is known to vary considerably from one subject to another and the ideal solution would appear to be a test to eliminate applicants with a marked basic clearance deficiency for dust. Unfortunately, clearance appears to be variable in time and it would be difficult to base a long-term prognosis on a single assessment. Moreover, clearance capacity tests, which at the moment involve inhaling labelled particles (Fe 59), cannot be used in occupational medicine because of the cost, the time required for response, and the fact that the particles are radioactive. Another possibility is that certain immune factors may encourage the onset and development of pneumoconiosis. This has been established for the rheumatoid factor, but in other biological fields (blood group, HLA system, etc) there is no established evidence. Therefore, apart from the rheumatoid factor which, in any case, would disqualify the subject for other reasons, there is no biological indicator for predicting the likelihood of pneumoconiosis which could be used as a routine test in occupational medicine.

The point of having an examination for fitness for work at the place to which a person is to be assigned is in fact primarily to provide an objective document, which can be used subsequently for comparison purposes, on the condition of the subject before exposure to the risk.

Secondary preventive medicine

This involves regular examinations at intervals laid down it the regulations. The Decree on industrial medicine makes an annual medical examination compulsory. More specifically, DM/H 1739 makes an annual chest X-ray compulsory and reduces the interval to six months for specific particularly dusty workplaces. Respiratory function tests are not compulsory but works medical officers are free to ask for any additional examinations necessary for the diagnosis of an occupational disease or for the assessment of fitness. Details of the procedure for examination can be found in J Deflandre's report.

The main aim of these regular examinations is to detect pneumoconiosis at the very outset. Detection is the beginning of the procedure for compensation of occupational diseases as per Table No 25, wich does not concern us here.

Another aim of these examinations is to place staff according to any likely unfitness for work in a dusty environment, and according to the healthiness of the site.

Workplaces are classified according to the results of systematic sampling (number or weight of dusts and silica content). The regulations give six categories (A - F); (F) means that normal working, has been prohibited, (E) applies to particularly unsalubrious sites, and these are no longer worked; in practice this leaves four categories : two (A and B) are below the allowable threshold value, while two (C and D) are above this threshold value, so that particular precautions have to be taken vis-à-vis the staff and the work processes.

The workers themselves are classified by the works medical officer in accordance with DM/H 1739 in five categories of fitness, one of which represents unfitness for high-risk sites - that is, in practice, underground work (with the exception of some jobs in airways). The criterion used in the regulations for classifying fitness is the radiograph evaluated according to the ILO classification, and using the rough hypothesis that lung clearance is in inverse proportion to the lung dust burden evidenced by the radiograph (Lidell). A table of correspondence between the ILO classification and the fitness rating is annexed to the regulations (for example, pneumoconiosis of category 1 or 2 corresponds to fitness rating 3). However, the works medical officer has to adjust his decision in the light of additional factors such as pneumoconiosis appearing before the age of 40 years, rapid development shown by successive radiographs, or presence of other bronchopulmonary diseases.

Lung function tests are not included in these regulations, firstly because it is rare for them to change in incipient pneumoconiosis, and secondly because if there is any change it will show up in other aspects of the fitness assessments, such as arduousness of the work, respiratory irritants, and so on.

In practice, the regulations preclude individuals suffering from confluent forms from underground work; those with X-rays in ILO category 3 must be assigned to workplaces where the dust level is less than half the threshold value, and those in categories 1 and 2, to workplaces where it is between 50% and 100% of the threshold value. Dr Deflandre's paper will show how this surveillance is carried out in practice. Suffice it to say here simply that it is extremely strict and that detailed statistics have to be drawn up each year and submitted to the Coal Board.

These statistics comprise information on compensation - that is, based on medical forensic decision (recognition of an occupational disease by the authorities) - for workers and for retired persons, which is unique in French legislation. Moreover, for workers only, the applicable pension rate for pneumoconiosis is shown according to age and the ILO radiographic category is shown related to length of service underground. The Mines Administration is also supplied with matrix tables quantifying the radiological changes over a year. The epidemiological graphs referred to in G Portal's paper are also drawn up each year. I have added to these mandatory statistics determination of the index of progression as elaborated by the Medical Service of the NCB. This is an overall index which covers both new cases (change from category 0 to 1 or over in the ILO classification and changes from category 1 or over to a higher level (eg 2 $\longrightarrow$ 3).

This system was gradually introduced in the Nord-Pas-de-Calais coalfield during the 1960s. It was codified by a local Coal Board office decision in 1968, on the basis of this regional experiment it was extended to all coalfields in a more elaborate form in 1975 under DM/Hs, and since 1976 these methods have been implemented in all French coalfields.

Although not strictly speaking part of our subject, it is not inappropriate to discuss the results of such clearly defined medical protection.

For the workers themselves taken individually, detection is the most obvious benefit; in 1978, for example, 55% of the new cases of pneumoconiosis compensated were detected by our medical officers. It is not surprising that a certain percentage of cases slip through the detection mechanism because between two mass X-ray check-ups, that is over a period of one year, a number of cases may arise which were not sufficiently marked to be identified during the check-up in year "n" and are discovered by the medical officer or lung specialist before the check-up starts in year "n + 1".

Transfer to healthy workplaces is standard practice in preventive medicine for all other occupational diseases. Is it really effective in the case of pneumoconiosis ? Of course, adding further dust can only aggravate existing pneumoconiosis. Removing the risk or transferring individuals to suitably healthy workplaces thus eliminates this additional cause of deterioration. Is it enough, however, to stabilize radiological development completely ? Nothing could be less certain. Various studies, such as those of Groetenbril, have shown in the past that stabilization is guaranteed in a large number of cases only where the X-ray does not exceed category 1 of the ILO classification. In other cases, development continues, even if it is slowed down by transfer. Since these studies were carried out, a large number of new cases have come to light in the Nord-Pas-de-Calais coalfield among retired people, in many instances several years after they have stopped work and without any evidence of further exposure to harmful dust.

The checks made under Professor Voisin (Lille) have shown that these were not previously undetected cases of pneumoconiosis but authentic new cases occurring after a considerable interval. This proves that coal worker's pneumoconiosis is not simply characterized by excess lung dust burden as was once believed, but evolves in a particular way. It is not simply a mixed-dust pneumoconiosis, but a mixed form of pneumoconiosis in which both excess lung dust burden and fibrosis coexist. In any case, removing the risk is clearly not enough to prevent the onset of pneumoconiosis, much less to check its development, and although this may well slow down, the statistical evidence so far is not very convincing. It is, however, highly likely that removal from a dusty environment will help to safeguard respiratory function.

Moving on from the individual aspect to consider miners as a group, it can be seen that the legislation on preventive medicine has had a considerable effect. Firstly, the constraints imposed on employment in clearly unhealthy workings (number of medical examinations doubled, restriction on time spent in the most dusty workplaces so that dust exposure over three months remains equivalent to what it would have been in a working improved to acceptable health standards, etc) have helped to encourage collieries to discontinue sites of this kind. In 1979, in fact, 97.66% of workings (1) had a dust level equal to or lower than the norm, thanks to a great deal of work on technical dust abatement measures.

Finally and more importantly, the annual statistics, together with the matrix tables showing radiological changes and the epidemiological graphs, ensure that dust control in the working is monitored. Firstly, as can be seen in G Portal's paper, these statistics contribute to the definition of threshold values and their regular revision. More simply, they enable us to see, by comparing one year with another, whether trends are sufficiently good and thus represent a real yardstick and guide to the work to be done by the medical officer, the colliery management and the Mines Administration. This underscores the extent of the responsibility given to the occupational medical officer and justifies the high quality rightly expected of surveys which have such substantial consequences on both workers and the undertaking.

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(1) Workings in class O : 14,63%, class A : 55,53%, class B : 27,50%

In view of the serious nature of the problem, medical officers have gladly submitted to the legislation, which entails considerable work for them and obliges them to comply with particularly strict epidemiological requirements not imposed by any other occupational health regulations in France. In doing so, they have willingly given up some of their traditional moral and technical independence. But can we rest fully satisfied with this ? Of course not. If the state of our basic knowledge could be improved far enough, many doctors would want workers to be removed from dusty workplaces while the lung dust burden was still below the level which would trigger off pneumoconiosis identifiable by X-ray. In France we do not yet appear to have enough reliable scientific knowledge to justify proposals for preventive action of this kind; and the effects on workers' careers would be sufficiently serious to deter one from taking this course without adeguate evidence.

More specifically, initial selection on employment (medical examination of fitness for the workplace) does eliminate one or two susceptible subjects and transfer provides protection against undue development, but selection does not prevent the disease and transfer does not guarantee stabilization. With our present information we cannot therefore say that the medical prevention of pneumoconiosis in individual subjects is possible as yet. However, the epidemiological studies carried out under DM/H 1975 have allowed us to set targets for technical preventive measures and to adapt them according to the development of pathological knowledge and the social requirements. These preventive techniques are thus effectively guided by data based on occupational medicine, and this is the purpose of the legislation.

5.1. DEFINITION AND LEGISLATION

E. DOFNY - Belgium

Belgian legislation on industrial hygiene and health in mines and quarries dates back to the "Arrêté du Régent" of 25 September 1947, under which a comprehensive system of industrial medicine suited to the specific conditions in these industries was set up for the benefit of workers in our mines. This legislation has been amended on many occasions by Arrêté Royal (AR) or Royal Decree, the main amendments being those dated: 10/8/50 - 24/3/55 - 16/4/65 - 11/3/66 - 2/6/66 - 24/8/71 - 21/12/71 - 10/7/72 - 10/1/79.

It would be very difficult, however, to find in this legislation a definition of medical prevention of pneumoconiosis in coalminers.

The main aim of industrial medicine is, of course, to prevent occupational diseases. This is stated in Article 33 of the Règlement Général pour la Protection du Travail (RGPT) : "The task of this (medical) service, whose function will be basically one of prevention, will be..... 7th indent : .....to monitor industrial hygiene conditions and all other factors which may affect workers' state of health; 8th indent : ..... to give constant assistance to the management and various departments of the undertaking, as well as to the representatives of the latter and those of its personnel, with a view to preventing occupational diseases and industrial accidents as effectively as possible : ....

Article 64 (7) state that "the industrial medical service will monitor hygiene conditions in the undertakings referred to in Article 1 which come under its jurisdiction. It will pay particular attention to the following :

1 - health conditions at workplaces and general hygiene of the undertaking (ventilation, lighting, etc).

2 - the risks of any sort of occupational disease, whether or not it is referred to in the annex to this chapter or in Title II, Chapter III, Section I, Annex II of the RGPT;

In determining and analysing these risks, the industrial medical officer will refer to the lists of diseases given in Annexes I and II to the Recommendation from the Commission of the European Economic Community to the Member States, dated 23 July 1962, on the adoption of a European list of occupational diseases etc....".

Article 64 (8) states that "with regard to the tasks laid down in the previous article, the medical officer will advise the employer, the departmental mangement and the Comité Sécurité Hygiène (CSH), etc." "Wen visiting an undertaking pursuant to the previous article, the industrial medical officer will present to these persons or bodies, as the case may be, any proposal or comment he deems appropriate."

Article 64 (9) empowers the industrial medical officer to "request that an agency or laboratory approved by the Ministry of Labour and Employment carry out sampling and analysis of the abovementioned substances and products, the working environment or any other substances presumed to be harmful, as well as monitoring of noxious agents such as .....
The employer shall inform and consult the industrial medical officer about any changes made to manufacturing processes, etc.....
The employer shall notify the industrial medical service and the CSH of the results and conclusions of the abovementioned analysis and monitoring as soon possible."

Article 64 (10) lays down that "the industrial medical officer shall provide workers with any useful information as part of his task in the field of hygiene and health."

Article 65 (6) gives industrial medical officers "the right of access to undertakings" but specifies that "they cannot enter and stay in underground workings unless accompanied by a person duly authorized by the employer or his representative. If he deems it necessary, the industrial medical officer shall ask the CSH to nominate one of its members to accompany him to such workings.

Employers, their officials or representatives, and workers shall be obliged to supply industrial medical officers with any information they request with a view to enabling them to carry out their task."

These excerpts from the law governing the main duties of the industrial medical officer in mines show that, although the legislator lays down strict and often very precise obligations, he nevertheless gives the medical officer every opportunity to act on his own initiative in specific matters, even if they are not as yet covered by the RGPT.

This is demonstrated by the fact that, in the regulations on initial examinations and periodic check-ups, the RGPT provides for the use of radiography and functional and biological analyses but gives the medical officer the choice of which examinations, tests, or analyses to carry out. This therefore gives the industrial medical officer full freedom of choice while laying down clearly his personal responsibility in the exercise of his science.

Accordingly, if an effective system of medical prevention were ever devised in one from or another, the industrial medical officer would certainly be able to apply it with a clear conscience, without running the risk of being disowned by his supervisory council.

We are aware of the efforts that have already been made in this direction, but we also know how many illusions have been shattered (UV radiation, calcium, inhalation of alumina salts, use of PVNO, etc).

The future basis of pneumoconiosis prevention does not seem to lie with a medical technique still to be discovered. The only technique that has proved effective to date is that of technical dust control about which Mr Degueldre spoke to us with his customary authority and clarity. After 25 years as an industrial medical officer in the mines of the Charleroi coalfield and the Basse Sambre, I have come to the conclusion that there is only one effective way of preventing pneumoconiosis, namely technical control of dust, and only one effective "doctor", namely the safety and health engineer responsible for this control.

The industrial medical officer can make an effective contribution to technical prevention, with a view to making it as efficient as possible, in two ways :

1 - by ensuring, by means of a rigorous initial examination, that the industry has a labour force with a very high standard of both physical and mental health, and by carrying out periodic X-ray check-ups concentrating on the lung functions and respiratory tract and placing any worker suspected of incipient pneumoconiosis in category workings;

2 - as a privileged observer of the results of technical control of dust, by cooperating constantly, intensively, and amicably with the engineer responsible for this control.

Furthermore, in the personal relationships with the work force arising from the initial examinations or periodic check-ups and his work on the CSH, he can also draw the attention of all concerned to the unfavourable factors likely to reduce or counteract the beneficial effects of dust control in certain circumstances, such as acute or chonic lung ailments, and the scourges of atmospheric pollution and above all smoking and probably chronic alcoholism as well.

Still from his position as a privileged observer, the industrial medical officer will attempt to correlate the period of exposure to the hazard and the nature of the hazard with the findings of his clinical, radiographical, and biological examinations. In this function the industrial medical officer is still a key figure. As can be seen, we do not assign him a dominant role in dust control, which in our opinion is dependent not on medical techniques but on techniques of dust suppression at the place where it is formed. That is the job of the dust control department's team of dust samplers, which passes the samples on to an ad hoc laboratory, the whole process being supervised by the mines authorities. The industrial medical officer contributes to this control, but only in the manner described above.

Placing hope in the preventive value of certain drugs has so far led only to disappointments for industrial medical officers. It should also be borne in mind that the use of a preventive drug throughout a person's working life raises the problem of the long-term side-effects. We do not, therefore, believe that medical prevention can be effective.

The only effective way of preventing pneumoconiosis discovered to date is by <u>technical</u> control of dust, and that is a task which we can entrust to our friends and colleagues, the engineers of the Service Sécurité Hygiène (SSH).

5.1. DEFINITION AND LEGISLATION

D. CASULA / F. SANNA-RANDACCIO - Italy

In Italy there are coal deposits in Tuscany, Calabria, and Sardinia. The first two fields mentioned are relatively small and one of them is no longer exploited. In Sardinia, apart from a deposit in the central part of the island, there is also an extensive field in the south-west (the Sulcis Iglesiente field). In previous decades this fiel had been extensively worked, in more recent years it was merely kept in being, but now production has started up again. A form of anthracosilicosis is found in Sulcis coalminers. The clinical, radiological, and functional characteristics of this conditions bear more resemblance to the symptoms of pure silicosis, a disease which we are accustomed to seeing in the employers of our ore mines, than to the types of pneumoconiosis observed in coalminers in other countries (France, Belgium, United Kingdom, and Germany).

At the present time in Italy, there is no law which is exclusively concerned with the prevention of occupatonal diseases. Some of the provisions in the field of prevention are to be found in the laws on compulsory insurance against occupational accidents diseases; others occur in provisions referring to several or single occupational diseases.

Protection from occupational hazards and diseases is regulated in Italy by a system known as the "restricted" list system (this referes to the clearly defined list of occupational diseases for which compensation may be provided).

More specifically, where pneumoconiosis is concerned, the situation is as follows. Silicosis and abestosis are not included in the general table of diseases eligible for compensation but are found in a seperate table, and as from 1943 (Act No 455 of 12 April 1943 : extension of compulsory insurance against occupational diseases to include silicosis and asbestosis) special provisions have related to them. The remaining pneumoconioses - and not all of them, since from the point of view of insurance/compensation our insurance system recognizes only those occupational diseases which are caused by the hazards and occupations specifically listed in the table - have only recently beenincluded in the table which was last updated in 1975. In previous years, the hazards resulting from other dusts were in fact eligible for compensation only when the occupations exposing workers to them also entailed the inhalation of silica.

Art. 4 of Act No 455 of 12 April 1943 defined silicosis as follows : "pumonary fibrosis, whether combined with pulmonary tuberculosis or not, caused by the inhalation of free silicon dioxide dust, and which manifests particularly" (in a subsequent provision it is specified "but not exclusively") as bronchitis and emphysema and with effects on the circulatory system, and appears in the radiological examination as a diffuse dispersion of miliary nodular shadows, which may or may not be confluent". Today, however, this definition is no longer legally valid, as a few years ago a new statutory provision (Act No 780 of 27 December 1975, Standards concerning silicosis and asbestosis) repealed the article of Presidential Decree No 1124 of 30 June 1965 which contained this definition and simply mentions silicosis without defining it.

It is our opinion that, in the absence of specific instructions, the definition proposed by the experts of an ILO working party at the Fourth International Conférence on the Pneumoconioses (Bucarest, 1971), and which is generally accepted, should be adopted as a standard definition, including for the purposes of insurance. According to this definition, the term pneumoconiosis signifies an accumulation of dust in the lungs and the reactions of the tissues to its presence (for the purposes of this definition "dust" signifies an aerosol of lifeless solid particles).

The main statutory provisions on the medical prevention of silicosis (and, in practice, of all pneumoconiosis caused by mixed dusts) are to be found in the abovementioned law on compulsory insurance against occupational accidents and diseases (Presidential Decree No 1124 of 30 June 1965).

This law states that, before taking up employment in occupations which carry a risk of silicosis (these are listed in a table appended to the law), workers must undergo pre-employment and periodic medical examinations.

These examinations must be carried out by the works doctor or by occupational physicians of approved institutions, be repeated at intervals of not more than one year, and include, in addition to the clinical examination, a standard chest radiograph. The Industrial Medical Inspectorate may authorize the substitution of a radioscopic examination for the standard chest radiograph, provided that the format is not less than 70 x 70 mm (if the X-ray image does not permit proper assessment, a chest radiograph will be taken).

The clinical and radiological findings must be noted on a personal record sheet, in accordance with a set model (appended to the law).

Periodic check-up examinations are compulsory; a worker who refuses to undergo them will no longer be considered suitable for occupations which carry a risk of silicosis. If a worker is found to be suffering from silicosis, even in its initial stages, his employer and the Medical Inspectorate must be notified, as must the appropriate department of the local health unit.

The Industrial Medical Inspectorate is the regional body under the Ministry of Labour and Social Insurance which is at present responsible for inspection and surveillance, pending the introduction of the new provisions of the recent law reforming the health service. Under the new regulations, these tasks will be assigned to the staff of the National Health Service.

Apart from the pre-employment and periodic medical examinations which are prescribed by the statutory regulations, the Industrial Medical Inspectorate (and, in future, the local health unit departments) may, where necessary, order medical check-ups to be carried out on all or some of the employees of an undertaking who are exposed to a pneumoconiosis hazard. The law also states that the Ministry of Labour and Social Insurance (in future the Ministry of Health) is empowered to issue special technical standards for medical examinations, with the aim of standardizing as far as possible methods for recording objective data, particularly where the radiological findings are concerned. So far the Ministry of Labour has not issued any regulations of this kind. Periodic check-ups (and all the related laboratory tests) may be performed at present by works doctors or by physicians of specially authorized institutions; any institution which intends to carry out these examinations nationwide must be specifically authorized to do so by the Ministry of Labour and Social Insurance. The most important of these national bodies, the Ente Nazionale per la Prevenzione degli Infortuni (ENPI) (National Institute for the Prevention of Accidents), was largely responsible for this task in previous decades; the recent legislation to reform the health service provides for its abolition and the transfer of its structures and staff to the National Health Service.

The so-called "redeployment allowance" may also be considered as a preventive measure. If an employee is found to be suffering from silicosis and leaves his job so that his condition does not worsen, he will be paid a special allowance (in lieu of salary) for a whole year to enable him to find another occupation which does not entail exposure to the hazard of silicosis. Although this measure is based on indisputably valid principles, both socially and from the point of view of prevention, it is of limited value in practice, because of the well-known difficulties in finding any new job, and because of the problems which stem from having to train for a new occupation.

Standards for the medical prevention of dust-induced diseases are contained in Presidential Decree No 128 April 1959 (Standards governing mines and quarries). These provisions require employees in mines and quarries to undergo a medical examination before employment and each year thereafter in order to ascertain their suitability for particular jobs. These examinations are carried out by the company's occupational health service, which, must be set up in all mines and quarries employing 100 or more workers in the busiest shift; if such a health service does not exist, examinations may be carried out by physicians appointed by the Industrial

Medical Inspectorate. With the agreement of the Industrial Medical Inspectorate, the chief engineer may order special supplementary medical examinations.

Another preventive measure to be found in the same law is that relating to the compulsory use of dust protection masks, whenever they are found to be required.

Other provisions of a preventive kind can be found in various other laws and are of a general character rather than relating specifically to pneumoconiosis. Presidential Decree No 303 of 19 March 1956, for example, lays down general standards of industrial hygiene. Apart from requirements with regard to hygiene conditions of working environments and in the health and welfare services, and standards to be followed in protecting workers from harmful agents, there are standards governing action to be taken in the field of health and prevention. This includes the regulation that employees exposed to the hazards listed in an appended table must undergo a medical examination when they are recruited, and subsequent examinations at different intervals according to the hazards to which they are exposed. The Industrial Medical Inspectorate (and from now on the departments of industrial hygiene and medicine of the local health units) may prescribe special medical examinations, in addition to the usual examination, when these are considered indispensable for ascertaining the state of employees' health.

Where dust-induced diseases are concerned, the table appended to the Presidential Decree makes explicit reference only to vegetable dusts (cotton, flax, hemp, jute), and to iron, sulphur, and talc dusts (provided such dusts are free from silicon dioxide; if the latter is present the provisions relating to the silicosis hazard are applicable). The provisions of Act No 977 of 17 October 1967 can also be included among preventive measures with regard to pneumoconiosis. This Act, which governs the working conditions of children and adolescents, states that persons under the age of 18 years cannot be considered suitable for work underground in quarries, mines, etc, and that persons under the age of 16 years cannot be employed in open-air excavation work in quarries, mines, etc.

Finally, Act No 300 of 20 May 1970 should be mentioned. According to this "Employees' Code", employees have the right to supervise, through their representatives, the implementation of standards for the prevention of accidents at work and occupational diseases, and to promote the identification and implementation of any measures to safeguard their health and physical wellbeing.

CONCLUSION

This account has summarized the main statutory provisions in Italy regarding the medical prevention of pneumoconiosis. To conclude, although such provisions may be considered incomplete and unable to meet all the requirements of preventive action, they would nevertheless be effective if they were correctly and systematically applied, which is not at present the case. It is a fact that, despite the vigilance of the Labour Inspectorate, the existing provisions are frequently evaded.

5.2. PRE-APPOINTMENT MEDICAL EXAMINATIONS AND SUBSEQUENT CHECK-UPS

J.S. McLINTOCK - United Kingdom

Pre-employment

Radiographic examination of the chest is an integral part of a detailed examination of all entrants to mining in Britain. However, as virtually all entrants are of British origin, the amount of significant abnormality found is small. In particular the prevalence of tuberculosis is extremely low.

Between 20,000 and 30,000 men are recruited each year. About two-thirds are new entrants who have not worked in mining before; of these the great majority are under the age of 25 and could be expected to have little or no pulmonary pathology.

The remaining one-third are men who have previously been coal-miners and are re-entering the industry. Here the average age is distinctly greater and it is not surprising that more abnormality is noted. However they are only refused mining work if such work would clearly affect their health.

Periodic examinations

As set out in the earlier paper, all British miners are offered chest X-ray examinations every four years. This is done by sending mobile X-ray units using full-size radiographs to each colliery on a four yearly basis. Our collieries, have, on average, 1000 men.

This scheme was started in 1959. At that time the interval was five years, but later in 1974 to anticipate future legislation it was reduced to four.

Figure 1 shows the overall results for each round of surveys.

In Britain when the coal mines were nationalised in 1947, they had had very little capital investment for 20 or more years. The first need was a massive infusion of new equipment, and in the 1950s there was little doubt that great improvement in ventilation then also reduced dust levels underground.

By the end of that decade supplies of oil were flowing into Europe and all our coal mining industries began to contract, but at the same time new techniques of coal getting were introduced in order to remain financially viable. The intensive mechanisation of the 1960s gave our dust control engineers new and more difficult problems to overcome and it was not until late in the 1960s that dust control techniques began to master with confidence the greater dust production of the new machines.

Also in our research we demonstrated in 1968/69 that the mass of respirable dust (rather than the particle number) correlated well with the pneumoconiosis risk and in Britain we turned then to a gravimetric standard which more accurately identified those work places where more intensive dust control measures were required.

Since 1970 our dust levels have steadily fallen and I am happy to pay tribute to the excellent work of my engineering colleagues in this field.

These phases of dust control have been reflected in the data collected by our Periodic X-ray Scheme. Figure 1 shows a definite improvement in prevalence between the first and second round of surveys, an improvement but of limited scope between the second and third rounds and then a substantial fall in the most recent.

However over the last 20 years the mining manpower has changed dramatically - from 700,000 at the start of 1979 to 230,000 now.

Such changes could by themselves influence the prevalence statistics (eg. if the men who left were all men with pneumconiosis). (At this stage, I should explain that in Britain men who are compensated for pneumoconiosis need not be significantly disabled and normally continue in mining employment).

Crude prevalence data are therefore inadequate to give a true picture of the trends in pneumoconiosis. We must look at a number of parameters.

During 1978 our mobile X-ray units visited 54 collieries. Of these 41 had been surveyed on four previous occasions. It is therefore possible to examine the trend in prevalence at these 41 mines (Fig. 2). A very substantial fall in prevalence is obvious.

If one looks at the prevalence by age group (Fig. 3) again a very satisfactory trend can be seen.

We also examine the progression of pneumoconiosis, ie. the increase in radiographic pneumoconiosis among men in the industry. The method is complex but a ranking index is produced and Fig. 4 shows the trend.

Up to this point I have concentrated on our radiographic survey as a monitor of the efficiency of dust control. Let me turn now to the health supervision of individual men.

Fig. 5 shows that there are 2,733 men under two-yearly medical supervision with continued recording of the dust levels at their working place. About 70% of them are over the age of 55 and are likely to leave the industry within the next five years. The number of men under such supervision has been falling rapidly in the last few years and this fall is certain to continue.

Turning to the working conditions of these men (Fig. 6) about 93 % are working in low dust conditions. The balance have chosen to continue in more dusty work.

All our records are computer-based and each year analyses are made mine by mine of the prevalence and pregression of pneumoconiosis. Additional details are maintained for men under two-yearly supervision and these include their work places and the dust levels there; again, on computer tape.

There are three subjects which I have not mentioned :

1) Pulmonary function testing

2) Medical research

3) Compensation of pneumoconiosis.

We carry out pulmonary function testing using a simple field test of FEV_1 (Forced Expiratory Volume in one second) whenever this is indicated clinically, and as a routine on all men under two-yearly supervision. I am not convinced that we have yet achieved a consistency of technique sufficient to justify the analysis of the results on an epidemiological basis, but we are aiming at this objective.

Our research has established the relationship between the mass of respirable dust and the risk of pneumoconiosis, but we believe that there is a further factor or factors, probably in the dust composition. We have been unable to demonstrate the part which quartz may play, but we are continuing research on this subject.

There are three particular fields of pneumoconiosis research, (apart from those on other respiratory diseases) which are the following

(a) The importance of dust composition

(b) The causation of Progressive Massive Fibrosis

(c) The identification of susceptible individuals

On compensation, In Britain this is the responsibility of the government through the Department of Health and Social Security. Whenever it seems appropriate we advise men to make application for compensation, but we play no active part in the decision to award compensation. I believe that Dr Hentz is considering a further conference on compensation practice in our various countries and I will do no more than show Fig. 7.

In summary our pneumoconiosis situation in Britain has improved very considerably, especially in the 1970s. Although we have some 2,700 employed miners with significant degrees of pneumoconiosis, this number is falling rapidly. I believe that we can continue this trend and that our pneumoconiosis problem will be very small within the next ten years. Nevertheless, it will be necessary to have sufficient knowledge of significance of dust compositions and of the causation of PMF to direct dust control measures to the best advantage and of factors in individual susceptibility to use medical supervision most successfully.

PREVALENCE OF PNEUMOCONIOSIS : GREAT BRITAIN

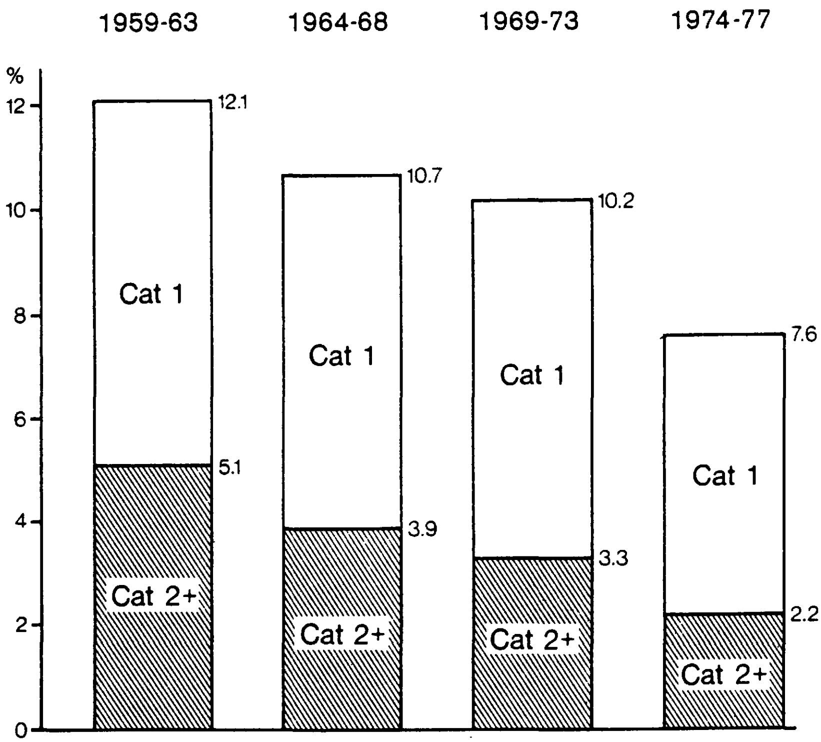
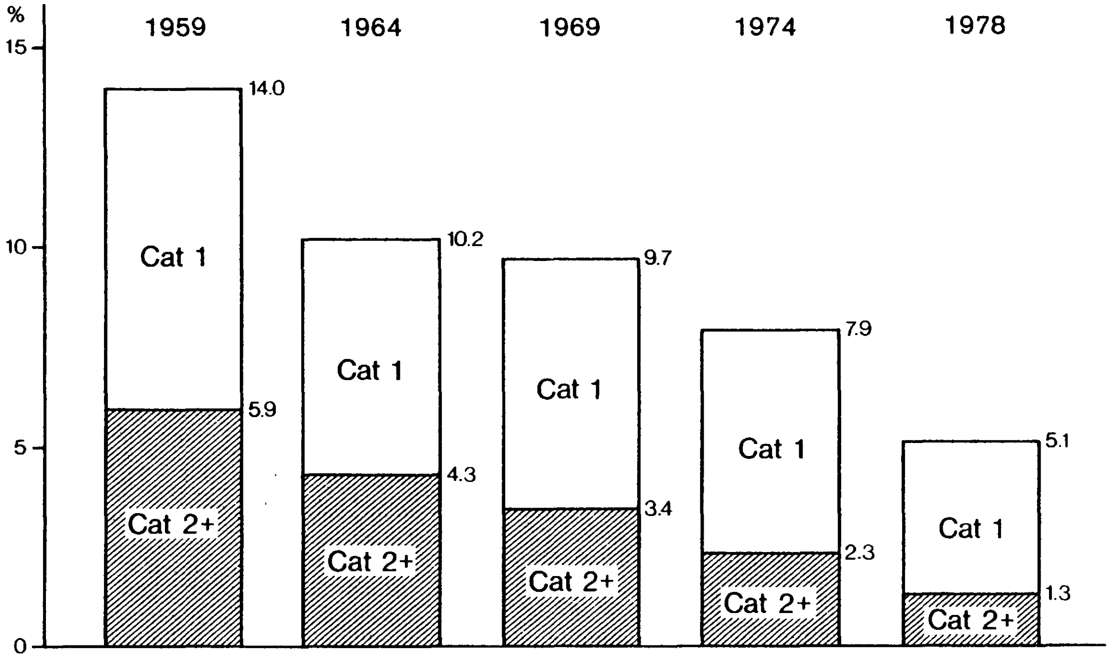


Figure 1

PREVALENCE OF PNEUMOCONIOSIS : GREAT BRITAIN
(at the same 41 collieries)



(Excluding men of 60 + years)

Figure 2

PREVALENCE OF PNEUMOCONIOSIS ACCORDING TO AGE
1978 COMPARED WITH 1974, WITH 1969, WITH 1964 AND WITH 1959

(% of men X-rayed in each age group)

(GREAT BRITAIN. Source: Periodic X-ray Scheme)

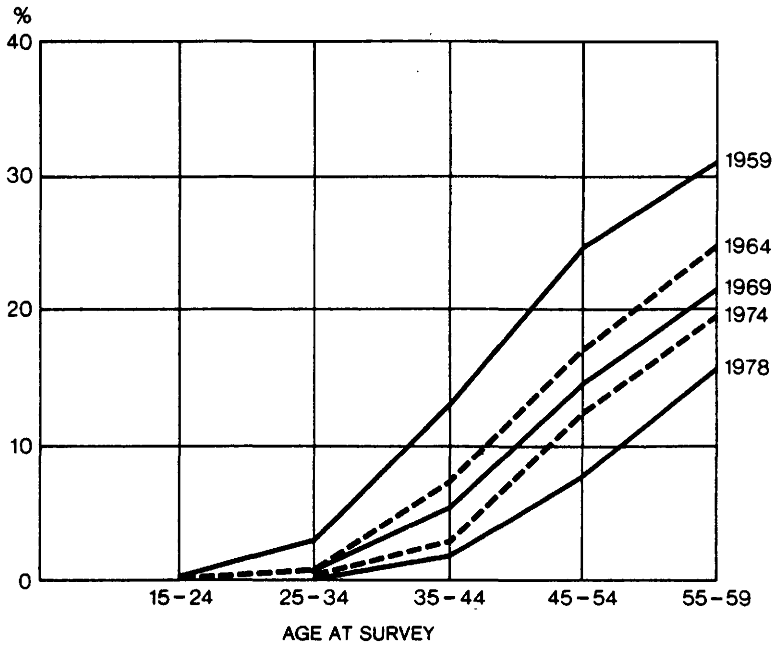


Figure 3

PROGRESSION INDEX

1964–1978

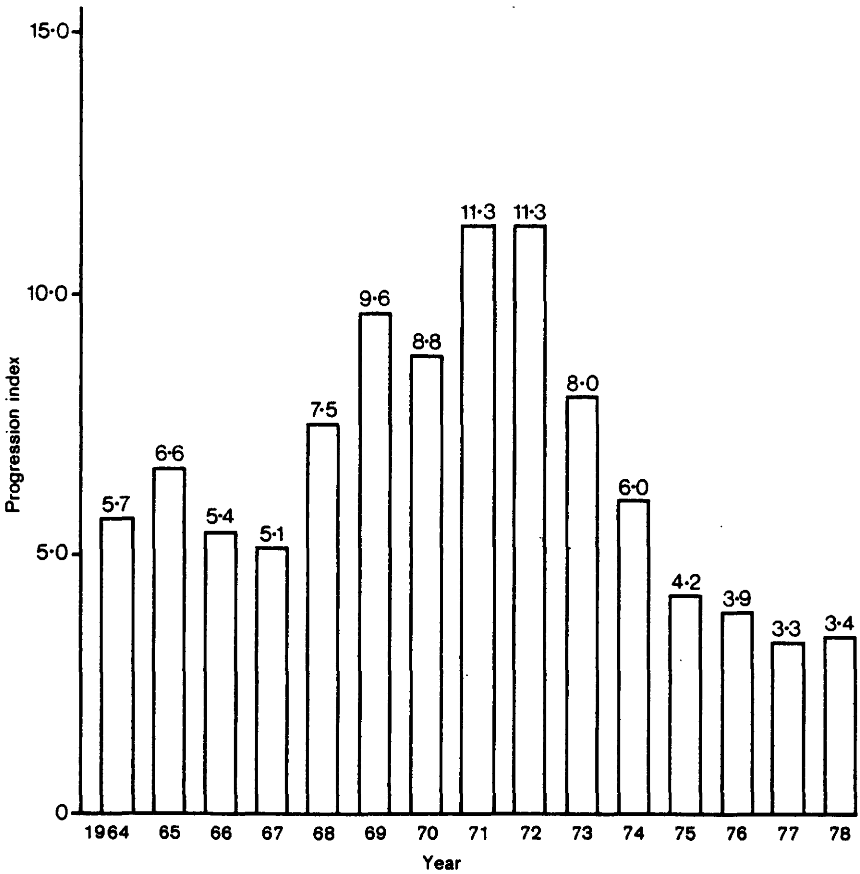
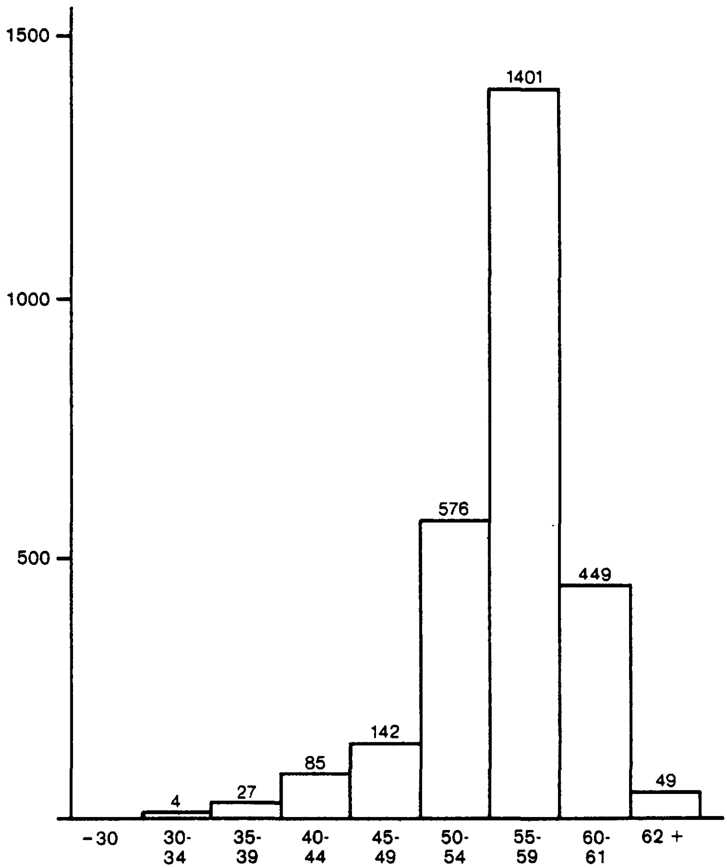


Figure 4

MEDICAL SUPERVISION

NUMBER OF PNEUMOCONIOSIS CASES BY AGE GROUPS

(AS AT MARCH 1979)



Total: 2733

Figure 5

MEDICAL SUPERVISION

NUMBER OF PNEUMOCONIOSIS CASES BY WORKING CONDITIONS

AS AT MARCH 1979

WORKING CONDITIONS	NUMBER OF MEN
Less than 3 mg/m^3	2,523
More than 3 mg/m^3	174
Not known	36
Total	2,733

FIGURE 6

PNEUMOCONIOSIS : NEW DIAGNOSES BY PNEUMOCONIOSIS MEDICAL PANELS 1965-78

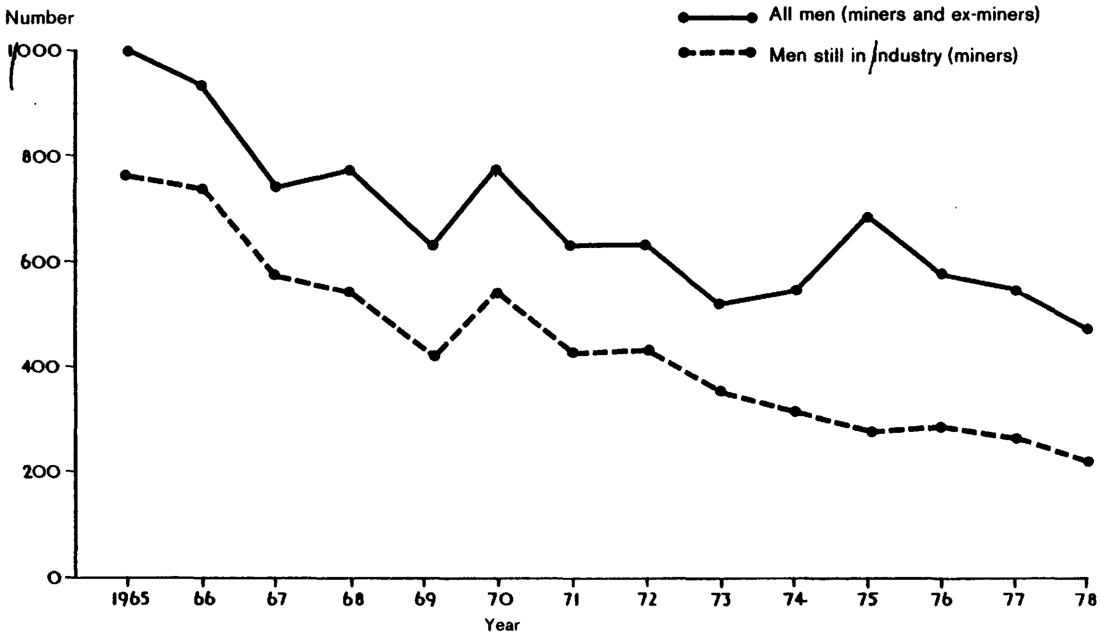


Figure 7

5.2. PRE-APPOINTMENT MEDICAL EXAMINATIONS AND SUBSEQUENT CHECK-UPS

J. SCHULTE - Germany

As already shown in the first section of this item on the agenda, medical practitioners in the German mining industry must place persons examined in an assessment group on the basis of their examination findings. Each mine authority is supplied with a medical certificate showing this assessment group.

Table 1 shows the assessment groups arranged in relation to the dust exposure categories which must be observed by the mines.

To comply with this mining regulation - classification in assessment groups - a number of conditions must first be met.

1. Medical practitioners must possess a special qualification regarding diagnosis of pneumoconiosis and be approved by the Chief Mines Inspectorate, the supervisory body.
2. The equipment used for examinations must satisfy minimum requirements. Requirements concerning the technique of taking and reading chest X-rays are set out in a special publication.
3. The examinations must be carried out in accordance with a programme approved by the Chief Mines Inspectorate. This ensures that the examinations are largely standard although the medical practitioner is allowed a certain margin for discretion.

The last point determines by and large the content of my report on medical assessment criteria for pre-employment examinations and check-ups.

For the majority of workers employed in the coalmining industry these examinations are conducted by the company doctor in occupational health departments run by the individual collieries. The examination generally involves an X-ray and a clinical examination.

Organization and technique differ from region to region but have little effect on the overall situation. For example, in the annual check-ups underground miners in the Saarland are generally X-rayed first of all by the mass miniature screening technique (Odelka), the standard-size film being used for suspect findings, whereas basically the standard-size film (35 cm x 35 cm) is stipulated.

In addition to the physical examination, the clinical examination comprises an exploratory ventilation test with determination of vital capacity, FEV 1, erythrocyte sedimentation rate, and urine status. If needed an ECG is taken.

The film of the chest X-ray is generally read by the competent company doctor. Where there are doubts or specific findings are made, arrangements are made for clinical observation in a specialist hospital or examination by a specially appointed team of doctors - for example, where early or rapidly progressing pneumoconiosis is suspected. The final assessment is made in conjunction with the company doctor.

The assessment is still based on the Johannesburg classification along with the 1958 ILO classification (table 2).

Table 2 : From medical certificate in accordance with paragraph 22

X-ray diagnosis : dust-induced changes

	None (0)	Question-able (x)	Slight (1)	Moderate (2)	Serious (3)
International classification (mark where appropriate)	0	z	p_1, p_2, p_3, m_1, m_2, m_3, n_1 n_2, n_3		A, B or C in the case of A + B with underground p, m or n

This dual system has been kept so far in order to maintain continuity, especially with regard to company doctors, expert opinion, and social security procedures, but will be replaced in the near future by the 1971 ILO classification using the 12-point scale.

Check-up intervals have already been mentioned. In addition to the intervals specified by regulation the medical practitioner can also stipulate a check-up at shorter intervals.

When considering medical assessment criteria a difference must be made between criteria for pre-employment examinations and check-ups.

1. Pre-employment examinations

In addition to the X-ray the doctor must look in particular for organic findings which may make the subject seem unsuitable for dust exposure work, especially greatly hindered nasal breathing which cannot be eliminated, major chest deformities, scars and thickening on the lungs, or respiratory and cardiac disorders. Existing pneumoconiosis changes naturally rule out employment of this kind.

Classification of persons into groups in accordance with the findings of pre-employment examinations

Assessment group A 1

Persons over 21 years without (0) or with questionable (x) dust-induced lung changes and without other physical damage impeding employment.

Assessment group A 2 a

Persons over 21 years without (0) or with questionable (x) dust-induced lung changes, but with other physical damage impeding employment.

Assessment group A 2 b

Persons over 21 years with dust-induced lung changes and with or without other physical damage impeding employment.

Assessment group A 3

Persons under 21 and persons over 21 years with dust-induced lung changes or other physical damage which makes them unsuitable for employment under and above ground.

2. Check-ups

Allocation to the different assessment groups in generally based on the X-ray findings.

Assessment group B 1

Without (0) or with questionable (x) dust-induced lung changes.

Assessment group B 2

Persons over 21 years with minor or slight (1) or moderate (2) dust-induced lung changes.

Assessment group B 3

Persons under 21 years with dust-induced lung changes
Persons over 21 years with silicosis which has led to an objectively detectable impairment of respiratory or circulatory function,
or
with early or exceptionally rapid progression of dust-induced lung changes or serious (3) dust-induced lung changes.

There is as yet no general statistical analysis of X-ray films and clinical and respiratory examinations, and hence an exact correlation between the various parameters, apart from individual projects such as special epidemiological surveys, is not possible.

Statistics are produced for the assessment groups, and the figure shows the percentage of miners with dust-induced lung changes (assessment groupe B 2 and B 3) from 1960 to 1978.

SUMMARY

In the German mining industry all underground miners are subjected to obligatory X-ray and, to a large extent, clinical examinations to prevent pneumoconiosis

- at intervals of not more than three years when there are no pneumoconiotic changes
- at intervals of not more than one year when there are pneumoconiotic changes or when a specific dust exposure threshold is set for the individual.

Examinations and assessments are performed primarily

- in colliery examination departments
- by the competent company doctor
- with standard-size X-ray films (35 cm x 35 cm)

- with the use of a dual classification system combining the Johannesburg and 1958 ILO classifications
- with determination of the ventilation parameters vital capacity and FEV 1.

Statistics are produced for the assessment groups and changes within these groups, but not for the overall results of the differentiated pneumoconiosis findings and clinical and respiratory examinations.

Table - Employment restrictions and time intervals between check-ups

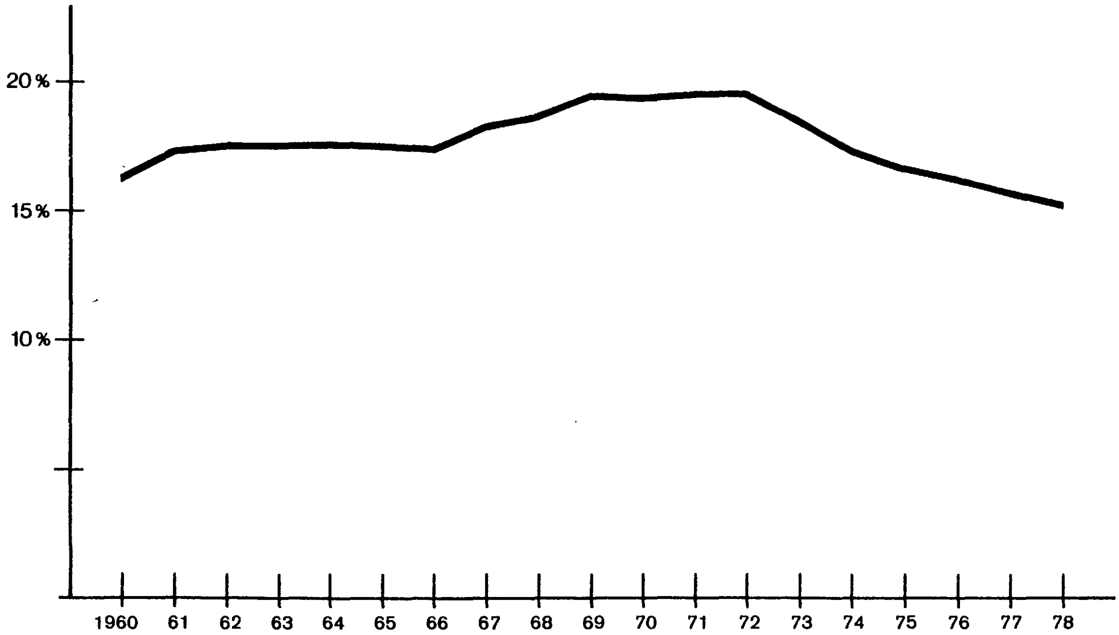
Assessment group	Underground employment at workplaces in dust exposure categories				Employment above ground with / without exposure to hazardous dust, gases, vapours, or mist		Longest period between check-ups in years taken over the duration of employment	
	1	2 Respirable quartz dust concentration		3				
		$k_q \leq 1$	$k_q > 1$		with	without	u	b and u_x
A 1	u	u	u_x	b	u	u_x	3	1
A 1 J) A 2 J)	u_x	u_x	prohibited	prohibited	u_x	prohibited	-	1
A 2 a without dust-induced lung changes	u	u	u_x	b	u	u_x	3	1
A 2 b with dust-induced lung changes	prohibited				u_x	prohibited	-	1
A 3	prohibited				prohibited			
B 1	u	u	u_x	b	u	u_x	3	1
B 1 J) B 2)	u_x	u_x	prohibited	prohibited	u_x	prohibited	-	1
B 3	prohibited				u_x	prohibited	-	1

Key : u = no restriction on duration of employment, check-ups at intervals of not more that three years

u_x = no restriction on duration of employment, check-ups at intervals of not more than one year

b = duration of employment restricted to 500 shifts for every five consecutive years/

Figure – Miners with dust-induced lung changes in the German underground mining industry



5.2. PRE-APPOINTMENT MEDICAL EXAMINATIONS AND SUBSEQUENT CHECK-UPS

J. DEFLANDRE - France

Décret No 54-1277 of 24 December 1954, amended by Décret No 55-300 of 14 March 1955 laid down "Special medical measures for the prevention of occupational silicosis in mines and quarries" amending and supplementing the measures laid down in the Law of 21 April 1880 and subsequently in the Décret-loi of 24 May 1938.

The 1954 Décret already contained the general framework upon which silicosis pneumoconiosis prevention measures are based.

Article 2 detailed the concept of work areas to which the provisions apply, and the frequency of medical examinations for persons employed in these work areas in relation to the particular hazard specific to different types of workings.

Article 3 stated that a worker may be assigned to a work area to which these provisions apply only if a medical certificate issued after a medical examination known as an "assignment examination" shows he is fit to work there, and that a worker may continue to work in a work area to which these provisions apply only if the certificate drawn up after each periodic medical examination provided for in Article 2 shows that he is still fit to work there. This fitness may moreover cover all types of work areas or be restricted to some types only.

Article 4 provides that a worker in receipt of an allowance for changing his type of work or of a pension for silicosis may no longer be employed in the work areas to which these provisions apply.

Article 5 states that "All medical examinations shall include either a teleradiogram of the thorax or radiophotograph of the thorax obtained by an approved procedure. Should there be any doubt about the interpretation of an X-ray film, a teleradiogram shall be carried out before the certificate is drawn up."

The assignment examination also includes a general clinical examination. This is required also if any abnormality is found on the X-ray. Subsequent articles lay down detailed rules for the keeping of files, record cards, and certificates by the occupational physician. In the event of any disagreement, the worker concerned or the employer, may, within a fortnight of the examination, consult a medical inspector who is a specialist in pneumoconiosis and who shall be given one month in which to prepare a report; proceedings shall be halted during this period.

The Arrêté of 30 November 1956 classifies the work areas to which these provisions apply in accordance with the way in which they are operated and ventilated, and lays down the intervals between regular medical check-ups which range from six months to two years. Long intervals are permitted only where effective technical preventive measures are taken, and this permission may be withdrawn at any time by the mines' engineer. A register which is constantly updated contains a list showing each work area with the interval adopted.

The Instruction of 30 Novembre 1956 essentially goes further into the technical aspects and gives details for the classification of work areas.

The Arrêté of 18 March 1958 sets out the terms of recommendations to be made to the doctor responsible for carrying out check-ups for the prevention of occupational silicosis in mines and quarries. The technical conditions for radiological examinations are laid down. Other radiological examinations may be prescribed by the doctor, as he thinks necessary. During the clinical examination, the doctor must ensure that the patient is in good general health and that the airways and cardiovascular system are not impaired. Further examinations, particularly lung function tests, may be requested to support the decision. It is also recommended that information be obtained on the previous jobs held by the worker (including any radiological records which may be obtained from the medical service of the previous employer).

Contraindications to the assignment of a worker to areas covered by these provisions consist essentially of bronchopulmonary disorders :

- active or suspected tuberculosis is an absolute contraindication;
- patients with pulmonary abnormalities or discrete and perfectly stable ganglio-hilardance, with the exception of those who are required to be examined medically every six months, may be declared fit to work in these work areas;
- minimal ganglio-pulmonary sequelae of primary infection are not a contraindication;
- other bronchopulmonary diseases, pleural sequelae, and deformations of the thorax constitute either an absolute or relative contraindication depending on their severity and how they affect respiratory function.

If a worker's X-ray shows suspect signs of incipient silicosis, account must be taken of age and duration of exposure. The lower these two factors are, the wiser it would seem to avoid assigning these workers to areas of work in which the interval between medical examinations is more than one year.

The rules for assigning workers suffering from silicosis are defined as a function of their residual capacity and tolerance levels and the requirements and hazards of the posts envisaged. These rules, already defined in previous legislation (Décret of 24 December 1954 amended by the Décret of 14 March 1955 and the Arrêté of 30 November 1956), and based essentially on the degree of functional impairment and the probability that the disease will progress, distinguish between workers according to whether the disability allowance granted for silicosis is above or below 10%. If it is above 10%, the worker will be reassigned to work areas not subject to these provisions or to areas governed by these provisions which are less dusty and for which medical check-ups are required every two years. If the allowance is lower than 10%, the above rule still applies but with exceptions for work areas which require an annual medical check-up.

Special measures are laid down on the one hand for persons under

30 years of age and those who habe been exposed to the hazard for less than 10 years, and on the other hand for individuals over 40 years, in order to provide greater protection where there is the greatest risk that the disease will develop.

Rules for approving the radiological equipment and the technical conditions for taking standard radiophotographs or radiographs are also laid down. Rules for drawing up statistics are set out in the Arrêté and the Circular of 15 April 1958.

The Arrêté of 10 May 1965 makes BCG vaccination compulsory for mining personnel and the conditions for carrying out this requirement are set out in DM/H No 455. Roughly speaking, this affects all workers under 25 years employed in work areas subject to the provisions, irrespective of the dust level or free silica content.

These are the foundations for all current legislation which was based for the classification of work areas on the continuous measurement of dust levels in the Nord-Pas-de Calais coalfield since 1965 using a Turbocapteur sampler. A knowledge of this classification of work areas made it possible for the Service des Mines to devise a special order for the coalfield called the "Consigne CALLOU" of 6 December 1968 for assigning staff on the basis of their medical fitness chart and the classification of work areas. I will not go into detail on this order which served as the model for the 1975 DM/Hs.

DM/Hs 1737, 1738 and 1739 of 15 December 1975 are derived from this order and place most importance on the X-ray code in the prevention of pneumoconiosis. They do, however, go further than the original order with a view to reducing the incidence of pneumoconiosis and slowing down the rate at which it develops in workers already affected. Work will be extended to the application of these statutory provisions concerning both the classification of work areas and the drawing up of dust codes on the fitness chart.

The classification of work areas is drawn up according to dust level measurements for which there are detailed rules both as regard frequency of sampling and the placing of sampling devices in relation to the nature of the work areas (type of activity - cutting, drivage, and so on and dust concentrations recorded).

Dust levels are measured constantly throughout the entire shift. The Turbocapteur samplers used previously for sampling by counting have been gradually replaced since 1975 by CPM.3 devices which measure by weight. Work areas are classified on the basis of a variable mean of four measurements, except at the outset when an overall value is taken by analogy with a work area of the same type and then corrected within 48 hours by the first of the measurements.

The dust hazard of a work area (e) is defined by the dust rating :

$$e = \frac{E}{E_o} \left[1 + a(T-7)\right]$$

where E is the result of a numerical count of particles of between 0.5 and 5 μ counted optically, t the free silica content of the respirable dust expressed as a percentage, a a coefficient equal to 0 if t $\leqslant$ 7 and E_o the reference dust level (2000 for the Turbocapteur sampler).

The formula for measurement by weight is identical :

$$e = \frac{P}{P_o} \left[1 + a(t-7)\right]$$

where P_o is fixed at 2 mg/m^3.

The detailed rules for application are set out in Annex 1.

All work areas are classified as a function of their dust as follows :

O with $e \leqslant 0.10$
A with $0.10 < e \leqslant 0.50$
B with $0.50 < e \leqslant 1.25$
C with $1.25 < e \leqslant 2.50$
D with $2.50 < e \leqslant 4.50$
E with $4.50 < e \leqslant 6.50$
F with $e > 6.50$ = <u>closed to staff</u>

Fitness chart codes

Under the "dust" heading to this chart there are five categories based on dust tolerance criteria, the first row of which contain the X-ray code according to the ILO classification, pulmonary clearance being roughly inversely proportional to the amount of dust already retained.

Factors likely to disrupt pulmonary clearance are also taken into account for example, pulmonary tissue made vulnerable by repeated broncho-pulmonary attacks, chronic infections of the upper airways, major sequelae of pulmonary tuberculosis, respiratory allergies, and patients thought to have bronchial hyperreactivity, the degree of which might well be determined by means of pharmodynamic ventilation tests. The same applies to the diagnosis of respiratory insufficiencies about which little is known. Since the procedure for studying the function of pulmonary clearance involves the use of radioactive materials, they are not suitable for use in occupational medicine, even though such a study might well provide valuable information.

The level of permanent incapacity attributable to silicosis is of secondary importance, since it is frequently known only long after X-ray changes have appeared. In contrast the duration of exposure to the hazard before the symptoms of the occupational disease appear is an important concept, since a short duration is a sign of an above-average dust intolerance.

An Instruction issued by the chief medical officer of the Nord-Pas-de-Calais coalfield on 26 December 1968 implementing the "consigne Callou" was used as a basis for the current provisions which are set out in an Instruction issued by the chief medical officer of the coalfield in January 1978 for determining the fitness of workers.

Fitness category 1 corresponds to :

- a normal lung X-ray code 0, with no previous history of active tuberculosis;
- no respiratory insufficiency;
- normal lung function tests (spirometry, CO transfer);
- no contraindications to the wearing of a respirator.

<u>Fitness category 2</u> corresponds to :

- a type 0/1 X-ray (formerly Z), with no sign of pneumoconiosis;
- discrete irregularities in lung function tests.

<u>Fitness category 3</u> corresponds to :

- type 1 X-ray (all ages)
  type 2 p or 2 m X-ray over the age of 40 years and with a partial pulmonary disability $< 20\%$;
- some slight deterioration in respiratory function;
- noticeable irregularities in the respiratory system (chronic bronchitis or early emphysema) or the cardiovascular system.

<u>Fitness category 4</u> corresponds to :

- type 2 p or 2 m X-ray under the age of 40 years or with paid compensation for invalidity of $> 20\%$; type 3 p or 3 m X-ray (all ages); type 2 N X-ray (all ages);
- minimal and stable sequelae of pulmonary tuberculosis;
- confirmed respiratory disease : dilation of the bronchi, chronic bronchitis, confirmed emphysema;
- obvious impairment of respiratory function.

<u>Fitness category 5</u> corresponds to :

- ability to work only in "dust free" work areas with no hazard ($e \leqslant 0.10$);
- type 3 N X-ray or confluent type A and to a greater extent B or C;
- significant sequelae of pulmonary tuberculosis or sequelae of uncertain stability;
- significant deterioration in respiratory function.

These recommendations are intended as a guide for the occupational medical officer who is completely free to increase the fitness code in the light of information at his disposal. Young workers under the age of 18 years may not be classified in fitness categories 1 or 2. Annex 2 illustrates the classification of workers as a function of dust tolerance and the classification of work areas.

Workers in category 1 employed in class D or E areas are monitored particularly carefully. The names of workers assigned to these work areas are entered on register published by the information departments in order to control the maximum number of authorized shifts. For work areas in class D the maximum number is 100 consecutive shifts or the wearing of mask, which remains optional. If a mask is not worn, assignment to a class D work area must be followed by an assignment of at least equal duration to less dusty areas (A, B, or C). Workers may not work in work areas in class E for more than 15 consecutive shifts; masks must be worn; after spending a period in a class E area, a worker must be assigned to a class A, B, or C area for a period at least 10 times as long as the period he spent in class E.

Special medical monitoring of these workers is carried out with standard 35 cm x 35 cm lung X-ray if they have been assigned during the year for at least 50 shifts to class D or 10 shifts to class E work areas.

In practice the coalfield has no areas in class E and very few in class D. The occupational physician is required to consult the registers of shifts spent in these work areas.

The chart of fitness codes as laid down in the DM/H 1739 is given in Annex 3. The time limit allowed for a change in assignment to a less dusty work area when a worker is placed in a different fitness category after a medical examination varies according to the class of the area in question : 15 days for workers in class B and C work areas; eight days for workers in class D work areas; and one day for workers in class E work areas.

Checking of personnel assignment

Assignment is checked a posteriori each month by computer which compares the codes for classification of work areas with the fitness codes. When a worker moves to class D or E, the Control Department immediately informs the employer and the administrative departments in order that assignments may be changed in the light of the new data.

Statistics which make it possible to follow trends in the hazard present are always based on the data in the Arrêté of 15 April 1958, with some modifications, taking account in particular of type 1 X-rays, with the preparation of epidemiological curves showing the prevalence of pneumoconiosis in relation to length of service underground. These curves are of great importance for establishing the reference dust level as Mr Portal explained in his paper.

In addition lists are published each fortnight of the names of new cases among both underground and surface workers. These lists are drawn up for each colliery or works and show the number of years worked underground and the total number of years worked. Thus it is possible to follow trends for each colliery and for the Comité de lecture des radiographies du Bassin to check systematically all new X-rays showing signs of pneumoconiosis, if they have not already received the films. This committee has been in operation for five years and is responsible for examining all new type X-rays or X-rays with a higher code which were previously type 0 or 0/1, seeing new A type X-rays, and also seeing a considerable percentage of 0/1 type X-rays to avoid missing type 1 borderline cases.

Radiological diagnosis is by annual high-voltage X-ray photographs in 10 cm x 10 cm format and recently 11 cm x 11 cm for the Nord-Pas-de-Calais. A wideranging reliability study of the method was carried out in 1977 in which Dr Amoudru and Mr Portal took part, and it appeared that if the films were read carefully type 1 images were successfully recognized and that less than 10% of the borderline cases were missed during the reading. To get closer to the problem a standard 35 cm x 35 cm film has for some time been systematically prepared for any cases where there is doubt; in addition a large format control film is prepared every three years for all type 0/1 X-rays.

In conclusion I should like to add that in addition to protecting workers suffering from pneumoconiosis in active employment, the Nord-Pas-de-Calais coalfield has extended its work to diagnosis and periodic monitoring of retired workers. This seems to me to be a very meaningful social action which does great credit to those who introduced it.

ANNEX I

Sampling intervals

e	Class	Opening of a new work area or similar Overall figure	Work areas under normal operation: If the upper limit of a particular class is exceeded	Normal periodical samples
	0	In the first 48 hours following opening, then every month for 3 months	Every month for 4 months if the excess is greater than 0.25	2 months
0.10	A	»	»	»
0.50	B	»	»	»
1.25	C	»	Every fortnight for 2 months if the excess is greater than 0.25	1 month
2.50	D	During the first 48 hours following opening then every week	Immediate classification in class E and sampling during each actual shift	2 weeks
4.50	E	During the first 48 hours after opening then during every actual shift	Immediate classification in class F and closure to staff	During each actual shift
6.50	F	Area closed to staff		

Work areas in class 0, A, B, and C are reclassified in the next class up within 48 hours of receipt of results of the last sampling if the arithmetic mean of the four last samples gives a dust level which exceeds the upper limit for that class.

ANNEX II

Classification of work areas / Dust code from the fitness chart	Possible assignment to work areas						
	0	0,10 A	0,50 B	1,25 C	2,50 D	4,50 E	6,50 F
1					special measures	special measures	
2							
3					closed to staff		
4							
5		After 3 months classification in fitness category 5					

ANNEX III

Coding of fitness for work with 'harmful dust' in relation to the X-ray image code based on the ILO 68/71 classification

Application of the DM/H 1739 of 15 December 1975

Type of X-ray image ILO 68/71	Fitness category		
	< 40 years	> 40 years	Partial pulmonary disability > 20 %
0	1	1	
0/1 (Z)	2	2	
1	3	3	4
2 p - 2 m	4	3	4
2 N 3 p - 3 m	4	4	
3 N A - B - C	5	5	

5.2. PRE-APPOINTMENT MEDICAL EXAMINATIONS AND SUBSEQUENT CHECK-UPS

F. LAVENNE / D. BELAYEW - Belgium

Awareness of the danger of pneumoconiosis in coalmines has not existed as long as one might think. To the best of our knowledge, the first work in this field was done in Germany. Before 1930, however, since people were convinced that silica was harmful and that coal was not, studies in this area concentrated on persons working in stone. Böhme's report to the Johannesburg Conference in 1930 is symptomatic of this tendency.

In Belgium, in 1955, the Fédération des Associations Charbonnières (Federation of coalmining associations) organized a study in the coalmines. Its purpose clearly shows that at that time only persons working in stone were expected to show signs of pneumoconiosis. In fact, according to Langelez (1946), this study covered 1000 miners with at least 10 years' experience of working underground, 900 being selected from among persons working in stone and 100 from among face workers, the latter acting as "controls". The results were something of a surprise : chest radiographs showed that 78% of the face workers as opposed to 70% of the persons working in stone had severe pneumoconioses lesions, and that 58% of the face workers as opposed to 40% of the persons working in stone had "advanced" pneumoconiotic lesions (stage 3 of the Johannesburg Classification).

From that moment on-that is, in the 1930s, most Belgian coalmines set up medical services which were designed, inter alia, to carry out pre-employment medical examinations and regular check-ups on the state of health of workers, despite the fact that legislation on preventive measures, which would have made this compulsory, did not come into being until 1947.

World War 2 saw the birth of the Institute d'Hygiène des Mines (Mines Health Institute), which brought together engineers and doctors and was to become increasingly active, working primarily in the area of pneumoconiosis prevention but also dealing with other problems concerning the health of mine workers, such as high temperatures and ankylostomiasis in particular. In the medical field, it was pre-employment medical examinations and fitness criteria on the one hand, and regular check-ups on the other, which were to receive particular attention.

Those in charge of the Institut d'Hygiène des Mines in Hasselt began work on pre-employment medical examinations as long ago as 1946. Many hours were devoted to preparation of recruitment criteria, which were published in 1948 by the Institute's medical committee. These criteria, classified under 20 headings refer to the various diseases and abnormalities which are contraindications to work underground.

As regards regular examinations, apart from developing a laboratory for lung function examinations the Institute d'Hygiène des Mines has been mainly concerned with improving the quality of radiological examinations, thereby acting as a pilot unit for the various coalmines.

Particular attention has been paid to investigating the value of small radiographs (7 x 7 cm) (10 x 10 cm) (10 x 12 cm). A statistical study carried out in 1958, which compared the readings made by 16 observers of large and small pictures, did not completely discredit the latter, even for the diagnosis of incipient pneumoconiosis (stage 1 in the ILO classification). In fact, we concluded this statistical study (Lavenne and Patigny 1960) with the following statement : "Small radiographs involve the risk of greater variation among individual diagnoses and accentuate personal bias, whether in an optimistic or pessimistic direction. For the average observer, the best way of reducing personal bias and errors of classification is to use large radiographs and to refer to a set of standard radiographs". However, we went on to say that "with training, at least some observers are able to classify pictures with extreme precision, even without referring to standard radiographs" and that "differences between various observers are so great that they totally mask the effect of being used to radiographs of a particular size. These differences may be due to physiological and psychological causes which merit further investigation. Indeed, for the correct diagnosis of the stage reached by a case of simple pneumoconiosis, the choice of observer is second only in importance to the radiological technique used". This probably accounts for the fact that small radiographs, which facilitate picture storage, are still preferred by some specially-trained individuals working in certain Belgian coalmines.

For pre-employment medical examinations, most centres always use large radiographs. In other centres, it is the doctor who, on the basis of a small radiograph, decides whether a large one is necessary.

The frenquency of subsequent X-ray examinations varies according to the age of the subject and his radiograph. Up to the age of 21 years (health protection scheme for young persons), regular examinations occur once a year, large radiographs being used. For those over the age of 21 years,a distinction must be made between rescue men and the large mass of mineworkers. For rescue men, X-ray examinations must be annual and large radiographs must be taken. For other workers, the examination takes place every two years and, in the absence of signs of pneumoconiosis, small radiographs are used although, if these indicate there may be disease, even in a discrete form, annual examinations making use of large radiographs are started.

Regular examinations of this kind, carried out in the Campine coalfield (virtually the only one still being worked in Belgium) produced the results given in Tables 1 and 2. It should be noted that the short classification of the International Labour Office has been used in Belgium ever since it appeared. Since 1971, the doctors at the Institut d'Hygiène des Mines have also been using the complete classification.

The tables, provided by G Degueldre (1979), show that pneumoconiosis (even of the incipient variety) is becoming much less common as technical dust control measures take effect.

In 1978, 95% of underground workers had not reached stage 1/0 of the complete classification after 10 and 14 years of exposure to dust. This percentage compares favourably with earlier figures of 62% (1959) and 64% (as recently as 1969) (Table 1).

Similarly (Table 2), between 1970 and 1978, the annual incidence of type 2 m radiographs dropped from 0.48 to 0.12% (among workers with 10 to 14 years' experience of working underground), from 0.89 to 0.23% (among those with 15 to 19 years' experience of working underground), and from 0.67 to 0.18% (after 20 to 24 years of working underground). Since pseudotumoural pneumoconioses - probably the only forms which by themselves cause real incapacity - hardly ever develop among coalminers except when type 2 pneumoconiosis is present, it can be seen that the risk to which they are exposed has virtually been eliminated.

Apart from their role in monitoring technical dust control measures, regular X-ray examinations obviously have medical implications for the individual. In this context, the Act of 24 December 1963 on compensation for injuries resulting from occupational diseases which is paid by the "Fonds des Maladies Professionnelles" (occupational disease fund) applies not only to compensation for pneumoconiosis but also to prevention of the disease. This led the technical committee of the Fonds to study the removal of workers from risk and to lay down precise medical criteria for this (Groetenbriel, Vande Weyer and Manette 1964).

Removal is recommended when radiographs show rapid changes, particularly when stage 1 is reached in less than five years, stage 2 in less than 10 years, and stage 3 in less than 15 years. Taking the figures in Table 1, this would have led to the removal of less than 0.5% of underground workers in 1978 compared with almost 20% in 1959 and nearly 10% as recently as 1969. This is further evidence of the great progress brought about in the last few years by technical dust prevention measures. The other criteria for removal suggested by the Fonds des Maladies Professionnelles are as follows :

- pseudotumoural pneumoconioses;
- miners with active or stabilized pulmonary tuberculosis, except where radiographs indicate primary lesions;
- chronic bronchitis, symptoms of obstructive disease, hyperactivity in the bronchi during provocative tests in such cases, removal is designed above all to avoid inhalation of inert dusts which might aggravate the bronchial inflammation.

That is why regular examinations in coalmines include, apart from clinical and radiological investigations, spirometric tests (vital capacity and forced expired volume in one second). Suspected cases are then refered to the Institut d'Hygiène des Mines for additional lung function tests.

However, we will conclude by reinferring a statement made by Dr Dofny - the medical preventive measures described can only complement technical dust control measures. Above all, they will remain a reflection of the effectiveness of these dust control measures.

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TABLE 1

Prevalence of pneumoconiosis in the Campine coalfield

Distribution of radiograph categories in relation to the number of years of exposure to dust, from 1959 to 1978

Radiograph category	Period or years	Length of service underground					
		<5 years	5 - 9	10 - 14	15 - 19	20 - 24	≥25 years
0/0 and 0/1	1959/60	90.21 %	77.33 %	61.37 %	51.00 %	38.70 %	30.71 %
	1969/70	95.01 %	88.97 %	63.40 %	54.13 %	42.81 %	39.69 %
	1974	99.64 %	97.13 %	92.67 %	80.00 %	69.95 %	57.32 %
	1976	99.68 %	99.02 %	93.54 %	85.24 %	74.93 %	66.38 %
	1978	99.76 %	98.95 %	94.98 %	87.76 %	77.66 %	70.26 %
1 (p, m)	1959/60	9.10 %	19.33 %	26.40 %	25.24 %	24.66 %	24.20 %
	1969/70	4.04 %	8.66 %	25.21 %	28.14 %	29.66 %	31.52 %
	1974	0.30 %	2.76 %	6.44 %	14.48 %	20.70 %	25.11 %
	1976	0.30 %	0.98 %	5.45 %	11.28 %	17.98 %	22.45 %
	1978	0.20 %	0.77 %	4.01 %	8.99 %	16.01 %	18.01 %
2 and 3 (p, m - n)	1959/60	0.69 %	3.34 %	12.23 %	23.76 %	36.64 %	45.09 %
	1969/70	0.95 %	2.37 %	11.39 %	17.73 %	27.53 %	28.79 %
	1974	0.06 %	0.11 %	0.89 %	5.52 %	9.35 %	17.57 %
	1976	0.02 %	-	1.01 %	3.48 %	7.09 %	11.17 %
	1978	0.04 %	0.28 %	1.01 %	3.25 %	6.33 %	11.73 %

TABLE 2

Incidence of type 2 pneumoconiosis (p and m) in the Campine coalfield

Distribution of new cases indentified during the year in terms of the number of years worked underground

Length of service / Years	10 - 14 years	15 - 19 years	20 - 24 years
1970	0.48 %	0.89 %	0.67 %
1972	0.31 %	0.45 %	0.60 %
1974	-	0.23 %	0.48 %
1976	0.06 %	0.17 %	0.19 %
1978	0.12 %	0.23 %	0.18 %

5.2. PRE-APPOINTMENT MEDICAL EXAMINATIONS AND SUBSEQUENT CHECK-UPS

D. CASULA / F. SANNA-RANDACCIO - Italy

This report concerns the criteria used in past pre-employment medical examinations and periodic check-ups, as well as the criteria applied at the moment and in the future.

In the years between the Second World War and the immediate post-war period some 18 000 workers from all over Italy were employed in the mines of the Sulcis coal fields. On appointment the company doctor simply gave them a clinical fitness test, as a rule without performing any examinations. Periodic check-ups were also based on clinical criteria (when available).

Since the 1950s company doctors have started to undertake annual check-ups with a stadard large-size chest X-ray using equipment installed in the medical departments of the mines.

At the end of the 1950s company doctors began to woth in conjunction with the "Istituto di Medicina del Lavoro di Cagliari" and since then international pneumoconiosis classification have been taken into account for the interpretation of X-rays taken by company doctors and Institute radiologists.

Between 1969 and 1973 these periodic check-ups included a case history taken by means of the standard ECSC bronchitis and emphysema questionnaire, standard lange-size X-ray. The technique used to take and develop X-ray films has always been the one recommended by the ILO working party on diagnostic radiography. As regards the classification of X-rays, ILO classifications have been used from the outset. The current ILO classification used is the 1971 one in its enlarged version - study of respiratory function by spirography (study of the residual capacity by the closed-circuit helium dilution method) on the basis of the standards contained in the ECSC technical memorandum for taking spirograms.

The data obtained from the spirographic examination are reported in absolute values and as a function of the corresponding ECSC theoretical values. An analysis has also been carried out by computer with printout of the spirographic diagnostic data.

The findings of check-ups are assessed on the basis of age and years of service. The type of work underground and at the surface is also taken into account.

What are the criteria and categories of unfitness ? It is generally accepted that pneumoconiosis can contraindicate work underground, especially in the case of respiratory deficiency, but it must equally be borne in mind that chronic obstructive bronchopulmonary diseases with obvious deficiency is also a contraindication.

The company doctor plays an important part in the deployment of workers in the various types of job, and in this respect a great deal of importance is attached to the X-ray although the clinical examination and respiratory tests are also taken into account.

Opinions on the use of a questionnaire, preferably the ECSC questionnaire, to detect any symptoms of cardiac and respiratory disorders in the check-ups of coalminers are favorable. Alongside the reduction in the number of cases of pneumoconiosis, witnessed in all our mining industries, our experience shows a high percentage of victims with a history of coughs and chronic expectoration for a number of years. For example, of the 500 workers in the Seruci colliery examined during our last clinical check-up, 94 (18.6%) reported a history of chronic cough and expectoration over a number of years, and of these, 55 has objective symptoms at the time of the check-up whereas fewer than 20 showed silicosis-type nodulation on the X-ray.

The use of a standardized case history form helps to avoid errors on the part of the examining doctor and of the worker who does not have, for example, regular expectoration, but may think that he has "chronic bronchitis" because this term is unfortunately overused.

The radiological examination is always carried out by standard large-size chest X-ray film. We feel that certain methods (7 cm x 7 cm - 10 cm x 10 cm X-rays), although still permitted by the regulations in force, are not suitable for early diagnosis and the study of the progression of pneumoconiosis (apart from the greater absorption of ionizing radiation which such methods automatically entail).

In our opinion the enlarged form of the 1971 ILO classification satisfies by and large the requirements of preappointment examinations and check-ups. As for the study of respiratory function in workers exposed to dust, the spirographic examination remains, in our opinion, one of the basic examinations. However attention must be drawn to the need to observe precise standards for the examination to be performed correctly. Monitoring of the graph by the technician during the examination is an indispensable aspect, in our opinion, and digital readout systems now on the market which only express the numerical result lend themselves, more readily to inexact results. On the other hand, we must remember that the spirogram has its limitations when it is wished to detect minor obstructive changes, such as those in the small airways. However, investigation of these changes for the assessment of associated bronchitis frequently found in miners leads us to analyse the forced expiratory volumes, such as can be obtained from an analysis of FEV1 curves (average respiratory volume between 25% and 75% and between 75% and 85% of the forced vital capacity) or from a study of the instantaneous forced expiratory volumes by pneumotachograph techniques.

Recourse to these tests is all the more useful since slight functional changes, which the spirograph does not show up, must be looked for in annual check-ups.

In a study of workers exposed to dust but without respiratory symptoms attributable to chronic bronchitis we found that the forced expiratory volume deteriorated over a period of three years, especially among smokers, and that this deterioration was not demonstrable by the vital capacity, FEV1, and residual volume.

Nevertheless, spirographic examinations can produce normal results even in the case of pneumoconiosis, and it is quite common to find that the ventilatory changes are not connected either with an extension of the nodular process or with the nodule size, marked changes in spirographic values being found as a rule only in the forms of confluent silicosis now considered as traditional. When they exist, spirographic changes are of the restrictive type, but also, because of the frequent association with bronchitis, of the obstructive type. Pneumoconiotic changes must therefore have a greater effect on lung capacity and blood gas exchanges, resulting in a possible reduction in PaO_2 and SaO_2.

Arterial blood gas in particularly important in this study and changes in these parameters may also occur before radiographic changes become evident. Practical difficulties connected with the implementation of the studies in company medical departments and a certain reluctance on our part to take arterial samples in these circumstances, even when convinced from our own experience that the technique entails no risks, lead us to exclude it from check-ups on miners. However, we feel that a study of gas transfer by the carbon monoxide method can provice useful information on blood-gas exchanges.

The simplicity of this test and its acceptability by the subject are well known. The method we use is CO transfer in a stable state. Our experience, which also tallies with that of various other authors, confirms the occurrence of a change in CO transfer in silicosis victims even when there are no spirographic changes.

The result is expressed both in absolute terms and as a function of the ventilation. Stable-state CO transfer is an overall measure of lung function in that it examines ventilation, distribution, and exchanges. However, our studies show that there is a statistical correlation between obstructive spirographic changes and CO transfer in bronchitis sufferers, whereas this correlation is not found in bronchitic and non-bronchitic silicosis sufferers, thus indicating that this test provides precise data on the actual exchanges. Useful information can also be derived from the single breath method, which has been used on 1500 workers in the mining industry over the past 10 years and appears simple to implement. We expect this method to be used on a wide scale on the future.

One of the most important functional tests is the test under effort, especially for miners with dyspnoea and abnormal X-ray results suggesting a form of incipient pneumoconiosis, and among those whose basic functional tests show little or no changes (for example, normal spirograph, inexplicable slight alterations in gas transfer with obstruction of the air passages or nodulation on the spirogram). In such cases the standardized ECSC effort test (30 watts, 3 min) shows a reduced tolerance to effort in terms of ventilation.

In a recent study of ours on a group of silicosis sufferers with forms of nodular silicosis without a history of chronic bronchitis and with slight ventilation changes at rest, the effort test showed a reduction in working capacity in terms of ventilation. This reduction indicates the beginning of hyperventilation at even modest work loads, as is borne out by the difficulty of oxygen transfer. This test will probably provide an additional, very important fitness criterion in case of doubt during the check-ups.

As already mentioned, the results of clinical and laboratory tests are assessed on the basis of age, length of service and of underground or surface work. However, it must be borne in mind that in our mines, especially in underground workings, there is a marked tendency to change frequently from one duty to another, which althoungh similar may entail a change in the exposure level (for example, the miner may be employed in shovel loading drilling, or clearing, etc). But even if a miner does not change jobs dust exposure levels can still vary greatly. In the past we have shown, in monitoring the dust exposure of coalminers, that the dust concentration can vary considerably in the space of one year at the same spot. Thus while we feel that the duration of underground work is a fundamental criterion, we must express our doubts as to the validity of subdividing it into various job categories, while recognizing, the absolute validity of monitoring over a period of time for each individual worker, which, if performed correctly, remains the best method with which to compare biological data.

Having said this, it is a simple task to recapitulate the measures currently taken during pre-employment medical examinations and to be taken at periodic check-ups. These comprise a case history by means of a questionnaire (in addition, of course, to routine examinations, such as ECG, haemoglobin determination, etc) an X-ray, and a respiratory function test, including in addition to the spirogram the forced expiratory volume and CO transfer, and possibly, if needed, an effort test. As for categories of disability, apart from all the bronchopulmonary diseases per se, we would point out that diseases of the upper respiratory tract, whether allergic on otherwise can also constitute a factor making for unfitness.

5.3. THE X-RAY CLASSIFICATION OF PNEUMOCONIOSIS
(ILO Classification)

J.A. DICK - Rotherham

Although interest in lung disease caused by the inhalation of mine dust has existed for some considerable time and individual contributions to literature were made as long ago as 1825, national and international attention to this problem can be said to have begun during the 1939-45 war, to have gathered momentum in the fifties and sixties and now in the late seventies it is universally accepted as the principal hazard in the industry, and conferences on the problem of coalminers' pneumoconiosis such as this one in Luxembourg are frequent. Such conferences can only be fruitful if a common language is used for the presentation and exchange of information on the subject under discussion. For coalminers' pneumoconiosis the common language is classification. Although not the first, the most important classification of pneumoconiosis was that agreed in Geneva in 1958. It resulted from a conference organised by the International Labour Office, was known as the I.L.O. (Geneva 1958) Classification and was accepted by most countries interested in this problem.

Briefly, the 1958 Classification divided pneumoconiosis into two large groups, simple and complicated (also known as progressive massive fibrosis). Simple pneumoconiosis was that form in which discreet opacities of a maximum size up to 10 mm were recognizable on the radiograph, and complicated was characterized by larger opacities of 10 mm diameter or greater. This was a natural distinction to make as simple pneumoconiosis differs in radiological appearances, pathology and natural history from complicated. The severity of simple pneumoconiosis was assessed by the extent and profusion of small opacities. Thus the earliest recognizable radiographic appearances was described as Category 1, the next stage was Category 2 and the most advanced was Category 3.

Because there were various sizes of small opacities and because it was usual for small opacities of approximately the same size to predominate on any one radiograph it was considered desirable to describe radiographic appearances in terms of opacity size. Three such groups were recognized. p (pinhead) for opacities up to 1.5 mm in diameter, m (micro-nodular) for sizes of 1.5 - 3 mm in diameter and n (nodular for sizes of 3 - 10 mm in diameter. Thus for simple pneumoconiosis a radiograph might be described as Category 2p or 3n.

Complicated pneumoconiosis was also described as having three stages or categories. Category A represented a large opacity or series of small opacities larger than 10 mm with a combined diameter up to 5 cm. Category B when the opacity was greater than 5 cm in diameter and occupied up to the equivalent of the right upper zone, and Category C where very large masses were present occupying more than the equivalent of the right upper zones.

In most cases of coalminers' pneumoconiosis the chest radiograph appearances are confined to simple or small opacity type. When complicated pneumoconiosis occurs it does so in the great majority of cases on a background of simple pneumoconiosis, thus the full classification of a particular radiograph might be Category 2nA or 1pC. The above were the essentials of the classification. Provision was also made of noting suspect cases of pneumoconiosis and also for indicating that some other condition was present.

As activity in prevention and research into the pneumoconioses developed in the late 1950's and 1960's it became clear that there were considerable limitations in the use of the 1958 classification for epidemiological purposes. There were two principle criticisms. The first was that the classification made no provision for dealing with asbestosis, and the second was that by using Category 1, 2 and 3 simple pneumoconiosis it was quite possible to fail to detect a considerable change (or progression) in dust retention as between one x-ray and the follow up x-ray some years later. In an attempt to meet these criticisms the I.L.O. organised a further review of the classification in 1968. Very shortly after this the American College of Radiology in conjunction with the U.I.C.C. (International Union Against Cancer) arranged a series of meetings culminating in Cincinatti, and largely directed towards including asbestosis in the classification. As a result of these meetings further changes in the classification were suggested. It was clearly undersirable that two differing classifications should be in use and that a international view should be achieved if possible. The result was an agreement reached at the Fourth International Conference on Pneumoconiosis in Bucharest in 1971. The resulting classification was known as the ILO/UC Classification and is that in current use. Two important changes relevant to coalminers' pneumoconiosis were made. To make it possible to measure much smaller changes in dust retention (or progression) as shown by radiograph changes between one x-ray and another, the elaboration of the 1958 simple categories devised by Liddell and adopted by the British National Coal Board was incorporated in the 1971 classification. This effectively divides each simple category into three sub categories by using the following method of reading. If during the process of deciding the category of simple pneumoconiosis the reader seriously considered another category as an alternative this is recorded. Thus Category 2/1 is profusion of major Category 2 but with Category 1 having been seriously considered as an alternative. Where the reader is in no doubt that no alternative category should be considered then this is recorded by repeating the category considered to represent a particular film. Thus an undoubted Category 2 would be recorded as Category 2/2. In this way the four point scale of major categories becomes a twelve point scale of minor categories. The second important change was that a new set of standard films was chosen and in many countries, including several represented here today, these standard films were considered to be unsatisfactory, so much so that several refused to use the 1971 standard films and retained for reading purposes the standard films issued in 1968. There is no doubt that the importance of the classification lies largely in its use for epidemiological investigations. And if data derived from epidemiology is to have any value on a national or international basis then two important conditions must be satisfied. These are that the classification used in reading trials should minimize the risk of observer disagreement and that strenuous efforts should be made to maintain consistency overtime by film readers. Judged by the first criterion the 1971 classification is far from perfect. For example in the past few years experts from Belgium, France, Germany and Britain (many of whom are present at this conference) studied 600 radiographs os miners and analysis of the results showed significant differences in reading standards.

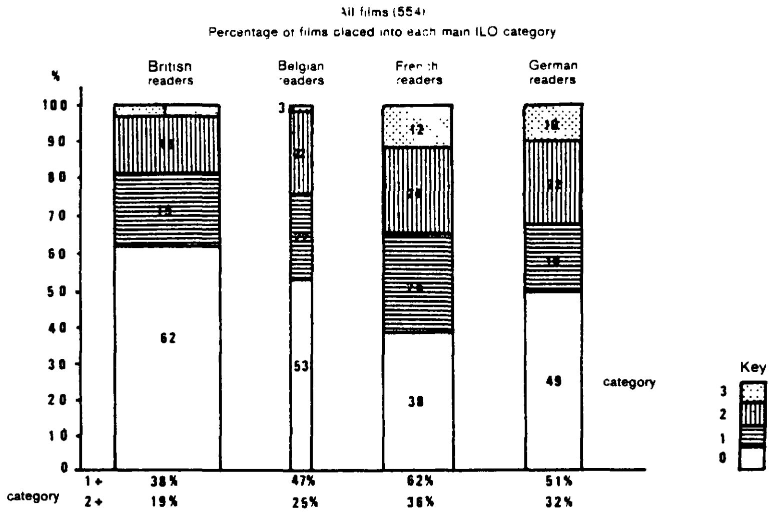

TABLE 1 - Consensus readings

As you can see British readers read considerably less pneumoconiosis on the same films as for example French readers did. At least part of this apparent disagreement was due to differing interpretations of written definitions of categories in the classification, and to definitions taking precedence over standard films. This and other problems have been considered in yet another review of the classification which has recently been completed. Following meetings at Washington, Caracas, Lannaken and Geneva agreement has been reached on the text of the 1979 I.L.O. Classification which will no doubt shortly be published. No alteration has been made in the level of x-ray change required for each category but more emphasis is given to standard films. Perhaps the most important aspect of this review is the choice of a new set of standard films. For the first time international reading trials have been used to select on a statistical basis films which by general agreement most closely represent specific categories. More than 70 readers took part in this exercise and this more scientific approach to the selection of radiographs together with the fact that copying techniques are now very much better than in 1971 should lead to much closer agreement within and between differing groups of film readers when using standard films.

With regard to the maintenance of consistency in film reading there may well be many methods of achieving this desirable aim, but it is essential that any exercises designed for this purpose should allow both intra and inter observer error to be measured. In the British National Coal Board two types of reading exercises are designed to meet this objective but there is insufficient time to describe these in detail.

It is fundamental to the effective use of the classification that chest x-ray films being used are of the best possible quality and every effort should be made to provide consistently first class radiographs. For large epidemiological surveys it is desirable to have some form of automatic exposure control and processing of the chest x-rays should also be automatic. If a change of technique is envisaged which may lead to changes in the appearances of chest x-rays then reading trials should be held to demonstrate whether or not changes in prevalence are the result of changes in technique and not to increased dust retention.

There is little doubt that successive revisions have improved the efficiency of the I.L.O. Classification as an epidemiological tool, but problems still remain and no doubt yet another review will be required in 1989/90.

5.4. LUNG FUNCTION TESTS APPLICABLE IN COLLIERY OCCUPATIONAL HEALTH SERVICES

G. WORTH - Moers

One of the most important tasks of occupational health services in the coalmining industry is to monitor the health of mineworkers exposed to harmful dusts. Nowadays, there is universal agreement that this necessitates an efficient X-ray machine, which, if possible, should also be capable of producing pictures with hard rays. However, it is impossible to assess a disease of the bronchopulmonary system and, in particular, the seriousness of a case of pneumoconiosis solely on the basis of a radiograph; in addition to the obvious clinical examination, lung function must also be measured.

In the last 10 years, this view has become generally accepted among specialists - due in no small measure to the results of the research projects aided by the Commission of the European Communities and the dissemination of these results.

Therefore it is all the more surprising that, in many instances, attempts to incorporate lung function tests into routine pre-employment medical examinations and subsequent check-ups and to purchase the appropriate apparatus still meet with considerable difficulty, although, in comparison with the price of X-ray apparatus, the cost is very low.

In the Federal Republic of Germany, while regular X-ray examinations of the lung for all persons working underground are clearly stipulated by the mines safety regulations of the regional mines inspectorates, there is as yet no corresponding stipulation regarding analytical lung function examinations. Occupational physicians in the

Ruhr and Aachen coalmining areas measure expiratory vital capacity and forced expired volume in one second (FEV_1). Regulations clearly stipulate that these lung function parameters must be measured regularly but as yet they only apply to persons exposed to heat and not to those exposed to dust. As some of the mineworkers are exposed to heat as well as dust, many occupational physicians carry out these measurements on all underground workers. If the findings produced by these examinations deviate sharply from the norm, arrangements are made for a thorough lung function analysis to be held in an appropriate centre.

For about two years some occupational physicians have also been using the oscillatory method of measuring resistance. Even without the patient's cooperation this method provides an objective parameter for the functional state of the bronchi. With the support of the European Communities, a reliable machine has been developed for this purpose over the last few years. In comparison with the considerably more expensive whole-body plethysmograph this machine has now become well-established.

Inquiries in the other coal-producing countries of the Community have shown that the situation in these countries is as follows.

In Belgium, occupational physicians measure vital capacity and forced expired volume in one seconde (FEV_1); however, there as yet no regulations making this compulsory. It is the individual doctor who decides whether these measurements should be made and the number required.

In France, also, there are no binding regulations on prevention. Some occupational physicians take simple spirometric measurements (VC and FEV_1).

In the United Kingdom, apparently, simple spirometric measurements are frequently, although not always, carried out during the pre-employment medical examination but not, it would seem, during check-ups, if pneumoconiosis is not present (the same is true of France).

In Italy, lung function is not tested during pre-employment medical examinations and check-ups, although it is tested during examinations carried out on a specialist's recommendation.

The outcome of these inquiries is very disappointing, especially for the researchers who are meeting here in Luxembourg in connection with the research projects assisted by the European Community and who have been dealing with this subject for over 20 years, and it should make us think about the reasons. On two previous occasions, at the ECSC symposium in Stresa in 1966 and at the symposium in Wiesbaden in 1970, we strongly emphasized the need for analyses of lung function to become a routine part of the health checks carried out on persons exposed to dust, especially since techniques for analysing lung function had already been developed to such a degree that tests of this kind are perfectly feasible and the time required is quite short.

Of course, it always takes some time before research findings and new techniques are applied on a routine basis. Nevertheless, why have simple techniques such as the measurement of vital capacity and forced expired volume not yet been generally applied ?

Firstly, it is probably parthy because many medical practitioners are still uncertain in their interpretation of test data. This, in turn may be due to the researchers in this field, who have failed to publish their findings and recommendations either in an adequate manner or in the right form. Here, there must be a wide dissemination of information - information which cannot be supplied by the equipment manufacturers alone. It would also be desirable if the occupational health bodies representing both employers and employees became more active in this area. Just as the interpretation of shadows in X-rays pictures is practised during courses in radiography, so should the use and evaluation of techniques for analysing lung function be taught as part of a course.

A second factor is the continuing widespread uncertainty as to which measurements are of most value in diagnosing lung diseases likely to occur in coalmining. The diagnosis of lung function first began with those measurements which are now gradually becoming more common in the coalmining industry, namely vital capacity and forced expired volume. Since then, however, researchers have made further progress and have criticized many aspects of these measurements, principally because they depend on the cooperation and and exertions of the test subject. If the latter fails to inhale to the maximum extent and then to exhale as rapidly and forcefully as possible, the measurements recorded will be too small and a functional disorders will be diagnosed erroneously.

Criticism has also been directed at the ambiguity of pathological measurements. A reduced vital capacity of forced expired volume found in a coal worker is not necessarily attributable to his work but may be the result of smoker's bronchitis, asthma, or, perhaps, merely a delicate constitution. This raises the question of finding valid reference values - a subject which has been and continues to be discussed with greater tenacity than in any other area to do with the medical diagnosis of function. Professor Tammeling will have something more to say about this later. The EEC commissioned standard tests as long ago as the 1950s and, in 1961, published a booklet containing reference values based on several thousand examinations in the countries then belonging to the Community. Since then there have been many other recommendations regarding reference values, but it is gratifying to note at this time that the values recommended by the EEC have been increasingly adopted by the Community countries.

However, the problem of the ambiguity of pathological values for VC and FEV_1 remains unresolved. Various research groups therefore have been trying to discover more and more new functional parameters with which specific lung changes in coal workers can be measured more precisely.

It is now fairly certain that these changes are not at all specific in respect to function. It is only the anatomist or pathologist who can show us that the lung changes he finds are caused by dust inhaled underground. This applies not only to silicosis but also to dust-induced pulmonary emphysema. Progressive airways obstruction and/or (!) impairment of gas exchange in the lungs can then develop as a result both of silicosis and of emphysema. On the other hand, some forms of pulmonary emphysema can develop without dust inhalation, but it is still not possible to distinguish these in terms of function. Moreover, obstructions and/or impairments of gas exchange can also be caused by these pulmonary emphysemas, which are not dust-induced.

Therefore, when an individual is undergoing a preventive examination, there is no need to know whether the functional disorder of his lung is caused by dust inhalation, another noxious agent, or both. When I have to give medical advice to a mineworker in whom I have diagnosed a functional lung disorder of whatever kind, I always advise him - even if an allergic asthma caused by rye pollen is the disorder in question - against exposing himself further to dust underground or anywhere else, because a previously damaged lung is definitely more prone to further damage than a healthy lung.

Before I come to my concluding recommendations, I must mention a third factor which has hampered and delayed the introduction of a standardized examination technique - namely, the variability of the findings. When I observe silicotic shadows or signs of pulmonary emphysemas on a X-ray picture, I can be certain that in six months' or five years' time these changes will not have become less extensive but will either have remained constant or will have grown.

Thus, if I now make a prognosis on the basis of such findings, I am bound to be right. This is not true of values measured when analysing lung function. A mineworker whose vital capacity I have just found to be 3.5 litres may, in one or two years' time, have a vital capacity of 4.5 litres - a much better result. If the lower standard limit for this man were 4.0 litres (related to age and body size), I would now have to describe his lung function as impaired (and take appropriate steps) whereas, next year or the year after, I would have to conclude that lung function was normal. Many people mistakenly consider these fluctuations to be caused by errors in measurement or to the unreliability of the method. In fact, such fluctuations are quite normal since there are variations in an organ's function. This applies equally to the heart, the liver, the kidneys, and even the brain. If a pathological value is obtained, one must always attempt to establish whether a reversible or irreversible condition underlies it. Repeating the test after one week or one month will provide appropriate indications. If this test should confirm the original "pathological" value of show that it has become worse, I must take this value seriously. If there is then uncertainty about the correct interpretation, a more thorough lung function analysis in a properly-equipped centre is advisable. Denpending on the findings of these additional tests, various steps will have to be taken, such as removal from the dusty environment, perhaps only temporarily in the first instance. If the function has improved after one year, this does not mean that the original step was the wrong one but that it has probably had a beneficial effect (just like a course of therapy, which does not have to be life-long either).

Now I turn to some practical recommendations. Vital capacity and forced expired volume (FEV_1) are those parameters in the analysis of lung function on which the most knowledge is available and which can be measured with a relatively simple apparatus. In many countries over the last 20 years, they have proved their worth and been used more and more. We also have suitable reference values, which can be used to evaluate test data. As regard VC, we must of course remember that it is sometimes measured during slow inspiration and sometimes during forced expiration. With some of the more modern machines, measurements can be made only during expiration. The EEC reference values, however, apply to VC measured during inspiration and cannot be used for measurement during expiration without some modification. In any case, VC measured during forced expiration provides more or less the same information as forced expired volume. It is therefore advisable to measure VC during inspiration. Thus, VC and forced expired volume are the basic parameters which should be the minimum requirement for every lung function analysis. A lack of cooperation on the part of the test subject can always be recognized when the results obtained from three separate measurements diverge by more than 10%. Nevertheless, this does not provide data which allow one to conclude that a disorder does or does not exist.

If one does not wish to rely on the cooperation of the test subject, the resistances which are hindering breathing must be measured directly. For use on a large scale, whole-body plethysmography will continue to be too expensive and complicated.

On the other hand, the oscillatory method - using a machine which costs only slightly more than a spirometer - also provides measurements which do not depend in the test subject's cooperation. If the resistance thus measured is high, one can safely assume that the breathing mechanism is impaired. With the same machine, it is now also possible to measure functional residual volume using the helium dilution technique. This method also provides indications as to the presence of pulmonary emphysema.

For the general diagnosis of impairments in respiratory gas exchange, preference is given - especially in English and French-speaking areas - to measuring the transfer factor for carbon monoxide. This is a bloodless and relatively simple technique which one would like to see more widely used.

In the near future, each occupational physician in the coalmining industry should be equipped with these tools - VC, FEV_1, RV, and T_LCO - so that he may detect functional impairments of the respiratory system in good time and protect the mineworker from serious damage.

5.5. HARMONIZATION OF LUNG FUNCTION REFERENCE VALUES

G.J. TAMMELING - Leiden

Pulmonary disease in coal and steel industry requires functional methods which are sensitive and specific to detect abnormalities, and which can be applied on a large scale and with relatively simple means. The sensitivity of a test depends on its power to discriminate between normal and abnormal. This again depends largely on the reliability of the reference values. Inevitably the criteria of normality must be valid for the workers in coal and steel plants, but they cannot be independent of those for other occupational groups and for the population as a whole. The specifity has to do with detection of abnormalities due to a specific disease, usually in a more advanced stage.

It is the aim of the working group to harmonize the reference values as well as the methods and procedures for assessment of pulmonary function, within and between the countries of the European Community for Coal and Steel. Harmonization is a first step to standardization, which has been a major objective for many years. Harmonization and standardization are processes which require updating at regular intervals. The present situation is as follows :

a. Some ECCS-reference values, e.g. lung volumes, do not apply to the normal working population in coal and steel and are therefore not applied in several ECCS-countries.

b. Insufficient data are available on the working age group of 16 - 25 years. This group of younger workers is extremely important in the context of prevention and/or early detection of pulmonary disease.

c. New functional methods provide presumably more sensitive and more specific tools for the detection of disease in comparison with the conventional methods. These new techniques must be evaluated for their applicability on a large scale in coal and steel.

d. When a new technique provides relevant information on occupational disease in coal and steel, but is not suitable for application on a large scale, comparative studies with simple and reliable alternative methods are required.

e. Technical and methodological developments of pulmonary function tests differ between the ECCS-countries. Therefore harmonization of pulmonary function testing in coal and steel should fit into the larger scope of occupational health control.

For practical reasons the working group focussed primarily on lung volumes[+)], ventilatory dynamics, lung mechanics and pulmonary gas exchange. The activities are directed to the execution of supplementary research as well as to the publication of recommendations :

a. terminology, abbreviations, definitions, units
b. harmonization (standardization) of lung function methods
c. harmonization (standardization) of reference values.

Inevitably the future work must be based on and must take into account previous activities and recommendations in this field :

a. ECCS document (Nr. 11) on spirometry and lung volumes.
b. the European Society of Clinical Respiratory Physiology (SEPCR)
c. the European branch of WHO
d. national activities in Europe
e. USA (Atlantic City, Snowbird workshop, Epidemiology standardization)
f. the editorial boards of major international journals.

These sources provide rather divergent or even conflicting recommendations on terminology, units, methods, procedures, measuring conditions and reference values. The guiding principle of the ECCS working group is to account primarily for the recommendations of European societies

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+) Static lung volumes are not included in this presentation and scientific journals, and to compare these with the American ones. The following examples demonstrate the difficulties :

a. In the European community and in most European scientific medical journals the SI-units are accepted. In the USA and in American journals SI-units have not yet been accepted. Our working group will presumably recommend SI-units and additionally within brackets the traditional units.

b. On the continent of Europe the VC is commonly measured as an inspiratory breathing manoeuvre, while in Anglo-american countries the expiratory VC is the standard procedure. The working group will presumably recommend the inspiratory VC as the standard lung function test.

c. The first-time derivate of volume is usually indicated by $\dot{V}$. However $\dot{V}$ can be used in two different ways : $\dot{V}$ as symbol for the instantaneous flow in l/s (f.e. $\dot{V}_{E,max}$); $\dot{V}$ as symbol for the time-averaged flow in l/min (f.e. $\dot{V}_{CO_2}$). The recommendation of the SEPCR is different : $\dot{V}'$ for instantaneous flow and $\overline{V}'$ for time-averaged flow. Probably the working group will follow to a large extent the SEPCR-recommendation, but the American notation will be accepted.

Harmonization and standardization of the reference values for lung function tests can be attained by the following procedures :

a. The reference value of a lung function index is harmonized by algebraic conversion to all other reference values of the same index. Inevitably this leads to an unmanageable system of numerous conversion factors.

b. The reference value is harmonized by one single conversion factor to a standard reference. The choice of the best European standard is a point of further discussion.

Quanjer compiled the reference values for lung volume ventilatory dynamics and gas transfer most commonly used in the countries of the European Community for coal and steel. This work is based upon information provided by the members of the working group. The results are as follows (table I) :

1. The ECCS-reference values are the most frequently used single reference values, and are widely accepted in about 50% of the EC-countries. Equations for the computation of ECCS-reference values are available. Its seems possible to harmonize reference values for static and dynamic

lung volumes in all EC-countries by applying appropriate multiplication factors on the ECCS-standards (table II).

2. The tables of the ECCS nomograms due to Amrein tend to overpredict FEV_1 and TLC in tall men and women at a young age and at all heights in elderly subjects, when compared with other reference values.

3. There is a poor agreement in predicted values of MMEF.

4. There is a very wide variation of indices derived from MEFV-curves. The effect of age on the shape of these curves and on the absolute values of effort-independent flows has not been satisfactorily established yet. It is likely that this is at least in part due to technical differences (equipment, instructions, presentation of data), so that these must be standardized before meaningful comparisons can be made.

5. No satisfactory data on MVV nor on the FRC are available.

It has also been suggested to transform the different regression equations into a new one (from now on referred to as summary equation) as has been done for children by Promadhat and Polgar. In doing so several simplifying assumptions had to be made :

1. TLC is dependent on stature only.
2. $FEV_{1,\%}$ is related to age only, as is K_{CO}.
3. Other variables can be predicted on the basis of stature and age, weight being neglected since it does not consistently reduce the residual variance.
4. In view of the large scatter in predicted values little if anything is gained by using non-linear models.
5. The residual variance of the new estimate of dependent variable can be taken to be the mean of the variance given by different authors.

The summary equations for men are shown in table III.

A more detailed analysis of the summary equations is required. Particularly attention should be paid to the validation of the summary equations by applying them to data on "normal subjects" in the various European countries, taking into account smoking habits, and paying attention especially to the possibility that linear regression equations might lead to slight overpredictions at a young ($\pm$ 20) and old ($\pm$ 60) age and a small underprediction at intermediate age. Ulmer et al. underlined the fact that body weight cannot be neglected. They prepared regression equations which yield results which fit very well to those obtained by the summary equation. It is a point of discussion in how far body weight should be included in regression equation. Furthermore, harmonization and standardization of reference values cannot be achieved without taking into account the methods used as well as the measuring conditions.

Three examples will be given to demonstrate this :

1. Cotes, Peslin and Yernault prepared a working document on dynamic lung volumes and forced ventilatory flow. Many indices may be used to describe the forced expiratory spirogram and the forced expiratory flow-volume curve. They are highly correlated, and it is common practice to use only two or three of them. The following are recommended :
   FEV_1; FVC, PEF, $FEF_{50\%\ FVC}$; MMEF
   optional : FIV; $V_{iso} - V'$; FEF_{60}; FEF_{75}; ΔFEF_{50}; $\Delta V'$; $FEV_{1\%FVC}$; $FEV_1\%VC$; $RV_{\%TLC}$.

   The authors indicated that the scatter of the reference values of MEFV-curves is usually very large. Therefore, interpretation of deviation from the reference values inevitably has a high margin of uncertainty. Peslin made a comparative study of eight different methods for calculating maximal expiratory flow-volume curves : among others (table IV) :

   - indices from the curve yielding the largest FVC (method I).
   - indices from the curve yielding the largest FVC + FEV_1 (ATS-recommendation) (method II).
   - indices of the composite curve (envelope-method) superimposing at TLC (method VI) or at RV (method VII), at 50 % FVC (method VIII).

   Taking into account both the problem of bias in the results and the reproducibility, it seems that method VI (envelope-method at TLC) may be recommended. This method is easy to implement and reference values using that method are available. A composite of 5 curves gives better results than a composite of 3 curves.

2. The working document on the pulmonary gas transfer factor (T_L) has been prepared by Cotes. T_L can be measured by at least six different methods. The $T_{L,CO}$ single-breath-holding-method is widely used and recommended as the method of choice. Because the determination of $T_{L,CO}$ is highly dependent on the measuring procedure, the method should standardized into details : analytical method, breathing manoeuvre, alveolar volume, calculation and correction, CO back tension, haemoglobin concentration. A subdivision of the $T_{L,CO}$ into a membrane component and a blood component is beyond a wide application. In practice the standardization of reverence values is performed only with respect to age and stature. The variations reflect in part technical differences between laboratories.

3. Yernault prepared a working document on the measurements of the technical properties of the lungs using the oesophageal balloon method. Lung elasticity is a basic determinant of lung volume and of forced expiratory flow. It probably is a sensitive and specific index of early fibrotic (pneumoconiotic) and emphysematous lesions. The method cannot be applied on a large scale but it is extremely important as a "second line" procedure to verify and specify pulmonary disorders detected by simple functional tests. It is a point of consideration which indices should be recommended for clinical practice :

   - static (quasi-static) compliance above FRC-level
   - dynamic compliance (frequency dependency)
   - transpulmonary pressure at TLC (P_{TLC})
   - coefficient of retraction (P_{TLC}/TLC)

   Very few recommendation are available for the technical procedure of the oesophageal balloon method. Lack of standardization of the measuring procedure explains why currently available reference values do not agree. Further work on harmonization of lung mechanics is urgently needed.

   Epilogue : Any work done in the field of harmonization and standardization provokes considerable resistance and reluctance because a doctor is very attached to his own experience with respect to methods and reference values. Therefore harmonization and standardization work requires patience, tenacity and diplomacy. This aspect receives due attention from the working group.

Country	static lung volumes	dynamic lung volumes	forced expiratory flow
B	ECCS	ECCS	Knudson
D	ECCS, Amrein	ECCS, Amrein	?
DK	Goldman, Kory Grimby, Cotes	Berglund, Cotes	?
F	ECCS	ECCS, Baldwin	Knudson
I	ECCS	ECCS	Knudson, Bass Cherniack, Polgar
NL	Tammeling	Tammeling	Ferris, Quanjer Collins, Birath
UK	Cotes, Goldman Kory, Grimby	Kory, Berglund Lindall	Leiner, Pelzer Birath

Survey of the reference values most widely used in the countries of the European Community for Coal and Steel

Table I

Index	multiplication factor	variability
VC	0.88	17%
FEV_1	0.88	19%
RV	1.00	30%
TLC	+)	20 %
FEV_1%	1.00	13%

+) Follows from RV + VC

Multiplication factors of the ECCS-standards for harmonization of reference values in European countries (according to Quanjer)

<u>Table II</u>

Index	regression equation	SEE
TLC	9.07 H - 9.14	0.77
VC	6.21 H - 0.024A - 5.07	0.54
FEV_1	4.49 H - 0.032A - 2.82	0.52
MMEF	2.28 H - 0.049A + 2.08	1.07
PEF	7.26 H - 0.038A - 1.65	1.53
FVC	5.81 H - 0.024A - 4.56	0.57
MEF_{50}	3.11 H - 0.035A + 1.20	1.32
$T_{L,CO}$	10.78 H - 0.064A - 5.73	1.38

Summary equations for reference values of men according to Quajner, working document EC-SLF-44

<u>Table III</u>

Method	M ± SD absolute values (l/s)	Reproducibility % relative difference (M+SD)
I	3.71 ± 1.95	12.2 ± 25.4
II	3.74 ± 1.95	9.6 ± 10.6
VI	3.85 ± 1.99	10.2 ± 8.5
VII	4.20 ± 2.05	13.2 ± 18.1
VIII	3.79 ± 1.96	11.6 ± 24.4

Comparison between various methods to calculate the FEF_{50} from 3 successive forced expirations in each individual person. The data are based on measurements in 89 persons. The envelope method at TLC (VI) is recommended (data provided by Dr. R. Peslin).

Table IV

Symbols, abbreviations and units

Second revision : August 1979

Simbols

Symbols for physical quantities are single italic (sloping) letters of the latin or greek alphabet with or without modifying signs, dashes, etc. and/ or qualifying or locating specifications.

Abreviations

Abreviations of physical quantities and functional indices are one or more roman capitals or lower case letters with or without modifying signs (dashes, dots, primes) and/or qualifying or locating specifications.

Specifications

Specifications of symbols and abbreviations are printed in roman small capitals or lower case letters. The order of specification is location (where), time (when) condition or quality (what, how). Specifications are printed in the same line as the primary symbol or abbreviation, or as subscripts (type writer).

General rules

X; x	roman capitals or lower case letters are used for abbreviations
X; x	italic capitals or lower case letters are used for physical quantities
X_A; X_a	specifications of X are printed in small capitals or lower case letters on the same line as X, or as subscripts (type writer)
$\overline{X}$	average value of X (must be specified)
X'	time derivative of X
X"	second time derivative of X
$\overline{X}'$	average X' per unit of time ($\dot{X}$ permitted)
X_A	time-dependent change of X for specification A
X_{A-B}	difference between X-values for specifications A and B
$X_{A,B}$	different specifications of X are separated by a comma
%X	X as percentage of the reference value
X%Y	X as percentage of Y
X/Y	division is indicated by a solidus (stroke)

X.Y	multiplication is indicated by raised dot
X/(Y.Z) X.Y/Z $(X.Y)^{-1}$	example of complex notations

Specifications of location, condition and quality

a	arterial
A	alveolar
ab	abdominal
abs	absolute
am	ambient
an	anatomic
ATPS	ambient temperature and pressure and saturated with water vapour at these conditions
aw	airway
awo	airway opening
b	barometric
bl	blood
br	bronchial
BTPS	body temperature, ambient pressure and saturated with water wapour at these conditions
c	pulmonary capillary
c'	end-capillary pulmonary
C	cardiac
cd	circadian
D	dead space
di	diaphragm
ds	down stream
dyn	dynamic
E	expiratory
$\bar{E}$	mixed-expiratory
ec	extra cellular
el	elastic
ep	extra pulmonary
f	functional
g	gas
I	inspiratory
ic	intracellular

im	intramuscular
it	intrathoracic
iv	intravenous
L	lung
lat	lateral
lam	laminar
m	membrane
max	maximal
mb	multiple breath
min	minimal
mo	mouth; buccal
mus	muscular
obs	observed
oes	oesophageal
phys	physiological
pl	pleural
pleth	plethysmographic
pred	predicted
pulm	pulmonary
pv	pulmonary venous
r	respiratory
rb	rebreathing
rs	respiratory system
s	specific
sb	single breath
sc	subcutaneous
sh	shunt
sp	spirometric
ss	steady state
st	static
STPD	standard temperature and pressure, dry
T	tidal
t	thoracic
ti	tissue
tm	transmural
tot	total
tp	transpulmonary
tr	trachea
trs	trans respiratory

tt	trans thoracic
turb	turbulent
us	upstream
v	venous
$\bar{v}$	mixed venous
va	vascular
vis	viscous
w	thoracic wall
we	wedge

Body characteristics

A	age (yrs)
B	body
BSA	body surface area (m^2)
BMR	basal metabolic rate (kJ)
F	female
H	standing height (stature) (m)
M	male
wt	body weight (kg)

Lung volumes and capacities (1 BTPS)

CC	closing capacity
CV	closing volume
ERV	expiratory reserve volume
FRC	functional residual volume
IC	inspiratory capacity
IRV	inspiratory reserve volume
RV	residual volume
TGV	thoracic gas volume
TLC	total lung capacity
TV	tidal volume
VC	vital capacity
VC_I	inspiratory vital capacity
VC_E	expiratory vital capacity
$VC_{I,E}$	two-stages vital capacity

Ventilatory dynamics

abreviation	symbol	
$FEF_{x\%FVC}$		forced expiratory flow at x% exhaled FEV (l/s)
FEFV-curve		forced expiratory flow-volume curve
$\Delta FEF_{50\%}$	$\Delta V'_{50}$	difference in $\dot{V}_{max}$ at 50% exhaled FVC between He-O_2 and air (l/s)
FES		forced expiratory spirogram
FET		forced expiratory time (s)
FEV_x		forced expiratory volume in x seconds (l)
$FEV_{x\%\ VC}$		FEV_x as percentage of the VC
$FEV_{x\%\ FVC}$		FEV_x as percentage of the FVC
$FIF_{x\%\ VC}$		forced inspiratory flow at x% inhaled VC (l/s)
FIV_x		forced inspiratory volume in x seconds (l)
FVC		forced expiratory vital capacity (l)
FV-curve		flow-volume curve
MEF		maximal expiratory flow l/s
$MEF_{x\%\ FVC}$		- at x% exhaled FVC (l/s)
$MEF_{x\%\ TLC}$		- at x% of the TLC (l/s)
MEFV-curve		maximal expiratory flow-volume curve
MMEF		maximal mid-expiratory flow (l/s)
MVV_x		maximal voluntary ventilation (at breathing frequency x) : (l/min)
PEF		peak expiratory flow (l/s)
PIF		peak inspiratory flow (l/s)
	V'	instantaneous gas flow (l/s)
	V''	gas volume acceleration (l/s^2)
	$V_{iso}-V'$	percentage exhaled FVC at with the MEFV-curve becomes density independant

Breathing mechanics

	C	compliance : l/kPa; formerly : l/cmH_2O
C_L/V_L		volumic (specific) compliance : kPa^{-1} formerly cmH_2O^{-1}
	E	elastance : kPa/l; formerly : cmH_2O/l
EPP		equal pressure point

abbreviation	symbol	
	F	force : N
	G	conductance : l/s·kPa
G_{aw}/V_L		specific (volumic) conductance : $(s \cdot kPa)^{-1}$
IVPF-curve		isovolume pressure-flow curve
	P	pressure; stress : kPa; mmHg (blood pressure only) formerly used : cmH_2O, mmHg, bar
	$\overline{P}$	mean pressure, with respect to time
	R	flow resistance : kPa·s/l; formerly $cmH_2O \cdot s/l$
	W	work (external) : J; kPa·l
	W'	power : kPa·l/s; W; J/s
	Z	impendance : kPa·s/l
	σ	surface tension : N/m

Ventilation

	V	gas volume
	V_L	lung volume, including airways
	V'	instantaneous gas flow : l/s
	$\overline{V}'$	time-averaged gas flow (ventilation) : l/min
	V'_{tot}	total ventilation : l/min
	f_r	breathing frequency : min^{-1}; s^{-1}
	t_E	expiratory breathing cycle time
	t_I	inspiratory breathing cycle time
	t_{tot}	total breathing cycle time

Circulation

C.O.	$\overline{Q}'_{tot}$	cardiac output : l/min
	f_C	cardiac frequency : min^{-1}; s^{-1}
BP	P	blood pressure; kPa; mmHg permitted
	Q	blood volume : l
	Q'	instantaneous blood flow : l/s
	Q''	blood volume acceleration : l/s^2
	$\overline{Q}'$	time-averaged blood flow (perfusion) : l/min ($\dot{Q}$ permitted)
	R	vascular resistance : kPa·s/l

Pulmonary gas transport (gas and blood)

abbreviation	symbol	
BMR		basal metabolic rate : kJ; formerly : Cal
BB		buffer base : mol/l
BE		base excess : mol/l
	C_i	molar concentration of component i : mol/l
	D	diffusing capacity : mmol/min.kPa; mol/s.kPa formerly : ml/min·mmHg
$D/\overline{Q}'$	$D/\overline{Q}'$	diffusion-perfusion ratio : mol/l·kPa
	F_i	fractional concentration of component i
Hb		haemoglobin : g; mol
ODC		oxyhaemoglobin dissociation curve
pH		unit of acidity
	n_i	amount of component i : mol
	n'_i	instantaneous molar flow of component i : mol/s
	$\overline{n}'$	molar transport of component i : mol/min ($\dot{\bar{n}}$ permitted)
	$P_{x,i}$	partial pressure of component i in medium x:
	$S_{x,i}$	saturation of component i in medium x
R		respiratory quotient; respiratory exchange ratio
	T_L	gastransfer factor for the lung : mmol/min·kPa formerly : ml/min·mmHg
K (T_L/V_A)	T_L/V_A	Krogh factor, transfer coefficient : mmol/s·kPa·l
$\overline{V}'/\overline{Q}'$	$\overline{V}'/\overline{Q}'$	ventilation-perfusion ratio: dimensionless
	θ_i	reaction rate coefficient of red cells for component i
	$\overline{V}'_i$	gas transport of component i : l_{STPD}/min

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CONCLUSION

A. MINETTE - Lanaken

As was pointed out during the first session of this seminar, epidemiology - the science concerned with the mechanics of health phenomena in a population in the widest sense of the term - does not as a rule enable the causes of disease to be determined with any certainty. To do that, other investigation methods have to be used. Generally, at least in occupational medicine, it is employed for other reasons; more often than not, it is used simply to determine the correlations which exist between the prevalence or incidence of various diseases in a population and the frequency and importance of the causes from which it is thought these diseases might stem. Nevertheless, seen in this way, epidemiological research can become a remarkable instrument of prevention in that it enables one to study the way in which a disease regresses as a function of the preventive measures taken against its causal factors.

It is obvious that such studies are feasible only if hygienists have valid disease-monitoring criteria which are sufficiently discriminating and specific, as well as reliable and reproducible methods for identifying and measuring harmful factors in the environment.

The work of this seminar can best be summarized by grouping the reports and discussions during the two days in question around these two research areas and by evaluating the findings of researchers working in this field in the Community.

I. Criteria for the early diagnosis of coalminer's pneumoconiosis

Discussions centred mainly on means of identifying the disease as soon as the first signs appear and at a stage when the full panoply of preventive measures can be implemented - in other words, at a time when the impairment of an individual's physical health does not appear to affect his normal life expectation significantly.

1. The clinical and functional signs of pneumoconiosis

It is known that pneumoconiosis eventually leads to various clinical disorders such as breath lessness, cough, expectoration of a serious kind, even including black sputum, as well as haemoptysis, particularly when there are tubercular complications. Specialists also know that, from a certain stage onwards (which varies in each case), the development of the disease is accompanied by various functional disorders which can be demonstrated in the laboratory.

Several reports and comments were made during this meeting on these clinical and functional aspects of the disease. Dr. Jacobsen mentioned the complexity of the possible links between radiological lesions and various clinical pictures or functional signs of respiratory insufficiency. In particular, some British findings suggested that cumulative exposures to dust could produce symptoms of bronchitis and a reduction in FEV_1, without pneumoconiosis being present. Various other speakers - Professor Worth and Professor Casula, as well as Doctor Sanna-Randaccio - also stressed, and rightly so, the importance and practical benefits of the past and current work carried out in Europe on the different aspects of chronic bronchitis and emphysema as well as on functional disorders observed in pneumoconiotics. Early diagnosis is required here, too, in view of the significant effect these disorders have on working capacity and on the survival of workers suffering from these complications. During these stages of the illness, the rôle of the doctor is of prime importance, both in identifying abnormalities and in reallocating or, indeed, treating the individual affected. Dr. Recht laid great stress on this vital rôle of the doctor, who is the only person capable of performing these tasks. Similarly, Prof. Worth placed great emphasis on the importance in this area of hospitals. In addition, Dr. Amoudru described the pioneering rôle played in the past by occupational physicians in the primary, secondary and "tertiary" prevention of pneumoconiosis and described in detail the various aspects of their work.

However, it has to be recognized that, for epidemiologists concerned with the prevention of coalminer's pneumoconiosis, the clinical and functional abnormalities accompanying pneumoconiosis do not appear in a very specific form. In any case, most of these abnormalities, including functional ones clearly of a pathological nature, are not sensitive indicators; as a rule, they appear only relatively late in the course of the disease.

Of course, one cannot rule out the possibility that improved knowledge of the natural history of pneumoconiosis which results from epidemiological studies in sufficiently representative groups might make it possible to validate certain clinical and functional pictures which we cannot fully understand in the early stages of the disease. This wholly justifies the continuation of research in these areas. In particular, it indicates that a study should be made of the value for this purpose of the lung function tests mentioned, among others, by Prof. Worth and Dr. Sanna-Randaccio. On the other hand, Prof. Tammeling pointed to the fundamental need for more extensive standardization in these areas.

Nevertheless, it is still the case - And this was explicitely stated or implied by many speakers - that coalminer's pneumoconiosis can be identified at its earliest stages only with the help of X-ray examinations carried out in accordance with specific standard procedures. The medical monitoring of preventive measures has therefore to be based on this technique.

2. Differences in X-ray examinations for pneumoconiosis

Various basic points about the radiological monitoring of miners were reemphasized, in particular by Dr. Dick and myself.

Nowadays, no one denies that in order to make valid comparisons between the findings of different coalfields and countries all researchers should use the procedures proposed by the International Labour Office for taking, reading and writing up notes on radiographs. Standardization of this kind also enables our West European data to be compared with those of other countries, notably of the United States and Eastern Europe. Only this will in future make our statistics comparable with those of the Third World, which we will also have to provide with technology. The international classification, based on the use of radiographs measuring 35 cm x 35 cm, also enables miners with pneumoconiosis to be followed up better over time and with an optimum degree of accuracy.

This classification was, of course, revised very recently, the aim being to establish a 12-point radiological scale of progression which was more elaborate than its predecessor, and to provide a better definition of profusion categories 1, 2 and 3. In addition, a collection of standard radiographs which is more satisfactory than earlier collections has been put together.

The meeting showed, however, that screen radiography was in fact still widely used in various countries, notably in Belgium, France and Italy. Very careful research carried out in Belgium at the end of the 1950s by Lavenne and Belayew produced findings which demonstrated in particular that, in ordinary medical practice, screen radiographs measuring 10 cm x 10 cm or 7 cm x 7 cm could, in the hands of trained observers, provide results which were just as good as those given by standard-size radiographs, even when the latter were used in conjunction with reference radiographs. As regards the reading and interpretation of radiographs, there is no doubt that the reader's own psychological and physiological qualities can wholly make up for the technical limitations imposed by the size of the radiographs.

Nevertheless, the fact remains that radiographs of a single size taken in accordance with standardized rules must be adopted for epidemiological research, this being an opinion shared by the vast majority of writers on this subject.

As for the frequency with which these X-ray examinations should be carried out, it was found that differences still existed in our various countries. In the Federal Republic of Germany, the frequency of regular examinations varies according to the risk faced and the state of miners' lungs as revealed by X-ray. German workers showing no signs of dust-induced pulmonary lesions have to be examined every three years; however, the examination must be brought forward when, in the course of one year, more than 100 shifts are worked in the presence of significant dust levels which are themselves defined by law. In belgium, the frequency of X-ray examinations for underground workers varies according to the age of the subject and his radiograph.

Up to the age of 21, regular examinations are held every year; some coalfields even hold them twice a year. Among subjects over the age of 21, a distinction must be made between rescue men and other mine workers. The former must undergo annual X-ray examinations; for the latter, examinations take place every two years if there are no signs of pneumoconiosis but they become annual when pneumoconiosis, even in a discreet form, is suspected. In France, X-ray examinations take place at least once a year, the frequency being raised to once every six months in the case of certain workings where dust levels are particularly high. In the United Kingdom, X-ray examinations are normally carried out every four years. However, persons with Category 2 pneumoconiosis, young persons with Category 1 radiographs and all workers whose radiographs show rapidly progressing disease are examined every two years. In Britain, X-ray examinations, with the exception of those carried out during pre-employment examinations, are not compulsory, although in practice 90% of workers have them. In Italy, regular examinations are compulsory and must be carried out at least once a year.

Undoubtedly, one is at fist somewhat taken aback by all these differences within our Community. The wish for harmonization expressed by some writers in this area is understandable. But one wonders whether such harmonization is really sensible or desirable. It is probably not essential that regular X-ray examinations should be carried out at the same intervals everywhere in all our coalfields. In fact, the different rules applied in the Community countries merely reflect the varying experiences of occupational physicians which, in turn, depend on the differences in the level of risk to which their workers are exposed. In other words, they reflect differences in the rate of progression of pneumoconiosis in our various coalfields. It seems obvious, in fact, that the varying reductions in the cumulative risk achieved by coalfields remove the need for very frequent examinations.

In addition, it should not be forgotten that too frequent exposure to X-rays is not completely devoid of risk either. The aim should therefore be to carry out examinations at reasonable intervals so that, in the context of reducing risk, the chances of detecting any radiological changes from one examination to the next are maximized.

II. Dust monitoring

After considering the parameters required for medical monitoring and emphasizing that radiology is of fundamental importance, necessary and, at the present time, irreplaceable as far as pneumoconiosis is concerned, we should give some thought to the means at our disposal for measuring risk and trying to reduce it. Dr. Recht stressed the very great importance of these efforts, especially at a time when the responsible authorities are looking closely at the total cost of the various energy sources which are available.

In this field of risk, the inevitability of dust arising underground is a fact which no-one would now think of disputing, especially when one thinks of the extraordinary drop in endemic pneumoconiosis over the last 25 years - set out notably in the reports given by Deflandre, Jacobsen, Reisner, Lavenne and Belayew - which has been due solely to dust control measures.

In assessing the results of these efforts, it should also be remembered that they were accompanied by a reduction in the total exposure time of workers to dust per day and per year, this being supplemented in various countries by a progressive reduction in the total length of one's working life spent underground.

A. Dust levels and co-factors

Many researchers, however, support the view that dust underground does not always provide a sufficient explanation and, in particular, that it fails to explain all the aspects which may be encountered as the disease develops. Certain writers have raised a similar question about massive fibrosis, in which various co-factors are thought to play a part. Dr. Jacobsen, in particular, referred to these problems. Tuberculosis, of course, used to be mentioned in this respect. Prof. Fritze emphasised this point. In addition, Dr. Dechoux pointed to the danger of tuberculosis which is contracted during pneumoconiosis. However, specialists have discovered since endemic tuberculosis became less common that many areas may develop condensed masses of fibrous tissue even when tubercle bacilli are absent. The question of co-factors in massive fibrosis therefore remains completely open. On the other hand, it should not be forgotten that the number of condensed forms has also been drastically reduced with the drop in dust levels in underground workings. Neverthless, the appearance of condensed forms at a later stage, in some cases long after the person has stopped working underground, is now beginning to cause concern. In this connection, Dr. Deflandre spoke of the regular monitoring which had become necessary in the Nord and Pas-de-Calais coalfields. He told us of the many difficult problems which this phenomenon, which gives a new dimension to the epidemiology of pneumoconiosis, created in monitoring miners after they had given up work.

Co-factors other than tuberculosis may, of course, also play a part. Thus, in respect of the simple forms of the disease alone, reference was made to the variations in time-lag before the disease appeared in different subjects who appeared to be exposed to identical dust levels. Certain immune factors, particular features of respiratory rates, individual differences in pulmonary clearance or the metabolization of dust, even the effects of certain general everyday health factors such as smoking, for example - in brief, all the factors normally grouped under the term hyperreactivity - may be mentioned in this connection and would be worth investigating.

B. Qualitative aspects of dust levels.

There are two facets to the problems relating to dust levels. The first one is qualitative.

In the past, an important if not decisive role was attributed to the presence of quartz in inhaled dust. Prof. Lavenne mentioned the stir created in this field by the data contained in Boehme's report, delivered at Johannesburg in 1930. Mention might also be made in this connection of the important series of projects financed by the European Coal and Steel Community in the 1950s and at the beginning of the 1960s that dealt with the way in which quartz acts in macrophages. A more modern reflection of these ideas on pathogenesis is provided by research recently carried out in the Federal Republic of Germany aimed at neutralizing the action of quartz in the cells by administering P204, and by other work done in France on the antagonistic effect of aluminium on free silica.

Such ideas still persist today, at least in part, in the way in which dust level measurements are understood and interpreted in our different countries. In the Federal Republic of Germany, Belgium, France and Italy, the importance of quartz is still implicitly recognized in legislation, if only because the latter refers to silicosis, a word which is still often used in these countries - incorrectly, as it happens - to denote coalworkers' pneumoconiosis. In the Federal Republic of Germany, Belgium and Italy, assessments of the harmfulness of dusts take the quartz content of the latter into account. In the United Kingdom, according to Dr. McLintock, no practical significance is attached to the quartz content of airborne dust except in certain workings (drivages). Dr. Jacobsen stated that the findings of British surveys did not indicate that quartz, in the concentrations currently found in workings, played a part in the aetiology of pneumoconiosis. However, Walton's work in 1977, carried out in the same country, suggested that although the total amount of respirable dust was the most significant factor as regards the risk of pneumoconiosis, the correlation was improved if analyses took account of mineral substances or quartz. One of the aims of the epidemiological studies currently being undertaken in the United Kingdom is to determine the real significance of silica in the genesis of coalworkers' pneumoconiosis.

The way in which these problems are viewed in the various European countries was admirably summarized by Drs Breuer and Le Bouffant. These two speakers described the new ideas produced by researchers in the last few years. Dr. Le Bouffant, in particular, referred to the considerable differences in endemic pneumoconiosis existing between two French coalfields, ie those of the Nord-Pas-de-Calais and Provence, which differ from one another not in the concentrations of dust measured in air or the granulometric properties of this dust but as regards the dust's composition and physico-chemical features. Naturally, as a result, these qualitative features are ascribed an important rôle in producing the disease. Dr. Le Bouffant, and subsequently Prof. Carta and Prof. Ocella, stressed the part which may be played by various dust constituents in association with silica, such as clays - kaolin and illite - micas and feldspars, which may slow down or accelerate the development of fibrosis. Moreover, the particular rôle played by coal has never been clearly explained although it is one of the most common constituents of mine dust. It is generally accepted that the harmfulness of coal increases with its quality, i.e. with its degree of carbonization. However, it is difficult to separate the effect of coal itself from that of other airborne mineral substances, which exist in the coal in various amounts depending on the quality of the coal concerned. Writers' views on this remain conflicting.

All these questions should be given further thought and examined in detail. These qualitative differences in the composition of dust might well be one of the causes, perhaps the main cause, of variations in endemic pneumoconiosis which are found between different coalfields or collieries, a point made in particular by Dr. Reisner in his general epidemiological report.

These considerations make it vital to continue the Community survey on these problems which Dr. Le Bouffant has recently been directing, and which aims to compare the harmfulness of 23 dust samples taken from coal mines in the Federal Republic of Germany, Belgium, France and the United Kingdom. The main purpose of this survey is to look for a relationship between epidemiological studies carried out on man and the harmfulness of dusts as determined in vitro. The importance of such a project is self-evident.

C. Quantitative aspects of dust levels

The second facet of the problems relating to dust is quantitative. First of all, there is the problem of particle size measurement. It has been known for some time that the dust in question must be respirable, i.e. must combine certain ideal properties for penetration and retention. The Hatch and Gross curve shows us that these conditions are met by particles between 1 μ and 3 μ in size.

Secondly, the quantity of dust retained has to be taken into account. Dr. Reisner and Dr. Breuer clearly illustrated the importance of this concept and emphasized the fundamental rôle played in the development of the disease by the successive accumulation of quantities of dust. In France and the United Kingdom, extensive research has led those responsible to base prevention on monitoring the amount of respirable dust.

All this explains and justifies the many projects which have been carried out since 1955, first by the ECSC and then by the Commission of the European Communities, in order to arrive at a better quantitative definition of these underground dusts. They are necessary both to specify sampling techniques and the frequency of sampling and to determine the most representative locations, workplaces and operations required for this type of monitoring.

Generally speaking, dust samples are taken in the return airways, 70 m from the face in the United Kingdom and 20 m from the face in Germany, France and Belgium. However, Dr. Degueldre made the point in the course of his report that, in spite of a lowering of the dust levels measured in the return airways of workings here in Europe, recent changes in coal winning techniques had led to very large localized releases of dust at certain points in the working faces. Therefore, it is not impossible that measurements may in future be necessary in individual mines at those points in the production process where the persons working are exposed to high risk.

A further aspect of the problem relates to the diversity of the equipment used for dust sampling in our various countries. In the United Kingdom, the MRE Type 113 A instrument is used; this takes in 2.5 litres of air per minute and produces a separation curve of the Johannesburg type. The MPG sampler, in official use in Germany, takes in 3 m^3 of air per hour and gives an identical separation curve. There is a dust sampler recently produced in France, the CPM, which also takes in 3 m^3 of air per hour but produces a separation curve much closer to the classical Hatch and Gross curve. A recently introduced German instrument, the TPF, which is used by Berbau Forschung, is equipped with the same cyclone preseparator as the French CPM. In Belgium, the Staser sampler has been in use since 1964; this is a non-self-contained filtering machine which samples all the airborne particulates more or less isokinetically. This apparatus therefore does not contain a preseparator suited to the particular dimensions of the dust. However, although this inevitably means it is imperfect from the granulometric point of view, it has turned out in practice to be more stringent than samplers equipped with preseperators since it has led to the automatic exclusion of workings which, purely as regards the respirable dusts found in them, were acceptable from the health point of view.

Recently, the work of the CEC research teams led to a comparative study of the various separators mentioned above, aimed at examining the possibility of drawing up a conversion table for the results obtained. Such a table would enable a better comparative assessment to be made of the epidemiological curves and, consequently, of the effects of preventive measures in our various countries. The value of such research cannot be overestimated.

III. Results obtained

In practice, regular comparisons of dust measurements with radiological statistics on pneumoconiosis have now enable the responsible bodies in our various countries to describe their workings in terms of the risk being run. In Belgium, workings are classified according to two parameters, namely, the overall concentration of dust and the ash content of all the particles suspended in the air. Thus, the Belgian mining regulations classify dust into 4 categories : I, II, III and IV. Work can proceed normally only in workings or plants designated as Category I or II. Appropriate dust control measures must be taken immediately in any workings or plants classified in Category III so that these can be reclassified under Categorie II or I within a fixed period. Work is stopped when the upper limit of Category III is exceeded. At the end of 1976, 88% of workplaces at the coalface were classified under Category I and 12% under Category II. No workplace was classified as Category III or above. In the Federal Republic of Germany, dust concentrations measured in workings are also classified or a 4-point scale; moreover, occupations involving exposure to level IV dust have been banned since 1965. In France, is a classification containing 6 categories, going from A to F. The two upper categories, E and F, have now disappeared. Categories C and D apply to workings which exceed the standard dust levels and here special preventive measures have to be taken both for staff and work procedures. In A and B workings, dust levels are below the permissible threshold value; in 1979, 97.6% of workings were classified in these two categories or in Category O. In the United Kingdom, too, quantitative rules based on dust weight values are used to assess the risks present in workings and to guide preventive measures.

In addition to the steps just described, regulations have been adopted in the various countries concerned specifying the measures which have to be taken to redeploy workers who contract pneumoconiosis within a short period of starting work. Many speakers, including Dr. Amoudru, Dr. Deflandre, Dr. McLintock, Dr. zur Nieden, Dr. Schulte, Dr. Dofny and Prof. Lavenne, explained the importance which the laws and regulations in their respective countries attached to this problem. At the same time, their statements revealed that considerable differences existed within the Community in this area. More technical improvements and new legislation are certainly required if one is to reach a sensible degree of harmonization in the Community or this question of resettlement.

Nevertheless, there is no doubt whatever that spectacular results have been achieved in the fight against endemic pneumoconiosis which has been conducted in our various countries since the Second World War, simply by means of measures aimed at reducing the total amount of dust inhaled.

Dr. McLintock and Dr. Jacobsen respectively summarized and commented at length on the excellent results of the large national longitudinal surveys carried out in the United Kingdom since 1959. It has already been stated above that one of the most important results of this research was to confirm that the total amount of respirable dust was a decisive factor in the development of pneumoconiosis. The striking fact is that this conclusion coincides completely with that yielded by simultaneous research in the Federal Republic of Germany and France, which was described so well by Dr. Reisner (for Germany) and Dr. Portal (for France).

It is true that epidemiological studies in the United Kingdom have established that in this country too there are large and still unexplained differences between the various coalfields and even collieries as regards the incidence of pneumoconiosis, whereas exposures to mixed dust seem to vary little. This, too, coincides with the observations made by Dr. Le Bouffant in France and Dr. Reisner's experience in the Federal Republic of Germany. In the United Kingdom as on the Continent, researchers are now looking into the qualitative composition of dusts and the rôle of individual susceptibility factors to see if these might affect the importance of the total amount of inhaled dust in causing pneumoconiosis.

However, everyone's attention is stell directed mainly towards the decisive rôle played by dust.

Finally, it is to be hoped that all the work done so far is only a step towards the establishment of maximum permissible dust concentrations. This idea was discussed by Dr. Portal, Dr. Breuer, Dr. Reisner and Dr. zur Nieden. As well as being important, this task is an ambitious one and will undoubtedly be delicate and difficult when one thinks of all the different factors involved - in particular, the various qualitative interactions which may take place between the various dusts found in our coalfields, collieries or, indeed, workings, and which complicate considerably any investigation of the subject.

At all events, one should emphasize the immense value in this particular field of the excellent theoretical research carried out in France by Ganier and Portal, following up the work done by Quinot. In particular, this research led to the notion that the reduction in dust levels required to extend the period before signs of pneumoconiosis appeared on a radiograph was a function of the square of the time extension required. The dust level which must initially be taken into account is generally referred to as "the historic dust level". In France and Belgium, it has been shown that by using this method it is now possible to calculate with reasonable accuracy maximum permissible dust levels which are suitable for the usual working life of a coalworker, exposing him only to a fairly low risk of pneumoconiosis at the end of his working life underground. In the United Kingdom, too, epidemiological studies have made it possible to establish the scientific basis for estimating the long-term risk of pneumoconiosis in relation to gravimetric dust standards.

For the effects produced by all these findings, one must pay tribute to the main protagonists in the compaign against dust conducted in our various countries. First and foremost, this means paying tribute to those responsible for dust control in our coalfields. Dr. Degueldre, on behalf of his colleagues and in his capacity as a member of the Mines Safety and Health Commission, told us of the problems entailed in this work, where data are constantly being questioned as a result of technical advances in mining. However he also described with an apparent simplicity which reveals his intimate knowledge of these problems, the way in which engineers and their assistants, foremen and workers managed to overcome these difficulties.

Of course, the effects of dust control on the health of workers can be monitored only by multidisciplinary teams, where occupational physicians, radiologists, statisticians, epidemiologists, anatomopathologists and research workers also have a rôle to play. Such teams have to work together in order to determine the objectives and monitor the results of dust control. However, as in the past, the only way to solve the medical problems of pneumoconiosis is to eliminate dust formation itself.

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