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The relationship between coal rank and the prevalence of pneumoconiosis

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ABSTRACT As part of the Periodic *X*-ray Scheme of the National Coal Board (NCB), a comparison is made between the previous and new films of all miners who were face-workers on the former occasion, five years earlier. This assessment is made by distributing the films randomly to all the NCB readers. This paper compares the rank of coal mined in each colliery with each colliery's percentage prevalence of pneumoconiosis of at least ILO category 1 in the films of previous face-workers obtained during the third survey round (1969–73). Of the NCB's 291 collieries in Britain, information enabling a rank classification to be made was available for 250, employing 62 362 face-workers. In these 250 mines a progressive and five-fold increase in prevalence was observed from collieries mining low-rank (bituminous) coal to those mining coal of high ranks (anthracite and high-grade steam (and coking coal). A possible reason for this is that, in the past, high-rank collieries may have had the highest mass-concentrations of respirable dust.

For some time, differences in the risk of developing pneumoconiosis have been recognised in different coalfields. For instance, the prevalence of category 1 or more pneumoconiosis for all miners in the South Wales Area in the National Coal Board's (NCB) third-round periodic *x*-ray survey, carried out from 1969 to 1973, was 23·8%, five times the rate of 4·6% found in the Scottish Area. Meiklejohn (1952) drew attention to such differences, basing his comments on the numbers of men diagnosed by Pneumoconiosis Medical Panels for compensation purposes.

The NCB's Pneumoconiosis Field Research (PFR) based at the Institute of Occupational Medicine, Edinburgh, has investigated the relationship between the progression of pneumoconiosis and measurement of airborne dust concentration at 26 collieries throughout Britain. The purposes and organisation of the PFR are set out in detail by Fay and Rae (1959). Jacobsen *et al.* (1970) studied respirable dust exposures and advancing radiological categories of simple pneumoconiosis in 4122 men in this PFR population over a period of 10 years. There was a high correlation (r = 0·80) between the number of steps of progression measured by the NCB elaboration of the ILO Classification and the colliery mean *mass* of respirable dust (particles of diameter 1–5 μm). The correlation with the *number* of particles was much lower (r = 0·44). A more recent paper (Walton *et al.*, 1977) confirms, for individuals, that the overall mass of respirable dust is the factor most closely related to the 10-year attack rate of pneumoconiosis among 3154 face-workers. However, these authors note that there are substantial residual variations between individual collieries, which appear to be associated to some extent with differences in the mineral content of the dust or with coal rank, but which cannot yet be fully explained.

'Rank' is a marketing term referring to the quality of the coal. High-rank coal (having a low number) is that which is relatively smokeless and free from bitumen, and includes anthracite, steam coal and high-grade coking coal. At the other extreme is low-rank (high-number), bituminous, smoke-producing house coal. The higher the rank, the higher the carbon content of the coal. Perhaps surprisingly, the quartz content of airborne dust is low when high-rank coal is mined and higher in low-rank coalfields (Walton *et al.*, 1977). The NCB uses nine

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Table 1 *Type and carbon content of different ranks of coal*

Rank	*Description*	*Carbon content (approx.)*
100	Anthracite	95·0–93·0
200	Low volatile steam coal	93·0–90·5
300	Prime coking coal	90·5–89·0
400		89·0–87·0
500	Coking/gas coal	87·0–85·0
600		85·0–84·5
700	General purposes coal	84·5–83·5
800	High volatile steam	83·5–81·5
900	and house coal	81·5–80·0

major rank groups, as shown in Table 1. The carbon content refers to dry coal free of mineral matter.

Some work has suggested that the development of pneumoconiosis may be related to the rank of the coal mined. Hart and Aslett (1942) in a study of 16 South Wales collieries, found the highest prevalence of radiographic abnormalities, including consolidation and 'reticulation', in the anthracite mines and the lowest in the bituminous coal mines, with steam-coal mines intermediate. Hicks *et al.* (1961) found a similar relationship in the 26 PFR collieries. They used three broad rank groups, 100–400, 500–600 and 700–900. It was found that the average period of work at the coal-face (coal-getting shift) required to produce a 20% prevalence of pneumoconiosis of at least category 1 was 8, 16 and 36 years respectively. These authors also discussed the physical and chemical changes in evolving coal which might underlie the differences in the prevalence of pneumoconiosis. In a study by the United States Public Health Service (Key *et al.*, 1971) a comparison of the prevalence of pneumoconiosis of at least category 1 in 2958 underground miners showed that in Appalachia (medium to low-rank coal) the prevalence was 11·1%, in Illinois and Indiana (low-rank coal) 7·5%, and in Utah (lower rank still) 4·8%. Another study within the Appalachian field gave 18% prevalence for eastern Pennsylvania (anthracite), 21% for central Pennsylvania (medium-rank coal) and 9% for western Pennsylvania (low-rank coal).

The apparently greater hazard of anthracite was reflected in the first British Coal Mine Dust Standards introduced in 1949, in which a limit of 650 particles/cm^3, 1–5 μm, was set for coal dust in anthracite collieries, compared with 850 particles/cm^3 in other collieries (Chamberlain *et al.*, 1971). With the development of dust-sampling instruments capable of measuring the weight of respirable dust (gravimetric sampling), it was found that there was a clear association between the mass-number index (MNI: the mass in mg/m^3 per 1000 particles/cm^3 of dust in the respirable range) and coal rank, a high MNI occurring with high-rank (low-number) coal (Dodgson *et al.*, 1971). The observed range of variation of MNI was 4·5:1, between the highest rank anthracite colliery in South Wales and a low-rank bituminous colliery in Scotland. Jacobsen *et al.* (1971) considered this to be the main reason for the better correlation of their index of progression with mass of respirable dust than with particle number concentration, and, indeed, to account largely for the 'rank effect'. These findings give further justification to the adoption by the British coal mining industry in 1970 of gravimetric dust standards which apply equally to anthracite and bituminous coal (Chamberlain *et al.*, 1971). These new standards had their greatest impact on the high-rank (high MNI) collieries and led to intensified dust suppression, especially in South Wales.

Reisner and Robock (1977) reviewed studies in West Germany which showed considerable differences in the risk of simple pneumoconiosis with exposure to similar mass-concentrations of dust. Where the mineral content of the coal was comparable, more pneumoconiosis occurred in collieries mining higher-rank coal, and cytotoxicity studies indicated that the damage done by respirable dust increased with geological age and with higher rank of the seams. Like Dodgson *et al.* (1971), Reisner (1971) found an association between high MNI and high rank of coal, the lowest-rank coal being associated with finer particle size.

The studies quoted are open to some criticism on the grounds that the samples of men included were taken from selected collieries and were usually not representative of the industry as a whole.

The NCB Periodic X-ray Scheme

In 1959 the National Coal Board introduced the Periodic *X*-ray (PXR) Scheme for British miners. Mobile radiographic units, using large-film techniques, visit each colliery and offer chest radiographs on a voluntary basis to all men employed there. Between 1959 and 1973 the cycle of visits was based on a five-year period; since 1974 the period has been reduced to four years. Thus the third cycle was completed over the years 1969–73.

Every effort is made to achieve maximum attendance at these colliery surveys and, over the period 1969–73, 91·6% of the mining population at the 291 collieries then operating was examined. Checks of the remaining 8·4% have shown that neither in terms of age nor of pneumoconiosis prevalence judged by previous surveys, did these men differ from those who attended.

In order to achieve an unbiased estimate of progression since the previous survey, a standard 'epidemiological' population is selected at each colliery. Face-workers are chosen for the assessment of progression, because they are the men with the greatest dust exposure. The standard population consists of men who worked at the coal-face at the time of the preceding survey and who have remained at the colliery throughout the intervening five-year period, but who are not necessarily at the coal-face at the time of the current survey. On average this group is 30% of the total colliery population. At each colliery the radiographs of these men were divided into 10 batches. In the period under study each batch of films was read independently by two doctors of the Board's Radiological Service, no two batches being read by the same two doctors. Five readers took part, each one of the six NCB Medical Officers taking his turn to rest for three months.

Assessments of the *prevalence* of pneumoconiosis in this group at each colliery were derived from the epidemiological film readings made by all the doctors of the Radiological Service.

Method

The prevalence rates used in this paper are those of the 'epidemiological' population at each colliery, described above. The definition of 'prevalence' is the percentage of the total readings at each colliery which showed pneumoconiosis of at least category 1/0 pneumoconiosis when assessed by the NCB elaboration of the ILO classification.

As one of the six NCB readers was omitted by three-monthly turns there is a small bias depending on the reading level of the odd man out at any time. No adjustment was made for this as it was not thought to be a major source of error. The NCB readers take part in regular joint film-reading tests to ensure uniformity of standards.

The prevalence of pneumoconiosis in 1969–73 thus obtained was correlated with rank of coal on the basis of information supplied by the Mining Department of the NCB, which gave details of the output of coal of different ranks in each colliery during the year 1970–71.

A colliery was included for analysis if it fulfilled one of the following criteria:

(1) all coal mined was of one rank;

(2) coal mined was limited to two adjacent ranks; the rank with the greater output was selected. At two collieries the tonnage was the same for both ranks, and the higher rank number was chosen;

(3) coal was limited to three adjacent ranks, the central representing more coal than either of the other two. In one case the output of all three ranks was the same. The central rank was chosen;

(4) coal was limited to three adjacent ranks, and one extreme represented at least three-quarters of the output. This extreme rank was used;

(5) if coal mined spanned four rank categories and three-quarters of the output was of one rank, that rank was chosen (one colliery).

In addition, data on mean colliery mass-concentrations of respirable dust at coal-faces were correlated with coal rank. These data were obtained by courtesy of the NCB Scientific Department and consisted of global annual means for all collieries in which measurements had been made for the six years 1970–71 to 1975–76. For the great majority of collieries a mean was available for each of the six years. The annual figures were averaged and rounded up or down to the nearest whole number to produce a single figure representing the respirable dust concentration for that colliery. Because a major change in dust measurement technique—from particle count to mass—took place in 1970, it was not feasible to use earlier data.

Epidemiological readings obtained in the third round of the PXR survey were available for 287 of the 291 collieries throughout Britain, and prevalence rates were derived from these. In six cases colliery amalgamations led to non-comparable groupings for prevalence and for coal rank. Information on coal rank was provided for 272 of the remaining 281 collieries. Twenty-two of these mined such a variety of coal ranks that they did not satisfy the criteria mentioned above, leaving 250 for the analysis of coal rank. Dust data were not available for three of these, so that dust concentrations were analysed at only 247 collieries.

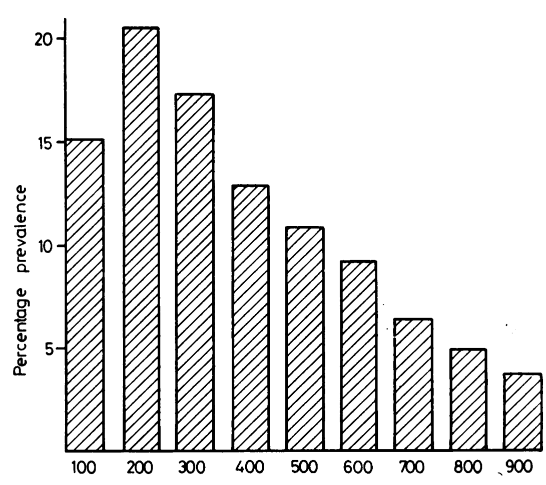

Figure *Prevalence of pneumoconiosis of at least category 1/0 in 62 362 face-workers, by rank of coal.*

Results

Table 2 and the Figure show that, among 62 362 face-workers grouped into 250 collieries, there is a well-marked relationship between the prevalence of pneumoconiosis of at least category 1/0 and the rank of coal mined, from ranks 200–900 inclusive, falling progressively within this range from 20·8% to 3·9%. Anthracite (rank 100 coal) is associated with a prevalence midway between that of rank 300 and rank 400 coal. This relationship cannot be ascribed to a rising gradient of mean ages between men mining low and high rank coal (Table 2), nor is it associated with higher mass-concentrations of dust in high-rank (low-number) collieries at the time of the survey; Table 3 shows that dust concentrations were uniformly distributed between coal of different ranks. It should be noted, however, that the prevalence figures are the consequence of exposure at a period considerably earlier than 1970–76 (the years to which the dust data refer) because of the long latent interval between dust exposure and the appearance of radiographic abnormality.

Table 4 examines coal rank within Areas. Although the number of collieries in each category is rather small it will be seen that, in general, the relationship between coal rank and prevalence is maintained within each Area. However there are three- to five-fold differences in prevalence between Areas at equal rank, which indicates that factors other than rank are of importance.

Table 2 *Relationship between coal rank and prevalence of pneumoconiosis category 1/0 or more in face-workers*

Rank	*No. of miners*	*Mean age (yr)*	*No. of collieries*	*Mean of colliery prevalences (%)*	*Standard deviation (%)*
100	1014	47·1	9	15·4	6·5
200	3838	44·5	23	20·8	8·7
300	4388	45·´	26	17·6	7·6
400	1392	46·5	8	13·1	7·2
500	14152	45·9	48	11·0	6·2
600	11549	46·0	42	9·3	4·7
700	10932	46·2	43	6·5	4·3
800	11347	46·0	36	5·1	2·8
900	3750	46·0	15	3·9	2·2
All ranks	62362	45·93	250		

Table 3 *Distribution of mean colliery respirable dust concentration 1970–76 and coal rank among 247 collieries*

Coal rank	*Number of collieries, with dust concentration*											*Total no. of collieries*	*Mean dust concentration (mg/m³)*
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10**		
100	2			4		2	1					9	3·1
200				3	5	7	5	3				23	5·0
300			1	2	7	9	3	1	1			24	4·8
400	1			1	3	2	1					8	3·9
500	1	2		2	9	13	13	4	3		1	48	5·2
600	1		3	3	4	10	13	4	3		1	42	5·3
700	2	1	2	3	4	11	11	7	1	1		43	5·1
800			2	4	5	9	10	4		1		35	5·1
900				1	1	6	5	1	1			15	5·5
All ranks	7	3	8	23	38	69	62	24	9	2	2	247	

*Dust concentration in mg/m³

Table 4 *Prevalence of pneumoconiosis category 1/0 or more in face-workers by rank and area. (Areas with at least four collieries at that rank)*

Area	*Rank* 100	*200*	*300*	*400*	*500*	*600*	*700*	*800*	*900*
Scotland						3·6	2·2	2·7	2·3
Northumberland					4·3		3·8		
Durham			23·4	16·3	11·1				
Yorkshire					13·3	10·2	6·6	7·6	
North-western					12·5	15·3	12·8		
North and mid-Midlands						8·5	8·2	5·4	
South Midlands									3·6
Staffordshire						9·3			
South Wales	15·4	21·6	16·1						

Discussion

Various studies (Jacobsen *et al.*, 1970; Dodgson *et al.*, 1971; Reisner, 1971; Reisner and Robock, 1977; Walton *et al.*, 1977) have demonstrated the importance of the mass of respirable dust in determining the development of pneumoconiosis, but have indicated that there are additional factors, perhaps associated with mineral composition and/or coal rank, that are not yet fully understood. The present results show a strong relationship between the rank of coal mined in British collieries and pneumoconiosis prevalence. High-rank collieries may, in the past, have produced a greater mass of respirable dust, and this may account for their showing a higher prevalence of pneumoconiosis.

Comparisons between collieries of equal rank in different Areas suggest that factors other than rank are also involved; previous differences in dust concentrations, possibly caused by different methods of mining or of controlling the dust, may largely account for these variations.

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