Pneumoconiosis

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PART I

IN THE COURSE of a lifetime everyone inhales some dust. Under rural conditions atmospheric dust contamination is slight, but in the lungs of those who live in smoky cities, many minute accumulations of dust are found. The dust retained under these conditions causes little or no anatomical damage and, so far as is known, results in no disturbance of health. The term pneumoconiosis is not used in reference to such lung states.

It is possible that urban atmospheric pollution may predispose to lung cancer and bronchitis, but a discussion of this possibility is outside the scope of the present paper.

In some industrial processes the air may become heavily laden with dust. It has been known for centuries that workmen engaged in some of these processes are liable to develop lung damage. A comprehensive list of the hazardous industries is given by Doig (1949). The term pneumoconiosis is usually reserved for a condition of ill-health resulting from the inhalation of harmful dusts at work. Perusal of the literature shows that special meanings are sometimes attached to the term pneumoconiosis according to the experience of the author. The radiologist regards it as a lung abnormality capable of producing characteristic x-ray changes, and the pathologist considers it as an alteration of pulmonary anatomy due to the effects of inhaled dust. For legislative purposes, Parliament has used pathological criteria in defining pneumoconiosis as “fibrosis of the lungs due to silica dust, asbestos dust or other dust and includes the condition known as dust reticulation” (National Insurance (Industrial Injuries) Act, 1946, 57, 3).

Experience has shown that some dusts encountered in industry are relatively harmless whilst others may cause rapidly fatal lung disease. It has been observed that workmen in sawmills, cement works and limestone quarries may tolerate dusty conditions for many years without contracting lung disease. In contrast, occupations involving exposure to dusts rich in free silica (SiO₂) carry a serious risk of ill-health. It is of interest that dusts containing silicon (Si) chemically combined as silicates are in general much less harmful than those which contain ‘free’ silica as silicon dioxide. With few exceptions, it can be shown that the risk of serious pneumoconiosis increases with a rise in the silica content of the dust.

Processes Involving Exposure to Highly Siliceous Dusts

Miners employed underground in South African gold mines were liable to develop nodular pulmonary fibrosis. Sometimes the lesion developed after a short period of employment and rapidly caused death. The gold-bearing ore might contain as much as 90 per cent of silica and much dangerous dust was produced in the drilling, blasting or crushing of the rock. Dusts of high silica content have been encountered in other industries, including quarrying or tunnelling in sandstone and granite, stone dressing, sandblasting, and in the manufacture of pottery, silica brick and abrasive soaps.

In fatal cases the lungs show areas of fibrosis (Fig. 1). In many the fibrous lesions are focal in type, seldom more than 1 cm. in diameter and more or less uniformly distributed throughout each lung. Microscopic examination of each lesion shows a structure composed of dense fibrous tissue arranged in a whorled pattern (Fig. 3). Examination by polarized light shows that particles of silica are present in the fibrous nodules. In some cases larger areas of fibrosis are present, sometimes involving most of a lung. These larger lesions appear to be made up of large numbers of contiguous small nodules. In lungs affected by focal or massive fibrosis, active tuberculosis commonly develops and rapidly progresses.
Fig. 1. A section of the left lung which was removed at autopsy from a sandstone quarry man. It shows discrete silicotic nodules, coalescing nodules and a tuberculous cavity. Compare Fig. 2.

Fig. 2. This chest film shows the discrete dense scattered opacities of silicosis and a large apical opacity due to tuberculosis. The patient was a man of 54 who had been exposed to highly siliceous dust in a sandstone quarry for 20 years. Compare Fig. 1 which shows a section of his left lung.

Fig. 3. The lesion shown was present in the lung of an American miner. Much of his work involved drilling and shot-firing in highly siliceous rock. The compact whorled fibrosis and relative absence of focal emphysema are typical of the lesions resulting from such work.
Pneumoconiosis Due to Dusts of Low Silica Content

The occupations involving exposure to dusts of low free silica content include coal mining, the use of natural graphite and the manufacture of synthetic graphite (Meiklejohn and Merrwether, 1956).

In Great Britain coal mining accounts for more cases of pneumoconiosis than the total of all other industries. The condition of coal workers' pneumoconiosis occurs in coal miners and in trimmers who load coal into the holds of ships. The disease is specially prevalent in the coal fields of South Wales. Chemical analysis of the coal shows that it is unusual for a sample to contain more than 1 per cent of free silica (Hicks, 1943). Coal miners are exposed not only to coal dust but also to dust from the stone and shale strata in the mine. These have a higher silica content and, in the past, the view was held that the miners' disease was due to exposure to dust from the non-coal strata. Following the radiological study of Collis and Gilchrist (1928), Gough (1940) showed that at autopsy the lungs of some coal trimmers contained lesions identical to those observed in coal miners. The trimmers had been exposed to dust derived only from commercial coal. It was thus established that coal dust itself could lead to serious pulmonary fibrosis. It is not known whether the lesion is due to the small amount of silica in the coal or whether it would occur if coal could be freed from its intrinsic silica. The question is not of any practical importance since all types of coal as mined and sold contain a small proportion of 'intrinsic' silica.

Among coal workers the incidence of dust disease is highest among those engaged in cutting the coal from the seam. The incidence is lower in those who are employed in transporting the coal from the coal face to the mine shaft. Experiments have shown that coal particles exceeding 5μ in diameter remain suspended in air for only short periods and are unlikely to be inspired. Such large particles as reach the air passages are trapped in mucus and excreted by ciliary action and coughing. Microscopic examination of the lungs shows that few particles which reach the alveoli and the pulmonary interstitial tissue exceed 2μ in diameter. There are grounds for believing that the risk of disease depends on the concentration of respirable dust in the air and the duration of exposure. It is unusual for pneumoconiosis to develop until exposure has occurred for more than 20 years and in most cases radiology shows that the condition progresses at a slow rate.

Two types of lung lesion can be distinguished radiologically and at autopsy. Direct observation post-mortem reveals two types of anatomical disturbance called, respectively, simple pneumoconiosis and massive pneumoconiosis (Gough, 1940 and 1947).

Simple pneumoconiosis of coalworkers is characterized by foci of dust accumulation scattered more or less uniformly throughout each lung (Fig. 5). The foci are black in colour, often stellate in shape and they seldom exceed 7 mm. in diameter. Microscopy shows that the foci consist of accumulations of dust-laden macrophages enmeshed in reticulin fibres. The lesions contain little or no collagenous fibrous tissue. In many cases the foci contain, and are surrounded by, dilated air spaces producing an emphysematous condition to which the term focal emphysema has been applied. Its pathogenesis has been described by Heppleston (1953).
Fig. 4. The lung from which this section was made was obtained at autopsy from a miner aged 45. He had worked underground for 20 years in the Kolar gold mines of India. The profuse minute dust foci are typical of the condition which occurs in these mines. Microscopy showed that the foci contained only a little fibrous tissue.

Fig. 5. A section of the whole right lung from a coalminer of 61. The numerous discrete dust foci with focal emphysema indicate an advanced degree of simple pneumoconiosis.

Fig. 6. The profuse minute opacities are typical of an advanced degree of coal-workers' simple pneumoconiosis. The patient was a coalminer of 61 who had worked underground for 38 years in South Wales pits. Fig. 5 illustrates a section of his right lung.
Fig. 7. The lesion illustrated was one of many seen in the lungs of an insurance agent aged 62. He had worked in a coal mine from the age of 12 to 31. The dilated air spaces around the dust focus can be clearly seen.

Fig. 8. The black area in the upper half of this section of the left lung represents coalworkers' massive pneumoconiosis with cavitation. The rest of the lung is affected by simple pneumoconiosis.

Fig. 9. The bilateral large opacities in the upper zones are characteristic of coalworkers' massive pneumoconiosis. The patient was a coalminer of 59 who had worked underground for 37 years. A section of his left lung is shown in Fig. 8.
Massive fibrosis may develop in one or more sites in lungs previously affected by simple pneumoconiosis. The fibrous mass is black in colour and sometimes partly liquefied by necrosis. Sometimes the masses are so large as to destroy almost the whole lung (Fig. 8). In most cases the lesions commence in the upper part of the lung, and the right side is affected more often than the left. Some authorities consider that the massive fibrous lesion is due to the effect of a large amount of dust acting for a long time. Others believe that it results from the combined effect of dust and tuberculosis (James, 1954).

**Pneumoconiosis Due to Silicate Dusts**

In many minerals silicon is present chemically combined in metallic salts of silicic acid. Dusts derived from these silicates are relatively harmless compared with those derived from minerals containing 'free' silicon dioxide. Nevertheless, it has been shown that prolonged inhalation of air contaminated with silicates may lead to serious pulmonary fibrosis. The occupations which involve substantial risk include asbestos processing, china clay processing, and industries requiring the use of powdered talc.

Mineral asbestos consists mainly of hydrated magnesium silicate. The actual mining process appears to carry little risk of pneumoconiosis but, in the subsequent spinning and weaving, numerous fine fibres are liberated. Many observers have shown that the fibres may reach the small air passages of the lungs where they can be demonstrated microscopically. After exposures of 10 years or more, employees may develop the dyspnoea, cyanosis and finger-clubbing characteristic of asbestosis. The radiological appearances are not specific, most cases showing only an ill-defined loss of translucency of the lower parts of each lung field.

At autopsy the condition is characterized by gross pleural thickening, diffuse pulmonary fibrosis and microscopically demonstrable altered asbestos fibres known as 'asbestos bodies'. Many observers have reported that asbestosis carries an increased risk of lung cancer.

**Pneumoconiosis in Relationship to Lung Cancer**

At autopsy it is sometimes found that the lungs of elderly men are affected by pneumoconiosis and lung cancer. In the past it has been suggested that in such cases the tumour was due to the pneumoconiosis. Recent extensive studies of bronchial carcinoma in gold miners (Smith, 1947) and in coal miners (James, 1955) have indicated that these two occupations do not lead to an increased risk of lung cancer. Lung cancer has been observed with undue frequency in men employed in processing chrome and nickel. There is also good evidence that workmen affected by asbestosis have an excessive mortality from primary lung cancer (Doll, 1955).

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Part II of this paper will appear next month.