Graphite pneumoconiosis

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Ranasinha, K. W., and Uragoda, C. G. (1972). *Brit. J. industr. Med.*, **29**, 178-183. **Graphite pneumoconiosis.** In this survey, which is the first of its kind in the graphite industry, 344 workers in a large mine in Ceylon were investigated for pulmonary lesions; 22.7% of them had radiographic abnormalities, which included small rounded and irregular opacities, large opacities, and significant enlargement of hilar shadows. They had worked considerably longer in the industry and were, on average, older than the rest. Only 19.2% of the affected workers had respiratory symptoms, of which dyspnoea and cough were the most frequent. Digital clubbing was seen in 21.9%.

In an age and sex matched control group, comprising 327 persons from a neighbouring village, only 8 (2.4%) showed radiographic abnormalities.

Graphite pneumoconiosis closely resembles coal miners' pneumoconiosis in many respects. It does not appear to be a pure silicosis, neither could it be considered a true carbon pneumoconiosis. It is likely that massive fibrosis is associated with tuberculous infection.

Pulmonary lesions have been described in graphite workers, but no systematic survey has been carried out in this industry. The present knowledge is based mainly on individual case reports of workers who were not actual miners. Dunner (1945) described the clinical and radiological findings in men exposed to graphite through unloading ships for periods of about 20 years. Lister (1961) reported a man who had been turning and grinding synthetic graphite bars for 17 years. Gloyne, Marshall, and Hoyle (1949) and Harding and Oliver (1949) reported some fatalities in workers exposed to a mixed dust containing graphite during manufacture of crucibles. Dassanayake (1948) carried out a survey of graphite miners in Ceylon. His investigation embraced various aspects of their health, and the pulmonary changes which comprised one of them were not reported in detail.

Graphite is crystalline carbon. It is also known as plumbago as it was originally mistaken for lead. It is used in lead pencils, foundry linings, paints, electrodes, and dry batteries, and in making crucibles for metallurgical purposes. Finely powdered graphite is also employed as a lubricant. The best quality

product on the world market comes from Ceylon and Madagascar. The Ceylon mineral may reach a degree of purity as high as 98% and is especially in demand for purposes where quality graphite is required, as in the manufacture of crucibles.

Deposits of graphite occupy veins and fissures in underground crystalline rocks. These veins vary from a few inches to 3 or 4 feet (1 m) in width but sometimes may reach even 12 feet (3.7 m). They may continue for several miles, even up to 50, in the same direction. Major deposits in Ceylon are confined to the south-western sector of the island (Cooray, 1967).

During the two world wars there was a boom in the graphite industry in Ceylon, the peak being in 1942 when 27 000 tons were exported. About 2 000 plumbago mines were worked during this period, but the majority of them were no more than pits, being under 100 feet (30 m) in depth. The current average production per year is 10 000 tons, the major portion of which is exported to the United Kingdom, the United States of America, and Japan. This output is mainly derived from three mines which are perhaps the largest in the world. The present survey was

carried out in one of them. It has been worked for about 100 years, and mining is presently being done at a depth of 2 200 feet (670 m), the deposits in the more superficial layers having been already tapped.

In this mine there are two electrically-powered lifts which operate in a vertical shaft down to a depth of 600 feet (182 m). From the level of the lower terminus of the lift workers descend by ladders. An alternative method of descent is available in the form of a system of large wooden buckets which go down in a relay of successive stages to the bottom of the mine. They are electrically worked by winches which are placed at different levels in the mine. Workers are discouraged from going down in these buckets in view of the risk involved. Their primary function is to haul up the mined graphite.

Basically, graphite mining consists of driving a downward shaft by blasting the rock until a graphite vein is encountered. This is then followed up, usually horizontally, by blasting the adjacent rock in order to provide an approach tunnel for the miners to work the vein. The graphite deposits which are in the fissures of the rock are dislodged with the help of dynamite. Blasting, whether in the rock or in graphite deposits, is done by boring shot holes, usually by electrically-operated drills. In situations where space does not permit their use, hammer and chisel are employed for the purpose. The shot holes are fed with dynamite, and the fuse is ignited by a man, called the blaster, after all the other workers have returned to the surface at the end of the day's work. The length of the fuse is suitably adjusted to enable the blaster, too, to be back on the surface before the explosion occurs. By the time the workers go down the next morning, the fumes have cleared. The dislodged graphite is collected and loaded into the buckets and hauled up. Most of the larger pieces crumble during this process. The graphite is then transferred into trolleys to be brought to the surface by lift. When they reach the surface, these trolleys are pushed along the rails to the curing shed where the graphite is separated from the rock. Each lump is lightly tapped with a piece of iron when a dull thud is produced if it consists only of graphite. A metallic sound indicates the presence of rock from which the graphite is then chiselled off. It is finally graded before export.

Only men are allowed to work underground where they usually work for about four hours per day. By early afternoon all the miners are back on the surface. Curing is done by women.

The entire mine is lit by electricity. Compressors pump fresh air into the depths of the mine. Water which collects at the bottom is pumped out onto the surface in stages.

Material and method

The mine in which this survey was carried out had a

labour force of 450 workers, but for various reasons only 344 were investigated. Each of them had a 70 mm radiograph of the chest taken by a mobile x-ray unit. The films were read by us independently, and those where both readers agreed were accepted as abnormal.

An occupational history of the 344 workers was taken. A clinical examination was carried out on all those who showed radiographic lesions, except five workers who in spite of persistent efforts could not be persuaded to present themselves for examination. From those who complained of a cough, a sample of sputum was examined by both direct smear and culture methods.

Control group

The population of one of the villages that was selected for a comprehensive survey on the problem of tuberculosis in Ceylon was used as the control group for the present study. A total of 36 villages and towns in the whole country were selected by a process of stratified sampling for this survey. One of these villages was about 10 miles from the graphite mine, and we chose this population as the control group in view of its random selection and the proximity of the village to the mine, which, too, was situated in a rural area. An added consideration was that this village population and the miners were radiographed on 70 mm film within a few months of each other.

The radiographs of these villagers were read by us, and a control group of 327 people matched for age and sex was selected by random sampling from this population.

Results

The average age of the 344 workers examined was 36.8 years, and their average length of service in the graphite industry was 15.7 years; 308 (89.5%) were men and 36 (10.5%) were women. Seventy-eight workers (22.7%) had radiographic abnormalities in the chest which were almost proportionately divided between the sexes (Table 1). On the other hand, only 8 (2.4%) of the 327 controls had lesions. This difference was highly significant.

The affected workers had, on average, served an appreciably longer period in the industry (20.6 years) than the rest (14.2 years) (Table 2). They were considerably older, too. Table 3 shows the age distribution of the two groups of workers. The majority

TABLE 1
INCIDENCE OF PULMONARY LESIONS

Workers	Males		Females		Total	
	No.	%	No.	%	No.	%
With lesions	69	22.4	9	25.0	78	22.7
Without lesions	239	77.6	27	75.0	266	77.3
Total	308	100.0	36	100.0	344	100.0

TABLE 2
AGE AND PERIOD OF WORK IN RELATION TO PULMONARY STATE

Workers	Average age (yr)	Average duration of work (yr)
With lesions	42.0	20.6
Without lesions	35.2	14.2
All workers	36.8	15.7

of the unaffected miners were in the third and fourth decades, while the affected were mainly in the fifth.

Table 4 shows the types of radiographic lesions in the miners and the controls classified according to the International Classification of Radiographs of Pneumoconioses (Revised, 1968). In the two miners whose radiographs were categorized as showing large opacities, size C, the lesions were bilateral and involved the upper and midzones, and were consistent with those of massive fibrosis. In the two cases which showed calcified pleural plaques, the lesions were unilateral and there was no obliteration of the costophrenic angle; neither did they give a history of previous pleurisy (see also Figs. 1 and 2).

Clinical examination which was carried out in 73 of the 78 workers showing radiographic lesions revealed that only 14 (19.2%) had symptoms, the commonest being dyspnoea (Table 5). Digital clubbing was noticed in 16 cases (21.9%). Samples of sputum were collected from those who complained of cough but revealed no acid-fast bacilli on direct smear. Culture also proved negative.

Discussion

Ceylon is one of the most important sources of commercial graphite in the world. In 1969 there were

TABLE 4
RADIOGRAPHIC LESIONS IN 78 GRAPHITE MINERS AND 8 CONTROLS

	Graphite miners (n=344)		Controls (n=327)	
	No.	%	No.	%
Small opacities	23	6.7	1	0.3
Rounded	13	3.8	1	0.3
Category 1	10	2.9	0	0
2	0	0	0	0
3	7	2.0	0	0
Type p	2	0.6	0	0
q	14	4.1	1	0.3
r	31	9.0	1	0.3
Irregular	9	2.6	3	0.9
Large opacities	5	1.5	2	0.6
Category A	2	0.6	1	0.3
B	2	0.6	0	0
C	2	0.6	0	0
Calcified pleural plaques	2	0.6	0	0
Significant pleural abnormalities	1	0.3	0	0
Abnormalities of cardiac size and shape	1	0.3	0	0
Eggshell calcification of lymph nodes	3	0.9	1	0.3
Opacities suggestive of active tuberculosis	0	0	1	0.3
Significant emphysema	6	1.7	0	0
Significant enlargement of hilar shadows	15	4.4	0	0
Pneumothorax	1	0.3	0	0

1 391 miners working in the graphite industry in the country. Thus the present survey, in which 344 workers were examined, covered nearly a quarter of the country's total labour force in this field.

The workers examined had served for several years in the same mine, the average being 15.7 years. They had attained by experience a semi-skilled

TABLE 3
AGE DISTRIBUTION

Age (yr)	Workers without lesions				Workers with lesions				Total			
	M	F	No.	%	M	F	No.	%	M	F	No.	%
10-19	6	0	6	2.3	0	0	0	0	6	0	6	1.7
20-29	85	3	88	33.1	9	1	10	12.9	94	4	98	28.5
30-39	76	9	85	31.9	13	4	17	21.9	89	13	102	29.6
40-49	48	13	61	22.9	35	4	39	50.0	83	17	100	29.1
50-59	22	1	23	8.6	12	0	12	15.3	34	1	35	10.2
60-69	2	1	3	1.2	0	0	0	0	2	1	3	0.9
Total	239	27	266	100.0	69	9	78	100.0	308	36	344	100.0

FIG. 1. Small irregular opacities best seen in the mid zones bilaterally.

FIG. 2. Bilateral upper zone opacities, size B.

TABLE 5
DISTRIBUTION OF SYMPTOMS IN 14 SYMPTOMATIC WORKERS

	No. of workers
Dyspnoea	12
Cough	6
Pain in chest	2
Loss of weight	1

status in their work. The attractive wages and other fringe benefits were mainly responsible for their remaining in the same occupation over long periods. It is reasonable to expect some of the workers with such a long history of exposure to show pulmonary changes that are likely to occur in association with this occupation.

Workers with radiographic abnormalities had served for an average of 20.6 years in the industry compared to only 14.2 years for the rest. The prolonged exposure associated with pulmonary lesions implies that these workers should be older than the rest. This was borne out by the difference of 6.8 years in the average ages of the two groups. This difference was highly significant ($P < 0.001$). The peak incidence for lesions was in the fifth decade.

Though there are several categories of workers, their functions are not strictly defined, for some work in more than one capacity or switch from one job to another. Further, labourers may get promoted to winch drivers or supervisors. Therefore all the underground workers are exposed to similar working conditions.

There are different views on the nature of graphite pneumoconiosis. Hunter (1962) considers it to be a slowly developing silicosis, while Perry and Sellors (1963) state that it is similar to coal miners' pneumoconiosis. There is also evidence that pure carbon dust could give rise to a pneumoconiosis. Miller and Ramsden (1961) describe a man who handled carbon black for 21 years. He had massive fibrosis in the upper lobes. This case and that of Lister (1961) suggest that non-siliceous carbon dust could by itself produce pneumoconiosis.

Even the purest commercial graphite contains about 2% of quartz. Harding and Oliver (1949) found that samples of graphite from Ceylon, South West Africa, and Korea contained 3.6 to 10% of free silica. Underground and surface workers are subject to different environmental conditions. Any silica dust that the surface worker inhales is derived from the siliceous impurity that is inherent in graphite. On the other hand, the underground worker is, in addition, exposed to silica dust that

is generated by blasting the rock that envelopes the graphite. If graphite pneumoconiosis is a slowly developing silicosis, then one would expect underground miners to have a higher incidence of pulmonary lesions than the surface workers. But this is not borne out by the results; 25% of the women who work solely on the surface had lesions compared to 22.4% of the underground workers. Dassanayake (1948), too, found that a higher proportion of surface workers had pulmonary abnormalities.

Silicosis is very rare in Ceylon though the granite industry, which is usually associated with this condition, is widespread in the country. In a survey of granite workers in Ceylon, Uragoda (1968) did not find a single case of silicosis, its rarity being attributed to the open air nature of the work and the absence of mechanization in the industry. Therefore it is unlikely that as many as 25% of the surface graphite workers inhaling a small proportion of siliceous impurities in the graphite would get silicosis when granite workers who are exposed to a much higher concentration of silica do not develop it under similar well-ventilated conditions. The epidemiological evidence is, therefore, against the contention that graphite pneumoconiosis is a silicosis.

The results of this survey show many points of similarity between graphite and coal miners' pneumoconioses. Both substances are basically carbon. Coal miners' pneumoconiosis is considered to be due to inhalation of a mixed dust consisting of coal together with a relatively small proportion of free silica (Hunter, 1962). The dust to which graphite miners are exposed also contains a mixture of carbon and silica. The clinical course is similar in the two conditions. Both develop after many years of exposure, and the radiographic abnormalities usually precede symptoms. In this survey only 19.2% of the workers showing radiographic lesions had symptoms. Dyspnoea was the commonest symptom, followed by cough. The radiographic picture in both conditions may show small rounded and irregular opacities, large opacities, and emphysema.

Commercial graphite always contains some siliceous impurity. Therefore graphite pneumoconiosis cannot be considered a pure carbon pneumoconiosis.

Massive fibrosis in coal miners' pneumoconiosis and in silicosis is invariably associated with tuberculous infection. This relationship has not been reported in graphite pneumoconiosis. Three miners from another graphite mine had proven pulmonary tuberculosis, and their subsequent progress suggested that tuberculous infection had complicated pneumoconiosis (Uragoda, in press).

Fifteen miners (4.4%) showed significant enlargement of hilar shadows, but none of the control group. This fact suggests that this abnormality may have resulted from exposure to graphite dust and

could therefore be considered a stage in graphite pneumoconiosis.

Calcified pleural plaques occurred in two workers. These are unlikely to have been the result of an earlier tuberculous infection, though this possibility cannot be dismissed altogether. Neither of these two workers gave a history of previous pleurisy, nor was there obliteration of the costophrenic angle to suggest an earlier effusion. The possibility that this calcification was caused by graphite itself cannot be ruled out in view of a similar finding in talc and mica pneumoconioses.

Dassanayake (1948) found that 30% of the underground workers and 82.3% of the surface workers engaged in curing graphite showed radiographic lesions. The present survey revealed 22.4% and 25% respectively. Therefore the figures in the two series are similar for the underground miners, but there is a wide disparity as regards the surface workers.

Digital clubbing was observed in an appreciable proportion (21.9%) of the affected workers. It may be recalled that it also occurs in coal miners' pneumoconiosis, silicosis, and in conditions resulting from inhalation of silicates such as asbestos and talc.

Only one worker, a man with massive fibrosis, was disabled to an extent that hampered his work. It would appear from this that the pulmonary changes occurring in graphite workers are not very disabling. Chronic bronchitis is uncommon in Ceylon, and this implies that environmental factors that predispose towards it are not present to the same extent as in a country like England where the condition is very common. If these factors were at work in Ceylon, also, it is difficult to predict whether these miners would then have been equally free of symptoms.

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References

- Cooray, P. G. (1967), *An Introduction to the Geology of Ceylon*, p. 204. National Museums of Ceylon Publication, Colombo.
- Dassanayake, W. L. P. (1948). The health of plumbago workers in Ceylon *Brit. J. industr. Med.*, **5**, 141-147.
- Dunner, L. (1945). Observations on pulmonary disease in graphite workers. *Brit. J. Radiol.*, **18**, 33-35.
- Gloyne, S. R., Marshall, G., and Hoyle, C. (1949). Pneumoconiosis due to graphite dust. *Thorax*, **4**, 31-38.
- Harding, H. E., and Oliver, G. B. (1949). Changes in the lungs produced by natural graphite. *Brit. J. industr. Med.*, **6**, 91-99.
- Hunter, D. (1962). *The Diseases of Occupations*, 3rd ed., p. 931. English Universities Press, London.
- International Classification of Radiographs of Pneumoconioses (Revised, 1968). International Labour Office, Geneva.
- Lister, W. B. (1961). Carbon pneumoconiosis in a synthetic graphite worker. *Brit. J. industr. Med.*, **18**, 114-116.
- Miller, A. A., and Ramsden, F. (1961). Carbon pneumoconiosis. *Brit. J. industr. Med.*, **18**, 103-113.
- Perry, K. M. A., and Sellors, T. Holmes, ed. (1963). *Chest Diseases*, vol. 1, p. 567. Butterworths, London.
- Uragoda, C. G. (1968). Occupational hazards among granite workers in Ceylon. *J. trop. Med. Hyg.*, **71**, 267-270.
- (1972). Pulmonary tuberculosis in graphite miners. *J. trop. Med. Hyg.*, in press.

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