Pneumoconiosis in Chromite Miners in South Africa

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Ten chromite miners in South Africa have been found to show radiological evidence of a fine nodulation; five of these miners had worked only in chromite mines. These cases occurred in a labour force of some 1,500 persons subjected to regular examination. Clinical evidence and the results of intratracheal injection of chromite suspension into rats indicate that the radiological changes are due not to fibrosis but to a benign deposition of chromite (Cr₂O₃FeO) dust in the lungs.

Interest in the effects of inhaled chromium and its compounds on the respiratory system has concentrated largely on carcinoma of the lung and perforation of the nasal septum. There have been claims that an increased prevalence of chronic bronchitis and emphysema may occur in workers in chromite works (Worth and Schiller, 1954) and in experimental animals exposed in such works (Lukanin, 1930). Asthma due to hypersensitivity to chrome compounds has been reported (Broch, 1949; Naidu and Rao, 1948).

Lukanin (1930) has also described the occurrence of some pulmonary fibrosis due to inhalation of chrome compounds in animal experiments. Spannagel (1950) described radiological changes ascribed to peri-bronchial and peri-vascular fibrosis, and Letterer, Neidhardt, and Klett (1944) considered that interstitial fibrosis may be brought about by chrome compounds. A report on pneumoconiosis in chromite miners appeared in the U.S.S.R. (Andrievskaya and Mislavskaya, 1949) which, with Rhodesia, South Africa, and Turkey, is one of the world's great chrome producers.

Gafafer (1953), who reported on a radiographic study of 897 chromite workers exposed in factories, found no case of pneumoconiosis attributable to this exposure nor were any mentioned by Bidstrup (1951) in a radiographic study of 724 exposed factory workers.

On the other hand, Mancuso (1951) and Mancuso and Hueper (1951) described a spotty, moderately severe but not nodular pneumoconiosis which they called chromitotic pneumoconiosis. The radiological changes consisted of an ill-defined mottling. On histological examination they reported collections of large amounts of black pigment in the interstitial tissue together with thickening, fibrosis, and hyaline change of interstitial tissue and the interalveolar septa.

This paper reports the occurrence of pulmonary radiological changes in chromite miners in South Africa and the correlation of these with dust counts taken in the mines.

The Chromite Deposits of South Africa

Chromite is the only mineral ore of chromium and consists of the oxides of chromium and of iron (Cr₂O₃FeO). The deposits which are mined are situated in the Transvaal province and occur as sheets of packed granules, each granule being about 0·5 mm. in diameter. The silicate gangue consists mostly of a pyroxene of calcic felspar but also includes some bowlingite (a hydrous silicate of magnesium and aluminium). The manner of distribution of chromite and these silicates gives the ore its mottled appearance. The chromite ore occurs in sheets in the basal part of the mafic rocks which are part of the bushveld igneous complex. These rocks consist of pyroxenite, norite, and anorthosite and are mainly disposed in layers resembling the beds of a sedimentary formation.

Occasional pegmatite veins, consisting of quartz, alkali feldspar, and mica, may transect the chromite seams, but these are narrow and unlikely to contribute significantly to the dust cloud. Very little free silica is present and it is certainly less than 5% and probably nearly always less than 1%. The chromite seams vary in thickness from 1 inch (25·4 mm.) to more than 6 feet (1·8 m.).
The deposits are usually mined by stoping from level adits and from incline shafts. The thickness of the chromite seam is in many places 40 or more inches (1 m.) and provides adequate stoping widths. In most places there is a well-defined hanging and foot wall of pyroxenite or anorthosite and clean mining of the chromite ore is practicable, though some contamination by the basic silicate rocks may occur and some hand sorting is then carried out. In one of the larger mines, where the thickness of the seam may be less than 12 inches (30 cm.), the procedure is to break about 2 feet (60 cm.) of hanging wall of pyroxenite and then to pick up the seam of ore in the foot wall. Mining is generally at shallow depths always less than 1,000 ft. (300 m.). Occasionally, the chromite seams are associated with minor seams, or irregular bodies, of magnetite containing small amounts of oxides of titanium and chromium; but this occurs too infrequently to make a significant contribution to a mining dust cloud.

The average chemical composition of the chromite produced is Cr$_2$O$_3$ 45.2%, FeO 26.6%, SiO$_2$ 2.1%, Al$_2$O$_3$ 15.4%, MgO 9.6%, CaO 0.9%. A small quantity of Vanadium, ranging from 0.05% to 0.81%, may be present (The Mineral Resources of the Union of South Africa, 1959). The average analysis of the pyroxenite is SiO$_2$ 55%, MgO 30%, FeO 9%, Al$_2$O$_3$ 2.2%, with very small quantities of calcium, nickel, titanium, and manganese oxides. Occasionally there is a small quantity of Fe$_2$O$_3$ (Hall, 1932).

Dust Conditions Dust concentrations were measured by the konimeter in the immediate vicinity of each person encountered underground. The samples were counted under dark-field illumination at a magnification of 150 times after ignition—immersion—ignition treatment to remove combustible and soluble salts, and represent particles of approximately 0.5 to 5 microns.

Before the introduction of wet mining methods in and shortly after 1949, these mines were very dusty. However, in the early 1940s the tempo of mining was not high and it is probable that dust counts may have remained at a relatively low level during these years, but with the increasing rate of production they subsequently rose until about 1947, when miners may have been exposed to a mean count in chromite mines of about 1,000 particles/cc., or a little less. In 1946 to 1948 inclusive, the average dust count of 2,256 spot samples was 580 particles/cc. Individual mines varied greatly and mines A, C, and D (Table) were the dustiest. By 1954 the average count had fallen to 180 particles/cc. and, according to spot checks since, has remained at this value.

The Cases The underground labour force in chrome mines has varied throughout the years. It was 2,800 in 1954 but had diminished to about 1,500 in 1965. The majority of the underground workers, both European and Bantu, tend to spend a relatively short time in chrome mines; few remaining longer than five years. The number of these who have not at some time been employed on other types of mining, or been exposed to other types of industrial dust, is smaller still.

Walters (1957), who conducted a radiological and clinical survey of chrome miners in the Western Transvaal for the Department of Mines, found, among 1,225 Bantu workers examined, cases who had radiological appearances consistent with pneumoconiosis and whose mining service, as far as could be established, was restricted to chrome mining.

On October 1 1958, most of the chromite mines in the Transvaal were brought under the Pneumoconiosis Act of 1956. Since that time both European and Bantu underground workers at these mines have been required to undergo regular clinical and radiological examination. As a result other chromite miners with radiological abnormalities were found.

Ten cases are described, of whom five appear to have worked only in chrome mines. In the other five cases a history of service in other types of mines was elicited from the men (Table). All the radiographs were taken on large plates, usually 12 × 14 in. (30 × 35 cm.), either in the Mobile X-ray Unit during the survey or at mine hospitals or nearby mission hospitals. Radiographs were accordingly not of standardized technique and quality.

Results

Radiology

The Nodulation Typically this consists of a very fine nodule, less than 1 mm. in diameter (Fig. 1). It usually appears first in the right upper zone and may be very profuse. Sparse, short, linear opacities of similar density to the nodules may be seen. When the changes are advanced the whole lung fields on both sides are profusely involved, though there is relative sparing of the extreme apices.

Generally speaking, the noduleation is finer in quality, though somewhat more radio-opaque, than in simple coalminers' pneumoconiosis. Occasionally there is an admixture of rather larger nodules, usually of approximately 2 to 3 mm. diameter. This larger form of nodulation occurs both in men who give a history of pure chrome mining and in those with mixed mining service.
### TABLE

#### Clinical Details of the 10 Cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age</th>
<th>Mining Service</th>
<th>Radiograph Reading</th>
<th>Clinical Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39</td>
<td>8½ yrs machines mine A, 1949-59</td>
<td>Profuse pinhead nodulation forming reticular pattern. Hila opaque, not enlarged (Fig. 1)</td>
<td>No complaints. No abnormal signs. Fit for normal work. Three sputa negative for <em>Mycobacterium tuberculosis</em> (direct)</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>10 yrs mine A, 1944-55</td>
<td>Profuse pinhead nodulation. Hila slightly enlarged, not dense</td>
<td>No complaints. No abnormal signs. Very fit</td>
</tr>
<tr>
<td>3</td>
<td>41</td>
<td>8½ yrs machines mine A; 5½ yrs tramming and cleaning in other chrome mines</td>
<td>Similar to above. Hila normal</td>
<td>No complaints. No abnormal signs. Fit for normal work</td>
</tr>
<tr>
<td>4</td>
<td>39</td>
<td>9 yrs tramming mine B; 12 yrs machines mine H, 1937-60</td>
<td>Moderately profuse nodulation. R. lung, sparse on L. Nodules 2 mm. diam. Hila normal</td>
<td>No complaints. No abnormal signs. Fit for normal work</td>
</tr>
<tr>
<td>5</td>
<td>36</td>
<td>10 yrs mine A, 1945-55</td>
<td>Profuse pinpoint mottling, more profuse on R. Hilar shadows slightly increased</td>
<td>No complaints. Clinically normal. Fit for normal work</td>
</tr>
<tr>
<td>6</td>
<td>31</td>
<td>9 yrs mine A, 1946-55; also iron 2 mths</td>
<td>Sparse medium-sized (2 mm.) nodulation upper zones. Calcified gland R. hilum with elevated lesser fissure</td>
<td>Clinically normal. Fit for normal work</td>
</tr>
<tr>
<td>7</td>
<td>55</td>
<td>16 yrs machines mine D, 1939-56; 1 year gold (1953), 3 yrs tin (1935-38), and 2½ yrs iron (1956-59)</td>
<td>Very profuse fine pinhead mottling both lungs. Hila opaque, not enlarged. Elongate opacity R. upper zone 4 in. long and 1 in. wide (101 x 25 mm.). Thickening of lesser fissure</td>
<td>Scattered crepitations. No complaints. Fit for normal work. No sputum</td>
</tr>
<tr>
<td>8</td>
<td>47</td>
<td>8½ yrs mines A, D, J, and K, 5 on machines; 2 yrs gold, 2 yrs iron, 6 mths platinum</td>
<td>Fairly profuse fine pinhead nodulation R. lung. Pleural thickening L. base. Some large mottling L. upper zone ? old tuberculosis</td>
<td>No complaints. Fit for normal work. Three sputa negative for <em>Mycobacterium tuberculosis</em> (direct)</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
<td>18 yrs mine C as underground bossboy, 1946-66; gold 6 yrs; diamonds 2 yrs</td>
<td>Rather sparse larger than pinhead (3 mm.) nodulation, more in left lung. Hila normal</td>
<td>No complaints</td>
</tr>
</tbody>
</table>

Mines A to K are chrome mines.

**The Hilar Shadows:** It is appreciated that consistent reading of minor enlargement, or relative degrees of radio-opacity in the hilar shadows, is difficult and usually a matter of impression. In two of these cases, increased radio-opacity, without enlargement, of the hilar shadows was considered to be present. In some of the other patients a slight increase in the size of the hilar shadows was seen but this was not as striking a feature as in persons with silicosis in South Africa. In no case were the changes in the hilar shadows sufficient to suggest the possibility of bronchial carcinoma.

Pleural thickening occurred in only one case in this series, suggesting that it was not related to
In four miners three sputa examinations for tubercle bacilli were made but none was positive.

Dust Conditions in relation to the Radiological Finding The calendar years of exposure were known for all the cases except case 3 and all of them, with the exception of case 1, had some years of service prior to 1949, i.e., during a period when dust conditions were at their worst. It is in fact possible that under present conditions no further cases will occur as none has occurred with service only in chrome mines since 1953, by which year dust surveys had shown a great improvement in conditions. Between 1949 and 1953 conditions varied in the mines, and case 1 may well have been exposed to high dust concentrations during this period.

Discussion

Cases with Mixed Service In case 6 the two months’ service in iron mines is not likely to have contributed significantly to the radiological change. Case 7 had four years (one in gold and three in tin mines) silica exposure, and case 8 had two years in gold mines. Both, however, showed nodulation identical to that in the ‘pure’ cases and quite unlike silicosis. In case 7 the elongate opacity in the right upper zone might be due to massive fibrosis but tuberculosis is considered more likely, although fibrosis from old non-tuberculous inflammatory disease cannot be excluded.

In case 9, with six years in gold mines (the two years in diamond mines would have resulted in little exposure to silica), the nodulation was larger than in the other cases and in this case silicosis cannot be excluded.

Case 10 had had 16 years in platinum mines where he was exposed to a silica-free dust very similar to that in chrome mines (derived from a porphyritic pyroxenite and anorthosite containing a small chromite seam). Surveys of workers in these mines have never revealed radiological changes suggestive of pneumoconiosis.

The Cause of the Nodulation No man who has worked only in chromite mines in South Africa and who has showed the radiological abnormalities described here has come to necropsy, nor are there any post-mortem reports from elsewhere.

It has been shown that chromite is demonstrable radiologically in the lungs of experimental animals who, after intratracheal injection of a chromite suspension, had disseminated some of the chromite via the bronchi through several lung segments. This
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is to be expected as the atomic weight of chromium is 52.01 and that of iron 55.85 (Theron, C. P., personal communication, 1965).

Experiments carried out at the Pneumoconiosis Research Unit indicate that chromite injected intratracheally into rats is not fibrogenic. Chromite, 50 mg. in 1 ml. saline, was injected intratracheally into young rats. The chromite consisted of 70 to 80% of particles of less than 1 micron. Some rats died in the early stages with an acute inflammatory reaction producing a diffuse fibrosis. The others were killed after one year; chromite deposits were identifiable (Fig. 2) but, apart from a minor macrophage reaction, there was no biological reaction of any kind to be seen (Goldstein, B., personal communication, 1965).

Worth and Schiller (1955) found that the intraperitoneal injection of chromite suspension in mice caused a mild lymphocytic reaction and most of the chromite lay free in the tissue; some chromite was transported and taken up by reticulo-endothelial elements in the liver and splenic sinuses. Some hypertrophy of these elements resulted but no parenchymal changes. In tissue culture of three-day-old mouse lung there was no evidence of pathogenicity.

The available evidence therefore suggests that pneumoconiosis in chromite miners is due to the deposition of radio-opaque chromite dust in the tissues and that the condition is benign and causes no fibrosis.

REFERENCES


Fig. 2. Rat lung, one year after intratracheal injection of chromite, shows scattered foci of radio-opaque chromite.