Silicosis among grindstone cutters in the north of Nigeria

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Warrell, D. A., Harrison, B. D. W., Fawcett, I. W., Mohammed, Y., Mohammed, W. S., Pope, Helen M., and Watkins, Barbara J. (1975). *Thorax*, 30, 389–398. **Silicosis among grindstone cutters in the north of Nigeria.** Many of the grindstones used in Nigerian homes are quarried from sandstone in a small group of villages near Kano in the extreme north of the country. Of an unselected group of 126 stonecutters from two of these villages 49 were found to have radiographic evidence of silicosis, with progressive massive fibrosis in 17.

Those with silicosis had worked longer in the quarries than 77 whose radiographs showed no evidence of silicosis. Sixty-three per cent of the silicotics had respiratory symptoms, the commonest being breathlessness on moderate exertion. Cough was the earliest symptom in 42%. Only 35% had abnormal physical signs in the cardiorespiratory system, 18% had clearly reduced ventilatory capacity, and airways obstruction was evident in 16%.

The prevalence of silicosis in these open-cast sandstone quarries is unexpectedly high. This is probably explained by the intensity of exposure and the particular kind of sandstone being worked.

Reduction of dust exposure in these quarries raises severe practical problems, but the inhabitants of this drought-ridden area can scarcely be expected to abandon their traditional livelihood.

Interest in the grindstone quarries of northern Nigeria was aroused in 1971 when a 25-year-old man (the index case) presented at Ahmadu Bello University (ABU) Hospital, Zaria with severe respiratory symptoms. He had been a stonecutter making grindstones since the age of 5 years; most of the men in his district were similarly employed and many of them had developed respiratory symptoms and died young. His sputum contained acid-fast bacilli and his radiograph showed diffuse nodular opacities, suggesting pneumoconiosis with superimposed appearances of active tuberculosis. An open lung biopsy showed evidence of indolent tuberculosis.

As a result of a preliminary visit to his village in 1972, a survey of this and a neighbouring village was arranged with the approval and co-operation of the Ministry of Health, Kano State

and was carried out in the second week of December 1973.

THE OCCUPATION OF STONECUTTING (HAUSA-SARANDUTSE, MAKO'DA)

The quarries are situated along a sandstone escarpment, one of the southern outliers of the Sahelian cretaceous sedimentary deposit, between the villages of Ganji (8°22'E, 12°22'N) and Marken Mako'da (8°22'E, 12°22'N) 70 km northwest of Kano. The traditional dry season occupation in these villages is chipping grindstones out of the rock using a simple steel-headed pick (Fig. 1). The finished grindstone consists of a larger 'mother' stone (Hausa-uwa), 35×52×4 cm, and a smaller 'son' stone (Hausa-da), 37×11×4 cm. These are used by housewives all

FIG. 1. Stonecutter in Hasiya pit, Marken Mako'da applying the finishing touches to a grindstone while sitting in the dusty bottom of the pit.

over Nigeria and in neighbouring countries for grinding grains and peppers (Fig. 2). Excavating the grindstone involves chipping a groove about 5 cm deep, a very dusty procedure (Fig. 3), and then cleaving out the stone in the plane of its grain. Trimming the stone and finishing it to give the grinding surface is usually done in the pit where it is dusty but shaded. Some quarries are merely shallow hollows while some have caves, but the commonest plan is a pit, approximately 7 m² and 4 m deep.

In recent years the stonecutters have realized that their occupation is unhealthy. They recognize that after 10–15 years' exposure chest pain followed by haemoptysis, breathlessness, and premature death may result.

SUBJECTS One hundred and twenty-six stonecutters volunteered for the study, representing all the stonecutters, active and retired, from Ganji and all but two of those who lived in Marken Mako'da. These two villages are 10 km west and 18 km south-west of Dambatta General Hospital, the organizing centre for the survey.

METHODS

Standard questionnaires covering details of occupational and clinical history were completed by a doctor and senior medical student who speak Kano Hausa as their first language.

A full physical examination of each subject included height and weight and concentrated on signs of cardiorespiratory disease and other types

FIG. 2. Grindstones in use. Hausa women grinding guinea corn in Zaria City using stones from Marken Mako'da.

FIG. 3. Chipping grindstones out of the bed rock, the dustiest part of the operation.

of occupational lesion resulting from stonecutting, such as hand and eye injuries.

Ventilatory capacity was measured by the forced expired volume in the first second (FEV₁) and forced vital capacity (FVC) using McDermott bellows spirometer which was frequently calibrated. Peak expiratory flow (PEF) was measured with a Wright peak flow meter. The best of three good efforts was recorded.

TABLE I
RADIOGRAPHIC APPEARANCES CLASSIFIED ACCORDING TO THE ILO U/C INTERNATIONAL CLASSIFICATION OF RADIOGRAPHS OF PNEUMOCONIOSIS 1971

Category	Total No.	Profusion	Rounded Small Opacities		Irregular Small Opacities		Large Opacities		
			Type	Zones	Type	Zones	A	B	C
			q r	Mean Range	s t u	Mean Range	wd id	wd id	wd id
0	77	0/- 0/0 0/1							
		0 74 3	1 1	2	1	1			
1	6	0/1 1/1 1/2							
		1 5 0	1	1	1 3 2	3·3 1-5			
2	31	2/1 2/2 2/3							
		4 19 8	15 7	4·7 1-6	11 8	4·3 2-6	4 2	2 2	0 2
3	12	3/2 3/3 3/4							
		5 7 0	1 11	5·5 2-6	2	3·5 2-5	1 0	0 1	1 2
Total	126		18 19		1 15 12		5 2	2 3	1 4

Category	Pleural Thickening				Ill-defined Diaphragm	Cardiac Outline	Symbols											
	Costophrenic Angle	Site	Width	Extent														
	R L	R L	a b	1 2			ax	ca	cn	co	cv	di	es	hi	od	tba	tbu	
0							1							3				
1					1							1	2	1				
2	1 5	4 7	3 4	2 5	3 3	0 2 1	9	1	4	3	4					4	2	
3	1 3	3 1	3 0	2 1	3 3	2 1 2	10	1			1		1				1	
Total							19	1	2	4	3	5	1	6	1	4	3	

A single fresh sputum sample from each subject was stained by Ziehl-Neelsen's method and examined for ten minutes for acid-fast bacilli.

Venous blood was sampled for measurement of haematocrit and rheumatoid factor (Greenwood, Muller, and Valkenburg, 1971).

Postero-anterior chest radiographs were taken in the ABU Orthopaedic Hospital at Dala, Kano, 56 km from Dambatta. (This was the nearest radiography department capable of taking high quality chest radiographs.) Radiographic appearances were described according to the ILO U/C International Classification for Pneumoconiosis 1971. The radiographs were read independently by two of the authors who then discussed them jointly.

The quarries, pits, and caves in which the men had worked were visited while stonecutting was in progress. Pit dimensions were recorded and dust and rock samples were taken for analysis by the Department of Geology, ABU, Zaria and the Petrographical Department at the British Museum, London.

RESULTS

PREVALENCE OF SILICOSIS The diagnosis of silicosis in this group of 126 sandstone cutters was based entirely on the chest radiograph. The abnormalities, classified according to the ILO U/C extended classification, are given in Table I. Seventy-seven men (61%) had radiographs classified as 0/0 and 0/1 which were regarded as showing no evidence of pneumoconiosis. Forty-nine (39%) had radiographs classified as 1/0-3/3 which were regarded as indicating pneumoconiosis.

Forty-three of the patients with silicosis had category 2 or 3 pneumoconiosis, and 17 had progressive massive fibrosis (PMF) representing 39% and 42% respectively of those with category

2 and category 3 pneumoconiosis; 77.4% had small opacities in five or six lung zones, and of the remainder 11 (22.4%) had opacities in the lower two-thirds of the chest radiograph only, compared with five (10.2%) in the upper two-thirds only. Egg-shell calcification was seen in the hilar nodes of one man with category 1 silicosis.

PREVALENCE OF TUBERCULOSIS Seven men had radiographs suggestive of pulmonary tuberculosis. All had silicosis, and acid-fast bacilli were observed in the sputum of three. Acid-fast bacilli were also found in the sputum of one man with PMF and in another man with category 2/3 type r pneumoconiosis in whom tuberculosis was not suspected radiologically.

CIGARETTE SMOKING (Table III) Two men were smokers and one of them had silicosis. Two men were ex-smokers. All except the man with silicosis had chest symptoms.

COMPARISON OF MEN WITH AND WITHOUT SILICOSIS

Age (Table II) The patients with silicosis were rather older than the rest. The maximum prevalence of silicosis and of PMF occurred in the 35-44 years age group.

Occupational history The men with silicosis had worked in the quarries longer than the stonecutters with no evidence of silicosis. In 49 with silicosis the mean total duration of work in the quarries was 22.8 (range 9-30) years compared to a mean of 9.8 (range 1-31) years for the 77 non-silicotics. The mean number of grindstones cut per day was 3.7 (range 2-7) for the silicotics and 3.0 (range 1-7) for the others. These differences were significant at the 1% level.

The prevalence of silicosis rose from 6% in those exposed for less than 10 years to 80%

TABLE II
AGE DISTRIBUTION OF 126 GRINDSTONE CUTTERS WITH AND WITHOUT SILICOSIS

Category	Age (years)					Mean	Range
	15-24	25-34	35-44	> 44			
0	13	36	20	8	30.5	15-60	
1	1	2	3	0	34.0	23-40	
2	0	6	18	7	39.1	25-65	
3	0	4	8	0	33.3	25-40	
Total	14	48	49	15	35.1	15-65	
Silicosis	1	12	29	7	36.0	23-65	
Prevalence %	7.1	25.0	59.2	46.7			
PMF	0	3	11	3	38.6	25-65	
Prevalence %	0	6.3	22.4	20.0			

those exposed for 20 years or more. No one who had worked for less than eight years in the pits had silicosis, and only one man who had worked for longer than 24 years did not have silicosis. Seven of the men with PMF had worked as cutters for only ten years. Four of these men were still active cutters and the other three had stopped cutting between six and ten years previously. Only eight of the men had worked in caves for one to six years; four of them had silicosis.

Fifty-one of the subjects had retired from stonecutting by the time of the survey. Half the 22 patients with silicosis who had given up stonecutting had done so because of respiratory symptoms whereas most of the other 29 had changed to another occupation for reasons other than symptoms.

Respiratory symptoms (Table III). Thirty-one (63%) of the 49 men with silicosis had respiratory symptoms compared with 31 (40%) of 77 men without silicosis, a significant difference ($P<0.02$). In men without silicosis symptoms occurred in 35% of those who had worked for less than 10 years and in 50% of those who had worked for over 20 years. The commonest symptoms were breathlessness on moderate exertion (cycling or stonecutting) and chest pain. The earliest symptoms noticed by the patients with silicosis were cough (42%), sputum (19%), chest pain (17%), breathlessness on moderate exertion (11%), breathlessness on mild exertion (8%), and breathlessness at rest (3%). Three of the 17 men with PMF admitted to no symptoms.

Physical signs (Table III) Seventeen (35%) of the 49 patients with silicosis had abnormal signs in the cardiorespiratory system and six (8%) of the 77 stonecutters without silicosis also had signs ($P<0.01$). Rales were the commonest sign. One of the men with silicosis had central cyanosis and

advanced cor pulmonale. Eight of the men with PMF had no abnormal cardiorespiratory signs. Eight men had hand deformities attributable to an occupational traumatic osteoarthritis. Abnormalities included destruction of the terminal phalanges, arthritis of the interphalangeal and metacarpophalangeal joints, and ulnar deviation at the wrist joint. Gross digital clubbing was seen in one man with silicosis and in another with no evidence of cardiorespiratory disease.

No eye injury was seen or reported to have been due to stonecutting.

Ventilatory capacity (Table IV) One hundred and twelve of the 126 subjects produced acceptable readings for FEV₁ and FVC. The remaining 14 were quite unable to perform the manoeuvre. FEV₁/FVC% is said to be independent of racial variation, although absolute values for FEV₁ and FVC are smaller in Africans than in Europeans of the same age and size (Cotes, 1968). Predicted normal FEV₁/FVC% was calculated using the regression based on age of Berglund *et al.* (1963) (Table IV). Eight patients with silicosis and two of the stonecutters without radiographic evidence of the disease had ratios more than two standard deviations less than predicted. These men were regarded as having airways obstruction. Airways obstruction was significantly commoner in the patients with silicosis ($P<0.02$).

One hundred and twenty of the 126 subjects were able to produce acceptable readings for PEF. Predicted normal values based on age and height were calculated using the regression of Elebute and Femi-Pearse (1971), which was derived from a population of urban Nigerians in Lagos. These subjects are likely to have larger thoracic volume for their height than the relatively taller, slimmer Hausa stonecutters.

Seven of the patients with silicosis and three of the other stonecutters had PEF values more

TABLE III
SYMPTOMS AND SIGNS IN 126 STONECUTTERS

Symptom	% of 49 Men with Silicosis	% of 77 Men without Silicosis	Sign	% of 49 Men with Silicosis	% of 77 Men without Silicosis
No respiratory symptoms	37	60	No cardiorespiratory signs	65	92
Breathlessness on moderate exertion	43	21	Wheeze or crepitations	24	4
Chest pain	43	29	Right ventricular hypertrophy	12	3
Cough	37	16			
Sputum	33	16			
Breathlessness on mild exertion	20	5	Thoracic distortion	4	0
Weight loss	12	8	Cervical lymphadenopathy	4	0
Breathlessness at rest	8	3	Consolidation	4	0
Haemoptysis	2	5	Hand deformity	4	8
Smoking	2	1	Digital clubbing	2	1
Ex-smoker	0	3	Hypertension	2	0

TABLE IV
VENTILATORY CAPACITY IN 126 STONECUTTERS RELATED TO RADIOGRAPHIC CLASSIFICATION

	No. of Standard Deviations less than Predicted Normal		Category of Pneumoconiosis				PMF
			0	1	2	3	
FEV ₁ /FVC %	> 1	< 1	54	4	14	2	9
	> 2	< 2	12	0	3	2	2
	> 3	< 3	2	0	0	1	2
	> 3	< 4	0	0	0	1	2
	> 4		0	0	0	1	1
Total with airways obstruction as defined Acceptable readings/failures			2 68/9	0 4/2	0 17/2	3 7/0	5 16/1
PEF (l/min)	> 1	< 1	64	0	15	4	6
	> 2	< 2	10	2	3	2	4
	> 3	< 3	3	0	0	0	1
	> 3	< 4	0	0	0	0	3
	> 4		0	0	0	1	2
Total with restrictive defect as defined Acceptable readings/failures			3 77/0	0 2/4	0 18/1	0 7/0	1 16/1

than two standard deviations less than predicted normal. Four of these ten men had normal FEV₁/FVC% and so were regarded as showing a purely restrictive type of ventilatory defect. There was no significant difference between the two groups of subjects.

All nine silicosis patients with abnormal ventilatory capacity had respiratory symptoms and seven had abnormal cardiorespiratory signs. Those with the most extensive radiographic changes had the most abnormal respiratory function.

On the other hand, ten patients with progressive massive fibrosis had ventilatory capacities that were either absolutely normal (four cases) or only mildly impaired (six cases) (FEV₁/FVC% or PEF more than 1 SD but less than 2 SD below predicted normal), and three of these had neither symptoms nor abnormal physical signs. Although symptoms, signs, and airways obstruction were significantly commoner in men with silicosis, the correlation between these and radiographic abnormality was not very close.

Haematocrits The mean PCV in 49 patients with silicosis was 41.5% and in 72 subjects without silicosis was 40.2%, an insignificant difference. Only two of the 121 stonecutters in whom PCV was measured had values below 35%. This measurement was considered as a crude index of

general nutritional state, systemic illness, and hookworm infection.

Rheumatoid factor (Table V) There were no significant differences in the presence of rheumatoid factor in low (1:20) or high (1:640) titre between men with and without silicosis and normal Nigerian control values (Greenwood *et al.*, 1971).

Description of rock samples The samples were of an impure sandstone containing larger detrital quartz crystals embedded in a hard matrix of kaolinite (clay) and microcrystalline quartz with variable amounts of iron oxides. Quartz formed about 80% of the sample. Approximately one third of the quartz was microcrystalline with particle size less than one micron.

DISCUSSION

In this survey the diagnosis of silicosis was made radiographically. Illustrative examples of radiographs are shown in Figs 4, 5, and 6; there seems little doubt that such radiographic appearances occurring in men employed quarrying sandstone containing 80% quartz, represent silicosis. Although the lung biopsy taken from the index case showed the histological appearances of indolent tuberculosis, this does not exclude

TABLE V
RHEUMATOID FACTOR IN THE SERA OF 126 STONECUTTERS AND IN NIGERIAN CONTROLS

Titre	Silicosis					Normal Radiograph	Nigerian Controls
	Simple	Progressive A	Massive B	Fibrosis C	Total		
≥ 1:20	18	3	1	3	25 (53.2)	35 (50.7)	(64)
≥ 1:640	7	0	2	0	9 (19.1)	6 (8.7)	(18)

Percentages are given in parentheses.

FIG. 4. *Chest radiograph of case 1320. Calcified diffuse micronodular (q type) opacities in a man who had been stonecutting for 20 years.*

FIG. 5. *Chest radiograph of case 1310. Diffuse nodular (r type) opacities with coalescence in a man who had been stonecutting for 20 years.*

FIG. 6. Chest radiograph of case 1116. Nodular (r type) medium irregular (u type) and extensive (C type) large opacities (progressive massive fibrosis), pleural thickening, and ill-defined cardiac outline in a man who had been stonecutting for 10 years.

coexistent silicosis. Of more than 600 patients admitted to ABU Hospital with sputum-positive tuberculosis since June 1971, none has had micronodular opacities on the chest radiograph, whereas 39% of 126 stonecutters seen in one week had radiographs suggestive of silicosis.

This survey has confirmed that silicosis occurs in grindstone cutters in the north of Nigeria. It is the first report of a microfocus of silicosis in West Africa, and since it was discovered by chance it seems possible that there may be other foci in this region. Palmer and Daynes (1967) have described silicosis in women from the Transkei who use grinding stones inside their huts to produce flour from maize.

It is of interest that the stonecutters themselves have noticed respiratory symptoms only since the introduction of metal-headed tools in the second and third decades of this century. Clearly the occupation became very much more dusty as this technological advance enabled the quarriers to produce many more grindstones per year.

One hundred and eighteen men in this survey had worked exclusively in open pits, and the

39% prevalence of silicosis seems exceptionally high for open-cast quarrying. Gupta *et al.* (1972) reported a similar prevalence (35.2%) among stone masons in the north of India but radiographic surveys in Britain have shown lower rates, ranging from 3% (Lloyd Davies *et al.*, 1973) to 17.6% (Hale and Sheers, 1963) in granite workers with a slightly higher prevalence of 19% (Ferguson, 1934) among sandstone workers. The higher prevalence of silicosis in sandstone workers than in granite workers is attributed to the higher content of free silica (75–95%) in sandstone and to the composition of the cement which binds the silica. Analysis of the stone obtained during this survey showed that quartz formed approximately 80% of the rock and that 20–30% of the rock was composed of fine-grained silica.

Dust concentration was not measured in this study but the occupation was observed to be extremely dusty (Fig. 3). This was particularly so in the deep pits, and the dust generated by the initial process of hewing out the stone was increased by the habit of shaping and finishing the stones in the shade of the pit rather than on the surface. This habit also increases the exposure

for each worker, and cutters reported that when work was in full swing it was impossible to see from one side of the pit to the other. Dust particle counts performed by Gupta *et al.* (1972) in India showed levels of between 15 and 51.5 million particles per cubic foot of air, far in excess of recommended levels for sandstone quarries. Environmental factors of extreme dryness and heat in this area of the Sudan savanna tend to increase the dust density. Gupta *et al.* (1972) considered that the high silica content of the stone coupled with the very high concentration of dust and the lack of any dust control measures were the major factors producing such a high prevalence of silicosis in their survey. Social factors which may contribute to the high prevalence of silicosis include the stoicism of rural underprivileged people (this was the first time in living memory that these villages had been visited by medical personnel) and the unrewarding nature of the major alternative occupation, which is farming, particularly during cycles of drought.

It is widely agreed that the early radiographic changes in silicosis are predominantly in the upper halves of the lung fields. This was not so in the present survey, and Gelfand and Morton (1970) in a survey of African gold miners in Rhodesia also found that the lower zones were involved as frequently as the upper zones in their patients.

Seven per cent of the samples of grindstone cutters had pulmonary tuberculosis, either suspected radiologically or proven by sputum microscopy. All had silicosis. This prevalence is the same as that found by Gupta *et al.* (1972); it is much higher than the estimated case prevalence in tropical Africa of 2% (Roelsgaard, Iversen, and Bløcher, 1964), but much lower than the figure of 34% among sandstone workers in Staffordshire who showed active pulmonary tuberculosis at necropsy (Meiklejohn, 1949).

Only one of the 126 men in this survey had cor pulmonale; he had PMF and pulmonary tuberculosis. Cor pulmonale was not reported by Gupta *et al.* (1972) in India, and Paul (1961) found few cases among copper miners with PMF in Zambia.

Rheumatoid factor (1:640) is found in 4–6% of British coal miners with simple pneumoconiosis (Caplan, Payne, and Withey, 1962; Soutar, Turner-Warwick, and Parkes, 1974). This is the same prevalence as in control populations. The same workers found a three-fold increase in the prevalence of rheumatoid factor in miners who

had developed PMF. In Nigeria 18% of control rural populations have rheumatoid factor and the prevalence in the stonecutters with or without silicosis was not significantly different from this.

Prevention of silicosis in this drought-stricken area of Nigeria raises special problems. Stonecutting is more remunerative than farming, and the people in this place have been accustomed to stonecutting for so long that they are unlikely to change to farming, particularly in view of the recent drought.

Conventional dust control measures used in Europe and America are unrealistic in this environment; water shortage prevents damping-down of the dust; it is too hot to wear respiratory masks and poverty precludes the use of more elaborate mechanical cutting tools.

The following recommendations were made to the stonecutters and village and district heads:

1. Abandon all caves and deep pits and excavate new shallow pits.
2. Avoid shaping and finishing the stones in the pits and erect simple shelters to provide shade so that this work can be done on the surface where there is natural ventilation.
3. Attempt to do most of the stonecutting during the rainy season or during windy weather.

The further possibilities which were discussed with the local government authorities were:

- (a) the provision of state drilled wells to increase the supply of water;
- (b) the hiring of mechanical cutters to the villagers by the state so that large masses of stone could be excavated and brought to the surface where the grindstones could be chipped out and finished under less dusty and better ventilated conditions.

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