PULMONARY DISEASE AMONGST SISAL WORKERS

BY

HUGH STOTT

Specialist Medical Officer in Occupational Health, Labour Department, Kenya Colony

(RECEIVED FOR PUBLICATION JUNE 11, 1957)

The sisal industry is economically one of the most important in Kenya as it employs about 8,000 Africans who are engaged on work in 69 sisal plantations in the Colony. This corresponds to about 2% of the total number of Africans employed in all public services, agricultural, and other industries.

Employees on sisal estates are broadly speaking subject to the same diseases as other agricultural workers except that possibly tropical ulceration of the leg is more prevalent amongst them. The dusty conditions created by the brushing machines in the sisal factories, may, however, cause special hazards, as, apart from the general nuisance value of the dust, and its irritative action on the eyes and the upper respiratory tract, there remains the possibility that it might be responsible for damage to the lung tissue.

The only reference in the literature which can be found which deals with the effect of sisal dust on the pulmonary tissues is that of an investigation carried out recently by Martins (1956) who clinically examined 118 operatives employed in the brushing rooms of three sisal estate factories in Mozambique. He reported that respiratory incapacity was more prevalent amongst brushing-room workers than others, and that he could find no "flagrant signs of pneumoconiosis"; but it should be pointed out that he had no radiological facilities.

Although this report by Martins is the only one available on sisal dust it is well known that other organic dusts of vegetable origin are capable of causing lung damage. Broadly speaking these dusts may affect the lungs in three different ways. First, they may produce allergic, asthmatic, and bronchitic conditions. A classical example is byssinosis, first described by Leach in 1863, and contracted by a considerable proportion of operatives working in the card- or blow-rooms in cotton mills. Asthmatic or bronchitic attacks may also occur amongst workers in the woollen industry (Moll, 1933), and amongst bakers (Anton, 1934; Ordman, 1947) and millers (Linko, 1947).

Secondly, pulmonary disease may be caused by the inhalation of organic dust containing bacteria, fungi and moulds, and in particular, pulmonary mycosis may occur amongst persons exposed to moulded grain or hay (Fawcitt, 1936; Törnell, 1946; Hoffmann, 1946). A variety of fungi may be the causative agents, but *M. albicans*, *M. candida*, and *A. fumigatus* appear to be the most frequent. Other fungi may also cause an allergic state giving rise to asthma and vasomotor rhinitis, and mites contaminating grain have been reported to give rise to pulmonary symptoms (Marcandier and Le Chuiton, 1928; Najera Angulo and Dantin Gallego, 1939). Caminita, Baum, Neal, and Schneider (1947) have incriminated *Aerobacter cloacae* as being responsible for "mill fever" in cotton operatives. Schilling (1956) has described the same condition in workers preparing hemp and flax for spinning.

A third possibility of pulmonary damage arising from exposure to vegetable dusts may be due, not to the effect of the dust itself, but to a high content of free silica mixed with it. Thus the pulmonary fibrosis in workers occupied in the stemming and redrying of tobacco from North Carolina is not due to the tobacco dust itself but to its admixture with free silica which occurs in high content in the soil in which the tobacco is grown (McCormick, Smith, and Marsh, 1948).

Finally there is a group of pulmonary affections caused by organic dusts the aetiology of which are in doubt. One such disease is bagassosis which was first described by Jamison and Hopkins in 1941, and which results from exposure to the dust of the fibre trash remaining after the extraction of sugar from the sugar cane. Dunner, Hermon, and Bagnall (1946) have reported radiological findings of reticulation, mottling, and fibrosis amongst dockers handling grain and seeds, and they concluded that mycotic organisms were unlikely to have caused these changes.

Scope of the Present Investigation

The present investigation was designed to deter-

mine whether sisal dust could cause pulmonary lesions and incapacity amongst workers exposed to it. A factory was chosen where the dust problem was apparently bad, the labour turnover was relatively small, the labour records were good, and the management cooperative. It manufactured "gunny" bags and rope from sisal, and was the only one of its kind in Kenya. In general the dust conditions in the carding room of this factory were similar to the dustiest brushing rooms of sisal estate factories elsewhere.

The investigation was started in January, 1955, but in the previous November an additional new factory had been opened on the premises for the purpose of manufacturing bags from jute. The present investigation centred on the old factory which was exclusively concerned with processing sisal.

Conditions in the Factory

A total of 1,314 Africans were employed, 1,038 of whom worked in the old factory. The great majority of the employees were men, but it had recently become the policy to employ more of the wives and female relatives of the male staff.

Fig. 1 shows the layout of the different departments of the old factory. The generation of dust was almost entirely confined to the batching and carding departments which can be seen at the bottom of the plan. A small amount of sisal dust was also produced from one machine in the rope plant, but otherwise airborne dust was virtually non-existent. The carding room was partially separated from the adjoining departments in the factory by a hessian screen which was hung from the ceiling to within about seven or eight feet of the floor. At the time the investigation was undertaken there was no artificial means of ventilation, but an extraction plant has since been installed with most satisfactory results.

The manufacturing process was started in the batching and carding rooms where sisal tow was passed through teaser cards in which the entangled lumps of short fibres were torn apart, and extraneous matter was removed from the tow. The fibre was delivered from these cards in the form of a fleece which was then hand sprayed with an oil-and-water emulsion. After this it was allowed to stand for several hours to allow the emulsion to permeate the bundles thoroughly. This was the batching process, and the purpose of spraying with oil was not to keep the dust down but to render the sisal fibres more pliable. The batched fleece was then broken down by a series of toothed rollers in a breaker card and emerged in a broad sliver. The sliver then passed through a finishing card, which operated in

the same way as the breaker card, but which produced a more refined and cleaner ribbon.

The sliver then left the carding room, and went through a series of processes none of which generated any dust. It was first refined in drawing machines by being drawn out and levelled on rollers; it then passed to the spinning department where it was converted into yarn by the action of flyers, and wound on bobbins. The bobbins of the weft and warp yarn were then rewound on the cop and spool machines respectively. A coat of sizing containing hot maize flour paste was applied to the warp which was then carried over heated drums in a dressing machine. The weaving was carried out on a Dundee hessian loom, and the woven cloth from the looms was taken to the finishing department where it was first passed through the four heavy rollers of a calendering machine, and then through a mangle which gave the finish to the cloth by ironing it out. Finally the sisal cloth was passed to the sewing department where it was cut into suitable lengths and made into bags by special sewing and hemming machines.

The factory operated four shifts. Three of them, each of eight hours, covered the 24 hours. The fourth was an extra shift worked daily between 6 a.m. and 2 p.m. The work in the factory was stopped at 6 a.m. on Sunday morning and restarted at the same time on Monday morning.

Sickness Rates in the Old Factory.—The firm operated two dispensaries; one was situated in the old factory block, and one in the labour lines. They were staffed by ex-army dressers who had gained a rudimentary medical knowledge in the army, and who were able to make simple diagnoses which were almost entirely referred to symptomatology. Thus the sick register contained such diagnoses as "cough", "chest pain", "diarrhoea", and "vomiting". The purpose of the dispensary in the factory was to provide first-aid treatment for the employees themselves either for medical or surgical conditions. The dispensary in the labour lines provided similar treatment for the families, and for those workers who wished to consult a dresser in their off time.

An analysis of all medical cases seen by one of the dressers in the factory dispensary over a period of four months was made from the register. All medical conditions diagnosed were classified into two groups. In the first group were classed all complaints referring to respiratory and chest conditions, whilst all other medical complaints were classed in the second group. A further subdivision of these groups was made by determining whether the patient was working in the dusty carding room or

FIG. 1.—The layout (approximately to scale) of the old factory in which the investigations described were undertaken. The batching and carding department is seen at the bottom of the chart, and the white dots indicate the dust sampling positions of the thermal precipitator.

in other departments where there was no dust when he developed his symptoms. Owing to the absence of any record of the ages of the workers it was impossible to compare their relative age structure, but from general observation of those at work in the different departments no great difference was observed in the ages of those working in the carding room and those working in other departments.

TABLE 1
PERCENTAGE OF ATTENDANCES OF ALL EMPLOYEES ON ACCOUNT OF CHEST COMPLAINTS IN WORKERS IN CARDING ROOM AND IN OTHER DEPARTMENTS

	Average Total Persons Employed	Total Attendances	%Attendances of Total Employed
Carding room	130	70	53.8
Other departments	908	232	25.6

Table 1 shows that the attendance rate for chest conditions was twice as high in workers in the carding room as in other departments. It will be observed that both sets of figures are abnormally high when compared with similar figures in other parts of the world, but the partiality of the African for taking medicine for the most trifling complaints is undoubtedly one cause. However, this high total rate should not affect the comparison between the two groups of workers in the same factory.

The exact nature of the respiratory infections contracted is again uncertain but it is probable that the majority of chest conditions were acute infections of the upper respiratory tract. Particular attention was paid to questioning the dresser, and also some of the long-term employees in the carding room. The dresser in seven years' experience could only remember seeing one case of asthma in a worker from the carding room, and all other persons questioned denied that they recognized chest tightness or respiratory upset of any kind occurring typically on a Monday morning or after a period away from work. It is considered improbable therefore that symptoms similar to those in byssinosis are caused amongst Africans as the result of inhalation of sisal dust.

A search of the medical records in the factory showed that since 1950 there had been 74 men with acute chest conditions who had been treated in hospital. In 48 of these cases it was possible to identify the department in the factory in which the man was actually working when he contracted the disease. It was noted that whereas carding room workers comprised about one-quarter (11 out of 48) of those admitted to hospital they represented only about one-eighth (130 out of 1,038) of the total factory population.

An attempt was then made to trace the hospital records of these 48 persons with a view to discovering the type of chest condition from which they suffered. Unfortunately many of the records had been destroyed, and it was only possible to obtain the bed head tickets of 24 of the cases. In three cases a diagnosis of acute bronchitis had been made, and there was nothing to indicate that the disease was anything more; none of these persons had ever worked in the carding room. In the other 21 cases a diagnosis of lobar pneumonia had been made, and an examination of the case histories confirmed that the disease was in every case almost certainly lobar pneumonia. Its predominating features were sudden onset of cough, chest pain, and pyrexia, with rusty sputum in many cases, unilateral chest signs, quick response to sulphonamides or penicillin, and rapid convalescence. Four of these persons had developed the disease while working in the carding department, and its course appeared to be as typical of pneumonia as in any of the others. No case had been radiographed while in hospital, but it was possible to radiograph 10 of those workers who had previously suffered from lobar pneumonia, and three of whom had developed the disease while working in the carding room. No abnormalities were seen in the lung fields of any of these patients, but four of them showed evidence of pleural or diaphragmatic adhesions, and two of these had been carding room workers. There was therefore some evidence to indicate that lobar pneumonia was commoner amongst workers exposed to sisal dust than amongst those not exposed to it.

It should be noted that Martins in his survey of sisal brushing room operatives also found that respiratory infections were commoner amongst these workers, but in contradistinction to the present investigation he found that asthma occurred more frequently in those exposed to sisal dust than in others. He gives the incidence of asthma in brushing room operatives as 1.6% against an incidence of 0.1% in other general workers.

Nature of the Carding Room Dust.—The atmosphere in the carding room was thick with dust, and it was obvious that the main concentrations lay around the carding machines, particularly the teaser cards, and in the batching area. The daily variation in the amount of dust produced was not marked. The operatives working in the room were invariably covered with a film of grey dust; some wore cloth masks over their mouths but the great majority wore nothing. To an unacclimatized visitor the dust had a mildly irritant effect on the upper respiratory passages, and caused some irritation to the eyes.

FIG. 2.—Photomicrograph of sisal dust collected by the thermal precipitator.

Dust Sampling by Thermal Precipitator.—Twenty-one samples of the dust in the carding room were collected with the thermal precipitator. The samples, which were taken at breathing level, were collected on different days and from different positions in the room. All sampling positions are indicated in Fig. 1. No dust counts were performed in other departments of the factory as it was obvious that dust concentration in these was minimal. A total and differential dust count was performed on each sample. An average of 1,000 particles were counted for each total count, and 500 for each differential count. A photomicrograph of a sample of the dust collected is shown in Fig. 2. The results of the counts are given in Table 2, and the estimated dust count in the room, as judged from the average of all 21 samples taken is shown. The average dust concentration in the neighbourhood of the carding machines, and also at the periphery of the room, have been calculated separately.

The concentration of dust in the neighbourhood

of the carding machines was found to be over twice as great as it was round the periphery of the room. The highest dust count which was recorded was 1,787 particles (0.5-5 μ range) per ml.; this sample was taken from near a teaser card. The lowest

TABLE 2
AVERAGE CONCENTRATION AND SIZE DISTRIBUTION OF DUST FROM 21 SAMPLES TAKEN FROM DIFFERENT POSITIONS IN CARDING ROOM

	Proximal to Carding Machines (14 samples)	Distal to Carding Machines (7 samples)	Average in Carding Room (21 samples)
Total count (particles per ml. 0.5-5 μ range)	302	124	243
Differential count (% in each size group):			
Over 5.0 microns			
5.0 "	5.0	4.8	4.9
4.0 "	2.4	2.1	2.3
3.0 "	3.6	2.8	3.3
2.5 "	4.6	3.8	4.3
2.0 "	5.0	4.1	4.7
1.6 "	5.6	4.7	5.3
1.2 "	8.0	7.5	7.8
0.8 "	11.2	8.3	10.2
0.4 "	17.2	14.6	16.4
0.2 "	19.3	22.5	20.5
0.1 "	18.1	24.8	20.3
Median size (microns)	0.72	0.56	0.66

count was 30 particles (0.5-5 μ) per ml. and this sample was taken from the periphery of the room. As most of the work in the carding room was performed in the immediate vicinity of the machines the workers were exposed for most of their time to the heavier rather than lower concentrations of dust. A further factor of some importance has to be considered. The addition of an oil-and-water emulsion to the sisal fleece in the batching process was said by the staff in the factory to have had a very noticeable effect in diminishing the amount of dust in the atmosphere. This procedure had only recently been introduced whereas previously it had been the custom to moisten the fibre with water only when necessary. For this reason it is probable that the concentrations of dust had previously been higher in the carding room than they were found to be at the time the present investigations were undertaken.

After the installation of the dust extraction plant in the carding room the reduction of the dust in this room was most noticeable visually. Two dust samples were taken from a sampling position in the middle of the room between two breaker cards, and from which seven samples had been taken before the installation of the plant. (The position can be identified in Fig. 1.) The average count of particles, between 0.5 and 5 μ , of the two samples taken after the installation of the extraction plant was 80 particles per ml. compared with an average count of 238 particles per ml. given by the seven original

samples. The differential counts remained approximately the same.

Chemical Analyses of Dust.—A chemical analysis of the dust obtained from the rafters in the carding room was undertaken by the Government chemist. The determination of its free silica content was done by treating the ash with alternate cold dilute acid and hot dilute alkali. The soluble portion of the ash was found to be 7.6% of the total dust sample, and petrological examination by Dr. Pulfrey, of the Mines and Geological Department, showed that it consisted mostly of amorphous silica. The insoluble part of the ash, which was 4.2% of the total sample, was found on petrological examination to contain a great deal of felspar and very little quartz. It can be accepted therefore that the quartz content of the dust was very low, and was unlikely to be of consequence as a cause of gross lung damage in the workers.

Investigation of the Workers

An investigation was next undertaken amongst certain of the workers to determine whether sisal dust produced disability or radiological evidence of pulmonary disease. For this purpose 93 persons, in three groups, were chosen from the factory records for investigation. The first group (37) had worked for six months or over in the carding room only. The second group (27) had worked for 10 years or over in other departments of the factory only, and the third group (29) had worked a total period of over two and a half years in the factory and had been employed for some of this time in the carding room. Inadvertently three persons, whose factory service was considerably less than two and a half years, were included in this latter group. Table 3 shows the average length of service and ages of the 93 workers selected.

TABLE 3
AVERAGE LENGTH OF SERVICE IN CARDING ROOM AND IN OTHER DEPARTMENTS OF 93 WORKERS SELECTED FOR EXAMINATION

Time Worked in Carding Room (months)	No. of Workers	Average Length of Service (months)		Average Age (years)
		Carding Room	Other Departments	
0-5	9	2.7	35.4	35.1
6-23	15	13.3	19.6	35.0
24-47	24	30.8	9.4	35.5
48-71	6	59.2	12.7	40.7
72-95	5	83.0	6.3	36.8
Over 95	7	122.4	0	39.1
All who had worked in carding room	66	39.5	15	35.3
Never worked in carding room	27	0	149.4	38.8

It will be observed that although those 27 workers who had never been employed in the carding room had a much longer service in the factory than had the others, the estimated ages in the two groups were much the same. This raises the whole problem of age determination in Africans which is difficult because so few are aware of their exact age. Ages therefore almost always have to be assessed, and this introduces an added source of error not usually present in this type of investigation. In the present study all ages were assessed by the author, and any error is therefore likely to be random, and should not invalidate the comparison between the groups examined. It may well affect a comparison with other groups of workers.

Medical Examination of Selected Workers.—A full history of the length of employment and the type of work performed in the factory of each of the 93 selected subjects was obtained from the factory record sheets, and from these it was also possible to determine the amount of leave taken or other broken duty occurring during each man's service. In addition an industrial history before engagement in the factory was obtained from each man's record of employment kept in the Central Registration Office in Nairobi. In no case was a history of contact with other potentially harmful dusts obtained.

Every person was radiographed, and the maximum breathing capacity (M.B.C.), the vital capacity, and sisal sensitivity tests were carried out on certain of the subjects. A clinical examination was not undertaken unless there was some abnormality in the radiograph as it was believed that the time expended on this would not be commensurate with the benefit gained.

Measurement of Ventilatory Capacity.—An attempt to assess the pulmonary sufficiency of certain of the 93 workers was made by measuring their vital and maximum breathing capacities. The vital capacity was determined with a water spirometer, and the best of three readings was recorded. The M.B.C. was measured on a gas meter spirometer into which the subject breathed to his maximum capacity for one minute timed on a stopwatch. The best of two readings was recorded, and as no fixed rate of breathing was insisted on each subject was allowed to breathe as he liked. It was evident that the effort of breathing for one minute was too much for many of the subjects, and it is certain that in future investigations of this type on Africans a much shorter time limit should be imposed. Owing to the fact that the water spirometer broke, and to certain difficulties in contacting the men, it was only possible to measure the vital capacity in 51 of the subjects, and the M.B.C. on 81 of them. There was,

however, no special selection of cases on which either test was performed. The subjects were all tested before they were radiographed and before they could be identified individually or collectively with their particular jobs. In this way any bias which might have affected the readings was eliminated. The coefficient of correlation between the M.B.C. and vital capacity in 51 subjects on whom they were both performed was +0.492, and although this was not considered very good it was thought worth while enquiring further into the results of each of the two tests.

TABLE 4

MEAN VITAL AND MAXIMUM BREATHING CAPACITIES OF WORKERS WITH TWO YEARS' AND OVER AND UNDER TWO YEARS' EXPERIENCE IN THE CARDING ROOM, AND NO EXPERIENCE IN THE CARDING ROOM

Time Worked in Carding Room	Vital Capacity (l.)			Maximum Breathing Capacity (l./min.)		
	No. Tested	Average Age	Mean	No. Tested	Average Age	Mean
24 months or over	23	38.3	2.60	36	38.6	52.56
Under 24 months	11	36.5	2.65	20	36.2	55.74
Never worked	17	38.0	3.07	25	38.5	61.1

It was found that the measurement of the vital capacity of those 23 workers who had worked in the carding room for two years or over was significantly lower than the average of those 17 workers who had never worked in the carding room. (The observed mean difference was 2.6 times the standard error of difference.) On the other hand, there was no significant difference between the mean vital capacities of those with over two years' service and those 11 workers with under two years' service in the carding room. The latter group, like those with longer service in the carding room, showed a significantly lower vital capacity than the group who had never worked in the carding room. (The observed mean difference was 2.2 times the standard error of difference.)

The numbers are small, and the results therefore open to some doubt; but the same tendency is observed when the results of the maximum breathing capacities are studied. In this instance it was found that the only significant difference was shown between the M.B.C. of those persons who had worked two years or over in the carding room and those who had never worked in the carding room. (The observed difference between the means was 2.5 times the standard error.) There was no significance in the difference between the M.B.C. of those with under two years' service and those with longer service in the carding room; or between those with under two years' service in the carding room and those with no service in it at all.

It will be observed from Table 4 that the average apparent ages of the workers in each group were very similar, and the results in this respect are therefore comparable. The findings suggest that persons who have worked in the carding room for two years or over have a significantly lower pulmonary function than those who have never worked in the carding room.

Sisal Sensitivity Tests.—Although it did not appear, either from the history or the medical records, that workers in the carding room were subject to allergic pulmonary manifestations, it was considered of interest to determine whether there was any special sensitivity shown by them to intradermal injections of sisal extract.

Two extracts of sisal dust, one prepared from the rafters in the factory (M.R.L.), and one prepared from dust taken from a different factory (H.B.), were injected intracutaneously into the forearms of some of the workers selected for radiological examination. The results, which were read 15-30 minutes after an injection of 0.1 ml., are given in Table 5.

TABLE 5

INTRADERMAL SENSITIVITY TESTS PERFORMED WITH TWO SISAL EXTRACTS ON WORKERS WITH OVER SIX MONTHS' EXPERIENCE IN THE CARDING ROOM AND ON WORKERS WITH NO EXPERIENCE IN THE CARDING ROOM OR FOR UNDER SIX MONTHS

	Extract	No. Tested	Mean Induration (mm.)
Workers with over 6 months in carding room	HB	45	10.27
	MRL	24	10.93
Workers with no experience, or under 6 months in carding room	HB	19	8.5
	MRL	17	11.9

It will be observed from the results of these tests that workers exposed to sisal did not show any peculiar reaction to it, and indeed it was found that a similar type and grade of reaction was observed amongst some of the African general hospital population who had never been exposed to sisal. Cayton, Furness, and Maitland (1952) had a similar experience when skin testing cotton dust extracts. The reaction of those with byssinosis did not differ from that of the adult urban population not specifically exposed to cotton dust.

Radiological Investigation.—A postero-anterior radiograph was taken of each of the 93 workers. Each radiograph was viewed by three assessors, sitting separately and unaware of any relevant particulars about the subject. In the interpretation of the radiographs each assessor was asked to pay particular attention to the presence of early or late stages of pneumoconiosis, especially pulmonary

reticulation, nodulation, and fibrosis. The reports of all three observers were the same for 61 films. In 26 instances the reports of two of the observers agreed, and for the purpose of this investigation the majority opinion was accepted. Differing reports from each of the three observers were obtained for six films, and a final decision on these films was arrived at by discussion between two observers sitting together. The differences which occurred in the interpretation of the radiographs were of a relatively minor degree only, and the reading of the films was consistent when moderate or gross abnormalities were present.

Table 6 shows the radiological findings in workers classified in the three occupational groups. Sixty-five radiographs were classified as showing no detectable abnormality, four showed apical pulmonary fibrosis, three showed appearances of heavy lung markings and linear striation, 13 showed evidence of pleural or diaphragmatic adhesions, and eight films showed evidence of other abnormalities.

Cases with Apical Pulmonary Fibrosis.—The four cases showing apical pulmonary fibrosis present an interesting problem. They all occurred amongst those who had only worked in the carding room.

A more detailed analysis of the exposure times of these four cases shows that their average exposure to dust in the factory was six and three-quarter years compared with four and a half years for all

those who had served in the carding room only, and three and a quarter years for all those who had at any time served in the carding room. Of further interest is the fact that no case of apical fibrosis was observed amongst those 23 persons who had been exposed to dust in the carding room for under two years. On the other hand, all four cases were amongst those 43 persons who had served in the carding room for a period of two years or over, whereas three of them were amongst those 18 operatives with four years' exposure or over, and two amongst those five persons who had been exposed from nine to 15 years. This association between length of exposure and radiological findings of apical fibrosis was found to be just statistically significant ($P = 0.05$).

All four cases of apical fibrosis were admitted to hospital and investigated, and their case histories are given below:

Case 1.—S. H., a male Kikuyu, was aged about 58 years.

This man had previously worked about 10 years in the fields planting sisal, and had not been exposed to sisal dust in the brushing rooms. After leaving this work he had been employed for 11 years in his present job working on a teaser card. During this period he had been absent on leave from his job for only two months.

He stated that he had had intermittent attacks of coughing for many years. These took the form of two

TABLE 6

SUMMARY OF RADIOLOGICAL FINDINGS IN (a) OPERATIVES EMPLOYED ALL THEIR TIME IN CARDING ROOM, (b) IN BOTH CARDING ROOM AND OTHER DEPARTMENTS, AND (c) ONLY IN OTHER DEPARTMENTS

Time (mth.) Worked in Factory	Departments Worked in	No. of Workers	Average Age	Radiological Findings					Average Total Time Worked in Factory (mth.)	Average Total Time Worked in Card Room (mth.)
				Apical Fibrosis	Linear Striation	Adhesions	Other Abnor- malities	No Abnor- mality		
0-23	Card room only	5	33.0	0	0	1	1*	3	10.6	10.6
	Card room and other departments	3	33.0	0	0	0	0	3	11.0	3.7
	Other departments only	0	—	—	—	—	—	—	—	—
24-47	Card room only	18	39.1	1	1	3	2*	11	30.9	30.9
	Card room and other departments	13	33.1	0	0	1	0	12	34.0	15.8
	Other departments only	0	—	—	—	—	—	—	—	—
48-71	Card room only	4	39.5	1	0	1	0	2	62.25	62.25
	Card room and other departments	5	39.2	0	0	2	2†	1	64.6	22.0
	Other departments only	0	—	—	—	—	—	—	—	—
72-95	Card room only	3	35.0	0	0	1	0	2	91.7	91.7
	Card room and other departments	5	37.8	0	0	1	1‡	3	79.6	22.6
	Other departments only	0	—	—	—	—	—	—	—	—
95 and over	Card room only	7	46.7	2	1	0	0	4	111	111
	Card room and other departments	3	36.0	0	0	1	0	2	121.3	55.7
	Other departments	27	38.8	0	1	2	2§	22	149.4	—

* Calcified foci in lung fields.

† One case of pulmonary tuberculosis and one case with transient infiltration.

‡ One case of left ventricular hypertrophy.

§ One case with transient infiltration, and one case of cervical ribs.

or three months of bad coughing followed by two or three months relatively free of it. He was in the habit of spitting up considerable amounts of greenish sputum but had never had any haemoptyses or blood-stained sputum. He had never had asthma or bronchitic symptoms when exposed to sisal, and had only once been in hospital (on account of an accident to his finger).

Clinical examination showed that he had slight clubbing of the fingers, poor chest expansion, and persistent crepitations at the left apex. He was afebrile. His urine was normal, and the blood slide was negative for parasites. The Mantoux test (10 T.U. old tuberculin) was positive after 72 hours. The E.S.R. (Wintrobe) was 18 mm. per hour, and the haemoglobin (Sahli) was 95%. The total white count was 7,250 cells per c.mm. (polymorphs 50%, lymphocytes 44%, large mononuclears 1%, and eosinophils 5%).

The sputum was copious and semi-purulent, and contained some black streaky flecks. Microscopic examination showed many polymorphs and mononuclears packed with light brownish granules which under the polarizing microscope showed the same birefractive pattern as did the sisal dust. The prussian blue reaction was negative, and no tubercle bacilli or fungi were seen. Culture of the sputum for fungi on Sabouraud's medium on eight occasions failed to produce any growth, and eight cultures for tubercle bacilli on Löwenstein-Jensen medium gave no growth. Guinea-pig inoculation on two separate occasions produced no tuberculous lesions in the pigs.

The vital capacity was 1,800 ml., and the M.B.C. was 57 litres per minute. The H.B. sisal extract gave an induration of 10 mm. a quarter of an hour after injection. An E.C.G. showed no abnormality.

The straight radiograph showed pleural thickening over both upper zones which was more marked on the left. There was evidence of bilateral fibrosis, atelectasis, and possibly cavitation at both apices, the appearances being more marked on the left. The tomogram showed that the pulmonary fibrosis was situated posteriorly at both apices, and was maximal at the 8 cm. cut. A bronchogram of the left apex showed crowded left apical bronchi with a moderate degree of dilatation, and there was marked distortion and deviation of the trachea.

A bronchoscopy was performed and showed no abnormality of the right upper, middle, and lower lobe bronchi. The left upper bronchus was slightly red and congested, and contained mucus of which swabs were taken and cultured for both tubercle bacilli and fungi with negative results.

This man returned to the factory to work and was given another job in the finishing store where he was exposed to no dust. Follow-up straight radiographs taken 16 and 22 months later showed no change in the radiological picture, and the sputum was still negative for tubercle bacilli after concentration. He now says that he has an occasional cough but feels quite fit.

Case 2.—K. N., a male Mkamba, was aged about 58.

Before his present employment he had worked for many years planting sisal in the fields. He was then engaged as a headman on a coffee estate for three years, after which he started his present job in the carding

room where he had been employed on a teaser card for nine years. He had had only one month's leave away from work during the whole of this period.

He complained that he had had a productive cough for a long time and much sputum. He had been in hospital for six days about two years previously with an illness which was diagnosed as a right basal lobar pneumonia. No radiograph had been taken at this time. He had no history of haemoptysis or any allergic susceptibility to sisal dust.

Clinical examination showed he had early clubbing of the fingers, poor respiratory excursion, and bronchial breathing over the left apex and mid zone. No abnormalities were detected in the urine, and the blood slide was negative for parasites. The Mantoux test (10 T.U. old tuberculin) was positive after 72 hours. The E.S.R. (Wintrobe) was 12 mm. per hour, and the haemoglobin (Sahli) was 100%. The total white count was 5,800 cells per c.mm. (polymorphs 38%, lymphocytes 57%, and eosinophils 5%).

The sputum was copious and semipurulent. On microscopic examination many polymorphs and mononuclears were seen packed with small brown opacities which showed the same birefractive pattern under the polarizing microscope. The prussian blue reaction was negative, culture for fungi on Sabouraud's medium on seven occasions gave no growth, and culture for tubercle bacilli on seven occasions on Löwenstein-Jensen medium also failed to grow organisms. Inoculation of the sputum into guinea-pigs on two occasions failed to produce any lesions.

The vital capacity was 1,900 ml., and the M.B.C. 34.5 litres per minute. The H.B. sisal extract showed an induration of 5.5 mm. 15 minutes after injection. The E.C.G. showed notching of the Q.R.S. complex, and S.T. elevation in lead VI but otherwise no abnormalities.

The straight radiograph (Fig. 3) showed pleural thickening over a fibrosed and partially atelectatic right upper lobe. There was considerable bowing of the trachea to the right, and the lesser fissure was displaced upwards. The tomogram showed that the fibrosis was situated posteriorly in the apex of the right lung, and was most marked at the 6 cm. cut. A bronchogram (Fig. 4) showed a moderate diffuse bronchial dilatation with crowding in the right upper lobe.

Bronchoscopy showed that the left bronchial tree was very pale and atrophic, and contained a number of dry crusts. The appearances in the right bronchial tree were very different and were most marked about the right upper lobe bronchus. The mucosa here was thick, red, and congested, and the bronchi contained much mucus. Swabs from the left and right upper lobe bronchi were cultured for fungi and tubercle bacilli with negative results.

He returned to work in the finishing store where he was no longer exposed to dust. Follow-up radiographs taken 16 and 22 months later showed no radiographic change, and the sputum was negative for tubercle bacilli after concentration. He now says that he has no cough and feels quite fit.

Case 3.—R. S., a male Embu, was aged about 48.

This man had previously worked on a sisal estate as a

FIGS. 3 and 4.—Radiograph and bronchogram in Case 2 showing apical pulmonary fibrosis.

herdsman before taking up his present employment as a worker on the carding machines. He had been in this job four and three-quarter years, and almost all of this time had been spent on the breaker card, but for a short period he had been working on a teaser card. During the whole of this period he had spent a total of three weeks away from work.

He had recently noticed that he had been becoming more breathless than usual, and he also complained of an unproductive cough. He had never been admitted to hospital, and had no history of asthmatic attacks, allergy, or haemoptysis.

On examination he had clubbing of the fingers, fair respiratory excursion, and bronchial breathing was detected at the right apex at the back. No abnormalities were observed in the urine, and the blood slide was negative for parasites. The Mantoux test (10 T.U. old tuberculin) was positive after 72 hours. The E.S.R. (Wintrobe) was 7 mm. in one hour, and the haemoglobin (Sahli) was 95%. The total white count was 4,100 cells per c.mm. (polymorphs 52%, lymphocytes 33%, mononuclears 1%, and eosinophils 14%).

The sputum was negative for fungi and tubercle bacilli on microscopical examination, and culture on Sabouraud's and Löwenstein-Jensen media on seven occasions each gave no growth of fungi or tubercle bacilli. Two guinea-pigs were inoculated with sputum and neither developed tuberculous lesions.

The M.B.C. was 39 litres per minute, and the skin sensitivity test for sisal (H.B. extract) showed an induration of 10 mm. after 15 minutes. A sigmoidoscopy, performed because of complaints of passing blood in the

stools, showed nothing abnormal, and a rectal biopsy showed no ova.

The straight radiograph showed right upper lobe fibrosis with marked deviation of the trachea to the right and considerable displacement of the lesser fissure upwards. There was a right diaphragmatic adhesion. The tomogram indicated that the fibrosis was mostly situated in the posterior part of the right upper lobe, being maximal at the 8 cm. cut. The bronchogram was a failure because of inadequate filling, but small, probably bronchiectatic, cavities were observed in the tomogram.

A bronchoscopy was performed and no abnormal appearances were detected. Swabs from the left and right main bronchi were cultured for tubercle bacilli with negative results.

After returning to the factory he refused to change his job in the carding room for another because it was more remunerative. By this time the dust extraction plant had been installed, and the dust concentrations in the carding room were very low. Follow-up radiographs 10 and 22 months later showed no radiological change, and the sputum was negative for tubercle bacilli after concentration. He now says that he occasionally coughs up a little sputum but feels quite fit.

Case 4.—M. M., a male Jalu, was aged about 49.

This man had previously been engaged as a farm labourer for three years, he had then worked as a cutter on a sisal estate for another three years. He started his present job in the carding room two years previously, and had been employed for three-quarters of the time on batching and for the rest of the time on a breaker card

machine. He had spent two weeks on leave away from his job.

He complained of a cough, and this he thought had started about 10 months previously after an acute illness accompanied by a severe cough. He did not go to hospital during this illness but had twice previously been in hospital with chest complaints. He had no history of asthma, allergic phenomena, or haemoptysis.

On examination there was doubtful finger clubbing, and his chest expansion was only fair, but otherwise no abnormality was found. His urine was normal and his blood slide was negative for parasites. The Mantoux test (10 T.U. old tuberculin) was positive after 72 hours. The sedimentation rate (Wintrobe) was 6 mm. in one hour, and his haemoglobin (Sahli) was 110%. The white blood count was 4,500 cells per c.mm. (polymorphs 42%, lymphocytes 52%, and eosinophils 6%).

The sputum was mucopurulent and scanty, and on microscopical examination was negative for fungi and tubercle bacilli. Culture of the sputum on Sabouraud's and Löwenstein-Jensen media on six occasions each produced no fungi or tubercle bacilli. Guinea-pig inoculation of the sputum on two occasions was negative for tuberculosis.

His M.B.C. was 31 litres per minute, and sisal sensitivity tests with H.B. extract showed an induration of 8.5 mm. 15 minutes after the injection.

The straight radiograph showed a streaky fibrosis of the right upper lobe, and to a lesser degree in the left upper lobe. There were also right diaphragmatic adhesions, and the lesser fissure was displaced upwards. The tomogram showed that the fibrosis was most marked in the posterior parts of both upper lobes, and was maximal in the 6½ cm. cut. A bronchogram of the right upper lobe showed deviation of the trachea to the right, crowding of the bronchi, and bronchiectasis.

He returned to work and was transferred to the new factory where he was no longer exposed to dust. Unfortunately he left this job a year later and could not be traced for follow-up radiographs.

The symptoms and physical signs of these four cases have in common cough, clubbing of the fingers, and signs of emphysema. The M.B.C. and vital capacities were low when compared with those of other workers of the same age and experience. The sputum of every case was consistently negative for tubercle bacilli on direct examination, culture, and guinea-pig inoculation, and in two cases in which it was examined for dust particles it was found to contain numerous intracellular foreign bodies which were similar to sisal dust under the polarizing microscope—an observation of some interest in that it indicates a degree of tissue reaction to the dust. The radiological pictures presented by the cases were also similar in many respects. The fibrosis was situated at the apex, was bilateral in two cases, was maximal in the posterior part of the lung, and tended to be concentrated at the periphery in the pleural and subpleural spaces. Crowding of the

Fig. 5.—Bronchogram showing varicose dilatation of both lower lobe bronchi.

bronchi and evidence of bronchiectasis was observed in three patients, and was strongly suspected in the fourth from whom a bronchogram was not obtained. The similarity of the clinical and radiological picture presented by these cases makes one suspect that they have a common aetiological basis.

Cases with Heavy Lung Markings and Linear Striation.—Of those three subjects whose radiographs showed evidence of heavy lung markings and linear striation the first had worked for eight years in the carding room. His radiograph showed an increased striation at both bases which was noted by all three assessors. The man had clubbing of the fingers and symptoms suggesting bronchiectasis. A bronchogram (Fig. 5) revealed varicose dilatation of both lower lobe bronchi. Whilst the association of bronchiectasis with sisal dust must be problematical it should be noted that all four cases of apical fibrosis also showed bronchiectasis, and that similar cases have been described as a chronic sequel to bagassosis.

The second case had had 13 months' previous experience in the brushing room of a sisal estate factory elsewhere, and his total exposure to sisal dust was three and a half years. The radiograph showed a streaky linear mottling in both lung fields which was commented on by two assessors. He

complained of no symptoms and showed no physical signs. A full investigation in hospital, including a bronchogram and sputum culture, failed to reveal any other abnormalities. The third and last case in this group was a man who had worked 12 years in the rope-making plant, and had been engaged on a machine which produced a small amount of sisal dust, but nothing comparable to that generated in the carding room. Two assessors reported that his radiograph showed bilateral fine reticulation. He had no symptoms, and clinical and other investigations in hospital, including a bronchogram and sputum culture, showed no further abnormality. The radiographs of the latter two cases could well pass as showing evidence of the earliest stages of dust reticulation but the appearances were so indefinite that it was difficult to make a confident diagnosis.

After investigation in hospital the two patients who had previously been working in the carding room returned to work in other departments in the factory where they were not exposed to dust. The third patient returned to his old work in the rope-making plant. A follow-up of all three cases over a period of 20 months has shown no change in the radiological pictures, and all say now that they are quite fit except for an occasional cough.

Pleural or Diaphragmatic Adhesions.—In no instance did the adhesions seen radiologically appear to be very extensive. In seven cases they were recorded as diaphragmatic, in four cases as costophrenic, and in two as pleuropericardial. There was nothing to indicate anything particularly specific about the radiological appearances, and it is considered that they were merely indicative of some previous respiratory infection.

It will be seen from Table 6 that adhesions were observed in six radiographs out of the 33 taken of persons who had worked in the carding room only (excluding the four cases of apical pulmonary fibrosis). They were observed in five radiographs out of the 29 taken of persons who had worked both in the carding room and other departments, and in two out of the 27 taken of persons who had never worked in the carding room. They were therefore two to three times as commonly observed in the radiographs of persons who had worked in the carding room as in those of persons who had not, and although this is not statistically significant ($P=0.3$), the finding is consistent with the observation that both respiratory infections and lobar pneumonia appeared to be commoner amongst carding room operatives.

Radiographs Showing Other Abnormalities.—Eight workers had radiographs showing various abnor-

malities which did not appear to be connected with dust exposure. A case of pulmonary tuberculosis was found which was proven bacteriologically and apparently uncomplicated by other pulmonary disease. The radiographs of two persons showed small pulmonary infiltrations which on further follow-up proved to be transient. One further radiograph showed left ventricular hypertrophy, another showed cervical ribs, and three showed calcified foci.

Further Investigations Carried Out in Three Sisal Estate Factories

An endeavour was made to extend the investigations undertaken in the sisal bag factory by carrying out a similar type of survey amongst workers in the brushing rooms of three sisal estate factories. These three estates (*A*, *E*, and *R*) were chosen because of the relatively low labour turnover which they were reported to have, and because of their proximity to facilities for radiography; but even so it was necessary to transport the workers from one estate a distance of 23 miles for radiological examination.

The investigations carried out in the three estates were purposely made as simple as possible. A radiological examination of the chest was performed on all available workers in the brushing rooms, ensuring that those with the longest service were included. The industrial history of each man examined was obtained, and this was checked with the estate records when these were available, and also with records at the Central Registration Office. It was found impossible to assess sick rates amongst the employees as none of the estates kept sick registers. Dust samples were taken with a thermal precipitator in each factory.

Dust Concentrations.—The dust in sisal estate factories is mainly generated by the brushing machines which, acting as carding machines with blunt combs, clean the decorticated fibre which is fed to them by hand. Exhaust ventilation was not installed in any of the factories investigated but as each was open sided on at least one and a half sides some natural ventilation was available.

The employees worked on a piecework system, and their total daily exposure to sisal dust ranged between four and six hours. It was obvious to the naked eye that those exposed to the maximum amount of dust were engaged on operating the carding or brushing machines; on the other hand, those engaged on baling and packing the fibre were exposed to minimal quantities of dust, and those working on sorting and grading the fibre were exposed to intermediate concentrations. These observations were confirmed by the results of the

dust samples (Table 7). The majority of samples were taken from around the brushing machines where those engaged on brushing, sorting, and grading worked, and a few were taken distal to the brushing machines from areas where those engaged on baling and packing worked.

TABLE 7

AVERAGE DUST CONCENTRATIONS IN THREE SISAL ESTATE FACTORIES TAKEN FROM POSITIONS NEAR AND DISTAL TO BRUSHING MACHINES

	Proximal to Brushing Machines		Distal to Brushing Machines	
	No. Samples	Average Count (particles/ml. 0.5-5 μ)	No. Samples	Average Count (particles/ml. 0.5-5 μ)
Factory A	3	284	1	60
Factory E	5	96	1	24
Factory R	2	126	1	30

The high concentration of dust around the brushing machines in factory A was due to the fact that the machines were situated in the centre of the room and thus all the dust generated by them was liberated directly into the room. The machines in factories E and R were, on the other hand, situated on a side wall and consequently much of the dust from them was blown outside.

Exposure Time of Workers Examined.—Seventy-six workers in all three factories were radiographed; 32 of these persons worked as brushers or carders, 30 as sorting and grading operatives, and 14 in baling and packing operations. Table 8 shows the average exposure time to dust of these workers, and it will be noted that not only was the total time worked less than that amongst the workers in the sisal bag factory but also the exposure time of each individual each day was about half that in the sisal bag factory.

TABLE 8

AVERAGE LENGTH OF SERVICE OF WORKERS EXAMINED IN FACTORIES A, E, AND R ENGAGED IN BRUSHING AND CARDING, SORTING AND GRADING, AND BALING AND PACKING

	No. Workers	Average Time Employed (months)	Previous Exposure to Dust (months)*
Brushers and carders	32	33	13.6
Sorters and graders	30	18.4	0.3
Balers and packers	14	39.4	3.4

* Previous exposure to sisal dust was accepted if any worker had worked on carding, brushing, sorting, or grading in any sisal factory.

There was also a considerable difference in the numbers of persons who had been exposed to dust for the longest periods; for whereas there were 16 workers in the sisal bag factory who had worked for four years or more on carding machines there were only five workers in the estate factories who

had worked this time on brushing or carding machines. In the only estate factory (A) where the dust concentrations were comparable with those in the sisal bag factory, the average daily exposure of the workers to the dust was half, and the total service two-thirds, of that of the workers in the sisal bag factory.

Radiological Abnormalities.—A chest radiograph of each of the 76 employees was taken, and the films were read "blind" by two of the assessors who had previously reported on those from the sisal bag factory. There was agreement in the interpretation of 69 films, and the remaining seven were given to another assessor for an independent reading which was accepted as final. Table 9 classifies the radiological findings, and it will be noted that none of the radiographs showed any evidence of apical pulmonary fibrosis or increased linear striation, but it can be observed that there was the same tendency for adhesions to occur in the films of those who had been most exposed to dust.

TABLE 9

SUMMARY OF RADIOLOGICAL FINDINGS OF 76 PERSONS WORKING IN THREE SISAL ESTATE FACTORIES

	No. of Workers	Adhesions	Other Abnormalities	No Abnormality
Brushers and carders	32	3	4*	25
Sorters and graders	30	1	2†	27
Balers and packers	14	0	2‡	12

* Two cases of pulmonary tuberculosis, 1 calcification, 1 severe scoliosis.

† 1 calcification, 1 old fractured ribs.

‡ 2 calcification.

The information obtained from these investigations was of a generally negative nature, but in view of the relatively low exposure times and low dust concentrations in the sisal estate factories it could hardly be expected that pulmonary disease due to chronic exposure to dust would be found.

Discussion

The four cases of apical fibrosis and bronchiectasis are rather strikingly similar, whereas the other case of basal bronchiectasis, although not radiologically alike, is similar in so far as occupational history and clinical findings are concerned. The occupational histories of these five cases are also similar—an exposure to sisal dust in the carding room of the factory for a number of years. The absence of any detected cases with pulmonary fibrosis or bronchiectasis amongst those who had either only been exposed to dust for short periods, or who had never been exposed to it, but who had, nevertheless, worked for similar or longer periods in other parts of the factory makes it seem probable that long

exposure to heavy concentrations of sisal dust may produce pulmonary damage.

Typically pneumoconiosis is bilateral and relatively symmetrical in the middle and upper zones of the lung fields. In two of the four cases showing apical fibrosis the radiological picture showed these characteristics but in the other two cases the changes were unilateral. But Dunner *et al.* (1946), in their investigation amongst dock labourers exposed to the organic dust of grain and seed, have shown that unilateral radiological changes, including fibrosis, were considerably commoner than bilateral changes.

The radiological appearances of the four workers showing apical fibrosis were not typical of silicosis, but did suggest chronic fibroid tuberculosis. However, it is unusual to find chronic tuberculosis of this type amongst Kenya Africans, and the chances of finding four such cases amongst 93 persons radiographed must be remote. Also guinea-pig inoculations and frequent microscopic and cultural examination of the sputa failed to demonstrate any tubercle bacilli.

Apical fibrosis is observed occasionally amongst the general African population of Kenya. But the radiological appearance is not similar to the distribution and type of fibrosis observed in these carding room workers where the fibrotic lesions were patchy but confined to the apices and posterior parts of the lungs, and not necessarily segmental, and tended to involve the pleural and subpleural areas.

Allergic manifestations of both the upper and lower respiratory tract are common in those in contact with organic dusts. Schilling, Hughes, Dingwell-Fordyce, and Gilson (1955) have shown that the asthmatic attacks, suffered by cotton operatives in the card and blow rooms, do not produce fibrosis nor do the radiographs show any characteristic change. No allergic history or the characteristic chest tightness on Mondays of byssinosis was obtained from any of the four cases; or indeed from any worker questioned in the carding room. Nor did an inspection of the sick register reveal any such condition. For what they are worth intradermal skin sensitivity tests with sisal dust showed no special sensitivity by any group of workers. In three cases of pulmonary fibrosis the blood eosinophil count was on the high normal side, 270 to 360 cells per c.mm. (5 to 6%). This was not considered especially remarkable for an average adult African. In the fourth case the count of 570 cells per c.mm. (14%) was high and unexplained.

Hunter and Perry (1946) have described two cases of bilateral fibrosis and bronchiectatic cavitation in men who were working on a bagasse shredder. The sputum of both these cases was consistently nega-

tive for tubercle bacilli and fungi, and they were considered to represent a chronic sequel to an earlier attack of bagassosis. These two cases appeared to be in many ways similar to the four cases of apical fibrosis and bronchiectasis and the case of basal bronchiectasis detected in the present survey.

Two of the five cases of bronchiectasis found in the survey gave a past history of an acute pulmonary disease whilst they were exposed to sisal dust, and although it was possible that this may have been an illness similar to the acute phase of bagassosis, the history of the condition given by the patients in retrospect appeared to be typical of pneumonia, and differed from the incapacitating, debilitating, and long-drawn-out disease of acute bagassosis.

It was considered possible that the apparent greater susceptibility of the carding room workers to "pneumonia" was due to an acute infection similar to bagassosis. But a search of the hospital records of carding room workers admitted to hospital with acute respiratory infections did not produce evidence to support this idea.

Hunter (1955) believes that bagassosis is due to a mechanical blocking of the bronchioles with vegetable dust, and it is of some interest to note that the chemical composition of bagasse and sisal dust is similar (Table 10). Other authors, however, believe that bagassosis is a bronchopulmonary mycosis.

TABLE 10
CHEMICAL COMPOSITION OF SISAL AND BAGASSE DUST COMPARED

	Sisal (Government Chemist)	Bagasse (Lemone <i>et al.</i> , 1947)
Lignin (%)	38	15
Cellulose (%)	30	55
Pentosans (%)	15	24
Acetic acid (%)	1	6
Moisture (%)	9	—
Ash (%)	12	—

In the majority of cases of bagassosis the acute disease process in the lung resolves completely, and therefore the acute condition is observed more frequently than the chronic. By analogy it would be expected that many of the carding room workers, who were constantly exposed to sisal dust, would suffer acute symptoms. However, no acute respiratory condition similar to bagassosis has been detected in the factory in a retrospective investigation of acute chest conditions, and a continual watch on the employees for the last two years.

The condition found amongst the sisal workers is more similar to the chronic lung condition described by Hunter (1950) amongst workers in the Hungarian pepper industry who were engaged in splitting the pepper by hand. Some of these workers, especially those with many years at the job, developed

apical fibrosis, cavitation, and bronchiectasis. The disease was presumed to be caused by a fungus, *Mucor stolonifer*.

Pulmonary disease caused by fungi can give very much the same radiological and clinical picture as the sisal factory cases. No direct evidence of any such causation was found in these patients as the result of the examination of their sputa, but it should be noted that no bacteriological investigations were carried out on the dust generated in the factory. However, the difficulties of incriminating fungi in pulmonary disease are well known, and it is considered that a fungal origin is the most likely aetiological factor in the four cases of apical fibrosis described. Whatever is the causation of the fibrotic bronchiectatic condition found in these cases it is difficult to avoid the conclusion that a single aetiological agent, which is connected with the inhalation of dust, is responsible.

Summary

A study was made in Kenya in a factory making ropes and bags from sisal to determine whether the dust produced causes pneumoconiosis or other chest diseases.

The average dust concentration in the card rooms was 243 particles per ml. (0.5 to 5 μ). Other parts of the factory were relatively dust free. Deposited dust had a very low silica content.

The respiratory illness sickness rate was twice as high in the card-room workers as in those working in other parts of the factory.

Radiographs of 37 workers with between six months' and 15 years' exposure in the card rooms revealed four with a similar type of apical fibrosis. Two showed heavy lung markings. In 46 films of workers of long experience in other parts of the factory only one showed heavy lung markings and none apical fibrosis.

The average maximum breathing capacity (recorded for one minute) was 53 l./min. in 36 card-room workers and 61 l./min. in 25 workers in other parts of the factory and of similar age. The difference is statistically significant.

No worker exposed to sisal dust gave the characteristic history of byssinosis. Skin sensitivity tests with extracts of sisal were uninformative.

A subsidiary radiological survey of men in three sisal estates showed no evidence of pneumoconiosis or apical fibrosis but the exposure of the workers had been short and the dust concentration low.

The apical fibrosis is unlike that seen in the general African population. Intensive investigations for tubercle bacilli were negative.

It seems possible that the fibrosis is related to occupation; its possible relation to the chest disease occurring in workers in bagasse and peppers is discussed.

I am most grateful to Dr. P. E. C. Manson-Bahr for providing me with beds in his wards in King George VI Hospital, and to Mr. P. Clifford for performing the bronchoscopies.

The photostatic copy of the plan of the factory was done through the kind assistance of Messrs. A. C. Holmes and W. Sutton of the Health Education Unit of the Kenya Medical Department. Mr. G. Davies Jones, of the Medical Research Laboratory, Nairobi, kindly took the photomicrograph of the dust shown in Fig. 2.

Finally I should like to thank the Labour Commissioner for permission to publish.

I should like to acknowledge the great cooperation and help given to me by the managing directors, the staff, and the employees of the factories in which these investigations were undertaken. I would like to thank Dr. E. R. N. Cook for carrying out all the bacteriological work, and together with Dr. A. Henderson Begg for providing me with the sisal extracts for intradermal injection. I would also like to thank Mr. F. McNaughton, of the Government Chemist's Department, for performing the chemical analysis on the sisal dust, and Dr. W. Pulfrey, of the Mines and Geological Department, for examining it under the petrological microscope.

Dr. Wallace Fox, of the Tuberculosis Research Unit of the Medical Research Council, Dr. W. H. S. Hopkirk, advisor in radiology to the Kenya Medical Department, and Dr. L. R. Whittaker, radiologist, Kenya Medical Department, rendered great assistance with their help in interpreting the radiographs.

REFERENCES

- Anton, W. (1934). *Med. Klin.*, 30, 1092.
 Caminita, B. H., Baum, W. F., Neal, P. A., and Schneiter, R. (1947). *Publ. Hlth Bull. (Wash.)*, No. 297.
 Cayton, H. R., Furness, G., and Maitland, H. B. (1952). *Brit. J. industr. Med.*, 9, 186.
 Dunner, L., Hermon, R., and Bagnall, D. J. T. (1946). *Brit. J. Radiol.*, 19, 506.
 Fawcitt, R. (1936). *Ibid.*, 9, 172.
 Hoffmann, W. (1946). *Schweiz. med. Wschr.*, 76, 988.
 Hunter, D. (1950). *Brit. med. J.*, 1, 506.
 — (1955). *The Diseases of Occupations*, 1st ed., p. 931. English Universities Press, London.
 —, and Perry, K. M. A. (1946). *Brit. J. industr. Med.*, 3, 64.
 Jamison, S. C., and Hopkins, J. (1941). *New Orleans med. surg. J.*, 93, 580.
 Leach, J. (1863). *Lancet*, 2, 648.
 Lemone, D. V., Scott, W. G., Moore, S., and Koven, A. L. (1947). *Radiology*, 49, 556.
 Linko, E. (1947). *Ann. Med. intern. Fenn.*, 36, 98.
 McCormick, W. E., Smith, M., and Marsh, S. P. (1948). *J. industr. Hyg.*, 30, 43.
 Marcandier and Le Chuiton (1928). *Rev. Hyg. Méd. Préventive*, 50, 672.
 Martins, A. F. (1956). *Bull. Inter-African Labour Inst.*, 3, No. 1, p. 26.
 Moll, H. H. (1933). *Lancet*, 1, 1340.
 Najera Angulo, L., and Dantin Gallego, J. (1939). *Arch. Mal. prof.*, 2, 337.
 Ordman, D. (1947). *S. Afr. Med. J.*, 21, 737.
 Schilling, R. S. F. (1956). *Lancet*, 2, 261.
 —, Hughes, J. P. W., Dingwall-Fordyce, I., and Gilson, J. C. (1955). *Brit. J. industr. Med.*, 12, 217.
 Törnelli, E. (1946). *Acta med. scand.*, 125, 191.