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GENERAL MEETING, 15th JULY, 1965

The Monthly General Meeting of members of the Association was held at the Wenela Hospital, Johannesburg, on Thursday, 15th July, 1965, at 2.30 p.m., with Dr. E. M. McLean (President) in the Chair.

There were present 12 members, two visitors and the Secretary.

The minutes of the Monthly General Meeting held 17th June, 1965, were confirmed.

AN EPIDEMIOLOGICAL STUDY OF THE RELATIONSHIP BETWEEN THE AMOUNT OF DUST BREATHED AND THE INCIDENCE OF SILICOSIS IN SOUTH AFRICAN GOLD MINERS

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1. INTRODUCTION

It is manifestly impracticable in dust control work in mines to achieve atmospheres completely free of dust. Some practical level of "permissible dustiness" must be set and efforts made to reduce the dust concentrations to which men are exposed to below this target level.

Many countries have agreed on such levels to suit their particular conditions and their methods of dust sampling; in some countries (but not in South Africa) these levels have been entrenched in legislation. However, in few, if any, countries have these agreed levels been founded on a scientific correlation between actual dust measurements and the incidence of pneumoconiosis; generally the levels have been based on intelligent guesses

as to what might be satisfactory or on what is regarded as attainable from the engineering point of view.

This paper describes an attempt to obtain this correlation for the conditions in South African gold mines.

The project, which started in 1956 and is still continuing, is described in broad outline only in this paper together with the main results which have been obtained to date. Full details are not given in regard to technical aspects or statistical methods used.

Measurements were made of the typical amounts of dust breathed in their daily underground shifts by approximately 650 different Europeans falling into 11 main "occupational groups". The incidence of silicosis in these same "occupational groups" (but not necessarily in the same individual men) was studied by analysing each man's full mining working history and the results of the regular Miner's Medical Bureau examinations for a population of approximately 1,200 European gold miners who had commenced work in the industry nearly 30 years ago. A significant percentage of this population had been certified in recent years to have contracted silicosis.

From these data values have been determined of the percentage of the original population certified to have silicosis after various lengths of underground service in different types of work.

To date, the correlation between the two parameters, namely "dust exposure" and "incidence of silicosis", has not been determined based on the 11 individual occupational groups, as there are complicating factors. A preliminary analysis has been

based on two broad categories into which the 11 groups can be condensed. This analysis shows that there is a high correlation between the amount of dust breathed and the incidence of certified silicosis.

In South Africa there is controversy as to which method of dust sampling is most useful and as to the parameter (number concentration, surface area or mass concentration) which should be used to express the results. In this project, therefore, the dust exposures were measured using a number of different sampling instruments and assessment techniques.

It is hoped, as a secondary objective, that some definite evidence can be obtained as to the method of sampling and assessment which correlates most closely with the health hazard. This study is, however, not yet complete.

2. MEASUREMENTS OF THE AMOUNT OF DUST BREATHED

2.1. Instruments and Techniques. To measure the dust to which each man was exposed it was decided to employ all three dust-sampling instruments presently in use in South African gold mines, namely, the konimeter, the standard thermal precipitator and the modified thermal precipitator.

The two thermal precipitators were mounted in a carrying device on the chest of the dust sampler, who followed the miner whose dust exposure was being measured.

The two forms of thermal precipitator were operated continuously throughout the full working shift (from surface back to surface) of the man whose exposure was being studied.

Samples on the konimeter (which is a snap-sampling instrument) were taken at 10-minute intervals throughout the shift.

2.2. Selection of Mines. It was decided to confine this investigation to 20 of the gold mines selected on a stratified random basis to include the various geographical areas in which the mines lie, to cover different mining conditions (e.g., deep and shallow; steep dip of the reef and flat workings; different mining methods, and so on), and to include mines from each of seven major mining groups. Five of these mines were selected for detailed studies, an average of about 100 men being

sampled on each of these, and the remaining mines were sampled on a smaller scale. At the end of the sampling portion of the project the results from the five main mines were compared with those from the remaining 15 and it was shown that trends were not significantly different. It was therefore concluded that the overall results were typical of the average of all mines.

2.3. Selection of Miners. It was decided to confine this study to European underground workers only. On each mine a list was first obtained of all the European underground workers. The number in each "occupational group" was determined from this. The number to be sampled in each group on that mine was determined from a statistical formula which took into account various factors.

Having determined the number of men to be sampled in each occupational group, the names of the actual individuals to be sampled were selected using a set of random numbers applied to the official mine records.

In order to obtain co-operation from the miners, the objects of the scheme and its importance in fundamental studies to reduce silicosis were explained to them, through both management and trade union levels. The man selected for sampling was informed the previous day that he was to be followed by a dust sampler; it was stressed to him that he should carry out his normal duties the following day and not alter his work pattern in any way because he would be accompanied throughout his shift. The vast majority of men selected for sampling were most co-operative. The dust samplers themselves were all experienced mining men, and if they considered that the man being sampled departed significantly from his standard practices the results of that sampling shift were discarded.

2.4. Results. The results are too numerous to be given in full in this paper; they will be confined to expressing dust levels in terms of the number concentration of particles of all sizes, as measured by the standard thermal precipitator and counted after the conventional South African acid-treatment.

Table I sets out, for each occupational group, the average result, together with the minimum and maximum values observed.

All values refer to the average dust measurement in particles per cubic centimetre multiplied by the length of the shift in hours.

TABLE I

Occupational group number	Average dust level	Minimum value	Maximum value	Number of men sampled
1	3,360	500	8,430	11
2	2,020	350	7,740	38
3	1,540	150	5,110	111
4	1,110	40	4,130	155
5	750	90	1,840	43
6	730	40	4,770	106
7	970	30	2,910	33
8	390	50	1,340	33
9	1,340	70	6,090	41
10	660	30	5,280	62
11	840	60	2,050	11

The results in Table I show that there are large differences between the dust exposures associated with the different occupations.

3. THE INCIDENCE OF SILICOSIS IN THE POPULATION STUDIED

3.1. Medical Records. South Africa is fortunate to possess excellent, possibly unique, medical histories of all underground workers in the gold mines.

The Annual Reports of the Miners' Medical Bureau give a great deal of information on its work but give no data bearing on the effect of different types of occupation on the incidence of silicosis.

For the purposes of this project, therefore, a study had to be made of the relationship between the type of work carried out and the concomitant incidence of silicosis.

3.2. Selection of the Population for Study. In consultation with the statistical consultant for this work (Dr. H. S. Sichel) it was decided that the correct way to analyse data to determine the effect the type of work (i.e., "occupational group") might have on the incidence of silicosis was to select a population all of whom had started work in the same period. This cohort system differs radically from another method which has been used by some investigators of examining all those who have contracted the disease at the same time, and investigating their histories, irrespective of when they started work.

After careful consideration it was decided that the selected population should consist of European underground workers who met the following conditions:

- Started work on South African gold mines between 1st January, 1934, and 31st September, 1938, inclusive.
- Had completed a minimum of 3,000 underground shifts.
- Had no known service in "dusty" occupations other than in South African gold mines.

The reasons for these conditions were:

- Starting date 1/1/1934 to 31/12/1938.* In the first place the starting date must be fairly far back in time to ensure that a useful number of men (from a statistical point of view) from the selected population will have developed silicosis in diagnosable degree. Approximately 25 years back seemed to be a reasonable starting point, as this period is, at present, approximately the average period of exposure of those certified to have contracted silicosis.

Secondly, it is known that no dramatic changes in average dust conditions in South African gold mines have occurred since 1934. Although some sources of dust production have been reduced, other mining processes which produce dust have been introduced or widely extended.

Thirdly, the present method of recording each person's service was introduced as from 1st January, 1934, and it would have entailed a considerable amount of extra work to include men whose careers started before this date.

Finally, this was a period of heavy enrolment of new workers into the gold mining industry and the number of cases selected for study was therefore certain to be high.

- Minimum of 3,000 shifts.*

A considerable number of men abandon mining as a career after a relatively short period of time and it was considered highly unlikely that such men would have contracted any significant degree of silicosis. The investigation

was therefore confined to men who had made mining a reasonably "permanent" career. This was defined, arbitrarily, as having completed 3,000 underground shifts at the time the names were selected.

(c) *No other 'dusty' service.*

Work in collieries, in mining areas such as Zambia, or in surface dusty occupations might add another unknown factor to the incidence of silicosis. It was considered better to omit such men; in fact only a relatively small number were eliminated for this reason.

It was found that approximately 4,000 men satisfied these requirements. This number was considered to be more than could conveniently be processed in this analysis, and it was reduced to about one-third by selecting from it those whose surnames began with the letters H to P.

3.3. Collection of Occupational and Medical Histories. The full occupational histories up to the end of 1964 for these men have been obtained from records kept at the mines. These show the number of shifts each man has worked in each occupational group, the mine on which this work was undertaken and the year in which each type of work was carried out. Many gold miners often change their occupations and the mines on which they work; for some of the population under study, the records consist of over 100 entries!

In a small percentage of cases these occupational histories could not be obtained due, for example, to mines having closed down, accidental loss of records and so on. These cases were eliminated from the study.

Parallel to obtaining the occupational histories, the records of the Miners' Medical Bureau were studied to determine which of this population had been certified to have silicosis, and if so certified, at what stage they were first certified. Unfortunately, from the point of view of this investigation, there have been three different Pneumoconiosis Acts of Parliament in operation during the time that some members of this selected population have been reaching the stage of being certified. Each of these Acts gave different medico-legal definitions of silicosis and its compensatable stages. Although it must

be stressed that, from a strictly legal and medical point of view, there is no exact relationship between the different definitions in the three Acts, it was necessary for the purposes of this statistical examination to assume that under each Act the first certifiable stages were approximately equal.

3.4. The Fate of the Selected Population. Table II sets out the fate of the selected population up to the end of 1964.

TABLE II

Total population investigated	1,186
Still working underground	521 (44 %)
Alive, but not now working underground	424 (36 %)
Dead (None died of silicosis)	241 (20 %)
Number of certifications in life	199 (17 %)
(Note: Findings of "borskwaal" have been ignored in this study)	
Of men still living, number certified ..	168 (18 %)
Post-mortem findings:	
Not certified in life/no pneumoconiosis in p/m	88 (46 %)
Not certified in life/pneumoconiosis found p/m	81 (42 %)
Certified in life/no pneumoconiosis in p/m	1 (1 %)
Certified in life/pneumoconiosis found p/m	21 (11 %)
No post-mortem result available ..	50

Table III shows the years in which men from this population were first certified, in life.

TABLE III

Year	Number of men certified in this year	Accumulative number	Accumulative percentage of total population
Before 1952	0	0	0
1952	1	1	0.1
1953	3	4	0.3
1954	3	7	0.6
1955	4	11	0.9
1956	26	37	3.1
1957	27	64	5.4
1958	7	71	6.0
1959	7	78	6.6
1960	6	84	7.1
1961	23	107	9.0
1962	19	126	10.6
1963	47	173	14.6
1964	26	199	16.8

3.5. The Effect of Occupation on the Incidence of Silicosis. It was stated above that many of these men continually change their type of occupation and the mine they work

on. This has complicated the analysis of their working histories and the attempt to associate specific rates of incidence with the 11 occupational groups. To date, no satisfactory statistical model has been found which enables the data to be analysed in this way, but work on this is at present in progress.

For a first analysis, the 11 different occupational groups were combined into two broad overall categories consisting of those occupational groups which were, from the mining point of view, reasonably similar. These broad categories contained the following occupational groups:

- Category A—Occupational groups 1 to 5
- Category B—Occupational groups 6 to 11

"Survivorship curves" were determined statistically for those men who had spent most of their working lives (over 60 per cent) in Category A, and also for men who had spent most of their lives working in Category B. These curves are given in Fig. 1. They show the percentage of men in each category who would have survived after working specified numbers of shifts if certification of silicosis had been the only factor producing losses in the original population. That is, the calculations have eliminated losses for other reasons, such as leaving the gold mining industry or death. The curves are not taken beyond 7,500 shifts because the number of men exceeding this value is too small, at

present, for reliable analysis. The two curves are significantly different from each other (at the 99 per cent level of confidence) throughout the range covered.

4. THE CORRELATION BETWEEN THE AMOUNT OF DUST BREATHED AND THE INCIDENCE OF SILICOSIS

It is now possible to compare the dust levels breathed by the two broad groups of men with the incidence of certified silicosis in these groups. Although these two parameters have been determined on different sets of persons, it is believed that both are representative of the whole population and that it is therefore justifiable to compare them.

Because the incidence of silicosis data has, at this stage of the investigations, been determined only for the two broad categories, the dust sampling data must also be reduced to comparable categories. This was done by weighting the dust level found for each "occupational group" by the total number of men employed in the mining industry in that group and obtaining the weighted mean dust index for the two categories.

These results are shown in Table IV, which also shows the percentage of men certified after working 7,500 shifts, taken from the smoothed curves in Fig. 1.

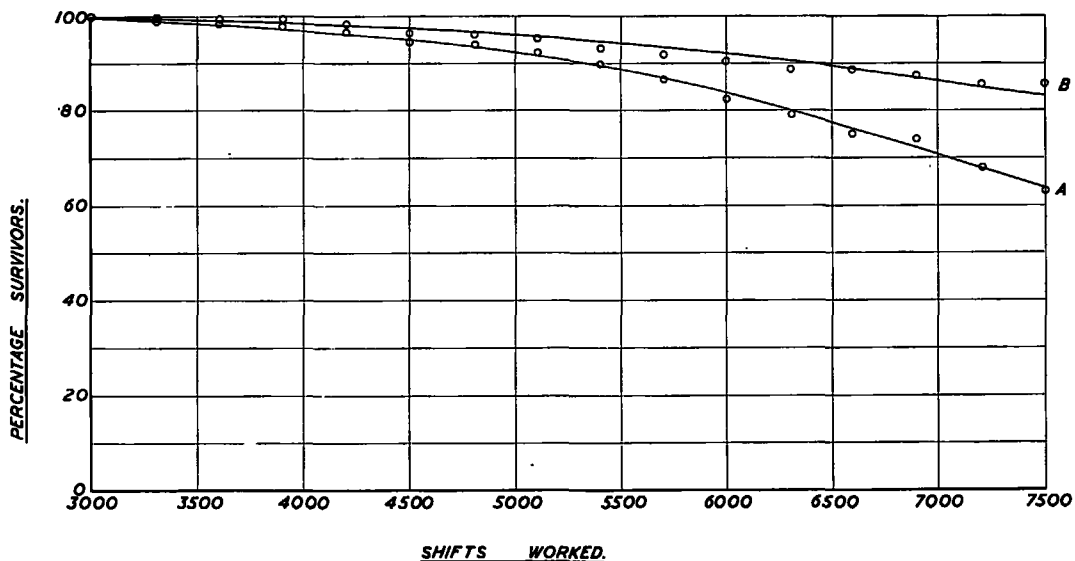


FIG. 1

TABLE IV

Occupational category	Mean dust index	Percentage certified after 7,500 shifts
A	1,280	36
B	700	17

It will be noted from Fig. 1 that the percentage of men certified in Category A is, at all stages of exposure, approximately double the percentage certified in Category B. Therefore, for purposes of correlation, it does not matter which figure is taken for the number of shifts at which the silicosis incidence is compared.

Although statistically there is a strong correlation between the two parameters which have been discussed, it is not necessarily only dust exposure which determines the certification of silicosis. Many other factors may play a part, such as infection by tuberculosis, personal susceptibility, and so on. In fact there is the possibility—however remote—that, despite the demonstrated correlation, there may be no real causal relationship between the amount of dust breathed and the production of silicosis. Stronger support for the hypothesis that there is such a relationship should emerge from the further studies that are planned, using all 11 occupational groups independently.

5. PROPOSED FURTHER STUDIES

5.1. Correlation with Radiological Findings. Hitherto the only medical factor considered in the investigation has been the incidence of silicosis as certified by the Miners' Medical Bureau. Certification of silicosis, particularly under the South African legislation in recent years, is a complex matter and many factors are taken into account, particularly the degree of disability present. Also the population studied has been certified at different times over a period of approximately a dozen years, during which the relevant Act of Parliament has been changed three times, and possibly different standards have been applied at different times. Certainly the persons making the decisions on certifications have changed from time to time.

In any study of this type it is highly desirable to have observations which are consistent

within themselves, and also, if at all possible, consistent with practice elsewhere.

It has been agreed, in consultation with the Director of the Pneumoconiosis Research Unit and the Director of the Miners' Medical Bureau, that an independent assessment should be made of all the X-ray plates for all the men whose working and medical histories have been studied in this survey. This will be done by a single radiologist rereading (without prior knowledge of previous decisions) all the X-ray plates for the selected population, according to the International (Geneva) classifications. Consistency tests will be included in this scheme by asking him to reread plates selected at random on which he has already made his decisions. Arrangements for this important part of the scheme have been made, and when the results are available, they will be compared with the dust indices.

5.2. Correlation with Post-mortem Findings. Decisions on the presence and stages of silicosis in living men are obviously subject to a number of difficulties and potential sources of error. However, when a post mortem is performed on a man it is easier not only to make a more exact diagnosis, but also to express the findings on some quantitative basis, e.g., the number and/or size of the silicotic nodules.

Most of the men of the selected population who have died have been examined post mortem, with particular reference to the state of the lungs. Dr. Ian Webster, Deputy Director of the Pneumoconiosis Research Unit and Head of its Pathological Section, has kindly offered to re-examine his extensive collection of data on these post mortems and reassess the degree of silicosis, if any, present in the men from this selected population.

These data will also be correlated with the dust indices and may well prove to be the most suitable method for determining the relationship between dust inhaled and the degree of lung disease caused thereby.

6. ACKNOWLEDGEMENTS

This paper is presented with the kind permission of the South African Pneumoconiosis Research Unit, which sponsored the whole investigation. The interest and support of the three Directors during the time the investigation has been in progress is warmly acknowledged. They were Dr. A. J. Orenstein, Dr. H.

Gear and Dr. L. C. Walters. The Deputy Director, Dr. Ian Webster, has also contributed a great deal of advice and practical assistance.

The Director of the Miners' Medical Bureau, Dr. G. K. Sluis-Cremer, not only permitted the use of the Bureau's medical records but has also provided much useful help in other ways.

The managements and staff of the various mines on which the dust measurements were made, and from whom the detailed working histories were obtained, have at all times been most helpful. The officer in charge of the "Records of Service" at the Chamber of Mines, Mr. C. Adkins, and his staff gave considerable assistance.

The statistical work has, throughout, been under the guidance of Dr. H. S. Sichel, Director of the Operational Research Bureau, Johannesburg.

Finally, members of my Dust Research Team at the Corner House Laboratories of Rand Mines, Limited have contributed significantly to the project, not only in the laborious work of taking and assessing the many tens of thousands of dust samples involved and in collecting and collating the occupational histories, but in suggesting new ideas in connexion with the project. I am deeply grateful to them.

DISCUSSION

Dr. Martiny asked if post mortems had been done on all the cases that had died.

Mr. Beadle replied that they had been done in about 80 per cent of the cases. Legally every case should go to post mortem, but some had died overseas or far away from Johannesburg.

In reply to a further question by Dr. Martiny regarding the time taken to develop silicosis, Mr. Beadle said they had decided to look only at people who had done 3,000 shifts (i.e. approximately 11 years' service) although they knew that a few men did contract silicosis in less than 3,000 shifts.

Dr. Martiny said that the Bureau liked to have a minimum of six to eight years' service before certifying a man. If a person had had only two years in a dusty atmosphere and had then been out of it for 10 years, would that two years' exposure not do virtually the same damage as if he continued working in a milder dusty atmosphere for a much longer period? One case on record was that of a man who had contracted very severe silicosis some 20 years after only two months' work in the Pennsylvania Tunnel.

Mr. Beadle said he thought that there were two time factors which had to be taken into account—the period for which the man had been exposed to the dust and the elapse of time since he had had that dust exposure. If he had had a certain exposure 20 years ago, he thought that that was likely to be more harmful than if it had been one year ago. They were investigating this. Their mathematical model was designed to analyse this factor and they hoped to be able to produce information relating to the second time effect, i.e., since exposure.

Dr. Coetzee thanked Mr. Beadle for his paper and asked whether it was correct to assume that their investigations would throw some light on the occurrence of silicosis amongst non-Europeans, who worked for a shorter period but in greater dust exposure.

Mr. Beadle said this was not in their terms of reference as they had to be able to trace the full working history. This was easier to do in the case of Europeans, which was one of the main reasons this investigation had so far been confined to Europeans. The present figures for certifications amongst Bantu were probably not complete, as many who returned home did not come back for a check by the Bureau. He personally thought it would be valuable to see a similar investigation done on the Bantu, who were exposed to higher dust levels but on an intermittent working basis.

The Chairman, on behalf of members, thanked Mr. Beadle for his most interesting and enlightening talk.