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ROUTINE AIRBORNE DUST SAMPLING IN COLLIERIES

(Members of the Transvaal and Orange Free State Chamber of Mines)

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Preface

This paper is published with the permission of the Transvaal and Orange Free State Chamber of Mines. It describes sampling procedures, the assessment of samples, and presents an analysis of sampling results for the years 1957 and 1958.

1. Introduction

Following the proposal of the Department of Mines to promulgate a new Regulation concerning the appointment of Dust Inspectors on collieries, and as a result of discussions thereon with the Government Mining Engineer, the Transvaal and Orange Free State Chamber of Mines decided, with the concurrence of the Government Mining Engineer, that there should be established Collieries Dust and Ventilation Laboratories in the Transvaal and Orange Free State. The last four years have seen the consolidation of the Collieries Dust and Ventilation Laboratories at Witbank and Vereeniging. Full scale routine sampling on collieries has been in progress since March, 1956, and up to now approximately 16,000 modified thermal precipitator samples have been taken on the collieries, members of the Transvaal and Orange Free State Chamber of Mines. These measurements of airborne dust concentrations were essential to the efficient direction of all measures for the prevention and suppression of dust.

The South African method of assessing airborne dust concentrations in coal mines is the modified thermal precipitator/photo-electric assessor technique. Investigations have shown that this method correctly used provides a reasonable measure of the dust in the air and for the purpose of routine dust control in coal mines is practical and satisfactory.

It may be noted that although this procedure was decided upon four years ago, the aerodynamic principle by which only respirable dust is collected by the sampling instrument, is in close accordance with the recommendation made at the Pneumoconiosis Conference held in Johannesburg in February, 1959. The trend of opinion in England is that the best measure of the health hazard for coal dust is either the mass or the surface area of the respirable material as selected by the aerodynamic

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procedure. The photoelectric reading is approximately proportional to the surface area.[3,6]

2. Sampling Procedures

The concentrations of airborne dust vary greatly between different mines and working places, and a knowledge of these variations can only be obtained by measurement which is an essential background for the manager engaged in dust prevention. Satisfactory instruments and measuring procedures should provide a numerical result which is approximately proportional to the quantity of dust which may be breathed and retained by the lung of a workman.[1,3] The reference instrument used for airborne coal dust sampling in collieries is the Modified Thermal Precipitator, which was designed to sample approximately according to the lung retention curve[2]. The primary merits of this instrument are its scientific principle, light weight and complete ease with which samples are taken and evaluated.[2,4]

The purpose of routine airborne dust sampling as carried out by these laboratories is specifically to pin-point the dusty places and to inform the managers as soon as possible so that they in turn know where and when to attend to dust suppression. In other words, routine dust sampling is done for the purpose of assisting managers in improving dust conditions on collieries. A failure to recognise that there are a number of quite different purposes for sampling can lead to much confusion,[1] e.g. there is the objective of the medical research worker who is concerned with establishing the dust exposure of a group of men and the objective of the engineer who may wish to compare the dust hazard of two mining operations. Alternatively the engineer may be concerned with ensuring conformity with prescribed standards of airborne dust concentrations. For each purpose of sampling an entirely different sampling procedure may be used. It is emphasised again that routine measurement is not concerned with the individual or average dust exposure of workmen, nor can it e.g. be concerned with the likelihood that a workman engaged in heavy labour retains more dust in his lungs than a workman who is inactive, nor can it be concerned with variations in the individual susceptibility of workmen. These are all matters which must be weighed in the balance in the formulation of standards.[1] Routine control is solely concerned with examination of working places, to ensure that suppression methods are in use, to pin-point the dusty places, and to submit the findings to the respective managers as soon as possible.

All underground sections and surface plants of registered collieries are sampled at least once each year. This ensures that both the good and the bad working places are sampled on each colliery, thus making the results of each years sampling comparable. Information regarding the working sections on each colliery is obtained from colliery survey departments.

The period of sampling is determined by the time required to obtain a set of samples which gives a clear representation of the average dustiness of a working face during the period of maximum dust production.[5] In this way peak dust counts show up when dust suppression methods are not in use. On the other hand, when sections are well ventilated and water is available at the faces for suppression, high dust sampling results are not usually found. If sampling does not take place throughout a whole shift, then sampling must proceed during the progress of the main mining operations. This procedure ensures that dust samples are taken during the period of maximum dust production.[1]

Airborne dust samples are taken in the underground workings of collieries in the intake air, at the coal faces, and in the return air. Intake samples are taken in the intake air to working sections either at several points in the airways leading to the sections, or in the mains. The coal face samples are taken at the coal faces at head height as close to the workmen as can be arranged, on the return side of the main mining operations. The return samples are taken in the return air leaving the sections, or in the mains, both cases being in the main upcast or return airways. In the case of sampling on the surface workings of collieries the samples are taken again at head height as close to the workmen as can be arranged, on the return side of points of dust production.

3. Evaluation of Samples

Modified thermal precipitator samples of airborne coal dust are dried to a maximum temperature of 220°C before being assessed.

All modified thermal precipitator samples are evaluated photoelectrically[4,7] and apart from this about half of them are examined under the medium power microscope for the number count and size frequency. The photoelectric reading for each sample is corrected to a volume of 100 ccs and referred to as P.E.R. an arbitrary unit. These units are not converted to surface areas because of the difficulties of getting a true measure of the surface area applicable to the hazard associated with the dust. All readings taken, however, are standardised in these units and may be compared with each other.[6]

The actual reading made on the instrument is electric current in micro-amperes—a " numerical answer " on a galvanometer. This galvanometer reading is approximately proportional to the surface area of the dust in the sample.

In order to confirm that the photoelectric readings are, however, giving a reasonable measure of the surface area of the particles, a comparison was made between the photoelectric readings and a figure proportional to the surface areas for the various operations, calculated from the average size distribution given by microscope counting. A constant shape factor was assumed. The results are given in Fig. 1, and it will be seen that they fall very nearly on a straight line.[8]

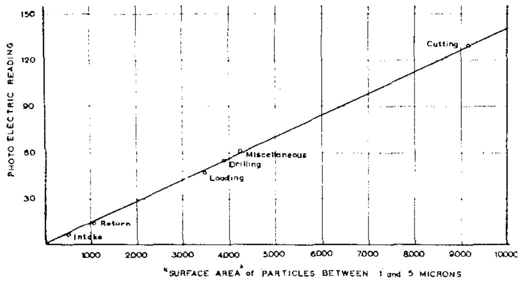

Fig. 1. Showing correlation between photoelectric readings and a figure proportional to the surface area calculated from the average size distributions for each operation for 1958.

The relative peıcentage frequency [7]occurrence of particles of dust of various sizes for coal cutting, loading and intake air may be seen by referring to Figs. 2–4. The graphs indicate a relatively coarse dust for coal cutting, medium for loading, and fine for intake air.

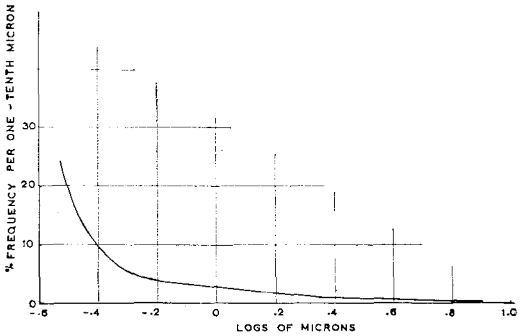

Fig. 2. Frequency Curve (Coal Cutting).

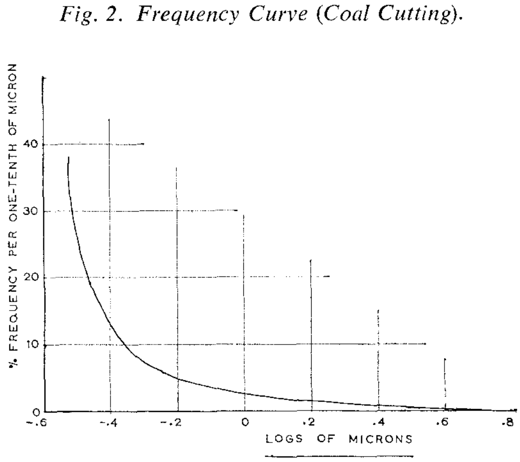

Fig. 3. Frequency Curve (Loading).

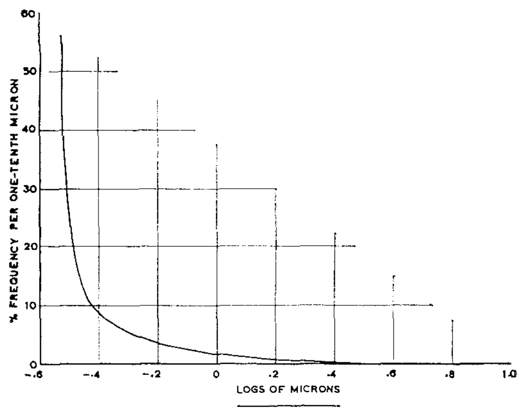

Fig. 4. Frequency Curve (Intake Air).

The percentage number of samples for coal cutting, loading and intake air falling in different ranges which are expressed in P.E.R., units, may be seen by referring to Figs. 5–7. The graphs indicate that the preponderance of coal cutting samples is found in the higher ranges, loading samples in the medium, and intake samples in the low.

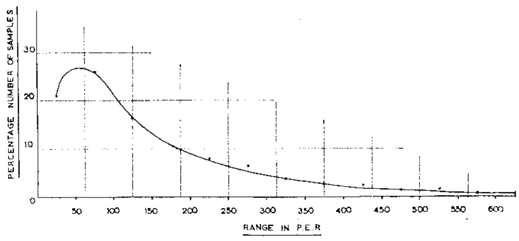

Fig. 5. Percentage of samples against P.E.R. range for Coal Cutting.

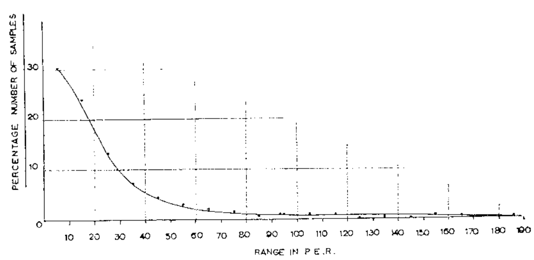

Fig. 6. Loading.

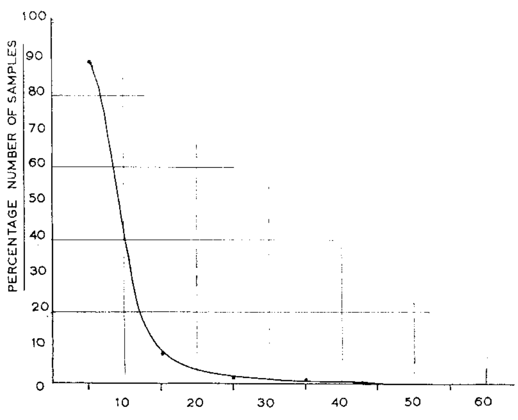

Fig. 7. Intake Air.

4. Data

The data consisted of all samples taken during 1957 and 1958 in the twenty-six Transvaal and Orange Free State coal mines. All samples were measured by means of the photoelectric counter.

A point of interest is whether there are any trends over the period of two years. The first step was to calculate average dust concentrations for each month in a few collieries in order to get an indication of what trends to expect. It soon became apparent that the individual readings were so widely scattered as to make comparisons between mines virtually meaningless.

There was a possible explanation for this large scatter. When sampling dust in coal mines, the dust inspectors attempt to take their samples in places where the dust concentrations are high; thus at any working area, say, the sample is taken in the dustiest place in that area. However, it can happen that a sample is sometimes taken at a place which is not as dusty as another place in the immediate vicinity. Statistically this means that two populations are being sampled, where the dust inspector is trying to sample only one population—the population of the dustiest places.

Instead of using monthly averages, which include samples from both populations, it was decided to use the averages of the three highest readings for the month in each of the mines. By doing this one would be reasonably sure of including samples taken only from the population of dustiest places. In fact, it was found that these maximum samples did have a much smaller scatter than the total samples.

Only samples classified under the headings Cutting, Loading and Drilling were considered. This was done because only a very small proportion of the samples fell under different headings, such as watering down, miscellaneous, etc., and it would be difficult to base valid deductions on such small groups.

5. Analysis

The procedure was then as follows:—

For each mine the average of the three highest readings for each of the 24 months was calculated. This calculation was done separately for Cutting, Loading and Drilling. The " maximum " monthly averages were then plotted on separate graphs of each of the 26 mines.

The following points of interest emerged from a study of the 26 graphs:—

(*a*) Cutting produces the most dust.

(*b*) Whatever trends are present tend to be shown up more clearly in the graphs for Cutting.

(c) The few mines which produce markedly less dust than the others show no trends.

(d) The more dusty mines apparently show a seasonal trend or cycle, but no long-term trend over the two years.

(e) The mines with a dust production lying between the above two extremes show both a seasonal trend or cycle, and a long-term downward trend over the two years.

In view of (c), (d) and (e) above, it seemed desirable to divide the 26 mines into these three classes. In view of (a) and (b) it was decided to use dust produced by cutting as the criterion for classification. The 26 mines were then arranged in the following three classes:—

(i) *Relatively Good Section:*—All mines with an average (for the two years) photoelectric reading for cutting of less than 100.

(ii) *Medium Section:*—All mines between 100 and 250.

(iii) *Relatively Bad Section:*—All mines greater than 250.

The result of this classification was:—

Relatively Good Section	—	4 mines
Medium Section	—	17 mines
Relatively Bad Section	—	5 mines

The average photoelectric readings for each month was calculated for each of the three groups. This was done for cutting, loading and drilling. These averages are depicted in Figs. 8, 9 and 10 corresponding to classes (i), (ii) and (iii) above.

Fig. 8 shows no trend.

Fig. 9 shows a marked downward trend for Cutting, a lesser downward trend for Loading and no trend for Drilling. The seasonal trend is quite apparent in the graph for Cutting; higher readings are obtained in winter than in summer.

Fig. 10 shows no general upward or downward trend, but the graph for Cutting shows an extremely marked seasonal cycle, the winter readings being much higher than the summer readings.

However, the above deductions were not accepted as valid until proved statistically significant.

The mean square successive difference test was used to test for significance of trend.

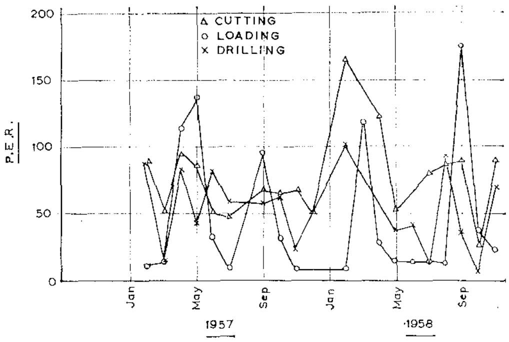

Fig. 8. "Good" Section.

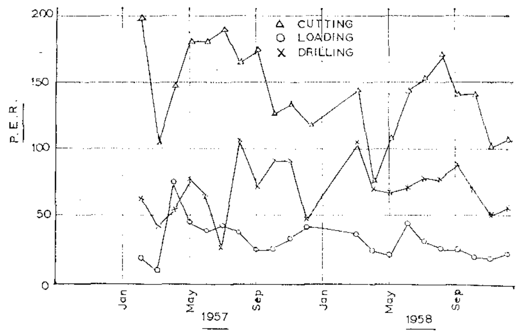

Fig. 9. "Medium" Section.

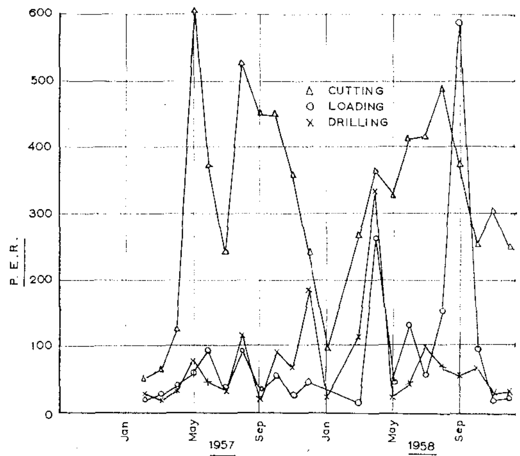

Fig. 10. "Bad" Section.

This was done in the following way:—

Let $x_1, x_2 \ldots x_n$ be the averages arranged in chronological order.

$$\text{Let } q^2 = \frac{\sum_{i=1}^{n-1} (x_{i+1} - x_i)^2}{2(n-1)}$$

$$\text{and } s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}$$

Then the ratio

$$r = q^2/s^2$$

is calculated and compared with its tabulated value (see Hald: Statistical Theory with Engineering Applications pp. 357–358).

For Cutting (Fig. 9), r was found to be 0·602 which is significant at the 95 per cent. level. This means that the trend for Cutting in the medium group is significant. Now part of this significance is due to the seasonal cycle and part is due to the general downward trend.

Thus it was necessary to test whether the downward trend by itself was significant. This was done by calculating the annual averages for 1957 and 1958. These averages came to 157·7 and 130·1 respectively. The value of q^2 (which was 595·6) was taken as an estimate of the variance for the monthly averages for Cutting. This gave a variance of 113·7 for the difference between the means.

$$\text{Thus } t = \frac{\text{difference of means}}{\text{s.d. of difference}} = \frac{27 \cdot 6}{10 \cdot 7} = 2 \cdot 5$$

which is significant at the 95 per cent. level. Thus both the seasonal cycle and the downward trend for the medium group were found to be significant.

The trend for loading was tested the same way. The trend was found to be not significant, but if the first two plotted points (i.e. those for February and March 1957) are omitted, r has a value of 0·39 which is significant at the 99·9 per cent. level. As this graph does not have the marked seasonal cycle of the graph for Cutting it was not thought necessary to test separately for a long term downward trend.

Obviously, if the figures for cutting, loading and drilling were pooled, the pooled figures would also show cyclical and downward trends. Note that the graph for drilling has no trend.

The cyclical tend for cutting in the relatively bad section is so pronounced that it was not thought necessary to apply the test. None of the remaining graphs have significant trends.

6. Conclusions

1. The 4 mines in the relatively good sections exhibit no trends. They were good in 1957 and remained so throughout 1958.
2. The five mines in the relatively bad section show no general improvement. However, the dust concentrations in these mines due to cutting exhibit a pronounced seasonal trend. In winter the concentrations are much higher than in summer. The real reason for this seasonal fluctuation is not clear. This point is being studied more fully and the findings will be reported when this further analysis is completed.
3. The mines in the medium section (containing all but nine of the 26 mines) show a definite general improvement in dust conditions over the two years 1957 and 1958. Of course, there may be some mines in this section which do not show an improvement, but as a group the mines in this section have improved. The seasonal fluctuation is also apparent in this section, particularly in the figures for cutting.

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