

Privy Council

MEDICAL RESEARCH
COUNCIL

CHRONIC PULMONARY DISEASE IN
SOUTH WALES COALMINERS

II.—ENVIRONMENTAL STUDIES

A.—REPORT BY THE COMMITTEE ON INDUSTRIAL
PULMONARY DISEASE.

B.—G.—REPORTS ON PHYSICAL, CHEMICAL AND
PETROLOGICAL STUDIES by T. Bedford and
C. G. Warner; H. V. A. Briscoe, P. F. Holt,
N. Spoor and others; G. Nagelschmidt; A.
Brammall and J. G. C. Leech; D. Hicks and
G. Nagelschmidt; J. Ivon Graham and D. F.
Runnicles; and co-workers.



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The late Dr. D. A. POWELL was also a member of the Committee during the period of these investigations.

PREFACE

This Report deals with the environmental aspects of the investigation of chronic pulmonary disease in South Wales coalminers which the Medical Research Council undertook in 1936 at the request of the Home Office and the Mines Department. It is thus complementary to the Report on the medical survey and related pathological studies which was issued last year (*Spec. Rep. Ser. Med. Res. Coun., Lond., No. 243, 1942*). The whole scheme of inquiry has been directed by the Committee on Industrial Pulmonary Disease, who have provided covering reports (Sections A of *Spec. Rep. Ser. No. 243* and of the present monograph), reviewing and summarising the conclusions of the individual investigators.

The medical survey showed that the pulmonary abnormality encountered among South Wales coalminers was not restricted to the anthracite area, but could be found in the whole of this coalfield; its incidence and severity were greatest, however, among colliers who had worked for long periods at the coal-face in anthracite mines. A relationship was established between the incidence of pulmonary abnormality among the colliers, as judged by X-ray evidence, and the rank of the coal mined at the different collieries, though within the anthracite area there were also distinct local variations in incidence. Furthermore, the results of the medical survey and the pathological studies established that the types of pulmonary abnormality in South Wales coalminers included a form of disabling pulmonary disease which did not come within the accepted definition of "silicosis" as used for the purposes of the workmen's compensation schemes. Both this condition ("dust reticulation"), and the more developed nodular and conglomerate radiographic changes also seen typically in colliers, differed in several important respects from the pulmonary abnormality found characteristically in hard-heading workers, which corresponded closely to the silicosis occurring in persons exposed to high concentrations of quartz. Finally, the pulmonary abnormality shown to occur in colliers was also found to some extent in coaltrimmers working at the docks.

While recognising the difference between the form of chronic pulmonary disease found in hard-heading workers and that found most typically in colliers, the Committee realised that the distinction would be impracticable in routine work, and they accordingly recommended that the comprehensive term "pneumokoniosis of coal workers" should be used in future to describe "all the pulmonary conditions described as due to dust in workers engaged in any operation underground in coalmines, in screens workers at collieries and in coaltrimmers at docks". Moreover, since dust-reticulation was clearly attributable to the industrial hazard and led to some degree of disability, it was recommended that the diagnostic criteria required for purposes of compensation should be widened in scope, so as to include not only the more fully developed lung changes but those established by the medical survey as comprising all the various stages of "pneumokoniosis of coal workers". The Council are glad to note that the Workmen's Compensation Act, 1943, gives power to make compensation schemes on the basis of these recommendations. Since the findings of the medical survey and pathological studies—together with the environmental researches described in detail in the present symposium—confirmed the opinion that the most important causative factor in the pneumokoniosis of coal workers was prolonged exposure to air-borne dust, the Committee in their first report made certain recommendations as to how exposure to such dust in coalmines might be lessened. In so far as further statutory powers are required to enable effect to be given to these recommendations, they also have been taken in the Workmen's Compensation Act, 1943.

The second report of the Committee on Industrial Pulmonary Disease deals with the environmental conditions in the mines which must be taken into

account in studying the causation of pneumokoniosis of coalminers. The term "environmental conditions" embraces the actual concentration of dust in the air breathed by the collier at the coalface, the nature of this dust and size of the dust particles, the composition and characteristics of the strata from which this dust is derived, the concentration in the air of irritant fumes derived from the explosives used in shot-firing, and the temperature and humidity of the air to which the miner is exposed during his work. Detailed reports on all of these factors in relation to the incidence of pneumokoniosis in the South Wales coalfield are given by the different investigators, and the Committee provide a covering report in which they are able to make certain recommendations with a view to diminishing the pneumokoniosis hazard. Some of these recommendations have already been made in the first report of the Committee.

In planning and carrying out the medical and environmental studies, the Committee and the investigators received much help from the Mines Department, and its officers, and a contribution to the cost of the work was made from the Miners' Welfare Fund. The Council gratefully acknowledge this co-operation, and, not less, that of the colliery owners, the trade union representatives, and the many coalminers and coaltrimmers concerned. They also wish to express their high appreciation of the services of the Committee and of all those who took part in the scientific studies. A list of the principal investigators is given on p. x.

19th April, 1943.

MEDICAL RESEARCH COUNCIL,
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(Detailed Tables of Contents precede Sections B to G.)

APPENDIX I

ABSTRACT OF REPORT ON THE SOLUBILITY OF MINERALS AND MINERAL GELS IN AQUEOUS DIETHYLAMINE

By *Geochemical Laboratories, London*

The work to be described was carried out on behalf of A. Brammall and J. G. C. Leech, with the object of obtaining further evidence regarding the nature of the groundmass constituents of South Wales shales and, in particular, ascertaining whether an amorphous silico-alumino-gel was present.

For this purpose base-exchange and solubility determinations were carried out on both original shales and 2μ fractions separated by means of air-elutriation.

Extraction with sodium hydroxide or sodium carbonate could be relied on to remove silica, alumina and silico-alumino-gels; doubtless such factors as temperature, time of extraction, concentration of alkali, etc., could be so adjusted as to reduce to a minimum any attack on the crystalline minerals.* Nevertheless, it seemed possible that more satisfactory results would be achieved by the use of an organic base, and attention was directed to the work of B. Sjollem (J. *Landwirtschaft*, 1902, 50, 371), who describes the separation of quartz from amorphous silicates with the aid of aqueous diethylamine. Other organic bases, e.g. pyridine, aniline, methylamine and trimethylamine, appeared to offer no advantages over aqueous diethylamine, and it was decided to employ the latter for the extraction of the shales received.

Solubility of gels in aqueous diethylamine

Sjollem describes the separation of quartz from "amorphous silicates" by refluxing with aqueous diethylamine; but no clue is given to the composition or origin of the silicates used in his experiments. Accordingly, at the outset of our investigations a number of gels were prepared and examined as regards solubility in the above medium.

Silica gel, prepared by acidifying a solution of sodium silicate with dilute hydrochloric acid, was almost insoluble in pure diethylamine but dissolved on refluxing with an aqueous solution containing one part by volume of diethylamine to two parts of water.

The pH of the latter solution (thymol-violet indicator) was greater than 13.0, and the strength of this base approaches that of caustic soda. Silica gel which had been fumed with sulphuric acid, and the dried form supplied for laboratory use as a desiccant, were also soluble (Table CII below). The filtered solutions were perfectly clear and could be refiltered without change in concentration through asbestos pads of the type used in bacteriological work for the removal of micro-organisms. The solutions were, however, colloidal and exhibited a well marked Tyndall effect. Addition of excess ammonium chloride or ammonium nitrate caused flocculation.

Procedure in these experiments was as follows:

Approximately 0.4 g. of silica gel was placed in a glass flask fitted with a ground-glass joint carrying a condenser and refluxed on a water bath for 3 hours with 30 ml. of 2 : 1 aqueous diethylamine.

The solution was filtered through a "sterimat", Grade S.B., and evaporated to dryness in a platinum basin. A few drops of sulphuric acid were added and the dish was slowly heated until sulphuric acid and organic matter had been removed.

After igniting to redness for a short time, the dish was cooled and weighed, and the residue treated with hydrofluoric acid. Blank determinations, carried out in exactly similar manner, yielded not more than 1.5 mg. extract, of which approximately 0.5 mg. was silica.

Alumina gel was less soluble than silica gel, 30 ml. of the solvent extracting only 0.015 g. of the freshly precipitated hydroxide prepared by the addition of ammonia to a solution of aluminium chloride.

Ferrous and ferric hydroxides were insoluble under the conditions of test.

Aluminium silicate gels. According to S. Mattson, the formation of the clay complex in soils is analogous to the mutual precipitation of a positive alumina sol by a negative silicic-acid sol under isoelectric conditions—when no electric charges are present on the precipitated alumino-silico-gel. The composition of the isoelectric precipitate varies according to the pH of the solution and the $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio, being approximately 2.4 at pH 4.5 and zero at pH 8.0.

Attempts to reproduce these conditions in their entirety were unsuccessful, and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios were limited in range 1.15–1.65.

The procedure was to mix a solution of aluminium chloride (5 millimols per litre) with a solution of sodium silicate (10 millimols per litre) and to adjust the pH of the solutions by precipitating in the presence of hydrochloric acid or sodium hydroxide. After vigorous stirring, the precipitate was then separated by centrifuging.

* The structure of silica and alumina gels has a material bearing on their solubility in alkaline reagents (Ganguli, A., *Acta. Physicochem. U.S.S.R.*, 1938, 9, 19; Lourky, A. R., *Z. anorg. Chem.*, 1939, 240, 198).

Aluminium silicates prepared in this way were readily soluble when refluxed with aqueous diethylamine, and they also dissolved in the cold solvent. When dried at 105° C. the gels appeared to become somewhat less soluble, although even under these conditions approximately 0.2 g. of gel could be dissolved in 30 ml. 2 : 1 aqueous diethylamine.

Mixtures of silica- and alumina-gels. Freshly prepared silica gel is very soluble in 2 : 1 aq. diethylamine, but it is insoluble or nearly so in a saturated solution of alumina gel in the same reagent (i.e. 0.015-0.020 g. alumina gel in 30 ml.).

Mechanical mixtures of silica and alumina gels in widely different proportions yielded only minute amounts of silica when extracted with aqueous diethylamine. As the ratio of silica to alumina gel is increased, the amount of silica extracted rises slightly, but even when the molecular proportions of the two gels are 9 : 1 it does not exceed 10 mg. *There is, therefore, very definite evidence that alumina exerts a protective action on silica gel.*

When alumina gel is refluxed for about $\frac{1}{2}$ hour with aqueous diethylamine, micro-crystalline needles are deposited. Under the microscope, these crystals are seen to be of an embryonic type, and to exhibit birefringence (with straight extinction). The crystals apparently consist of aluminium oxide, probably in a hydrated form. It is not yet certain whether the formation of these crystals is connected with the protective action of the gel, although in this connection it is of interest to note that L. H. Germer and K. H. Stocks (*Chem. Tr. J.*, 1939, 104, 382), in the course of their work on the protective action of aluminium powder, have shown by X-ray diffraction measurements that aluminium combines with water to form a crystalline hydrate ($Al_2O_3 \cdot 3H_2O$), which is then deposited on the surface of quartz particles.

The employment of aqueous diethylamine for dust-solubility determinations is open to the objection that the figures so obtained bear little relationship to solubility in body fluids. But, in the present instance, its use is justified by the fact that *the primary object of the experiments was to endeavour to differentiate between the amorphous and the crystalline constituents forming the groundmass of the South Wales shales.* For the latter purpose, an alkaline reagent in which silica, alumina and aluminosilico-gels are all soluble is preferable to water or to physiological salt solution.

Experimental procedure

In order to obtain comparable results, it was necessary to standardize the conditions under which solubility determinations were carried out, and, unless otherwise stated, figures quoted in this report refer to the extract obtained when a 0.5 g. sample was refluxed for 3 hours with 30 ml. 2 : 1 aq. diethylamine, the operation being performed on a water bath in glass flasks (150 ml. capacity) fitted with ground-in reflux condensers. The solution was then filtered through a Ford "sterilmat" contained in a Gooch crucible, transferred to a platinum dish and evaporated to dryness. A few drops of sulphuric acid were added and the dish placed on a hot plate until fuming had ceased. The residue was gently ignited to remove carbonaceous matter and weighed. Blank determinations made under precisely similar conditions yielded approximately 1 mg. extract.

Filtration was not regarded as satisfactory until a perfectly clear solution was obtained, but normally only one filtration was necessary. In the event of turbidity the solution was refiltered through the original pad. The pores in these filter pads are small enough to remove all coarse colloidal particles but permit silicic acid solutions to be filtered without change in concentration. The average pore space of the grade employed needs to be taken into consideration in the interpretation of results.

TABLE CII
Gels

Description of gel.	Mol. ratio SiO_2/Al_2O_3 in gel.	Total extract.	Mol. ratio SiO_2/Al_2O_3 in extract.	Remarks.
(0.4 g. approx.)		g.		
Fresh silica	—	0.42	—	Solution complete.
Silica gel (dessicant) ..	—	0.105	—	Some excess gel.
Fresh alumina	—	0.015	—	Some excess gel.
Aluminium silicate ..	1.15	0.0517	1.15	Solution complete in the cold.
Aluminium silicate ..	1.41	0.1093	1.41	Solution complete.
Aluminium silicate ..	1.65	0.2275	1.65	Solution complete.
Aluminium silicate (dried) ..	—	0.1865	1.4	Some excess gel.
SiO_2, Al_2O_3 mixed ..	0.65	0.0219	0.09	Some excess gel.
SiO_2, Al_2O_3 mixed ..	1.03	0.0117	0.21	Some excess gel.
SiO_2, Al_2O_3 mixed ..	1.3	0.0469	0.25	Some excess gel.
SiO_2, Al_2O_3 mixed ..	9.2	0.0206	1.5	Some excess gel.

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TABLE CIII
Minerals

Mineral.	Weight of sample.	Weight of extract.	Mol. ratio SiO_2/Al_2O_3
Quartz	g. 0.3	g. 0.0007	—
China clay, "Devolite"	0.5	0.0019	—
Fuller's earth (Nutfield)	0.5	Nil	—
London clay	0.5	Nil	—
Muscovite (Malvern) :			
1st extract	0.5	0.0142	1.0
2nd extract	—	0.0064	1.1
3rd extract	—	0.0025	—
<2 μ fraction (air elutriated)	0.5	0.0151	0.9
Slate (Delabole) (freshly ground)	0.5	0.0036	—
Slate dust (air blown)	0.5	0.0020	—
Bentonite (Wyoming)	0.5	0.0179*	—
Talc (Bergen), micronised	0.5	Nil	—

Blank deducted from all figures.
* Includes 0.0164 g. of alkalis.

TABLE CIV
Rocks of collieries A.2 and A.3

Sample.	Weight taken.	Weight of extract.		Composition of extract.		Mol. ratio.
		g.	Per cent.	SiO_2 .	Al_2O_3 .	
Colliery A.3 (C.) clod	0.5	1st extract	0.0214	0.0100	0.0111	1.6
		2nd extract	0.0061	0.0031	0.0026	—
		3rd extract	0.0027	0.0012	0.0015	—
		4th extract	0.0009	Nil	0.0010	—
	1.5	6.22				
		1st extract	0.0646*	0.0282	0.0325	1.5
		2nd extract	0.0187	0.0082	0.0092	1.5
	Colliery A.2 clod ..	0.5	3rd extract	0.0111	0.0049	0.0064
6.30						
Colliery A.2 clod ..	0.5	1st extract	0.0097	0.0043	0.0039	1.9
		2nd extract	0.0037	0.0013	0.0009	—
Sericite-rich crust-and-film :		2.68				
	Colliery A.2 ..	0.5	1st extract 0.0042†	0.0004	0.0002	—
Colliery S.4 shale ..	0.5	1st extract	0.0344	0.0170	0.0173	1.67

* Contains 0.0015 g. alkalis (as oxides).
† Contains 0.0020 g. alkalis.

TABLE CV

Fractions air-elutriated from clods of collieries A.2 and A.3

Sample.	Weight taken.	Weight of extract.	Weight of SiO ₂ in extract.	Particle Size.
Colliery A.3 clod.. .. .	g. 0.5	g. 0.0197	g. 0.0099	<2 μ
Colliery A.2 clod.. .. .	0.5	0.0093	0.0049	<2 μ
(Showing that air-elutriation to this grade merely "samples" the clod mass. Cf. Table LXII, p. 134.)				

TABLE CVI

Alkalinity of aqueous extracts

Sample.	Approximate pH.
Colliery A.3 clod	8.3
Colliery A.2 clod	8.4
Sericite-rich crust-and-film (Colliery A.2)	8.2

TABLE CVII

Base-exchange capacity

	B.E.	pH.
<i>Colliery A.3</i> : milled sample of clod	69	8.3
After one extraction with aq. diethylamine	B.E. falls to 50	
After four extractions	B.E. falls to 32	
Air-elutriated fraction <2 μ grade	58.6	7.9
Water-elutriated "fine fraction"	25	
<i>Colliery A.2</i> : milled sample of clod	33	8.4
Air-elutriated fraction <2 μ grade	34.4	8.0
Water-elutriated "fine fraction"	34	
<i>Colliery A.1</i> : Water-elutriated "fine fraction"	41	
<i>Colliery B.3</i> : Water-elutriated "fine fraction"	24	
<i>Colliery S.4</i> : Water-elutriated "fine fraction"	46	
<i>Minerals</i> :		
Quartz	Nil	
Kaolin	Nil to feeble ..	
Sericite (Colliery A.2 var.)	16.4	
*Montmorillonite in fuller's earth	88-122	
*Beidellite	107-120	

* Brammall, A. & Leech, J. G. C., *Geol. Mag.*, 1940, **77**, 102; Nagelschmidt, G., *Min. Mag.*, 1938, **25**, 140.

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APPENDIX II

THE COMPOSITION OF THE DUST IN THE RUN-OF-MINE COAL

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and

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1.—Introduction

At an early stage of the inquiry into the environmental factors in chronic pulmonary disease in South Wales coalminers, it was desired to have comparatively large samples of dust from different collieries for animal experiments (of which the results will be published separately). One method of obtaining such dusts is to screen it from the run-of-mine coal—i.e., the coal as it comes direct from the working places. The dust so collected will not necessarily be of the same composition as the air-borne dust at the coalface, but it will be similar to this, as it will contribute largely to it. For a preliminary study such samples had the advantage of being easily obtainable under comparable conditions, unaffected by ventilation or other variables which might be encountered in the technique of obtaining samples of the air-borne dust. When, later in the inquiry, a number of large samples of air-borne dusts became available, the study of screened fractions of run-of-mine coal was discontinued. These, therefore, do not represent the full range of coals discussed in other parts of this symposium.

2.—Description of Samples

When the trams from the selected places arrived at the pithead, the large coal was carefully removed and then the small coal was screened by hand into a number of fractions. The coal of size smaller than $\frac{1}{4}$ -in. was reduced in bulk by mixing, coning and quartering, and afterwards brought to the laboratory, where it was screened into five fractions, namely $\frac{1}{8}$ -in.-72-mesh, 72-100-mesh, 100-240-mesh, 240-300-mesh and through-300-mesh B.S.* sieve. The last fraction was the dust used in the animal experiments, and forms the subject of this report. (The aperture of a 300-mesh B.S. sieve is 53 μ .)

Samples were taken at the following places:—

Colliery.	District.	Seam.
*A.1	Douglas	Lower Pumpquart.
*A.2	No. 5	Lower Pumpquart.
A.3	1	Stanlyd.
*A.3	2	Stanlyd.
A.8	West	Nine Feet.
*S.4	South	Two Feet Nine.

* Samples used for animal experiments.

3.—Screen Analysis and Percentage of Ash in Screened Fractions

The screen analyses in Table CVIII show that the size distribution of the $\frac{1}{8}$ -in.-0 material from all the sources is very similar, but that the percentage of the $\frac{1}{8}$ -in.-0 fraction in the coal from the trams is lowest in the high rank anthracites, A.1, A.2 and A.3, and highest in the low rank anthracite, A.8, and in the steam coal S.4.

It will be noted from the results given in Table CIX that the percentages of ash in the various screened fractions from any particular coal are very similar to each other, i.e. the coarse material has a similar ash content to the fine material. This applies generally to the full range of the sized grades. Moreover, the through-300-mesh fraction usually has an ash content similar to the fraction of size even as big as 2-1-in. It will thus be probable that the dust of respirable size would also contain a similar quantity of ash. The air-borne dust arising from the handling of the run-of-mine coal at the coalface will not necessarily be of the same composition as these samples, because there might be a selective action when the dust is raised.

The percentage of ash in the samples from different sources shows a wide variation, and in this selection it ranges between 4.2 and 23.5. There is no relationship between the rank of the coal and the ash content of the through-300-mesh fractions. Not only is there considerable variation from colliery to colliery, but there are also marked changes in the ash content of samples from different districts of the same seam at the same colliery—as, for example, at A.3, Districts 1 and 2, where the through-300-mesh fraction in the coal from District 1 contains 23.5 per cent. of ash, and that from District 2 only 12.7 per cent. These variations are not due to changes in the ash content of the coal itself, but mainly reflect changes in the section of the seam. In District 1, at the time of sampling, 7-12-in. of clod separated the main coal from the bed of coal above it, and 2-3-in. of rashes separated this from another layer of coal at the top of the seam. Between the top layer of coal and

* British Standard screens.

the roof there was also a variable thickness of clod, which was brought down at the face by the collier. The full section of the seam was mined, and in parts of the district the ground was disturbed, which also would contribute to a high ash content in the small coal. The considerable total thickness of clod is chiefly responsible for the high percentage of ash in the run-of-mine coal. In District 2 there was no clod and the seam consisted of 65-in. of coal, most of which had a fairly low ash content. The small coal in this district was contaminated only by rashes from a thin layer at the bottom of the seam and by a little of the cliff roof; thus, as would be expected, the raw smalls contained a comparatively low percentage of ash.

Mention should be made of the low ash content of the S.4 sample. The seam here consists of 5ft. of coal, containing only 2 per cent. of ash, with no intermediate layers of clod or rashes. There is little or no contamination from the hard fireclay floor, and the roof is ripped only in the roadways, this being a separate operation from coal-getting. The thin layer of bast at the top of the seam, which contains 33 per cent. of ash, parts readily from the remainder of the seam, and is stowed in the gobs.

The small coal from the Two Feet Nine seam in this and neighbouring takings is notably low in ash, and very much lower than the small coal from other seams in the Lower Coal Series in this area; the small coal from the latter varies in ash content from approximately 15 to 20 per cent. Because of this difference, caution must be exercised in generalising from S.4 for the steam coals as a whole.

3.—Chemical Analysis and Mineralogical Composition

The analyses of the ashes given in Table CX require no detailed comment. There is no striking contrast which can be correlated with change in rank of the coal or with the incidence of pneumokoniosis ("medical incidence").

The mineralogical composition has been calculated in the way described in Section F of this monograph, and the results are given in Tables CXI, CXII and CXIII. Table CXII also gives the X-ray diffraction data obtained from ash residues prepared by incinerating the dusts at 380° C.

The percentages of quartz in the dusts are in all instances low, namely, 2.4 or less. The dust with highest quartz content is that from A.1, a high incidence mine, but the quartz content of the dust from A.2, a low incidence mine, is the next highest in the series. The dusts from A.8 and S.4, medium and low incidence mines respectively, contain 0.4 per cent. of quartz, but that from District 2 of A.3, which is a high incidence mine, contains only 0.2 per cent. It may be said, therefore, that this selection of samples shows no relationship between the incidence of pneumokoniosis and the quartz content of the through-300-mesh fraction of the run-of-mine coal. This confirms the conclusions of Nagelschmidt (Section D) from analyses of samples of air-borne dust.

The proportions of different minerals, given in Table CXII, again show no regular change with rank of coal or medical incidence, although the percentage of quartz in the two highest rank anthracite samples, A.1 and A.2, is greater than in any of the others. The relative amounts of the major constituents—illite and kaolin—which together amount to 55–80 per cent. of the total minerals, also show no tendency to be related to rank of coal or medical incidence. It might be argued that the analyses of the through-300-mesh fractions could possibly be very different from that of the dust of respirable size. No experiments have been done to separate dust of respirable size from the through-300-mesh samples, but a comparison of the latter with the air-borne dusts at the coalface shows close similarity. Thus, the mean ash percentages and the proportions of siliceous minerals in the ash of the through-300-mesh samples and of the air-borne dusts from the same four anthracite mines were as follows:—

	Mean ash percentage.	Minerals per cent. ash.		
		Illite.	Kaolin.	Quartz.
Through-300-mesh samples ..	15	30	37	7
Air-borne dust samples	12	30	41	6

Three sized fractions bigger than the through-300-mesh have been analysed, and the calculated mineralogical compositions are given in Table XCIV. There is a slight decrease in the percentage of quartz, a marked decrease in the amount of illite, and a corresponding increase in the amount of kaolin, as the size of the dust decreases from $\frac{1}{2}$ in. to through-300-mesh. These changes might extend to the dust of respirable size, but the comparisons given above indicate that they would be unlikely to do so in marked degree. Indeed, the similarity of the through-300-mesh fractions and the air-borne dusts suggests the possibility of obtaining large samples of mine dust in a far simpler way than by the technique described on p. 96 of this monograph. The rock part of the air-borne dust—in so far as it is due to ripping as distinct from coal-getting—may, however, to some extent be lacking in such samples.

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Summary and Conclusions

1. Dust of size less than 300-mesh B.S. screens has been screened from run-of-mine coal from two anthracite collieries where the incidence of chronic pulmonary disease ("medical incidence") is high, and from one anthracite colliery and one steam coal colliery where the incidence is low.

2. Screen analyses suggest that the quantity of dust in the run-of-mine coal increases with decrease in the rank of the coal. The percentage of ash in the dust is similar to that in other screen fractions, and bears no apparent relation to the medical incidence nor to the rank of the coal. An example is given of markedly different ash contents in coal from different districts at the same colliery, explicable by differences in the seam section at the two places.

3. Kaolin, mica and carbonates were found to be the chief mineral constituents, with quartz amounting to 0.2-2.4 per cent. of the air-dried samples. Two of the high-rank anthracite samples contained the highest proportions of quartz, but one came from a high-incidence and the other from a low-incidence mine.

No other relationship is found between the chemical and X-ray diffraction analyses of the ash of the dusts and the medical incidence or the rank of the coal.

4. The average mineralogical composition of the through-300-mesh anthracite samples of run-of-mine coal is similar to that of the air-borne dusts at the coalface collected from the same mines.

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TABLE CVIII
Screen analysis of the coal of size $\frac{1}{8}$ -in.-0-in. in the run-of-mine coal
(Per cent. air-dried coal)

Colliery ..	A.1.	A.2.	A.3.		A.8.	S.4.
			Dist. 1.	Dist. 2.		
<i>Medical incidence ..</i>	<i>High.</i>	<i>Low.</i>	<i>High.</i>	<i>High.</i>	<i>Medium.</i>	<i>Low.</i>
$\frac{1}{8}$ -in.-0 fraction per cent. of coal in trams.	4.7	7.6	5.9	9.8	11.2	12.9
$\frac{1}{8}$ -in.-72-mesh B.S.S. per cent. of $\frac{1}{8}$ -in.-0.	75.2	74.2	78.5	72.4	77.0	77.8
72-100-mesh B.S.S. per cent. of $\frac{1}{8}$ -in.-0.	7.5	6.8	4.9	5.8	5.4	5.2
100-240-mesh B.S.S. per cent. of $\frac{1}{8}$ -in.-0.	7.1	9.3	8.9	11.2	8.9	9.1
240-300-mesh B.S.S. per cent. of $\frac{1}{8}$ -in.-0.	2.0	1.8	2.3	2.4	2.6	1.7
<300-mesh B.S.S. per cent. of $\frac{1}{8}$ -in.-0.	8.2	7.9	5.3	8.2	6.1	6.2

TABLE CIX
Ash in screened fractions
(Per cent. air-dried coal)

Colliery ..	A.1.	A.2.	A.3.		A.8.	S.4.
			Dist. 1.	Dist. 2.		
<i>Medical incidence ..</i>	<i>High.</i>	<i>Low.</i>	<i>High.</i>	<i>High.</i>	<i>Medium.</i>	<i>Low.</i>
$\frac{1}{8}$ -in.-0	16.0	13.6	21.8	11.6	13.8	4.8
$\frac{1}{8}$ -in.-72-mesh B.S.S.	16.1	14.0	21.7	11.8	14.1	4.9
72-100-mesh B.S.S.	15.4	12.1	22.0	10.7	13.3	4.2
100-240-mesh B.S.S.	14.9	11.4	21.9	10.2	12.8	4.2
240-300-mesh B.S.S.	14.2	12.3	22.3	10.6	12.3	4.8
<300-mesh B.S.S.	16.4	14.3	23.5	12.7	12.8	5.5

TABLE CX

Analyses of the ash of through-300-mesh B.S. screen fractions of run-of-mine coal

Colliery ..	A.1.	A.2.	A.3.		A.8.	S.4.
			Dist. 1.	Dist. 2.		
<i>Medical Incidence</i> ..	<i>High.</i>	<i>Low.</i>	<i>High.</i>	<i>High.</i>	<i>Medium.</i>	<i>Low.</i>
Ash, per cent. air-dried coal ..	16.36	14.30	23.47	12.72	12.82	5.45
CO ₂ , per cent. air-dried coal ..	2.03	1.45	2.05	1.23	0.66	0.32
Sulphate sulphur, per cent. air-dried coal.	0.01	0.01	0.04	0.06	0.03	Trace
Pyritic sulphur, per cent. air-dried coal.	0.04	0.04	0.27	0.61	0.14	Trace
<i>Per cent. of ash—</i>						
SiO ₂	43.48	42.15	42.66	36.91	45.64	48.18
TiO ₂	0.72	0.64	0.68	0.54	0.80	0.86
Al ₂ O ₃	22.14	25.23	29.34	28.18	33.21	31.72
Fe ₂ O ₃	10.53	10.20	5.22	9.11	4.98	7.24
CaO	8.41	7.03	11.27	11.43	4.30	0.66
BaO	Nil	Nil	Nil	0.02	0.02	Trace
MgO	4.13	3.68	1.90	2.26	1.99	2.57
K ₂ O	1.86	1.86	1.95	1.38	2.60	1.89
Na ₂ O	1.19	1.50	1.15	0.59	0.91	0.71
SO ₂	6.66	7.20	3.40	7.10	3.20	4.11
P ₂ O ₅	0.29	0.50	0.79	0.60	1.02	0.98
Loss on ignition at 800° C. . .	0.45	0.29	2.23	2.53	1.17	0.64
Total	99.86	100.28	100.59	100.65	99.84	99.56

TABLE CXI

Calculated mineralogical composition of the through-300-mesh B.S. screen fraction

(Per cent. of air-dried coal)

Colliery ..	A.1.	A.2.	A.3.		A.8.	S.4.
			Dist. 1.	Dist. 2.		
<i>Medical Incidence</i> ..	<i>High.</i>	<i>Low.</i>	<i>High.</i>	<i>High.</i>	<i>Medium.</i>	<i>Low.</i>
Illite	5.2	4.5	7.8	3.0	5.6	1.7
Kaolin	5.1	5.6	11.4	6.8	6.4	3.0
Quartz	2.4	1.4	1.2	0.2	0.4	0.4
Pyrite	0.1	0.1	0.5	1.1	0.3	Trace
Iron carbonate	1.0	0.7	Nil	0.1	0.5	0.5
Calcium carbonate	2.3	1.6	4.2	2.2	0.6	Nil
Magnesium carbonate	1.2	0.9	0.7	0.5	0.3	0.2
Calcium sulphate	0.1	0.1	0.2	0.4	0.2	Trace
Apatite	0.1	0.2	0.4	0.2	0.3	0.1
Rutile	0.1	0.1	0.1	0.1	0.1	Trace
Fe ₂ O ₃ (unaccounted for)	0.9	0.8	0.7	0.3	Nil	Nil
Na ₂ O (unaccounted for)	0.1	0.2	0.2	0.1	0.1	Trace
Total	18.6	16.2	27.4	15.0	14.8	5.9

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TABLE CXII

Composition of mineral matter in the through-300-mesh B.S. screen fraction
(Per cent. of total minerals)

Colliery ..	A.1.	A.2.	A.3.		A.8.	S.4.
			Dist. 1.	Dist. 2.		
<i>Medical Incidence</i> ..	<i>High.</i>	<i>Low.</i>	<i>High.</i>	<i>High.</i>	<i>Medium.</i>	<i>Low.</i>
Illite	28.0	27.8	28.5	20.0	37.8	28.3
Kaolin	27.4	34.6	41.6	45.3	43.2	49.2
Quartz	12.9	8.6	4.4	1.3	2.7	7.2
Pyrite	0.5	0.6	1.8	7.3	2.0	Trace
Iron carbonate ..	5.4	4.3	Nil	0.7	3.4	8.3
Calcium carbonate ..	12.4	9.9	15.3	14.7	4.0	Nil
Magnesium carbonate ..	6.5	5.6	2.6	3.3	2.0	3.9
Calcium sulphate ..	0.5	0.6	0.7	2.7	1.4	Trace
Apatite	0.5	1.2	1.5	1.3	2.0	2.1
Rutile	0.5	0.6	0.4	0.7	0.7	0.7
Fe ₂ O ₃ (unaccounted for) ..	4.8	4.9	2.6	2.0	Nil	Nil
Na ₂ O (unaccounted for) ..	0.5	1.2	0.7	0.7	0.7	0.3
Total	99.9	99.9	100.1	100.0	99.9	100.0
<i>X-ray Diffraction Analysis of Ash prepared at 380° C.—</i>						
Mica	Low-medium.	Low-medium.	Low-medium.	Low-medium.	ND	Low-medium.
Kaolin	High	High	High	High	ND	High
Quartz	Medium	Medium	Low	Very low	ND	Medium
Calcite	—	—	Medium	Medium	ND	—
Ankerite	High	High	—	—	ND	Low

TABLE CXIII

Through-300-mesh fraction
Per cent. of minerals containing SiO₂, Al₂O₃, K₂O and Na₂O

Colliery ..	A.1.	A.2.	A.3.		A.8.	S.4.
			Dist. 1.	Dist. 2.		
<i>Medical Incidence</i> ..	<i>High.</i>	<i>Low.</i>	<i>High.</i>	<i>High.</i>	<i>Medium.</i>	<i>Low.</i>
Illite	40	39	38	30	45	33
Kaolin	40	48	55	68	51	58
Quartz	19	12	6	2	3	8
Na ₂ O	1	1	1	<1	1	<1
	100	100	100	100	100	99

TABLE CXIV

Sized fractions in run-of-mine coal from colliery A.3, District 2
Per cent. of minerals containing SiO₂, Al₂O₃, K₂O and Na₂O

Size of Fraction.*	$\frac{1}{8}$ -in.- $\frac{1}{4}$ -in.	$\frac{1}{16}$ -in.-72-mesh.	100-240-mesh.	Through-300-mesh.
Illite	65	61	41	30
Kaolin	30	34	57	68
Quartz	4	4	1	2
Na ₂ O	1	1	1	< 1
	100	100	100	100

* British Standard screens.

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