CHAPTER IX

CHEMICAL AND MINERALOGICAL ANALYSIS OF DUST

Although the dust generated in some industries is comparatively pure, such as lead dust, industrial dust more generally consists of a mixture of several minerals. It contains nothing not found in the parent substance but the *percentage* of distribution of the various constituents is not necessarily the same as in the original material, nor is it constant for different sizes of particles (page 59). We have seen that the *mineral* composition of most industrial dusts is of greater hygienic interest than their chemical make-up; on the other hand, the minerals themselves are generally complex chemical substances which require special methods of analysis for quantitative identification. For the same reason and because of the complications introduced by the presence of large amounts of extraneous organic matter, the study of biological specimens, such as dust deposits in autopsied lungs and in sputum from living persons, also requires special methods of analysis.

COLLECTION OF AIR SAMPLE FOR ANALYSIS

It was pointed out in Chap. IV that, because of differential disintegration and selective settlement of air-borne dust, it is not wise to judge the chemical and mineralogical composition of dust that actually gets into the lungs of exposed workers from an analysis of the parent substance or of a deposit of coarse settled dust such as a rafter sample. On the contrary, the sample should be taken from the air at the breathing zone and subsequently divided into a series of size fractions so that the composition with respect to size can be determined. Analysis of size fractions obtained by elutriating a rafter sample may reveal the same change in composition with size that is shown by the sample collected directly from the air, but, because a settled deposit is inherently coarser than the dust in the air, it is impossible to calculate the true distribution of the various constituents from the data thus obtained. A rafter sample is as unsuited for this purpose as it

Chemical and mineralogical analysis of dust
ACL Doc 25350 · Page 1 of 22
Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/1

is for determining particle size since the relative number of particles of any given size in the settled deposit is increased in proportion to the square of its diameter, e.g., the ratio of numbers of 10 μ to 1 μ particles in the deposit is 100 times their ratio in the air.

A homogeneous and rather pure substance like zinc oxide may be sampled in any convenient way and a few milligrams suffice for quantitative analysis; we have used a double impinger (two instruments in series) and also the electric precipitator as sampling instruments. Sometimes a suitable portion can be obtained from material settled or condensed out in pipe lines, on furnace hoods, and the like, but a direct air sample is usually preferable.

Because of the extensive analytical procedure involved in the study of mixed dusts, a large sample is desirable. We like at least 25 grams—an amount too great to be collected in the common dust-sampling instruments.

For sampling mixed dusts, one may use a paper vacuum-cleaner bag connected to a light, portable exhaust fan having a capacity of 50 to 75 cu. ft. per minute against a resistance of 6 in. or more of water. The dusty air is drawn in through a simple hood located at the proper sampling point; this is connected by means of an 8-ft. length of 2-in. flexible hose to the fan from which the dust-laden air discharges to the filter. The bag "dusts" at the outset but after a few minutes of plugging it retains fine and course particles alike at an efficiency which exceeds that of the impinger. After cutting the bag open, a suitable quantity of the collected dust is removed with a soft brush; no attempt is made to recover the whole sample since to do so only contaminates it with paper fibers.

A composite sample may be obtained from the air-cleaning apparatus of an exhaust system by mixing proper proportions of material from the various stages of the apparatus. If, for example, the dust collector removes 80 per cent and 20 per cent, respectively, in the primary and filter compartments of a two-stage apparatus, the sample should be made up of the same percentages. When dusts produced by the several processes connected to an exhaust system differ markedly in their composition, it is necessary to collect separate samples from each.

Separating Sample into Size Fractions. For studying the variations in chemical and mineral composition of dust with

respect to particle size, we divide the sample into four size groups: (1) greater than 10 μ, (2) 5 to 10 μ, (3) 2 to 5 μ, and (4) less than 2 μ. This is done by elutriation (page 141) in a suitable liquid in which the dust does not dissolve or flocculate to any extent. Deflocculating agents like ammonia may be added and washings are repeated, sometimes for several days, until clean fractions are obtained. The elutriation should be conducted with quantitative care in order to determine the percentage of distribution by weight and the number of particles in the four fractions.

RECOVERY OF DUST FROM LUNGS

Dust in lungs or other tissue must be concentrated by wet or dry ashing before chemical and petrographic analyses can be made. The concentrating process must not affect the particles of dust and especially it must not dissolve them.

Wet Ashing. Jones (139) advises treating the lung specimen in strong nitric acid for 7 to 10 days, then pouring the slime into hot water, stirring, and filtering through Whatman's No. 54 paper which is free from loose fibers. The residue is returned to a beaker of hot water, is filtered, and is washed until it is acid-free; then it is transferred from the filter to a platinum dish, is heated carefully until no more acid gases evolve, and then is ignited in the usual way. The weight of this residue represents the total acid-insoluble inorganic matter present in the original specimen.

Dry Ashing. In obtaining their series of analyses of total silica in lung ash, Riddell and Rothwell (204) dried a 50- to 450-gram specimen of lung with a towel to remove excess formalin, weighed the sample in a large porcelain evaporating dish, and then dried it for 48 hr. in an electric oven at 100° to 107°C. The weight of the dried lung was noted and the sample was then ignited in a platinum dish, the ignition being completed in a muffle and the weight of the final ash being determined.

Preparation of Lung Sections. The application of micro-incineration and subsequent microscopy of sections of dusted lungs has been applied usefully by Irwin (136), Policard (198), and Jones (139). Irwin cuts lung sections in the usual way from tissue imbedded in paraffin. The preparation of such sections is a routine measure and is described fully in textbooks on pathology. He advises that they be not over 5 μ thick to

avoid "spitting" on incineration, which is carried out at 550° to 600°C. This temperature is not too high for ordinary glass but he remarks that "white-edged slides are found to resist heat better than green-edged ones." The incinerated section is then examined microscopically by oblique illumination for unconsumed carbon. If carbon has been removed, he treats the ash with concentrated hydrochloric acid; 1 cc. is allowed to remain on the slide for 30 min. and is then drained off; the preparation is rinsed with flowing distilled water and is air-dried in a vertical position.

Generally it is only the white ash which is of significance in the study of silicotic lungs. This is insoluble in concentrated hydrochloric, nitric, and sulfuric acids but is readily soluble in hydrofluoric acid. Irwin states:

> The ash pattern of definite silicotic nodules is so typical and constant, that . . . if such an ash is present it represents a silicotic nodule, even if the corresponding area in the stained section has degenerated beyond recognition. If an area of ash does not contain any siliceous particles, . . . such an ash represents an area of nonsiliceous fibrosis.

DETERMINATION OF FREE AND COMBINED SILICA

Pure quartz consists of only one chemical compound—silica. A rock like granite, on the other hand, contains, in addition to quartz, varying proportions of several other minerals such as feldspar and mica, which also include silica although it is present in the form of silicates rather than as SiO_2. Quartz and other forms of the chemical compound SiO_2 are spoken of as *free* silica, whereas that contained in feldspar and other silicates is known as *combined* silica. By chemical analysis all silica is determined as SiO_2 without distinction between the free and combined forms. Mineralogical analysis, on the other hand, gives the percentage composition of the various mineral constituents without necessarily determining their chemical structure. Thus a granite that contains the proportions of minerals shown in Table 25 will show by chemical analysis the composition given in Table 26.

TABLE 25.—MINERALOGICAL COMPOSITION OF GRANITE

Mineral	Per Cent
Feldspar (orthoclase)	70
Quartz	25
Mica (muscovite)	5
	100

TABLE 26.—CHEMICAL COMPOSITION OF GRANITE

	Per Cent
SiO_2 (total)	72.55
Al_2O_3	14.80
K_2O	12.42
H_2O	0.23
	100.00

This rock contains 72.55 per cent total silica, free and combined, but only 25 per cent quartz. Since the free silica is of greatest hygienic interest, it is clear that the ordinary chemical analysis fails to yield the desired information regarding the silicosis-producing possibilities of an industrial dust.

The study of the mineralogical composition of rocks is known as petrography; it is based upon the systematic evaluation of certain physical properties of the various minerals including specific gravity, hardness, color, crystal structure, pleochroism, refraction, birefringence, and optical character, including the optical sign, value of the optic axial angle. These properties have been tabulated systematically in convenient tables (160).

The minimum particle size which can be identified petrographically is a function of the birefringence of the mineral. Hence, quartz with a value of $B = 0.009$ requires particles very much larger in size than is the case with calcite ($B = 0.172$) or sericite ($B = 0.042$) to give the same optical effect.[1] Orthoclase feldspar has approximately the same strength of birefringence ($B = 0.008$) and a refractive index also close to that of quartz (1.52 compared with 1.54). Hence, it is not easy to distinguish between these two minerals under the polarizing microscope unless they are present as fairly large grains. Knopf (155) gives 10 μ as the minimum grain size for the

[1] According to Watkins-Pitchford and Moir (246), the thickness of particles necessary to produce polarization color must be greater than $\theta = 0.35 \div B$, where θ = thickness of particles and B = birefringence. Thus, for this phenomenon to be seen, quartz particles must be greater than 40 μ in thickness; sericite requires a thickness of more than 8 μ and rutile a thickness of 2 μ.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/3

ain petrographic identification of quartz. Hence, petro-
phic methods alone are not sufficient for the study of
strial dusts, a majority of whose particles are less than 1 μ
iameter. It is necessary to combine with the petrographic
lysis the chemical determination of certain broad groups of
stituents in order to obtain a complete analysis.

The Determination of Total Silica in Mineral Dusts. The
hod of Riddell and Rothwell is a convenient adaptation of
brand's (128) standard procedure for silicate analysis.
as intended for the analysis of lung ash but it can be applied
veniently to the proximate analysis of atmospheric dust
ples as well.

A dried sample of about 1 gram is mixed with 12 parts of
ium carbonate and is fused in a platinum crucible; the melt is
ssolved to a small amount of water in a pyrex beaker and
beaker is heated with an excess of 1:1 hydrochloric acid.
en the melt has broken up completely, the sample is dried
the residue is baked overnight at 120°–130°C. It is then
ted with concentrated hydrochloric acid, water is added,
the solution is heated to boiling, after which the residue is
ered, washed with distilled water, and dried at 110°C. to
stant weight.

At this point the usual procedure is to ignite the residue (which
y not always be white) in order to drive off all water. How-
r, Riddell and Rothwell omit the ignition and add a few drops
concentrated sulfuric acid followed by 10 to 15 cc. of hydro-
ric acid, a step recommended by Hillebrand when the sample
tains over 60 per cent silica. The crucible is next heated
wly over a low flame; after volatilization of the acids, the full
me is applied but the blast is not used. The loss in weight
the crucible represents total silica.

Hillebrand points out that the hydrofluoric acid treatment
y have to be repeated and that further amounts of silica will
recovered in subsequent steps in the complete analysis.
wever, these items are of no importance in the present problem
can be ignored.

Combined Chemical and Petrographic Method. The follow-
procedures have been employed by Knopf (153):

Ignition. A weighed portion of the sample (about ½ gram)
nited in a platinum crucible at low heat for 30 min. The loss

in weight represents the amount of organic matter present,
together with some water of crystallization.

2. *Hydrochloric Acid Treatment.* Concentrated hydrochloric
acid is added to the crucible and the contents are gently heated
for a period of about ½ hr. The sample is filtered in ashless
paper, is washed, and is returned to the same platinum dish
for slow ignition. When iron is present, the hydrochloric acid
treatment may have to be repeated one or more times; then
only the supernatant acid is poured from the dish onto the filter
and fresh acid is added for the second and successive treatments.
The loss in weight caused by hydrochloric digestion is explained
by the presence of carbonates and other acid-soluble substances
remaining after the first ignition.

3. *Hydrofluosilicic Acid Treatment.* Hydrofluosilicic acid,
H_2SiF_6, is added to the contents of the platinum dish in moderate
excess and the sample is set away in a cool place to digest for a
period of 24 hr. or more, even up to 3 days. The purpose of
this treatment is to dissolve silicates without attacking free
silica; the temperature therefore must remain below 70° to 80°F.,
since at higher temperatures the hydrofluosilicic acid decomposes
into silicon tetrafluoride, SiF_4, and hydrofluoric acid, HF, which
readily attacks free as well as combined silica. At the end of
the period of digestion the contents of the dish are washed onto
filter paper and the washing is continued until all the H_2SiF_6
has been removed. This may be determined by adding to the
wash water a mixture of dilute potassium chloride in 95 per cent
alcohol, which causes the formation of a fine precipitate in the
presence of the acid. When no more acid is present, the filter
paper and undissolved material are returned to the dish, ignited,
and weighed. The loss in weight equals the content of silicates
in the sample and the material remaining in the crucible is the
free silica. The necessary period of digestion varies with the
nature of the sample and the hydrofluosilicic acid treatment
should therefore be repeated in uncertain cases until the weight
of the residue remains constant.[1]

[1] Since writing this it has been found that the action of H_2SiF_6 against
pure quartz increases with decreasing particle size and therefore fails to
distinguish between free silica and silicates in the case of microscopic dust.
(Moke, Charles B., Solubility of Quartz in Hydrofluosilicic Acid, *J. Indust.
Hyg. and Tox.*, 18, p. 299 (1936).

4. *Volatilization of Residue with Hydrofluoric Acid.* A check on the purity of the free silica remaining in the residue is given by volatilization with hydrofluoric acid, since with this treatment all silica, combined and free, is removed. If no residue remains after hydrofluorization, the material was all quartz; the bases present in any silicates remaining after digestion in hydrofluosilicic acid are not removed by this final treatment.

5. *Microscopic Examination.* The original sample should be examined under the petrographic microscope to determine the nature of the treatment required and a minute portion of the residue after each step in the chemical analysis should be removed for examination. By this means it is possible to identify the substances that contribute to the loss in each case. It is particularly important to determine, so far as possible, by petrographic methods, the nature of the silicates in the sample as well as the purity of the quartz remaining after step 3. The petrographic analysis for the identification of the silicate minerals will have to be limited to the coarser fractions of the sample. This is satisfactory so long as one is permitted to assume that the proportions of the various minerals in the silicate group do not change with size. On the other hand, when interest is directed toward the change in concentration of a particular silicate with size, it is necessary to make more elaborate chemical analyses (such as determining metals and bases) in order to identify this particular silicate among the other silicates in the fine fractions. The above method was designed primarily for the determination of the amount of free silica in the sample, with only mild interest directed toward the other substances present.

Immersion Method. Ross and Sehl (207) found the above method for the determination of free silica time consuming and inaccurate owing to the uncertain efficiency of digestion of the silicates in hydrofluosilicic acid. They use instead the well-known immersion method of identifying quartz (or any other nonopaque mineral) by its optical behavior in an immersion medium having an index of refraction slightly different from the quartz; this is the so-called *method of central illumination.* The principle is described by Larsen (160) as follows:

> As the immersion method is ordinarily used, nearly all fragments are thinner on the edges than in the center, and if the fragments differ from the surrounding material in refractive index they will act as small

> imperfect lenses toward a beam of nearly parallel light emerging from the condenser. If such a lenticular fragment has a higher index of refraction than the embedding medium, it tends to focus the light above its plane, and if the microscope is first focused on the grain and then raised above focus the interior of the grain will appear more highly illuminated. As the microscope tube is raised higher above the focus, this highly illuminated area contracts and becomes brighter—a bright line moves into the grain. If the tube is lowered below focus, the grain appears less highly illuminated than the rest of the field and a highly illuminated halo surrounds it. As the tube is lowered this halo moves out from the grain.
>
> If the grain has a lower index of refraction than the embedding medium, it will have a virtual focus below its plane, the phenomena are reversed, and the grain becomes centrally illuminated as the microscope tube is lowered below focus.

Quartz has two indices of refraction, 1.544 and 1.553. Other minerals encountered in industrial dusts have higher and lower indices, some of which may be close to the values for quartz. If a small portion of dust is well dispersed in fennel-seed oil (refractive index = 1.54) and examined microscopically, the quartz particles and others of higher refractive index will exhibit central illumination when the objective is raised slightly above focus. The remainder will have dark centers. In the same way, another portion of the dust dispersed in mononitrobenzene (refractive index = 1.55) will also show bright and dark particles, but in this case the quartz will be included among the dark particles. Thus, if the proportion of bright and dark particles in each suspension is determined by the standard light-field low-power method of counting impinger dust samples (page 117), and if A and B are the percentages of bright transparent particles in the fennel-seed oil and mononitrobenzene, respectively, then:

$$\textit{Percentage number of quartz particles} = A - B$$

Ross and Sehl devised a simple procedure for weighting the particles according to their size, thus yielding a free silica determination by weight. When the air-borne dust sample is separated into size fractions and each portion is analyzed separately, the percentage by number of the quartz particles closely approximates the percentage by weight and no further correction is required.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/5

portant objections to the immersion method are that it not distinguish between quartz and other minerals having ximately the same index of refraction, such as certain rals of the feldspar group, and that it is of little or no value dealing with particles below 2 μ, since such particles are under the light-field microscope only with the greatest culty, even when the refractive index of the mounting medium arkedly different from that of the dust. It is superior to chnique of Sartorius and Jötten (212), who simply count al amount of dust, such as on an Owens ribbon, before and f flooding the sample with a liquid (tetralin) having the same x of refraction as quartz.

Calculation of Results from Analyses of Size Fractions. The portance of analyzing separate size fractions of nonuniform xed dusts instead of the total sample is well emphasized in the owing example, which gives the results of a size analysis as well as of the chemical analysis of the four size fractions of an borne foundry dust sample, Table 27 (116). Seventy-three

TABLE 27.—SIZE ANALYSIS AND CHEMICAL ANALYSIS OF GENERAL AIR-BORNE DUST IN IRON-FOUNDRY CORE DEPARTMENT

	Size of fraction			
	>10 μ	5 to 10 μ	2 to 5 μ	<2 μ
Size analysis				
ntage by weight	73	13.5	7.7	5.8
ntage by number	1.1	1.7	7.8	89.4
Chemical composition				
rbon, organic matter	12.0	35.7	44.4	69.9
rbonates, iron, other HCl soluble	6.8	9.8	12.3	13.1
icates	8.9	26.3	20.6	13.7
ee silica	72.3	28.2	22.7	3.3
tal	100.0	100.0	100.0	100.0

rcent of the weight of the sample, one observes, is contributed e particles greater than 10 μ in size; these constitute only r cent, however, of the total *number* of particles. It will served further that the percentage chemical composition

varies markedly with particle size. In Table 28 the data have been recast to show the distribution of the four principal constituents (combustible, acid soluble, silicates, free silica) of the foundry dust according to particle size.

TABLE 28.—PERCENTAGE OF DISTRIBUTION ACCORDING TO PARTICLE SIZE, BY WEIGHT AND BY NUMBER OF PARTICLES, OF THE PRINCIPAL CONSTITUENTS IN IRON-FOUNDRY, CORE-DEPARTMENT DUST[1]

Constituent	Distribution according to size					
	>10 μ	5 to 10 μ	2 to 5 μ	<2 μ	<10 μ	Total
Percentage by weight in each fraction						
Carbon, organic matter	8.7	4.8	3.4	4.0	12.2	21.0
Carbonates, iron, other HCl soluble	5.0	1.3	1.0	0.8	3.1	8.0
Silicates	6.5	3.6	1.6	0.8	6.0	12.4
Free silica	52.8	3.8	1.7	0.2	5.7	58.5
Total	73.0	13.5	7.7	5.8		100.0
Percentage by number of particles in each fraction						
Carbon, organic matter	0.1	0.6	3.4	62.4	66.4	66.5
Carbonates, iron, other HCl soluble	0.1	0.2	1.0	11.7	12.9	13.0
Silicates	0.1	0.4	1.6	12.3	14.3	14.4
Free silica	0.8	0.5	1.8	3.0	5.3	6.1
Total	1.1	1.7	7.8	89.4		100.0

[1] Data from Table 27.

The percentage by weight of free silica in the total sample is 58.5 per cent, a figure that compares closely with the result commonly obtained by analyzing a foundry rafter sample (178, 207); the amount of free silica with a particle size less than 10 μ is only 5.7 per cent by weight of the total sample, and only 0.2 per cent by weight is made up of quartz particles less than 2 μ in size. In the same way, only 6.1 per cent of the total number of particles in the sample is made up of free silica; of these, 5.3 per cent (of the total) is made up of particles less than 10 μ and only 3 per cent of particles less than 2 μ in size. Thus, a careful study of the chemical composition with respect to

icle size leads to an entirely different conclusion regarding ygienic importance of this dust than is obtained from a single ysis of the whole sample (last column, Table 28).

THE MICROSCOPY OF SPUTUM

he coloring of the sputum and nasal discharge of persons sed to dust is, of course, commonplace. It has always been as evidence of dust inhalation and is sufficiently sensitive rve as a test for the effectiveness of a respirator (page 268). resh untreated sputum or nasal discharge, diluted if necessary, e prepared for microexamination by smearing on a slide and g with the direct flame. Irwin's microincineration technique e 135) is then useful if the preliminary examination indicates icient mineral residue and it is essential if a polarizing micro- e is to be used. Irwin says of his technique that the "silis material present in a single alveolar phagocyte of an mal exposed to silica dust can readily be demonstrated."

Burke's procedure (36) can be applied when samples of 100 cc. more are available. The sputum is heated in a beaker over open flame until most of the water has been evaporated. ty cubic centimeters of aqua regia are added and the mixture tored 24 hr. at room temperature, being shaken at intervals; n then centrifuged at high speed for 1 hr. The residue is ared on chemically clean slides and incinerated.

Dust as a medical diagnosis requires an accurate case history, the mineral or chemical identification of dusts in sputum, al discharge, or lungs requires a history of recent dust osure. Sometimes the color alone suffices for identification more often the dust particles appear dark, even black, before roincineration. Some of this coloring is caused by pigmenta- n from blood corpuscles and can be removed by treatment with centrated hydrochloric acid. Stains such as the histologist ds for much of his work are best avoided.

The value of sputum and nasal-discharge examinations for dust, routine preventive measure, like most other preventive meas- depends upon the local situation. Freedom from dust in both tum and nasal discharge can be understood by layman and med- expert alike. The results can be given photographically and entire procedure carried out by any person familiar with micrography once the technique has been demonstrated.

The dust in phagocytic cells from human sputum was studied by Drinker (65), who was able to identify several minerals in the cells and to establish figures of average particle size in phagocytes. In order to examine dust in phagocytes, the sputum sample must be fixed when fresh, and it is best to make several slides, some stained and some unstained. Stains interfere seriously with the microscopy of the particles but help one to pick out the dust cells from extraneous matter. Aging of the sputum results in bacterial action upon the cells which destroys their outline, and must be avoided.[1]

The cells from silicotics (coal miners) which we have seen recently contained a great percentage of carbon and little else. Since there is little difficulty in getting such cells from patients with silicosis or with a history of recent dust exposure, more such examinations might easily and profitably be made.

It should be borne in mind that the presence of dust cells in human sputum does not of itself prove any lung pathology. This may be a normal finding and often occurs in the healthy city dweller, particularly if he is a smoker. But in the case of the individual with proved dust exposure, the presence of numerous dust cells in sputum may help in diagnoses.

THE IDENTIFICATION OF ASBESTOSIS BODIES

For the identification of the "curious" bodies (see Fig. 15, page 33) found in asbestos workers, Stewart (223) employs the following technique:

About half an ounce of sputum is dissolved in an equal quantity of undiluted antiformin in a wide test tube. This takes from a few minutes to an hour or so, and is aided by heat (37°C. incubator) and gentle agitation. Two or three ounces of water are then added and the mixture allowed to stand for a few hours or overnight. The bulk of the supernatant fluid is now poured off and the remaining 12 to 15 cc. centrifuged at moderate speed for 10 min. The amount of deposit which comes down varies in different specimens, but in any case the whole of the supernatant fluid may be poured off by simply inverting the centrifuge tube. The deposit and the trace of fluid which remain are thoroughly

[1] It is assumed that any person examining the dust particles in sputum or in nasal discharge will familiarize himself with the accepted routine of sputum examinations as carried out in ordinary medical diagnoses. He need observe only the methods of preparing the specimens and need not be concerned with bacteriological or pathological matters.

mixed by means of a fine pipette and transferred to an albuminized slide or slides. Too much force must not be used in the mixing process or at any previous stage in order not to disintegrate any *clumps* of asbestos bodies which may be present. As a rule the whole deposit from half an ounce of sputum may be spread over an area of 1 sq. in. of a microscope slide, or less, and in any case a thick film is desirable. After thorough drying on a hot plate and final fixation over a Bunsen, the film is very gently washed in water, dried and mounted in Canada balsam. The washing in water must be done with the greatest care, as, in spite of the albuminization of the slide, the film is very easily detached, especially if it is thick.

After washing and drying, the film may be treated with ferrocyanide of potassium and hydrochloric acid to demonstrate the Prussian blue reaction given by the bodies. It is then dried and mounted in balsam as before. Alternatively the centrifuged deposit may be covered with a small quantity of a 5 per cent solution of ammonium sulfide, when the bodies are colored black. No special staining is required, however, as the natural greenish yellow, golden, or brown color of the bodies renders them sufficiently conspicuous even under the low power. My practice is to examine films with the ½-in. objective and 10× ocular, confirming the presence of asbestos bodies with the ⅛-in. objective.

It is necessary to cleanse thoroughly all test tubes, centrifuge tubes, and pipettes after use; otherwise there is a risk of contamination of subsequent specimens from a positive sputum.

Asbestos bodies are demonstrable by this method in the great majority of asbestos workers provided they have any expectoration. In the older workers, especially during a bronchitic attack and in the later stages of pulmonary asbestosis, bodies are present in profusion, but, even in those who have only been engaged in the industry for a year or two, they may be demonstrable in small numbers. Their presence indicates merely that asbestos dust has been inhaled into the lung and that it has remained there long enough for "bodies" to form around individual fibers, a period of months at least. It does not necessarily mean that there is pulmonary fibrosis. The finding of radially arranged *clumps* of bodies similar to those demonstrable histologically within the lung alveoli has much more serious significance. It indicates disintegration of living tissue, either by suppurative bronchopneumonia or by tuberculous caseation, and may be taken also as presumptive evidence of an underlying asbestosis.

Bodies somewhat similar to asbestos bodies but much coarser and more irregular have been recovered from the lungs of coal miners who had never worked in asbestos. The morphological differences are so great, however, that there is little or no risk of confusion.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/8

here should turn on his breathless disability rather than on his radiological abnormality. It must be remembered that these two most important variables hardly correlate at all (Fig. 4).

Silicosis with active pulmonary tuberculosis is a sinister combination and more serious than either condition alone. The patient should be removed from the dust, treated, and thereafter supervised as a case of tuberculosis, and after recovery he should be advised to obtain work where he will not be likely to breathe siliceous or other dust again. At first, all such patients should be treated in bed in hospital so long as they have a positive sputum or other signs of infection, so that the period of bed rest will be variable. When such signs disappear and the sputum becomes negative they may be allowed up for a gradually increasing length of time each day until over a fortnight they become fully ambulant. Chemotherapeutic treatment should be continued for two years in all. In every case a careful history of previous chemotherapy must be sought and the notes of previous treatments obtained, copied, and incorporated in the patient's new file. Twelve specimens of sputum must be tested for tubercle bacilli fortnightly, and it should be kept at the back of the mind that even the best bacteriological department can occasionally return a false positive. In every case the sensitivity of the organisms must be determined towards para-amino-salicylic acid (P.A.S.), isoniazid, and, if necessary, streptomycin at the beginning of the treatment. If the organisms are fully sensitive to streptomycin the dose can be as low as 1 g. thrice weekly, combined with P.A.S. 20 g. and isoniazid 200 mg. daily. With less sensitive organisms streptomycin 1 g. daily should be considered, together with the calculated risk of vestibular toxicity, since many of these patients will be over forty years old.

DP 4492

disability rather than
must be remembered
ables hardly correlate

uberculosis is a sinister
ither condition alone.
on the dust, treated,
of tuberculosis, and
to obtain work where
ficeous or other dust
uld be treated in bed
positive sputum or
period of bed rest
sappear and the spu
e allowed up for a
each day until over a
ar. *Chemotherapeutic*
two years in all. In
evious chemotherapy
evious treatments ob
the patient's new file
e tested for tubercle
kept at the back of
tological department
ve. In every case the
determined *towards*
niazid, and, if neces
of the treatment. If
reptomycin the dose
ombined *with* P.A.S.
With less sensitive
hould be considered,
vestibular toxicity,
over forty years old



Figure 1. The man with the left hand skiagram is well and doing a full day's work. The man with the right hand picture is completely disabled.

This risk is about one case in ten when the drug is given in this dose for six months. When the patients become ambulant the ferric chloride test for P.A.S. in the urine must be performed regularly. Isoniazid and P.A.S. should be given in a combined cachet which is small enough to be swallowed without effort. Between 15 and 20 per cent of patients are affected to some extent by P.A.S., either with gastro-intestinal symptoms which can be lessened by taking the drug after meals, or with the sensitivity symptoms of a rash, fever, and feeling ill. If these are bad enough, desensitisation may have to be done or the drug even stopped. The physician should realise that this kind of therapy taken over many months when nothing very much is apparently happening to the patient is very likely to lapse. The importance of continuing to take the drugs should be explained to him in simple language, together with the reason for the urine test; and better still, explained to his wife as well. He should be told to take the cachets at the same time each day and to link their taking to some other diurnal habit, such as eating a meal.

Under this plan sputum conversion should happen in from one to eight months but little, if any, change in the chest x-ray, exercise tolerance or working capacity can be expected. But these patients will feel better, gain weight and cease to be a danger to their families, workmates and other people with whom they come into contact. There is no evidence that combined chemotherapy of this kind has any effect upon the sputum-negative progressive massive fibrosis seen in some cases of mixed dust pneumoconiosis. In sputum-positive cavitating cases, the more the fibrosis the more reserved should the physician be about the results of his drug treatment.

Before the advent of antibiotics, surgery may have had

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/11

a place in some selected cases of silico-tuberculosis, but not now, with the possible exception of the solitary massive fibrotic lesion which is occasionally removed, because it was thought to be a malignant tumour, to the delight and relief of everybody. The initial mortality of operating in this condition is about 7 per cent. About the same proportion of patients need secondary thoracoplasty, are left with a bronchopleural fistula, or persist with a positive sputum. This type of treatment is, therefore, considerably more dangerous than doing nothing.

The therapy of the bronchitic and emphysematous elements of silicosis and the mixed dust pneumoconioses must be directed to each component of the symptomatic picture. In a cold and damp climate the symptoms are at their worst in the winter, especially when the body is cooled, such as on going to bed between cold sheets, on getting out of a warm bed in the morning, or by sitting in a draught. "Keep warm all the time" is the right advice, and this means attention to such homely details as warming the bedroom before going to bed or moving the bed downstairs into the warm parlour. Two domestic, but none-the-less useful, preventives must be mentioned here: the hot water bottle in the bed, thus avoiding the coughing brought on by contact with the cold sheets, and the stove or fire in the bedroom, again to keep the air warm enough so as not to cause coughing. A common cause of feeling cold all over is cold or damp feet, so that footwear needs to be warm and watertight. Sweaty socks, moreover, soon become cold socks, so they should be washed out at the end of the day and replaced next morning by a warm dry pair. They will also last longer if this is done. Keeping these men warm prevents them coughing and wheezing. The worst time for this is on getting up in the morning, and it is no uncommon thing for

a man to sit on the edge of his bed wheezing, coughing and spitting for half-an-hour before he can "pull himself together." Deep breathing through the mouth from a jug or can of steaming hot water with a towel enclosing the head and the jug also often helps symptomatically. Bad attacks of breathless wheezing are best managed by breathing a mixture of adrenalin or isopropyl nor-adrenalin and atropine from a simple hand spray fitted with a rubber bulb and comfortably fitting nosepiece. It should be handy enough to be carried about in the pocket. Another approach to the problem of wheezy waking in the morning is to take ephedrine ½ gr. (30 mg.) by mouth or isoprenaline 20 mg. under the tongue. The cardiovascular side effects of rapid pulse palpitations or gooseflesh may limit the use of these drugs, as also may difficulty in passing water in elderly men. For patients who are wheezy all the time a theophylline preparation is worth trying, such as choline theophyllinate 200 mg. thrice a day. Sometimes this drug causes anxiety from its stimulating effect on the brain. This can sometimes be dealt with by giving a sub-hypnotic dose of a quick-acting barbiturate as well. There are some proprietary preparations which contain both.

Superimposed infective chronic bronchitis is a major problem in pneumoconiosis with repeated attacks of cough and purulent sputum each winter. Each period of disability tends to become longer as the years go by. The best way to handle this recurrent problem is to treat each attack of bronchitis smartly with an antibiotic as it occurs. At present tetracycline is the drug to use in doses of 0.25 g. four times a day which can be diminished to twice a day when the sputum becomes clear. If it does not do so within about a fortnight the drug should be stopped in any case, as it will be doing no good. For those who benefit,

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/13

l wheezing, coughing
he can "pull himself
he mouth from a jug
towel enclosing the
symptomatically. Bad
t managed by breath-
pyl nor adrenalin and
fitted with a rubber
e. It should be handy
pocket. Another ap-
king in the morning
.) by mouth or iso-
The cardiovascular
ns or gooseflesh may
lso may difficulty in
tients who are wheezy
tion is worth trying.
g. thrice a day. Some
its stimulating effect
dealt with by giving
barbiturate as well.
ations which contain

bronchitis is a major
ated attacks of cough
Each period of dis-
years go by. The best
lem is to treat each
ntibiotic as it occurs.
to use in doses of
diminished to twice
. If it does not do so
should be stopped in
or those who benefit,

however, there are two courses open, either to treat each respiratory infection separately as it occurs, starting with the earliest possible upper respiratory symptoms, or to maintain a prophylactic dose of tetracycline throughout the season of likely chest infections. If this course is chosen, 0·25 g. tetracycline twice a day is sufficient. But there are snags in seasonal prophylaxis. It is expensive and the risk of the development of resistant strains of bacteria, particularly staphylococci, must be considered, more especially if the patient is in hospital where others can be infected than if he is in relative isolation at home. Continuous antibiotic treatment of this type, moreover, is apt to upset the normal bacterial flora of the intestine and also perhaps the synthesis of some members of the water soluble 'B' group of vitamins. On the other hand, long periods of disability every winter season may be saved. But of the two methods it is probably the rather better one to attack each infection as it comes, and as early as possible.

There are a number of points of practical detail which must also be considered in caring for these patients. Some of them suffer from pain in the chest, usually for a reason which has no obvious clinical cause. Local radiant heat is the treatment for this. Sometimes they cough up dramatically large amounts of black material. This is usually not serious. The patient should be calmed and the sputum cultured for acid fast bacilli as a precaution.

On recovery from the bronchitis attack, breathing exercises should be instituted and, indeed, generally increasing bodily exercise should be gradually encouraged. The breathing exercises should be active, with the aim in view of getting the patient to make the very best use of his diminished respiratory reserve. The muscles of the shoulder girdle must, therefore, be called to the aid of the inter-

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/14

costals and the abdominal muscles to those of the thoracic cage.

Sooner or later these patients become blue from a central cyanosis and the therapy of this may not be as simple as it seems, because a few of the worst of them are running with carbon dioxide retention. Oxygen will diminish the dyspnoea, but will also therefore diminish the carbon dioxide elimination, and the tissue CO_2 may rise to such a high level that the patient becomes unconscious. It is therefore wise to give oxygen either in low concentration or intermittently. Thirty years ago oxygen was given with apparent wasteful inefficiency by holding a glass funnel in front of a patient's face. Then passed a stage of oxygen tents and close fitting oro-nasal masks, both of which gave high concentration. But now, at full circle, we are back again at something like the oldfashioned funnel for blue emphysematous patients with CO_2 retention. The guiding line is, therefore, the level of the plasma CO_2. Cyanosis with significant retention suggests dilute or intermittent oxygen, but without retention it should be given in high concentration by mask or tent. In cases where the breathing has stopped because of CO_2 hypnosis, artificial respiration should be started. Nikethamide given intravenously in doses of 5 to 10 ml. of the 25 per cent solution can be given slowly to stimulate the sluggish respiratory centre.

In a few patients there is a case for using a portable oxygen set when some activity which cannot be avoided has to be undertaken which makes them very breathless. Going upstairs when it is impossible to sleep downstairs comes under this heading.

The use of hypnotics in patients with industrial pulmonary disease with a superimposed emphysema and anoxia needs care and a steady head. It is easy for the inexperienced physician to be tempted to overdope a

restless, shouting and semimanic case of anoxia, particularly if he is being a nuisance to other patients or a trial to the nurse's nerves. But the patient is behaving like this because his cerebral cortex is short of oxygen and this should, therefore, be supplied. Morphine and its derivatives are forbidden and the barbiturates are dangerous, because they both depress the respiratory centre further and are likely to make the anoxia worse. The oldfashioned paraldehyde draught 1½ fluid ounces (45 ml.) which contains 60 minims (4 ml.) of paraldehyde is the safest drug in the difficult case.

The story of aluminium therapy, its rise, fall and present standing must now be mentioned. About twenty-five years ago it was shown that the more soluble the quartz particle, the more toxic it was. Quite recently there has been optical confirmation of this from electron-microscopic studies where small groups of quartz molecules can, in fact, be seen outside and inside cells. This research has shown that small numbers of these molecules (oligomeric quartz) pass through the outer wall of the cell without indentation or other visible damage, but when inside they apparently polymerize and form much more easily visible particles. The tridymite form of silica has been demonstrated to decrease both the glucose metabolism and the dehydrogenase activity of phagocytes. But it has been shown, too, that aluminium can reverse this action. Now, earlier researches have shown that if quartz has already adsorbed an impermeable film of aluminium hydroxide it does not pass into oligomeric solution with only a few connected molecules, or through the cell wall. In short, the toxicity of the quartz is neutralised. Aluminium metal has a similar but less marked action, perhaps because to become fully effective it has first to become hydrated to aluminium hydroxide, or to alumi-

nium monohydrate ($Al_2O_3H_2O$).

In addition to the coating action of aluminium upon quartz, there are two effects which tend to diminish either the quartz availability or the ease with which it can enter the cell. First, flocculation of quartz powder solutions is brought about by aluminium, and this happens independently of its influence on true solubility. Secondly, silica in the form of quartz is removed from solution by its adsorption on to aluminium or its compounds. In addition to the chemical facts of the matter, experiments with rabbits show that they can be protected against silicosis if, at the same time, they breathe enough grease-free metallic aluminium powder of particle size less than 5 μ, so as to give a minimum concentration in the lung of at least 1 per cent. But this exciting observation was originally made on only eight rabbits. At necropsy their lungs merely showed aggregates of dust cells containing irregularly shaped opaque particles. There was no evidence of silicosis which had, in fact, been exchanged for an aluminium metal pneumoconiosis which was too mild for its possible significance to be appreciated. Nowadays, however, with the valuable help of hindsight, this can be more easily done. Repeat of the work with rats was, in general, confirmatory, but the foreign body reaction to the aluminium was rather more marked. The warning was, therefore, repeated that the pneumoconiosis produced by the aluminium might not turn out to be as insignificant in other species of mammal—such, perhaps as man—as it so far seemed to be. Some rather less direct evidence from man showed that shale depressed the solubility of silica, probably by releasing aluminium, therefore protecting against silicosis. This brings us to the time of the opening of World War II, and during this a number of favourable reports of varying degrees of caution and incaution were

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/17

published, suggesting that inhaled aluminium powder regularly administered would retard, if not indeed prevent, silicosis in man. However, after the war a carefully controlled trial on pneumoconiotic coal miners and silicotic pottery workers showed no differences between an aluminium treated and a control group. There were reports, moreover, of massive spontaneous pneumothoraces in the chests of workmen who had breathed aluminium powder. We are now, therefore, back at the position from which we started, i.e.

(1) Silicosis and the mixed dust pneumoconioses can only be prevented by suppressing the dust.

(2) Their therapy is the therapy of their symptoms and complications.

Finally, mention must be made of three types of therapy which have been, and perhaps still are, being used, but which appear not to do any objective good. Careful clinical trials do not suggest that sulphonamides are effective upon the superimposed purulent bronchitis of pulmonary dust disease. Neither do they show that detergent aerosol mists are particularly helpful in loosening or liquifying sputum, as opposed to bronchodilator mists which are effective in bronchoconstriction.

Cortisone does not help in those cases of massive fibrosis of mixed dust pneumoconioses in which tuberculosis is not apparently present and, of course, in cases in which it is, it is dangerous to give it. Histologically, cortisone has the interesting effect of decreasing the transport of quartz dust from the lungs to the hilar nodes, and it also appears to inhibit the formation of pulmonary collagen. It is difficult to believe that retarding the clearance of a pathogenic dust from the lungs can be a good thing.

REFERENCES

Chemistry

Becklake, Margaret, R., Zwi, Saul, and Lutz, W.: Studies on the nature and actiology of respiratory disability in Witwatersrand gold miners free of radiological silicosis. Brit. J. Industr. Med., *16*:290-296, 1959.

Englebrecht, F. M., Yoganthan, M., King, E. J. and Nagelschmidt, G.: Fibrosis and collagen in rats' lungs produced by etched and unetched free silica dusts. *A.M.A. Arch. Industr. Hlth.*, *17*:287-294, 1958.

Greenwood, N. N.: Patterns of the Invisible: The Shape of Atoms and Molecules. Inaugural Lecture of the Professor of Inorganic Chemistry, King's College, Newcastle upon Tyne. University of Durham, 1962.

Gye, W. E., and Kettle, E. H.: Silicosis and miners' phthisis. *Brit. J. Exper. Path.*, 3:241-251, 1922.

King, E. J., and Nagelschmidt, G.: The Physical and Chemical Properties of Silica, Silicates and Modified Forms of these in Relation to Pathogenic Effects. Proceedings of the Pneumoconiosis Conference held at the University of Witwatersrand, Johannesburg 9th-24th February, 1959, pp. 78-83. A. J. Orenstein (Ed.). London, Churchill, 1960.

King, E. J., and Nagelschmidt, G.: Chronic Pulmonary Disease in South Wales Coalminers—III. Experimental Studies. Med. Res. Coun. Spec. Rep. Ser., Lond. No. 250, 1945.

King, E. J., Mohanty, G. P., Harrison, G. V. and Nagelschmidt, G.: The action of different forms of pure silica on the lungs of rats. *Brit. J. Industr. Med.*, *10*:9-17, 1953.

King, E. J., Schmidt, E., Roman, W., and Kind, P.R.N.: The effect of silica and silicic acid on enzymes. *Enzymologia*, *17*:341-351, 1954-56.

King, E. J.: Solubility theory of silicosis. *Occup. Med.*, *4*:26-49, 1947.

Marks, J.: The neutralization of silica toxicity in vitro. *Brit. J. Industr. Med.*, *14*:81-84, 1957.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/19

Nagelschmidt, G.: The Part Played by Free Silica in the Pathogenesis of Coal Workers' Pneumoconiosis. Proceedings of the Pneumoconiosis Conference held at the University of Witwatersrand, Johannesburg 9th-24th February, 1959, pp. 290-298. A. J. Orenstein (Ed.). London, Churchill, 1960.

Sheers, Geoffrey: Prevalence of pneumoconiosis in Cornish kaolin workers. *Brit. J. Industr. Med., 21*:218-225, 1964.

Therapy

Crofton, J.: *Amer. Rev. Tubere., 77*:869, 1958.

Denny, J. J., Robson, W. D., and Irwin, Dudley, A.: The prevention of silicosis by metallic aluminum. Canad. M.A.J., *40*:213-228, 1939.

Denny, J. J., Robson, W. D., and Irwin, Dudley, A.: The prevention of silicosis by metallic aluminum. *Indust. Med., 8*:133-146, 1939.

Denny, J. J., Robson, W. D., and Irwin, Dudley, A.: The prevention of silicosis by metallic aluminum. *Canad. M.A.J., 37*:1-11, 1937.

Edwards, Gordon, Buckley, A. R., Fear, E. C., Williamson, G. M., and Zimmermann, K.: Adult chronic bronchitis—the infective factor and its treatment. *Brit. Med. J., ii*:259-264, 1957.

Gardner, Leroy U., Dworski, Morris, and Delahant, Anthony B.: Aluminum therapy in silicosis. *J. Ind. Hyg. & Toxicol., 26*:211-223, 1944.

Gilson, J. C., and Kilpatrick, G. S.: Management and treatment of patients with coal-workers' pneumoconiosis. *Brit. Med. J., i*:994-998, 1955.

Goralewski, Godehard: Zur Symptomatologie der Aluminium-Staublunge. *Arch. Gewerbepath., 10*:384-408, 1940.

Goralewski, Godehard: Klinische und tierexperimentelle Studien zur Frage der Aluminium-Staublunge. *Arch. Gewerbepath., 9*:676-688, 1939.

Goralewski, Godehard: Zur Klinik der Aluminiumlunge. *Arch. Gewerbepath., 11*:106-116, 1941.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/20

Goradewski, Godehard: Weitere Erfahrungen zum Krankheitsbild der Aluminiumlunge. *Dtsch. Tuber.-Bl.*, *17*:3-10, 1943.

Goradewski, G., and Jaeger, R.: Zur Klinik, Pathologie und Pathogenese der Aluminiumlunge. *Arch. Gewerbepath.*, *11*:102-105, 1941.

Jager, R., and Jäger, E.: Kolloidchemisches und Histochemisches zur Frage der Lungenschädigungen durch Aluminiumstaub. *Arch. Gewerbepath.*, *11*:117-130, 1941.

Kennedy, M.C.S.: Cortisone in pneumoconiosis with and without reversible bronchoconstriction. *Lancet*, *i*:77-79, 1954.

Koelsch, F.: Die Lungenerkrankung durch Aluminiumstaub. *Beitr. klin. Tuberk.*, *97*:688-693, 1942.

Lancet, *II*: 1361, Dec., 1962 (Leading article).

McCallum, R. I.: Treatment of Progressive Massive Fibrosis in Coal Miners. Proceedings of XIIIth International Congress on Occupational Health, 1960, New York, 1961, p. 741.

Meiklejohn, A.: What Advice should be given to a person in the early stages of (a) Silicosis, (b) Coal Workers' Pneumoconiosis, (c) Asbestosis, (d) Other Pneumoconioses. Proceedings of the Pneumoconiosis Conference held at the University of Witwatersrand, Johannesburgh 9th-24th February, 1959, pp. 567-571. A. J. Orenstein (Ed.). London, Churchill, 1960.

Miall, W. D., Oldham, P. D., and Cochrane, A. L.: The treatment of complicated pneumoconiosis with isoniazid. *Brit. J. Industr. Med.*, *11*:186-191, 1954.

Miller, Seward E.: Role of the Physician in Combating Pulmonary Occupational Disease. Paper read before the Eighth Conference of McIntyre Research Foundation on Silicosis, held in Toronto, Ontario, Canada, October 22, 23 and 24, 1956.

Morrow, C. S.: The results of chemotherapy in silicotuberculosis. *Am. Rev. Respiratory Dis.*, *82*:831-834, 1960.

Moyer, R. E.: Transactions of the 11th Conference on the Chemotherapy of Tuberculosis. Veterans Admin., U. S. A., 1952, p. 83.

Published by AsbestosClaims.Law
asbestosclaims.law/library/25350/21

Razemon, P., and Ribet, M.: Surgical treatment of pulmonary tuberculosis asociated with anthracosis and silicosis in coal miners. *J. Thoracic and Cardiovas. Surg.*, *41*:281-290, 1961.

Ramsay, J. H. Rolland, and Pines, A.: Results of treatment of pneumoconiosis complicated by tuberculosis. *Brit. Med. J.*, *ii*:345-348, 1959.

Scadding, J. G.: Drug treatment of chronic bronchitis. *Brit. Med. J.*, *i*:107-109, 1959.

Stacy, B. D. and King, E. J.: Silica and collagen in the lungs of silicotic rats treated with cortisone. *Brit. J. Industr. Med.*, *11*:192-197, 1954.