CHAPTER IV

PERMISSIBLE DUSTINESS

DUST RETENTION OF MAN

The dust-catching mechanism of the human respiratory system is not unlike a commercial viscous filter: there are tortuous moist passages to the walls of which dust particles can stick. In addition, the hairs in the nose catch some dust during respiration. But this whole mechanism, like the viscous filter, easily is overloaded and functions poorly when the particles approach a size corresponding to the lower limits of microscopy. Then the momentum of the dust particle is slight and its chances of being centrifuged out against the walls of the respiratory tract are poor.

G. Lehmann (164) has determined the nasal filtering capacity of normal men and of silicotics. Also, he studied men with and without colds in order to note the effect on the nasal passages of excessive mucous secretion. His technique was ingenious and simple: the subject held his breath and opened his mouth, and air of known dustiness was blown into his nostrils through right-fitting tubes or catheters. The dustiness of the air that escaped from his mouth was then determined.

Lehmann's subjects were 426 miners, of whom 241 had silicosis, while 185 were normal. In Fig. 21 we have replotted Lehmann's original curves, using arithmetic probability paper. It is seen from the plots that the median or geometric average of nasal filtering efficiency is 27.5 per cent for the silicotics and 46 per cent for the normals—differences that are significant.

Lehmann's data indicate that the "silicotic susceptibility" of workers with poor nasal filtration is much greater than that of men with good nasal filters." He advises that "jobs with a silicosis hazard be held only by men with good nasal filters" and that mouth breathers are an especially bad risk. He suggests that the "dust-retaining capacity of the nose be used as an index

of the individual's qualification for working in a silicosis-producing atmosphere."

If one can accept the analogy between the human respiratory filter and the commercial viscous filter, it should be possible to gage nasal-filtering efficiency simply by measuring resistance to nasal inspiration. It is known, for example, that the dust retained by a given viscous filter correlates fairly well with resistance; similarly made filters can be compared for efficiency on the basis of resistance.

This general idea was suggested recently by Dr. H. J. Sternstein,[1] who measures nasal obstruction of persons with pollen

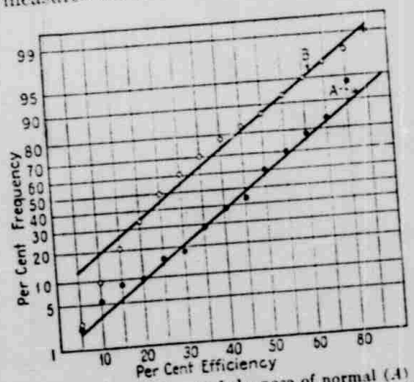


FIG. 21.—The dust filtering efficiency of the nose of normal (*A*) and of silicotic (*B*) men. (*Adapted from Lehmann, courtesy J. Ind. Hyg.*)

asthma and notes how rapidly the swelling subsides when the irritant (*i.e.*, pollen) has been removed from the air or when treatment with ephedrin has been given. It is possible that Sternstein's technique for measuring nasal resistance could be developed into a simple procedure for selecting men best adapted to dust exposure. As it now stands, Lehmann's method is too complicated for routine use.

From certain of his many fascinating experiments, Tyndall concluded that exhaled air is dust free (239), a belief that Owens (194) has shown needs revision. The first work of real hygienic significance on this subject, however, was done in K. B. Leh-

[1] Boston, Mass.

ann's laboratory in 1912 by Saito, who worked only with animals but who later collaborated with Lehmann (165) in studies on man. Neither G. Lehmann's nor K. B. Lehmann's technique permits normal breathing, and their dust concentrations were not well controlled or reliably measured.

One of the most troublesome problems in experiments involving respiration is the avoidance of unusual resistance to breathing. A filtering device, for example, which catches respirable dust effectively will impose a high resistance unless the filter area is inconveniently large. Baumberger (15) avoided this difficulty by using an electric precipitator with tubes having negligible resistance and he was thus able to determine tobacco smoke retention on "puffing" and "inhaling" cigarettes. He reported that 67 per cent was retained on puffing and 88 per cent on inhaling, figures that we believe are too high.

The percentage retention of lead oxide fume was determined in a few tests by Sayers *et al.* (215) in connection with their tetraethyl lead studies. For concentrations of 0.35 to 10.4 mg. of lead per cubic meter of air, they found that only 15 per cent was retained. This low retention figure was attributed to the minute size of the lead-fume particles. Their dust determining device was, like Baumberger's, an electric precipitator.

With a modification of Sayers' technique, Drinker *et al.* (72) in 1926 made a number of dust- and fume-retention studies on normal adults, but it was not until Brown's papers (31, 32) that extensive data were made available.

In Brown's experiments the subject inspired dust or fume-laden air from a large cabinet and expired into a spirometer or gasometer in which the volume of exhaled air was measured. Dust in the exhaled air was collected for measurement by means of an electric precipitator in the line (Fig. 22). It was possible, with this arrangement, for the subject to sit at rest breathing air of accurately known dustiness, to breathe by nose or by mouth, and to breathe at a predetermined fixed rate. Some experiments were performed when the subject rode a stationary bicycle and others when he breathed air enriched with carbon dioxide, in order that respiration might simulate the deeper and more rapid conditions of exercise.

In Fig. 23 are shown the most important of Brown's curves, from which it is possible to calculate the average amount of dust

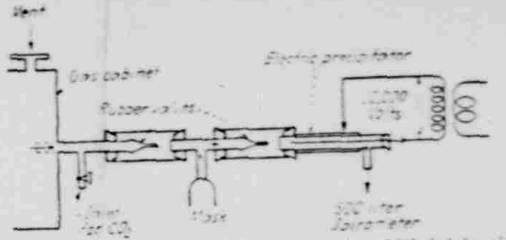


FIG. 22.—Apparatus used for determining the retention of inhaled dust by man. (*After Brown, courtesy J. Ind. Hyg.*)

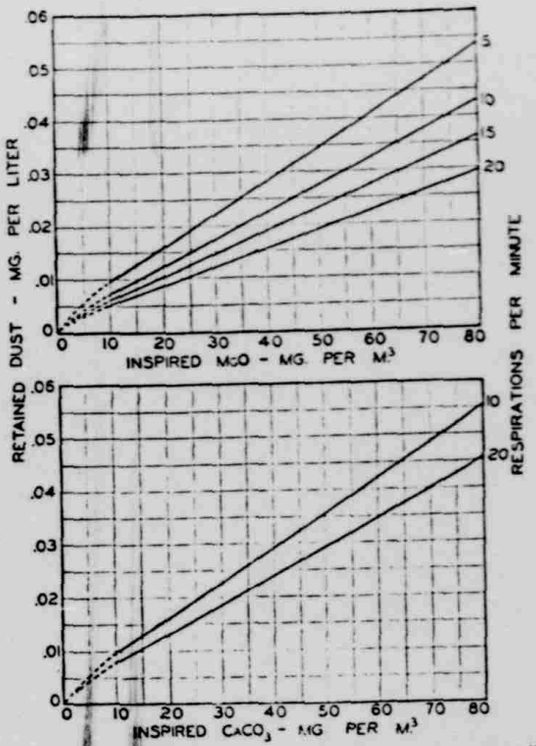


FIG. 23.—Retention of magnesium oxide and calcium carbonate at different concentrations. (*After Brown, courtesy J. Ind. Hyg.*)

or fume a normal man will retain on breathing air containing a known amount of dust. The average man, breathing at twenty respirations per minute, for example, inhales about 10 liters per minute and retains 60 per cent of inspired dust. Thus, in a very dusty atmosphere containing 40 mg. per cubic meter of mineral dust, he will retain 0.024 mg. of dust from each liter breathed and in one hour a total of 14.4 mg. of dust will be held in his lungs. A mouth breather will retain somewhat less dust than a nose breather.

One can say, roughly, that the retention of common silicosis-producing dusts and the like is about 50 per cent, but the way in

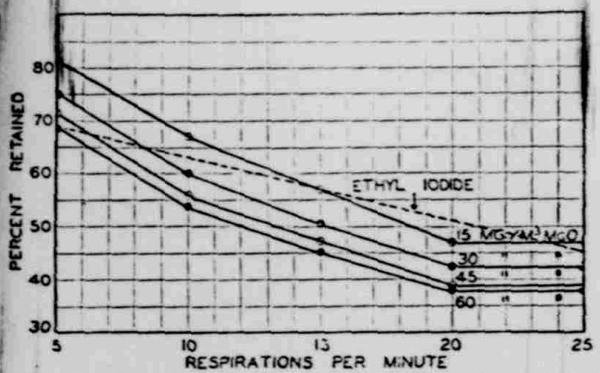


FIG. 24.—Variation in percentage retention of magnesium oxide and ethyl iodide with respiration rate. (*After Brown, courtesy J. Ind. Hyg.*)

which this is divided between the upper respiratory passages and the alveoli is not clearly defined.

Of interest also are Brown's curves in Fig. 24, which show that the percentage retention decreases with increasing respiratory rates up to twenty respirations a minute. No further change occurs with higher rates. Blumgart (25) found the same sort of relationship between respirations per minute and the retention of ethyl iodide gas. Drinker *et al.* (71) observed in their earlier investigations of metal-fume fever that slow deep breathing at the unnatural rate of five to six breaths per minute was much more likely to produce the fever than was the normal rate of fifteen per minute; this is explained, in the light of Brown's curves,

by the higher retention associated with slow, deep breathing. Brown attributed this inverse relationship to the fact that the length of time for dust or fume settlement in the lungs increases as the rate of breathing is reduced.

Bearing out the earlier forecast by Sayers, Brown also found that retention increases with particulate size. Thus, the silicosis-producing dusts are retained to a greater extent than are very finely divided suspensions like tobacco smoke. Still higher retentions may be expected with substances like plant pollens although actual data are lacking.

AMOUNT AND COMPOSITION OF THE ASH OF DUSTED LUNGS

It is desirable to know what is the maximum amount of dust that can be held in the lungs without producing injury and also how much is to be expected in silicotic lungs as well as in the lungs of persons who have had harmless dust exposures.

The lungs of the city dweller are always more pigmented than those of the country resident. Or perhaps it would be better to say they contain more black pigment, generally carbon. The fact is of no medical importance whatever, but is nonetheless evidence of a pathological change (150). The heavy pigmentation of coal miners' lungs, on the other hand, may be associated with the inhalation of a dangerous amount of silica and the pigmentation then takes on a medical significance because the carbon particles are in bad company (51).

The first important analyses of the ash from silicotic lungs were made by McCrae (180) in 1913 and by Watkins-Pitchford and Moir (246) in South Africa. The wet weight of the excised lung was noted; the lung was boiled in water for some time and was then ashed in a platinum dish over a free flame; the carbon was burned off in a muffle furnace kept at dull red heat.

The ash was analyzed, presumably by the usual procedure in silicate analyses. McCrae stated that "the material described as 'silica' is mainly silica, but may contain small amounts of very refractory silicates." The material volatilized by hot hydrofluoric acid would, of course, fit this description, which is probably all that is meant. His results are given in Table 11.

In comparison with other analyses which we give below, it should be noted that in the control lung McCrae found that the silica amounted to 14.7 per cent of the total ash and 0.73 per cent

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of the dried lung. (The estimation of the dry weight he did not consider done "with very great accuracy.") The silicotic lungs 1 to 6, it will be observed, had at least two to three times as much total silica as did the control lung.

Riddell and Rothwell (204) found the lungs of three "city dwellers" to contain from 0.60 to 2.67 per cent silica in terms of the total lung ash; one other lung, described as in a condition

TABLE 11.—ASH OF SILICOTIC LUNGS[1]

Case	Normal	1	2	3	4	5	6
Wet weight	649	967	1928	1672	1335	1497	1998
Dry weight	76	2[illegible]	336	232	215	208.5	233.5
Ash	3.77	9.07	21.796	12.70	20.00	13.55	15.20
Silica	0.55	2.70	6.38	5.19	9.60	6.21	6.57
Ash: percentage of dry matter	4.96	4.54	6.46	5.47	9.30	6.4[illegible]	6.51
Silica: percentage of ash	14.7	30.7	29.4	40.8	48.0	45.8[illegible]	43.2
Silica: percentage of dry matter	0.73	1.39	1.99	2.23	4.47	2.98	2.81

After McCrae.

of "uncomplicated silicosis," had 33.12 per cent silica; another, from a miner accidentally killed after 7½ years of drilling and blasting, showed 18.86 per cent silica; the lungs of still another man, who died of "silicosis complicated with tuberculosis" after nine years of underground mining, showed 15.23 per cent silica, whereas a man who had worked for four seasons of six months each in a quartz-crushing room showed 33.26 per cent silica.

The figures published in 1933 by Sladden (220) are especially important. Since he records silica, presumably total silica, in percentage of the dried lung, his results cannot be compared with Riddell's and Rothwell's but are comparable with McCrae's. He states that

> . . . fibrosis of an important extent, clearly contributory towards death, is usually present when the silica content of the lungs determined chemically exceeds 1.0 per cent of the dried lung substance. Quantities below this are not necessarily negligible but have seldom been associated with deaths attributable to pulmonary disease *except when tuberculosis has intervened.*[1] When the silica content exceeds 1.6 per cent the fibrosis

[1] Our italics.

> associated is with practically no exceptions very severe and sufficient in itself to lead to death. . . .

We have condensed the data from Sladden's six tables into Table 12.

TABLE 12.—SILICA CONTENT OF LUNG AND FIBROSIS[1]

Group	Silica in dried lung, per cent	Degree of fibrosis
I: 9 cases	<0.3	Trivial or negligible fibrosis
II: 6 cases	0.3–0.6	Varying amount of fibrosis, not serious
III: 8 cases	0.6–1	Fibrosis often advanced. Pulmonary deaths only if tuberculosis intervenes
IV: 16 cases	1.0–1.6	Fibrosis featured, pulmonary deaths frequent
V: 9 cases	1.6–2.4	Important fibrosis, often tuberculosis, death usually pulmonary
VI: 12 cases	over 2.4	Advanced fibrosis in all. All but 1 death due to the fibrosis

[1] After Sladden.

Cummins and Sladden (51) divided the results of analyses of coal miners' lungs into three groups, averaged as follows: class A—2.36 per cent, class B—1.24 per cent, class C—0.13 per cent. The content of nonsiliceous and of combustible material in the ash of these lungs was, as would be expected, highest in class A and lowest in class C.

McNally (181) concluded from a series of lung analyses that the silica content of the normal lung amounts to 0.113 per cent of the dried tissue and that a lung containing over 0.2 per cent is indicative of unsafe exposure to a dusty atmosphere. King (152) considers 0.14 per cent as normal while Sladden, noted previously, claimed no reasonably certain diagnosis unless 1 per cent silica was reached.

Badham and Taylor (11) have furnished some very useful figures and are critical of prior analytical procedures because only "total silica was determined and this was not separated into free silica or quartz and combined silica or silicates." All of Badham's and Taylor's figures can be compared with Sladden's or McNally's and fit in well with them.

Fowweather (81), cooperating with M. J. Stewart in the chemical examination of a considerable series of lungs, confirmed

the figure of less than 0.12 per cent silica for the normal person. But he also showed that the actual degree of fibrosis in silicosis with tuberculosis is not necessarily proportional to the silica content of the lungs.

Deaths from simple silicosis are rather rare, the immediate cause being usually some pulmonary infection, which can occur without a high percentage of silica in the lung ash. The value of lung analyses in the appraisal of silicosis is therefore limited. Of great practical value, however, is the fact that such analyses are easily understood by persons not necessarily familiar with silicotic pathology. As a rough guide, it can be said that a total silica content as high as 0.2 per cent of dried lung may be considered normal and that a silica content of 1 per cent or more constitutes strong evidence of excessive dust exposure and generally is associated with disabling fibrosis.

PERMISSIBLE DUSTINESS

Dusty processes for which the threshold or permissible dust concentration has been estimated are the exception and not the rule. Commenting upon the paucity of the present data, a recent memorandum from the British Home Office (131) states that "such standards may be of value in estimating the relative efficiency of the methods used for suppressing dust in a single industry, but it would be wrong to adopt any of these standards as the measure of safety under different conditions and in other industries."

Quartz. The first suggestion of a threshold figure comes from the South African gold mines. The results of twenty-five years of practical experience in dust control in these mines are shown in Fig. 25 (175). Before control measures were instituted on a large scale, concentrations averaged 150 mg. per cubic meter. This was reduced to 20 mg. by 1910, with a further reduction to 5 mg. by 1915. During the next ten years it was lowered to 1 mg. per cubic meter. The reduction in the prevalence of miners' phthisis lagged about five years behind the drop in dustiness, and in 1934 Irvine (135), present chairman of the Miners' Phthisis Medical Bureau, stated: "No 'New Rand Miner' who has entered the industry since August, 1923, *i.e.*, 10½ years ago, has as yet contracted silicosis. These facts demonstrate that the engineering and medical measures which have been directed

against silicosis have achieved a very significant degree of success." A concentration of 1 mg. per cubic meter is now commonly called the South African standard.

Of course freedom from silicosis during a working period of 10½ years is not proof that the hazard has been eliminated. But there is no doubt at all that the severe or rapidly fatal silicosis which gave the Rand mines their bad name has been wiped out. The engineer's job in controlling dustiness continues but Mav-

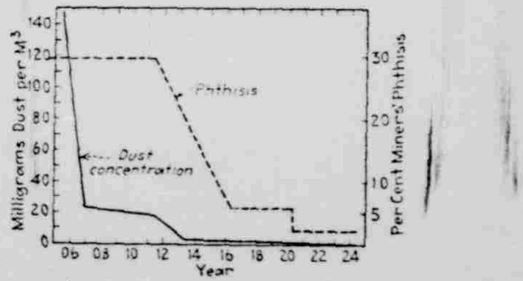


FIG. 25.—Dust control and silicosis. (*Adapted from Mavrogordato, courtesy South African Inst. Med. Res.*)

rogordato seems to feel that the medical problem now is mainly one of controlling infective tuberculosis.

The first extensive field investigation of silicosis in the United States was reported by Higgins, Lanza, Laney, and Rice (127) of the U.S. Public Health Service and U.S. Bureau of Mines in the zinc and lead mines of the Joplin, Mo., belt, where the rock is notably high in quartz and where silicosis was common. Under the heading "What Constitutes a Dusty Mine," they had the following to say:

> Practically all air, both inside and outside of mines, contains some dust. The most reasonable standard then appears to be one based on the quantity of dust that will remain in suspension after the best known methods have been put into use for its abatement.
>
> It has been demonstrated in the sheet-ground mines of the Joplin district that by the proper use of water and the regulation of certain details of mining the quantity of dust in the mine air can be kept below 1 mg. per 100 liters of air; so it seems reasonable to use 1 mg. as standard at least for the Joplin district.

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It is to be noted that, like the South African figure, the Joplin figure is based upon practical mining and dust-control experience rather than upon physiological or statistical evidence.

In 1929 Russell *et al.* (210) published the results of several years' intensive field study in the Barre, Vermont, granite field, where the rock commonly contains 25 to 35 per cent quartz. From results obtained with the impinger sampling technique and light-field counting they concluded that " . . . it would appear that a safe limit lies somewhere between 9 and 20 million particles" (per cubic foot) and later that this limit "can be obtained by the use of economically practicable ventilating devices applied to the source of dust."

In drilling tunnels through sandstone with a high percentage of silicates, Badham in Australia (9) suggested a limit of 200 particles per cubic centimeter as determined with Owens' counter, though he hinted that 100 particles would be safer.

From a consideration of general experience, Cummings (211) suggests 5 million particles per cubic foot as a threshold for dusts high in quartz. This figure is based upon a combination of South African, Australian, and American experience but lacks entirely any published data in its support.

Coal Dust. Recently Sayers and his associates (214) completed an extensive field study in the Pennsylvania anthracite district, as a result of which they suggest a figure of 50 million particles per cubic foot for coal dust containing not over 5 per cent quartz, 10 to 15 million for dust with 13 per cent quartz, and 5 to 10 million for the hard-rock workers exposed to dust containing 35 per cent free silica. A critical study of the amount of pulmonary damage found in this industry as compared with that found among granite cutters (210) suggests that these figures are too severe, although both engineering and hygienic common sense support them. Of prime importance is the clear proof in the report that these requirements are not only attainable but that in many operations they are being bettered today.

Cement and Limestone. The first field study of importance in the cement industry was made by Thompson and others (231). The dust under study was recognized then, largely because of Gardner's work with marble (86), as being comparatively harmless. Though it was high in lime (36 to 61 per cent) and low in quartz (6½ to 1 per cent), they suggested a very rigorous objective

of cleanliness from a hygienic standpoint, namely, 10 to 20 million particles per cubic foot by the impinger sampling method, light-field counting. This is a perfectly reasonable figure, however, from the engineering standpoint. Recent work by Dreessen (59) among Vermont marble finishers confirms the universally accepted opinion that dusts high in calcite and low in quartz do not produce disabling fibroses.

Lead. After years of industrial medical inspection for the British Home Office, Legge and Duckering (163) suggested a threshold figure of 0.5 mg. per cubic meter for lead dust, presumably litharge and white lead. This figure was lowered by Russell (209) to 0.15 mg. on the basis of the comparative solubilities of different lead substances in blood serum, since the less soluble compounds are less toxic.

Zinc Oxide and Metal-fume Fever. The studies of Drinker *et al.* (71) resulted in threshold figures for the avoidance of metal-fume fever. It was found that concentrations of 14 mg. of zinc oxide per cubic meter, calculated as zinc, could be breathed for 8 hr. and that as much as 45 mg. could be breathed for short exposures without reaction.

In modern electric or acetylene welding the welder occasionally works in a confined space with inadequate ventilation. He then may breathe heavy concentrations of iron oxide, zinc oxide, lead oxide, or whatever else results from boiling metal in the high temperature of the torch. In addition there will be formed a certain amount of nitrogen peroxide, which is very toxic. Under these conditions Drinker *et al.* (66) recommend that oxide-fume concentrations, whether ferric or zinc oxide, be kept below 10 mg. per cubic meter. Such concentrations are easily attained by exhaust-hood ventilation.

Elsewhere (page 35) it was pointed out that fume-fever reactions, as distinguished from true poisoning, can be produced by the inhalation of extremely fine particles of manganese dioxide, lead oxide, or probably many other substances. No threshold data for the avoidance of the fever from these substances have been determined.

Manganese. Some fifteen to twenty years ago, a number of men working in a concentrating plant of a mining company developed manganese poisoning following exposure to heavy concentrations of dust containing about 10 per cent manganese.

dust-control equipment, put into operation in 1919, has reduced and maintained the concentration *below* a maximum of 50 mg. per cubic meter, calculated as *pure manganese*. Since 1919 there have been no new cases of manganese poisoning, so that the figure of 50 mg. per cubic meter may be taken as a practical safe concentration. Probably higher concentrations would also be safe, but on this point there are no data. From the engineering standpoint the safe limit is easy to maintain.

Limitations in Standards of Permissible Dustiness. The idea of adopting standards of permissible dustiness for each harmful dust has a medicolegal appeal that is not at all justified by the data available today. Having had no compensation laws covering silicosis until recently, certain states are now drafting regulations defining permissible dustiness in precise figures which will not stand the most elementary analysis. In contrast to this practice, Great Britain, South Africa, Australia, and Canada operate under general compensation laws for silicosis without even suggesting figures for permissible dustiness.

In none of the original studies was there a single suggestion that the threshold figures were usable as legal standards. In the report on the cement study (231), for example, it is emphasized that " . . . the variations in dustiness were so great as to make impractical an attempt to study the sickness rate in relation to dustiness except in a general way." In spite of this, there is a strong temptation to plot a curve with permissible concentrations and content of free silica as coordinates and then to interpolate or extrapolate freely from this curve to obtain the standard of dustiness for any industry. We cannot admit the soundness of this practice from a medicolegal standpoint, but, on the other hand, there is much to recommend the use of figures thus obtained as basic criteria in the design and operation of dust-control equipment and as general guides in the appraisal of working conditions. It is essential, however, to consider the limitations of these threshold values when applying them to industries not included in the original studies. Some of the limiting factors are discussed below.

1. *Mineralogical Composition.* We have shown elsewhere (page 59) that the composition of certain mixed dusts changes with particle size and that the silica content of the minute particles which contribute most to the development of lung fibrosis,

is not necessarily the same as the percentage of silica in the material from which the dust is generated or in the total dust sample. It is not possible, therefore, to compare two dusts with respect to their silicosis-producing capacities on the basis of their silica content without considering also the variation in the amount of free silica with respect to size. Foundry dust, for example, contains approximately 50 per cent quartz, and on this basis it is said to be more dangerous than granite dust, which contains 35 per cent quartz. A differential analysis of foundry dust, however, showed in one case (page 62) that the amount of quartz contributed by less than 10 μ particles was only 5.7 per cent by weight and that only 0.2 per cent was contributed by particles under 2 μ, so that the silica content of the particles of hygienic interest is far below 50 per cent. Unfortunately, a differential analysis has not been made of Barre granite dust, and until this is done one must take great care in comparing other dusts with it with respect to the health hazard associated with them.

2. *Dust Floods.* A plant in which dust of any kind is heaped upon rafters or a dry mine in which dust is lying about is in ideal condition for the freeing of dust floods. Undue vibration in the plant, such as occurs in starting motors and belts, or a misdirected blast of air from a hose or the exhaust of a rock drill will dislodge this dust, with the consequent development of unusually heavy dust concentrations in the neighborhood.

Referring to the effect of dust floods upon workers in quartz dust, Mavrogordato (176) writes: "Lesions of silicosis in a mild degree can be produced in an animal by 30 hr. exposure to intense dust clouds, and one is inclined to suspect that it is intermittent exposure to relatively dense clouds that is the deciding factor in producing the disease in susceptible human subjects." Analogous arguments apply with equal force to toxic dusts like lead and manganese.

Unfortunately, it is impossible to evaluate dust exposures medically with the arithmetic nicety that we should like. Yet it is commonly claimed—by laymen—that prolonged exposure to low concentrations is just as serious as short exposures to heavy concentrations. This claim is contrary to a fundamental law of physiology. In discussing the subject Clark and Drinker (40) remark that " . . . a sub-threshold stimulus (dust inhalation

r a long time produces no reaction whereas a relatively brief per-threshold stimulus may cause a reaction."

There is little excuse for dust floods since they can usually be revented by ordinary methods of good housekeeping. If workers re to be exposed, however, to sudden heavy concentrations, we elieve that the threshold values suggested previously will be eriously weakened.

3. *Industrial Selection.* An important factor which determines in a measure the conditions of health among any group of industrial workers is the process of natural selection of the fittest and the continuous elimination from industry of the unfit. Brundage (34) has pointed out that this factor acts among the general industrial population since such a group "is composed of individuals who are ordinarily able to engage in wage earning occupations," whereas the general population includes "invalids and persons with physical impairments so serious as to preclude attempts at factory employment." Hence, "if an industry involves no health hazards of consequence, the sickness rate among its employees should be lower than in the general population." In a hazardous industry this process of natural selection is of greater importance than in nonhazardous plants since it acts to remove those especially unfitted for exposure to the particular hazardous material involved.

The way in which industrial selection limits the value of the standards of permissible dustiness is obvious. The studies must be made upon the men at work with little or no consideration of the condition of those who quit. Hence, the resulting standards are based only upon the reaction of the men after selection of those best fitted for exposure to the dusts under investigation (34). The effect of this is illustrated by the findings of the cement study mentioned earlier (231). It was found that the respiratory-disease rate was 68 per cent higher among those who quit during the progress of the study than among those who remained at work. A study of lead poisoning in a storage-battery plant showed a "high rate of labor turnover, especially in the departments with the greatest lead exposure" (209). Similar findings have been obtained in other studies.

In this connection, the difference between the granite and foundry industries is interesting. The heaviest dust exposure in granite sheds is that of the pneumatic-tool operators—a group

of highly skilled artisans who adopt this craft through choice and who are therefore willing to remain in the industry in spite of respiratory trouble. In the foundry industry, on the other hand, unskilled workers on the shakeout and the like are exposed to the highest dust concentration while the skilled molders (comparable to expert granite cutters) produce relatively little dust during molding. The unskilled foundry worker, having no deep feeling for his work, quits if he experiences any respiratory trouble. Thus there is a high labor turnover which accounts, in part, for the relative absence of silicosis and tuberculosis in this industry.