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Industrial Hygiene

A Handbook of Hygiene and Toxicology for Engineers and Plant Managers

by

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L.B.C.
W.M.

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(11) In carrying out resuscitation it may be necessary to change the operator. This change must be made without losing the rhythm of respiration. By this procedure no confusion results at the time of change of operator and regular rhythm is kept up.[3]

Drowning, asphyxiation from carbon monoxide, and the manifold hazards in industry create a vital need for widespread knowledge of the technique of artificial respiration and a trained man should be as familiar with it as he is with methods of putting out fires. As soon as this treatment has been instituted, steps should be taken to keep the patient warm and inhalations of mixtures of oxygen and carbon dioxide may be given while the artificial respiration is being carried out.

[3] In case more than one person is available for carrying out artificial respiration, the efficiency of the procedure will be augmented if the assistant employs one of the procedures of the Holger-Nielson Method of respiration. When this method is used in combination with the Schaefer Method, the assistant kneels at the head of the subject and just as the operator relaxes his pressure upon the lower ribs to permit inspiration the assistant, who has grasped the subject by both elbows, moves the arms upward and outward without changing the position of the head or hands. This raises the chest slightly and the pull of the muscles increases the capacity of the chest and the volume of inspiration. As the operator again applies pressure to effect expiration the assistant quickly returns the arms to their usual position, lifting them again when the pressure on the lower chest is released. With practice in synchronizing the movements of the operator and his assistant, the associated procedure will definitely increase the effectiveness of artificial respiration.

CHAPTER XI

DUST DISEASES

Definition of Dust. Dust may be defined as a dispersed system of finely divided solid particles in air. The definition as given excludes gases, vapors, mists and fogs, and fumes from liquid sources. Fumes arising from the action of heat upon solid materials or from chemical action are not considered as dust, in part because of their mode of formation and in part because of their nature and low mean-particle size (generally below 1 micron). Properly speaking, smoke is a suspension of finely divided solid particles in air but it is not considered in the category of dust as it is generally of organic origin and usually arises from combustion. It is further to be differentiated from most dusts in that its mean-particle size is in most instances below 0.5 micron. When speaking of industrial dust, the kind with which we are concerned in this discussion, we limit the definition further so as to include only those particles suspended in air which are of a size that can be inhaled, that is, less than 10 microns in diameter. These dusts usually are caused by some manipulation such as grinding, drilling, or other procedures in which solid material is reduced to small size. The use of the term *dust* implies a certain tendency on the part of the solid particles to settle. Particles below 0.1 micron in size which behave like gas molecules and show no tendency to stratify or settle are not considered as dust. We may therefore arbitrarily modify our former definition of dust to state that an industrial dust is a suspension in air of finely divided solid particles having a mean size from 0.1 micron to 10 microns and found in association with or as a consequence of the utilization, processing, or handling of solid materials in industry.

Characteristics of Dust. Associated with the fine state of subdivision of dust, fumes, and the like is an enormous increase in the surface area as compared with the original unbroken material. This great increase in surface area greatly accelerates the rate of the chemical and physical reaction of the material. As many of these reactions are of hygienic importance, it follows that the significance of many dusts and fumes from the point of view of production of poisoning is greatly influenced by their particle size. The settling velocity of particles is a function of the volume and density of the particle, the density of the air, and the gravitation constant, and as the size of dust particles is reduced, the settling velocity correspondingly decreases. Rate of chemical reactivity and solubility are increased with increasing subdivision and the rate of absorption of the materials is correspondingly increased. In the case of dusts readily susceptible to oxidation, such as coal dust, flour, and dusts of some metals, extremely fine states of subdivision may increase the surface area and enhance the rate of oxidation sufficiently to bring about spontaneous combustion or explosion and cause the accidents which occasionally occur in mines, flour mills, etc.

Methods of Estimation of Dust. Most of our concern in this section has been with the particle size of the dust; however, the chemical composition of the dust is of paramount importance in dealing with dust of toxic materials. Dust is part of the normal environment of man and city air usually contains approximately 500,000 particles per cubic foot, which is equivalent to about 1 milligram per cubic meter of air. In industry, however, amounts far in excess of these are frequently encountered. Examples of counts obtained during various surveys made by the United States Public Health Service are given in Table IV. Extensive surveys have established that there are few workmen indeed who are not exposed to amounts of dust greater than those which occur naturally. In considering the hygienic significance of this dust exposure of workmen, two factors are of the greatest importance; first, the chemical composition of the dust, and secondly, its concentration. The composition is determined by collection of a

TABLE IV [1]

AVERAGE DUST COUNT IN CERTAIN DUSTY TRADES

Industry	*Dust count in millions of particles per cubic foot of air*
Slate finishing mills:	
Floormen	1,598.0
Loaders	1,276.0
Disc-crusher operators	312.8
Talc mining:	
Jack-hammer drillers	2,159.8
Muckers	44.8
Talc finishing mills:	
Crushers and cylindermen	14.0
Packers	50.1
Marble carvers	19.1
Marble cutters	32.8
Granite quarrying:	
Leyner drillers	144.4
Jack-hammer drillers	112.1
Plug drillers	36.9
Cement mill, average of all operations	26.0
Granite cutting:	
Hand pneumatic-tool operatives	59.2
Machine pneumatic-tool operatives	35.9
Attendant labor	17.0
Anthracite coal mining:	
Miners and miners' helpers	231.5
Attendant labor	31.1
Bituminous coal mining:	
Coal cutters and coal loaders	112.3
Attendant labor	3.9
Silverware manufacturing:	
Dusty processes	5.2
Non-dusty processes	1.7
Municipal dust (street cleaners):	
Congested district	4.1
Residential district	1.8
Cotton industry:	
Carding room	8.6
Weaving and spinning room	4.5

Bloomfield, J. J., and Dallavalle, J. M., "The Determination and Control of lustrial Dust," Public Health Bulletin No. 217, April 1935, p. 42.

suitable sample and subsequent chemical analysis, while the concentration is determined and expressed in several fashions, depending upon the composition of the dust. In the case of dust of relatively high toxicity and immediate effect, the concentration is usually determined and expressed in terms of milligrams of the toxic material in a unit volume of air. Dusts which are not easily susceptible of chemical analysis, or are of low toxicity, are usually determined and expressed in terms of number of particles per unit volume of air. Dusts which are inflammable or explosive are usually reported in terms of weight of dust per unit volume of air without regard to the composition of the dust at the time of collection.

It is in the estimation and control of the hygienic hazards associated with dust that the engineer and the physician are jointly concerned. The methods for measurement of dust are matters of concern to both, while the designing and maintenance of equipment to reduce existing hazards falls usually upon the engineering staff. The medical consultant can set the level of permissible dustiness, but it is up to the engineer to obtain the results. The adequacy of his results can be gauged only by repeated estimations of the dustiness of the air after the installation of appropriate equipment. In the case of the toxic dusts, which are estimated in terms of milligrams of toxic substance per cubic meter of air, the establishment of safe levels of concentration has in most cases been carried out or can be done readily in a given industry or operation. Where the effects of harmful materials are rapid, or where physiological changes or measures of excretion of harmful substances can be used as a gauge of significant absorption, the setting or modification of a standard can be carried out without too much difficulty. However, when one is dealing with materials of low toxicity or with the silica-bearing dusts which produce characteristic lung changes, the effects of the dusts may not be apparent until many years have elapsed since exposure. As a consequence standards can be set only with difficulty and modifications made only after long periods of study and observation. A further difficulty in the consideration of these dusts, especially silica, is the fact that the concentration is expressed in terms of numbers of particles per unit of air and the number of particles obtained and counted is dependent to a great degree on the method selected for collecting the sample and counting it. More than fifty instruments and methods have been used for the collection and counting of dust in air. Many are impractical and all vary in their results when compared to one another. This variation is particularly pronounced when dusts of different mean-particle size are counted or when different optical systems are used for the counting. As a consequence it is not yet possible to correlate the results obtained with one instrument with those obtained with another or with standard figures unless identical instruments are used or unless appropriate formulae for conversion have been obtained. The results of a dust determination in air must be interpreted in terms of the instrument used in obtaining the sample and the optical system used in counting.

At the present time, there are a number of instruments in general use. The one most frequently used and the one upon which most standard figures are based is the Greenburg-Smith impinger. In this instrument the dust is collected in water or some other liquid medium by drawing the air to be tested through the liquid in a flask, the wetting of the dust particles being done by means of an impinger tube, which is essentially a tube with a narrow orifice situated at a fixed distance (5 mm.) from an impingement surface (the bottom of the flask). The high velocity imparted to the air by the orifice of the impingement tube accomplishes sufficient wetting of the particles on the impingement surface and they are retained in the liquid. The instrument is quite efficient for particle sizes above 1 micron. Recently a micro-impinger has been developed which gives essentially the same results as the full-sized instrument. The instrument is lighter, the cost is less, and the heavy equipment for securing the suction flow can be dispensed with where other sources of suction are available.

Electrical precipitation devices operating upon the principle of the Cottrell precipitator in which high voltages are used to discharge the electrostatic charges on the particles are perhaps the most efficient of the sampling devices.

Thermal precipitation devices, in which dusty air is deposited on a small cell upon glass cover slips by means of a hot wire, are quite efficient. (Their use at present is limited to Great Britain.) Air impingement methods in which the dust is deposited upon clean or oiled slides by means of sudden compression and expansion of the sample have been in use for a number of years. A convenient instrument called the Bausch and Lomb Counter which is based upon this principle has been developed recently in the United States. An optical system for counting is an integral part of the machine and the samples, which are collected as a ribbon on a glass disc by means of impingement, are simply rotated within the machine into the field of the microscope for purposes of counting. Counting by this instrument is done in the dark field which may reveal some 20 to 100 times the number of small particles in the smaller-sized groups.

Space does not permit detailed comment upon the relative merits or uses of the various types of instruments. Not only are they frequently modified but the continuing improvement in the reduction of dustiness indicates that the need may well be for more and more sensitive instruments. Most instruments have a definite range of optimum usefulness. Those which will retain the very small particles have limited use when the dustiness is excessive, while those such as the impinger which are very efficient with the larger particles are limited when the mean size of the particles is small and danger from loss of particles by solution becomes increasingly great as the size of the particle is reduced. For details on instruments and a general discussion of industrial dusts the reader is referred to the book of Drinker and Hatch.[2]

Dust Control. The necessity for the control of toxic dust is apparent, and for those dusts of low toxicity and delayed effect such as silica dust, the establishment of permissible standards of

[2] Drinker, Philip, and Hatch, Theodore, *Industrial Dust: Hygienic Significance, Measurement, and Control*, New York, McGraw-Hill Book Co. (1st edition, 1936).

dustiness has provided a basis for the institution of proper control measures. In the case of inflammable or explosive dusts the need for adequate control is likewise apparent. Even in the case of those dusts which have not been shown to be harmful, the installation of measures of dust control has been found to be beneficial. Excessive quantities of dust in the working atmosphere are psychologically disturbing to the workman. He suspects atmospheric pollution and not only fears injury but also suffers from reduced comfort and efficiency. The desirable features of cleanliness alone should justify reasonable control of these dusts. In industrial operations the commonest method of controlling dust in the working atmosphere is by removal of the dust at its source. In most cases this is accomplished by local exhaust ventilation. This method has many advantages. It not only removes the dust at its source and helps maintain the general cleanliness of the plant but when properly constructed it is also very highly efficient in the recovery of materials. The money thus saved may be applied to reduce in part the cost of installation. The principle is applicable not only to dust but equally to smoke, fumes, gases, vapors, or mists, so that many potential hazards may be removed by the one protective mechanism. In mobile operations such as drilling or with types of equipment to which local exhaust ventilation is not applicable, wetting of the dust at its source by means of streams of water or sprays will control the evolution of dust to varying degrees. This method is not as efficient as a properly designed exhaust system but under certain conditions it will reduce the dustiness to a safe level. Isolation of the dusty operation by means of chambers or enclosures may be indicated in operations where exhaust ventilation either is not economically feasible or cannot be satisfactorily applied. In these cases the isolation of the dusty hazard into one enclosure for which ventilation may be provided at least keeps the air of the plant in general free from the dust. In some operations local exhaust ventilation together with enclosure of the entire machinery may be very effective. In some operations, as for instance in reaction chambers or in discontinuous grinding processes, where the greatest hazard occurs during operation of the machinery or while the temperature is elevated, danger can be eliminated by the use of local exhaust ventilation combined with housing of the equipment and control and observation of the operation from outside the chamber. The great differences in the kinds of operations and materials create varying situations to which one control method may be better adapted than others. More than one measure of local control may be required, and indeed in some instances no local measures of control are adaptable. In these cases protection of the workmen by respiratory devices is necessary (Cf. chapter XII). These are essentially temporary measures and should be used only where exposure is intermittent. For continuous exposure and regular use during work, they should not be used. Not only must they be constantly tested for efficiency but their use is attended with inconvenience and discomfort and constant supervision is necessary to assure their being worn.

Pneumonoconioses. Distinguished from the dusts which have appreciable solubility in body fluids and exert general toxic effects characteristic of the compounds of which the dusts are formed, there exists a large class of dusts of low solubility in water and body fluids. Inhalation of these dusts leads to damage to the lungs, although no immediate general poisonous effect may be noted. Many of this latter group of dusts on prolonged inhalation will produce a fibrosis of the lung called pneumonoconiosis, a condition in which the thin, distensible, elastic tissue normally present in the lung and alveoli is involved by increasing amounts of fibrous or scar tissue. Replacement of normal lung tissue by fibrous tissue leads to interference with gaseous exchange and markedly reduces the expansibility of the lung; furthermore, in certain of these dust diseases of the lungs there is a markedly increased susceptibility to tuberculosis.

Pneumonoconiosis is a general term; different varieties are distinguished on the basis of the type of dust producing the fibrosis. Organic dusts such as those from vegetable fibers—cotton, hemp, etc.—produce a more or less characteristic thickening of the lungs, associated with heavy local deposits of the dust. Anthracosis, which is caused by the breathing of coal dust or finely divided carbon, is common among coal miners. Asbestosis is caused by the breathing of fine particles of asbestos dust. In this disease not only is there a heavy deposit of the asbestos dust in the lungs but a general lung fibrosis follows and disability is marked. Metals in certain states of subdivision may also cause pneumonoconiosis. The most important of these are siderosis, caused by the breathing of iron particles, and chalcosis, which is produced by copper dust. By far the most important form of fibrosis of the lungs, however, is that produced by silica dust and known as silicosis.

Silicosis is unique among the pneumonoconioses for several reasons. Silica is widely distributed in nature, both free and combined, and is found abundantly in rocks, ores, building materials. and mineral products. The abundance of silica and the wide distribution of silica-bearing materials in industry results in the exposure of a larger number of men to silica-bearing dust than to any other type. It is estimated that in the United States alone approximately 1,000,000 workmen are exposed to silica dust in varying amounts, the exposure being sufficiently severe in the case of about 500,000 to make possible the occurrence of silicosis. It is further estimated that approximately 100,000 of the total number of exposed workers have some degree of silicosis, although only 4,000 or 5,000 of these manifest any disability. Not only are the numbers of workmen exposed to silica-bearing dusts greater than in the case of other kinds of dust but silica dust seems to be more damaging in some respects than many others. Dusts such as those from carbon, slates, cement, limestone, and many organic dusts set up a diffuse fibrosis of the lungs in which the dust itself is deposited in high concentrations. Some of the dust is dissolved and carried away while most of it remains in a relatively inert condition. Silica dust, on the other hand, sets up a reaction in the lungs with the development and formation of a large amount of fibrous tissue which later forms a series of nodular structures about the silica deposits. These fibrous nodules and the diffuse general fibrosis cause great limitation of the expansibility of the lungs. The chest no longer expands freely, there is shortness of breath, the capacity for work is lessened, and with it there is a definitely increased susceptibility to tuberculosis. Though silica dust is encountered in many industrial operations and widely outside industry, the hazard of silicosis is particularly acute in certain operations. Important among these are metal mining, mining of anthracite coal (in which the coal veins are associated with rock bearing a high percentage of silica), in quarrying, drilling, and tunneling operations in granite, ganister, and in some forms of sandstone, in smelting and refining, pottery industries, glass works, and in all operations involving sand blasting, grinding and buffing where sand- or silica-bearing grinding surfaces are used. In many of these operations the dust is of mixed composition and the hazard of the dust from the point of view of the production of silicosis is dependent upon several factors: (1) the chemical composition of the dust, that is to say, the percentage of free silica, (2) the concentration of the dust, which is usually measured in terms of number of dust particles per cubic foot of air, and (3) the mean size of the particle. With silica dust, as with other dusts mentioned above, particles greater than 10 microns in diameter are not considered significant. They settle quickly and when inhaled into the lungs are usually entrapped in their passage by the secretion on the walls of the bronchi and are removed with the removal of the secretion. The arbitrary standard which has been set up as representing the safe level of concentration of silica dust in air is 5,000,000 particles per cubic foot (collected by the impinger method and counted in the light field). Information accumulated since this standard has been set up indicates that it represents a safe level of concentration and moreover is feasible of accomplishment by good engineering methods. This figure of 5,000,000 refers to dust particles composed of pure silica. Where the dust contains less than 100% free silica, the maximum permissible concentration in the air can be arrived at by multiplying the percentage of free silica in the total dust count by the total number of particles. If the result is below 5,000,000 the working conditions may be considered safe;

above 5,000,000, they are dangerous. For example, if a dust contains 50% free silica with an average total dust count of 10,000,000 particles per cubic foot the product of the percentage concentration of free silica and the total dust count would equal 5,000,000, which is the upper limit of safe concentration. It is to be remembered that all sampling and counting is to be done with the same kind of instrument and the same methods as were used in arriving at the standard figure. Whenever other methods are employed the results must be converted into figures comparable to those obtained from impinger counts. In any case dust concentrations greater than 100,000,000 particles per cubic foot are unsatisfactory and should not be permitted regardless of the silica content.

Silicosis, like the other pneumonoconioses, comes about slowly. Usually about seven years of exposure are required before definite evidences of disease are manifested. Only unusually severe exposure will cause symptoms to appear earlier than this. The gradual deposition of the dust and the low solubility of the silica in the body fluids very gradually produce the irritative conditions which cause the increasing development of fibrous tissue. It has been assumed that it is the solubility of silica which determines the production of silicosis. The hardness and sharpness of the particles were held for a time to be the cause, but it has now been established that carborundum and other artificial abrasives of a hardness and sharpness far in excess of that of silica dust will not produce the condition of silicosis.

Although silicosis is one of the oldest industrial diseases, much remains to be learned concerning the factors which influence its occurrence. It has been established that about 70% of the particles found in industrial dust are between ½ and 3 microns in diameter and that dust particles larger than 10 microns are not hygienically significant, but there are enormous numbers of particles associated with these dusts which are less than ½ micron in diameter and are not usually included in counts because they are outside the optical limits of the methods of counting. The physiological effect of these particles has yet to be investigated, and more needs to be known concerning the effects of the silica compounds of varying degrees of solubility in body fluids. Other dusts of organic or inorganic nature associated with silica dusts seem to influence the production of silicosis. Therefore when one considers the potential hazard of silicosis in any industrial operation, a complete survey of the situation is necessary before any conclusions are justified. In addition to the collection of samples of dust which should be counted and subjected to chemical analysis, such a survey should also include a careful medical study of the employees to establish evidence of existing injury or toxic effect. The distribution of men in the industry should be studied and a very careful analysis made of the labor turnover. Serious hazards may occasionally be overlooked because of the use of temporary labor or of high labor turnover at the particular work. A system for making this study, as well as the details of the method of study of the general sanitary conditions, can be obtained from the Bureaus of Industrial Hygiene maintained in most of the industrial states. In addition, advice on the actual carrying-out of industrial surveys is offered as a service by insurance companies which carry large amounts of industrial insurance.

CHAPTER XII

RESPIRATORS, GAS MASKS, AND BREATHING APPARATUS

The function of all these devices is protection of the respiratory tract from harmful materials present in the air. The offensive material from which the workman must be protected may be dust, smoke, fumes, vapors, or gases; breathing apparatus is further indicated in situations where the oxygen content of the air is below 16%.[1] Most of these devices cannot be relied upon to give complete protection from hazards of long duration and they are essentially supplementary to other control measures. As equipment for eliminating dust and toxic fumes and vapors at their source is expensive, plant managers tend to employ some type of breathing apparatus in preference to constructing ventilating equipment. In spite of the fact that constant supervision is required wherever such devices are used and although they are not in all cases satisfactory, there is nevertheless a definite field for respirators, mainly in situations where exposure is intermittent and the hazard, though definite, is not of a severe type. Different types of protective breathing equipment have been designed as safeguards against the various types of hazards and the principles upon which they operate vary. Some function by removal of the harmful material from the inhaled air, either by physical or chemical filtration, while others isolate the workman from the surrounding air, pure air being supplied through systems of hoses or from compressed or liquid oxygen incorporated in the equipment. Some, such as those which isolate the workman, offer protection against all risks while others are more limited in their uses; and many, such as the canister type which depends upon chemical combination and filtration for efficiency, are

[1] Cf. p. 159, footnote, 160.