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# The Analytical Chemistry *of* Industrial Poisons, Hazards *and* Solvents

BY

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# CHAPTER I

# INDUSTRIAL HYGIENE AND INDUSTRIAL POISONS

## *1. Introduction*

The vast expansion of chemicals used both in industry and in the home has made the study of these chemicals and their effect on our health of immediate importance. One need only think of the greatly increased use of refrigerants, fumigants, insecticides, fungicides, germicides, organic solvents, diluents and plasticizers, plating solutions, and the possible use of war gases to realize how widespread the use of chemicals is and how closely they affect us both in commerce and at home.

The World War of 1914-1918 very likely was the greatest single factor in the introduction of care in the manufacture of organic materials, for it drew an impressive picture of the dangers of gases and vapors. It certainly stressed the need for protection against these hazards. The huge increase in the production of organic chemicals to meet the needs of this war as explosives, chemical agents and other war matériel made it necessary to learn how to protect both workers and soldiers using or subjected to this matériel.

It has become increasingly evident that the control, regulation and prevention of industrial hazards lies in the hands of the physician, sanitary engineer or inspector, and the chemist or chemical engineer. Governmental agencies must necessarily play their part. The earliest and unquestionably the most important progress of the past in recognizing, treating and remedying industrial hazards was made by the medical profession. In more recent years the role of the sanitary engineer and the chemist has become relatively more important. Though the control and regulation of industrial hygiene should, perhaps, remain in the hands of the physician, the prevention of industrial hazards is mainly a function of the engineer and chemist.

The chemist supplies the necessary analytical devices and methods. His results indicate how much of a toxic, noxious, or hazardous material is present. The ability to estimate quantitatively the amount of a toxic or otherwise hazardous material is a most important factor in the lessening of any menace to the health of employees. Based upon these quantitative analytical results, the corrections and improvements needed to alleviate a hazardous condition can be made. The knowledge of the amount and location of contamination is of inestimable value in designing the means of prevention and elimination of the poison. In testing the air of a large garage, it was found that ten feet away from the exhaust of a running car, there were 1000 parts of carbon monoxide per million parts of air [0.1 per cent by volume] present, whereas thirty feet away from the same car it was impossible to get a positive test for this poisonous gas.[1] The prevention of hazard in such an instance and in analogous cases needs special design and treatment that can more readily be obtained with the aid of the analysis made by the chemist.

Where new materials or substances are developed or where well-known substances are used for new procedures, the chemist can devise methods for the estimation of these substances taking into consideration the method of use.

## 2. *Industrial Hygiene*

Industrial hygiene is an applied science as distinguished from the theoretical sciences, such as mathematics or physics. Its aim is to protect and improve the health of workers. As an applied science, it has a number of major subdivisions among which may be mentioned:

Industrial Medicine which includes industrial medical care, prevention of industrial illness, hospitalization and medical aspects of compensation.

Industrial Mental Hygiene which includes behavior of the worker and the mental state and health of workers.

Industrial Management which includes hours of labor, rest periods, adequate food, supervision and the general economic relationships of laborers and their health.

Industrial Sanitation which includes environment of the worker, buildings, machinery, air conditions, ventilation, exhaust and in general all engineering aspects.

Industrial Hazards which includes detection and estimation of hazards; prevention, diminution and elimination of hazards, toxicity, etc.

Our main study will be with the one section of industrial hazards that

[1] Sayers and Davenport, *U. S. Pub. Health Service*, Bull. No. 195 (1937).

deals with the detection, estimation and determination of industrial poisons and other harmful industrial substances.

### a) Historical Background

Poisons were known and used from time immemorial. The Bible and ancient myths make reference to such use. But poisoning due to occupation was not so clearly defined in the minds of ancient and medieval men. Hippocrates [about 460-357 B. C.] described lead poisoning as an occupational disease only in the smelting of metals. The poisonous qualities of sulfide ores and carbon monoxide were known to the Greeks and Romans. Avicenna [980-1036], the Arabian writer of the eleventh century, recognized the poisonous properties of arsenic trioxide. In somewhat later medieval times, it was known that arsenic and lead compounds were toxic. The first printed book (*Morbi metallici*) on industrial hazards was written by Ulrich Ellenbog of Feldkirch about 1524 and discussed the hazards of lead and mercury. In the seventeenth century, Ramazzini [1633-1711, born in Carpi, died in Padua] regarded as the "father of industrial hygiene," wrote *De Morbis Artificum*[2] (Diseases of Tradesmen).

Though some few books were written and some physicians were aware of the problem, actually there was practically little known, done, or thought about with respect to industrial hygiene until recent times.[3] Dr. Charles Turner Thackrah, a British physician, was one of the earliest observers and commentators on industrial hazards and hygiene. He wrote a short but significant book, published in 1831, which was entitled: "The Effects of the Principal Arts, Trades, and Professions, and of Civic States and Habits of Living on Health and Longevity, with a Particular Reference to the Trades and Manufactures of Leeds, and Suggestions for the Removal of Many of the Agents which Produce Disease and Shorten the Duration of Life."[4]

Had England listened to this pioneer for the betterment of working conditions, the cause of safe and adequate industrial care would have been advanced at least fifty years. It was not until much later that interest in this major problem was again aroused. Dr. Thackrah unfortunately died young and many of his ideas died with him.

Hermann Eulenberg wrote a text on the noxious and poisonous gases in 1865 ("Lehre von den schaedlichen und giftigen Gasen", Braunschw[illegible] bei Vieweg) and

[2] Goodman, *Diseases of Tradesmen by Bernardino Ramazzi[illegible]*, [illegible] York 1933.
[3] Legge, *J. Ind. Hyg.*, 1, 475 (1919-20).
[4] Legge, *J. Ind. Hyg.*, 1, 578 (1919-20).

later followed this with a more general text on industrial hygiene ("Handbuch d Gewerbe—Hygiene auf experimentelles Grundlage," Verlag von August Hirschwa 1876).

The United States in the past lagged behind o: r nations in i interest in industrial hygiene. But interest has fin lly been arouse matching that of any other country. Governmental regulation of indu: trial hazards in the United States is nevertheless practically a recer development. One need but recall that it was only in 1912 that the Esc law was passed. This law prevented the use of white phosphorus (yello phosphorus) in matches by placing a prohibitive tax on its use for th purpose.[5] This substance is the cause of the horrible phossy jaw of matc workers.

It has been known for centuries that workers in dusty atmospher were less healthy than those not exposed to dust. More particularly, was known that atmospheric dust was a cause of pulmonary fibrosis b investigators interested in industrial hygiene and occupational disease: The United States Public Health Service and Bureau of Mines, how ever, did not interest themselves in this problem until 1914. Thes agencies published the first report of their joint study made among th hard-rock miners of the Joplin (Missouri) district in 1915.[6] Since tha report much important work has been done by these agencies in the stud of this hazard and in developing devices and procedures for its elimina tion. The term "silicosis" that is applied to the illness brought about b exposure, generally over a period of years, to inhalation of silica dust, i now a household word. To some medical authorities, this term is pref erable to the term "miners' phthisis," because it indicates the chief caus of the disease and does not stress the wasting symptom which may no always be present in a silicosis victim. The condition of pulmonar silicosis, one of many types of pneumonokonioses, develops more rapidl the more intensive the exposure and the finer the particles of silica dus encountered.

It is probable that organic dusts do not cause pneumonokonioses bu unquestionably silicosis is not limited to mines, quarries, and knife fac tories. In almost every modern factory in which steel and iron are prin cipal raw materials for the manufacture of other materials, there is th possibility that some steps in the process of manufacture will present a industrial hazard because of the silica dust produced.[7]

[5] Hamilton, *J. Ind. Hyg.*, 1, 89 (1919-20).
[6] Greenburg and Bloomfield. *U. S. Pub. Health Service*, Reprint No. 1528 (1935).
[7] Britton, *J. Ind. Hyg.*, 6, 199 (1924).

An analogous type of pulmonary occupational disease is known as "asbestosis". It is caused by long exposure to asbestos dust.[8,9]

### 3. Governmental Problem

That industrial hygiene and the prevention of industrial hazards in the United States has at last become a recognized major problem is clear from the following quotation from an address given by Dr. R. R. Sayers, Chief, U. S. Bureau of Mines, on "Industrial Hygiene Activities in the United States." [10]

"The United States Census for 1930 shows that, at that time, there were approximately 49 million persons gainfully employed in the United States. Of this number, manufacturing, mechanical and mineral industries accounted for nearly 15 million workers. If the term "Industrial Hygiene" means the protection of the health of the worker, it is at once apparent that it is a major problem in public health.

"More important than specific occupational diseases associated with the industrial environment is the fact that the incidence of other diseases as tuberculosis, pneumonia and degenerative conditions are greater among the industrial workers than the general population. It has also been shown that the life expectancy of the industrial worker is less than that of the non-industrial worker.

"In recent years large industrial establishments have contributed much toward the protection of the health of their workers. However, as nearly 90 percent of the plants in the United States employ less than 100 persons, many establishments are not prepared to handle effectively the problem of industrial hygiene alone. It would seem, therefore, that the protection of the health of our workers is indeed an important health function and one which can be handled best through a governmental agency, such as a State or local department of health cooperating with the employers and workers.

"Responsibility for safeguarding the health of industrial workers rests chiefly with State and local governments. The Federal Government's agencies concerned with industrial hygiene are engaged in collection and dissemination of information, conducting field studies, laboratory research, and protection of the health of Federal employees."

An added factor in the furtherance of industrial health activities is the provision in the Federal "Wage and Hour" Act of 1938 which forbids the employment of children under 16 or boys or girls of 16 or 17 at hazardous or unhealthful work. This provision of the act will necessitate some determination as to whether an occupation [illegible] is not hazardous or unhealthful.

[8] Ellman, *J. Ind. Hyg.*, 15, 165 (1933).
[9] Sayers and Dreessen, *Am. J. Pub. Health*, 29, 205 (193[illegible]
[10] Sayers and Bloomfield, "Industrial Hygiene Activiti[illegible] the United States" *U. S. Pub. Health Service*, 1936.

### *4. Role of Chemist*

While all this has been realized by public spirited citizens and concientious civil workers and much work has already been done, even more actual work for protection needs to be accomplished before one can feel that the problem has been adequately attacked. In this, the chemist should play a most important role. Chemists and chemical engineers should be part of the personnel of every industrial hygiene division, be it of a large industrial establishment, of a medical unit, or of a governmental arm. The plant chemist could well employ part of his time in work that would lead to the diminution and elimination of hazards.

The employer should realize that adequate industrial hygiene, the prevention, diminution and elimination of industrial hazards and industrial poisoning is of direct financial importance to him. He gains because of better work obtained, for the prevalence of fatigue is diminished. Less time is lost due to illness. Expenses caused by the need of medical care and hospitalization are reduced to a minimum. The reduction in compensation losses alone is enormous. Sappington[11] notes that of the closed cases in the State of Wisconsin for 1936, "noxious dusts" with 71 cases accounted for only 6.6 per cent of the total number of cases of occupational disease disability indemnified during that year. However, the payment of compensation for these cases was $119,737.00 or 54 per cent of the total indemnity paid to the entire group.

Not only industry and commerce but every taxpayer, citizen and consumer is affected by proper industrial hygiene, for in the last analysis, the cost of every item and the governmental budget, itself, reflects the cost of compensation and the cost of care of the ill and the disabled. Not only does the individual worker gain from the adequate control of hazards and baneful substances but industry and commerce also profit.

The industrial hygiene chemist can aid in the diminution, elimination, prevention and cure of hazards and poisoning by being able to detect industrial poisons in concentrations far below any quantity that can cause an injurious or toxic effect. The ability to do this implies, in general, the ability to keep such concentrations down to harmless levels.

#### a) Differentiation of Industrial Hygiene Chemist from Toxicologist

The role of the industrial hygiene chemist should be differentiated from that of the toxicologist. Toxicology is that department of pathology or

[11] Sappington, *Medicolegal Phases of Occupational Diseases*. Chicago 1939.

will, consequently, fall into one or another of these group types of analysis.

### c) Effects of Industrial Poisons

The effect produced in and on the human body by a specific industrial poison will be discussed in the sections devoted to the methods for the analysis of that harmful substance. The damage arising from the inhalation, swallowing or absorption of an industrial poison may be either local or remote, and depends upon whether the material is a protoplasmic poison, whether it is caustic in reaction, or whether it is absorbed into the blood stream and carried to other centers which are in turn affected.[20,21]

Briefly, the effects of industrial hazards may be summarized as follows:[22]

1) Irritation of the mucous membranes—chlorine, nitrous fumes, sulfur dioxide, formaldehyde and others.

2) Alteration of the components of the blood—This effect is peculiarly the property of nitro and amido derivatives of benzene, arsine and carbon monoxide. Greenburg[23] and his coworkers state that the glycols belong to this group.

3) Action on the brain and nervous system—carbon disulfide and unsaturated carbon compounds.

4) Remote action on the metabolism, by action on organs and tissues—lead, phosphorus, tetrachloroethane, benzene, toluene and their nitroderivatives.

5) Action on the respiratory tract, such as action on the lungs—silica and asbestos dust.

Chemists are interested in the effects and symptoms of industrial poisoning because they are in immediate contact and control where poisonings of this nature are liable to occur. A physician is unlikely to see a case until it is too late to remedy or alter the industrial condition.[24]

Sayers, DallaValle and Yant[25] summarize more fully the effects of industrial poisons on the body.

[20] Fairhall, *J. Ind. Hyg. Toxicol.*, 18, 669 (1936).
[21] Sayers, *U. S. Pub. Health Repts.*, 53, 217 (1938).
[22] Legge, *J. Ind. Hyg.*, 2; 293 (1921).
[23] Greenburg, Mayers, Goldwater, Burke and Moskowitz. *J. Ind. Hyg. Toxicol.*, 20, 134 (1938) *N. Y. State Ind. Bull.*, 17, 269 (1938).
[24] Henderson and Haggard, *Noxious Gases*. New York [illegible]
[25] Sayers, DallaValle, and Yant, *Ind. Eng. Chem.*, 26, 12[illegible] [illegible]934).

**Action of Air-Borne Contaminants on the Body.** The action of su substances upon the body differ widely, but in general they may ha the following effects:

(1) They may cause skin irritation or dermatosis, or affect the muco membranes of the respiratory tract and eyes. This is true of acid vapo and certain caustic compounds easily distributed into the air.

(2) They may enter the lungs or be absorbed by the blood stream a produce systemic poisoning. Such substances as benzene vapors and le fumes or dust are typical examples. Substances in this group may ha their action on the blood, on the nervous system, or on the other bo tissues, and may produce deleterious effects when the exposure is seve or prolonged.

(3) They may produce asphyxia directly or indirectly as in the ca of excessive amounts of hydrogen cyanide, hydrogen sulfide, or carb monoxide. The action of these gases is varied. They may affect t respiratory center or the nerve endings in the lungs, causing a cessati of breathing, or, as in the case of carbon monoxide, so combine with t hemoglobin of the blood that oxygen cannot be furnished the tissues.

(4) They may, as in the case of certain dusts such as silica, grani and asbestos, cause a fibrosis of the lung tissue which predisposes tuberculosis.

(5) They may exhibit a combination of the above effects. Some su stances, such as nitrobenzene, not only cause a dermatosis when in co tact with the skin but may also act as systemic poisons.

(6) They may produce no demonstrable effects on prolonged exposu This is particularly true of cotton and some wood dusts.

**Skin Affections.** Industrial skin affections according to available st tistics account for the largest number of occupational disease claims any one group of causes.[26] Occupational dermatergoses have been clas fied by White[27,28] and Schwartz[29a].

**Acute and Chronic Poisoning.** Industrial poisoning is of two m types, acute and chronic. The first is induced by large or relativ massive doses of a poisonous or baneful substance. The latter is t result of repeated small doses. Thus for instance, acute poisoning fr carbon tetrachloride vapors does not result until an exposure to a co

[26] Sappington, *Medicolegal Phases of Occupational Diseases*. Chicago 1939.
[27] White, *J. Ind. Hyg.*, 8, 367 (1926).
[28] White, *Dermatergoses*. London 1934.
[29a] Schwartz, *U. S. Pub. Health Service*, Bull. Nos. 215 (1934), 229 (1936), 249 (19

# CHAPTER V

## THE CHEMICAL AND MICROSCOPIC ESTIMATION OF DUST

Dust is the greatest single industrial hazard. More workmen capacitated for duty because of exposure to dust than for any othe This incapacitation results from the damage to which the resp tract, in particular, and the body, in general, is subjected by inh of dust. It was explained in Chapter I that silicosis is caused by halation of dust which contains quartz. Silicosis is defined as a c disease of the lungs in which there is a marked increase of fibrous tissue. Associated with diseases like silicosis and asbestosis, which respectively, from the inhalation of silica and asbestos bearing du the increased morbidity and mortality rate from the respiratory di like tuberculosis, pneumonia, chronic bronchitis and pleurisy. Th halation of metal bearing dusts, such as lead dusts or fumes of mang and other metals causes general systemic poisoning of industrial wo It is important to realize that the silica bearing dust hazard is n any means limited to mining in, or working with high silica content or quarrying.

As an example of other industries in which this hazard exists we take that of foundry workers. In a report[1] of a study on the dust ha in foundries of New York State, it was found that 2.7 per cent of 1 workers had silicosis and that 4.5 per cent had fibrosis. Hatch[2] shows in foundries this hazard is due to the dispersion of silica dust from sand used in the molds and cores for metal castings. The steps of m pouring, of shakeout (that is, the removal of castings from molds, the core from the casting), and of sand reconditioning for further provide the opportunity, if not sufficiently guarded against to disp large quantities of silica bearing dust.

Fairhall[3] lists as the most important inorganic dusts and fume addition to silica bearing and asbestos bearing dusts, those of ars

[1] *N. Y. State Ind. Bull.*, 17, 61 (1938).
[2] Hatch, *N. Y. State Ind. Bull.*, 17, 114 (1938).
[3] Fairhall, *J. Ind. Hyg. Toxicol.*, 18, 669 (1936).

lead, phosphorus, manganese, zinc, hexavalent chromium compounds, fluorides, silicofluorides and the basic salts of calcium and barium hydroxides. Among the more important organic chemical dusts he lists *p*-nitroaniline, dinitrobenzenes, chloronitrobenzenes, picric acid, nitronaphthalene, *p*-phenylenediamine and tar dust.

There can be no question that the diminution of the dust hazard in all trades will result in a corresponding diminution of morbidity and mortality from tuberculosis and other respiratory diseases.

## A. Definition of Dusts, Fumes, Smokes, Mists and Fogs, and Vapors

Particles dispersed in the atmosphere both of the outside and of the workshop may be classified into a number of groups based on particle size, degree of dispersion, and whether they are accidentally present in the atmosphere due to some mechanical or chemical process of dispersion or whether they are normally present. The particles normally present in the atmosphere are due to the action of the winds, rain, tides, variation in weather, volcanoes, meteoric dust and from the decomposition of vegetation and animal matter. The particles accidentally present in the atmosphere are those which have come about through the development of civilization. Every fire, whether for the production of heat or of power, every grinding or rubbing action, and in general all mechanical friction, industrial and constructional activity creates dust. For the purposes of the study of industrial dusts and air pollution, atmospheric components, other than the normal gaseous components, can be classified as particulate and non-particulate matter. The particulate matter consists of Dusts, Fumes, Smokes, Mists and Fogs. The non-particulate matter consists of Vapors and Gases.

### *1. Dusts*

Dusts may be defined as aerosols of a particular type, that is they are disperse systems in which air is the continuous phase or the dispersion medium and some solid material is the dispersed phase or the dispersoid. Dusts are sometimes called colloidal systems but such a definition is too strict, for in the main dusts are not true colloidal systems even though they are disperse systems. They settle out, whereas a true colloid will not settle.

Broadly speaking atmospheric dusts are dispersions of solid materials in air. The particles of which they are composed vary in size from the

In the analysis of the gross components of air or of mine gas or fuels, such as natural gas and producer gas there are but a few well known components of these gas mixtures for the absorption of which but few absorbents are used. For complete details concerning the analysis of gas, the reader is referred to the bibliography at the end of Chapter XI, page 357.

The principal absorbing solutions used in the analysis of gross components of gas mixtures are: sulfuric acid, potassium hydroxide, silver nitrate, pyrogallol, cuprous chloride, acid ferrous sulfate, nitric acid and bromine.

In the analysis of industrial hazards the number of substances used as absorbents is very much greater. Each determination notes the absorbent to use and the concentration that will give a relatively high efficiency. Table 4 lists the device, absorbing reagent and the efficiency of absorption for some of the gases and vapors commonly sampled.

## References


Fieldner, Oberfell, Teague and Lawrence, *Ind. Eng. Chem.*, 11, 519 (1919) "Methods of Testing Gas Masks and Absorbents"

Elkins, Hobby and Fuller, *J. Ind. Hyg. Toxicol.*, 19, 474 (1937) "Determination of Atmospheric Contaminants"

Taylor, *Treatise on Physical Chemistry*. New York 1931.

Zhitkova, Kaplun and Ficklen, *Poisonous Gases*. Hartford, (1936).

Prausnitz, *Ind. Eng. Chem.*, (Anal. Ed.) 4, 430 (1932).

Getman and Daniels, *Outlines of Theoretical Chemistry*. New York 1937.

*Am. Pub. Health Assoc. Yearbook* (1939-40) p. 92 "Report of Sub-Committee on Chemical Methods in Air Analysis. Sampling and Sampling Devices."

submicroscopic to the visible. Drinker and Thomson[4] define dusts as particles or aggregates of particles, 150 [150 μ] to 1 micron [1 μ] in diameter, that are thrown into the air by mechanical agencies during the processes of grinding, crushing, blasting, drilling, and other industrial and constructional processes. One micron is equivalent to 1 μ, that is one-thousandth of a millimeter [0.001 mm.]. Expressed in other units, one micron is equivalent to $1 \times 10^{-4}$ cm., that is one-ten thousandth of a centimeter and to 10,000 Å, ten thousand Ångstrom units.

For the industrial hazard aspect, dusts may be considered as particles or aggregates of particles suspended in the atmosphere, of some size that is capable of being inhaled.[5] This restricts the particle size to the range of 0.5 to 10 μ.

The particle size of true colloidal systems is arbitrarily set as that of particles having diameters between 0.001 μ and 1 μ. Those disperse systems having particles smaller in size are generally considered true solutions and those having particle sizes larger than 1 μ are generally considered ordinary matter. Thus we see that only in the lower limits of particle size do dusts fall within the definition of colloidal systems.

### 2. Fumes

Fumes are colloidal systems which are formed from chemical reactions or by processes like combustion, distillation, sublimation, calcination and condensation. The particle size varies from 0.2 to 1 μ. Examples of fumes are the disperse systems formed from burning zinc or magnesium with the formation of zinc and magnesium oxides; the formation in air of ammonium chloride from the reaction of ammonia and hydrogen chloride; the reaction and condensation of water with titanium tetrachloride and burning phosphorus.

### 3. Smokes

Smokes are colloidal systems which are generally formed by the incomplete combustion of carbonaceous and other material. Particles of a smoke are generally less than 0.3 to 0.5 μ in diameter. Drinker and Hatch[6] use the word with particular reference to the disperse systems that are organic in origin, such as the smoke from burning tobacco, wood,

[4] Drinker and Thomson. *J. Ind. Hyg.*, 7, 261 (1925).
[5] Bloomfield and DallaValle, *U. S. Pub. Health Service*, Bull. No. 217, (1938).
[6] Drinker and Hatch, *Industrial Dust*. New York 1936.

il, coal, etc. Necessarily, as is clear from the chemical warfare point of iew, a prerequisite of smoke is that it have a definite degree of optical lensity.

### 4. Mists and Fogs

Mists and fogs are disperse systems in which the particle size varies greatly. They are akin to fumes rather than to smokes. They carry the implication of a liquid rather than that of a solid dispersed in the atmosphere. They are generally formed by the condensation of water vapor on nuclei such as submicroscopic particles of dust or gaseous ions, or by the atomization of liquids.

### 5. Vapors

Vapors are gaseous bodies which are formed from liquids by increase of temperature but which readily resume their fluid form because of decrease in temperature.[7] Obviously, as true vapors they form true solutions with the atmosphere. Our interest in them lies in the fact that while they do form true solutions with air in their vapor state, as soon as they regain their liquid state they form mists, fogs and fumes.

## B. Classification and Physiological Action of Dusts

It is, as has been explained, possible to classify dusts according to particle size, according to origin and to place them into two main groups according to physiological action, namely, those which cause respiratory disorders and those which cause systemic poisoning. It is of value, however, to classify dusts with respect to physiological action on a broader basis. Thus Oliver[8,9] divides dusts into those which have a mechanical and irritant action, and those of the chemical and toxic, or caustic types.

Thompson[10] divides the physiological action of dust on human beings into four types:

1) Mechanical obstruction of air passages.
2) Laceration of mucous membranes.
3) Conveyance of toxic material into the system.
4) Conveyance of germs into the system.

[7] Flury and Zernik, *Schaedliche Gase*. Berlin 1931.
[8] Goldberg, *Occupational Diseases*. New York 1931.
[9] Oliver, *Diseases of Occupation*. New York 1916.
[10] Thompson, *Occupational Diseases*. New York 1914.

Actually dusts cannot be placed into groups which show a specific type of physiological action because no dust is composed of a single variety of material.

The physiological response to dusts is grouped as follows by Drinker:[11]

1) Specific lung diseases such as silicosis and asbestosis.

2) Toxic systemic effects caused, for example, by breathing of such toxic dusts as lead, cadmium and radium.

3) Metal-fume fever which follows the inhalation of finely divided particles such as zinc oxide.

4) Allergic manifestations which result from breathing dusts such as pollen and certain types of pulverized wood and flour.

The physical, chemical and physiological actions of dusts may also be grouped as in the following classification:[12]

1) Cutting dusts. These are in the main composed of minute crystalline or amorphous particles which have sharp cutting edges such as sand, stone, lime, steel, asbestos, glass, minerals, etc.

2) Irritant dusts. This group is composed of vegetable and animal matter such as wood, ivory, hair, and fibers such as wool, silk, cotton, flax, hemp, and the fabrics and cordage made from them.

3) Inorganic poisons and compounds of mercury, copper, arsenic, lead and even soluble compounds such as the sulfates of iron, copper and sodium.

4) Organic poisons such as tobacco, and in general, organic compounds and drugs.

5) Obstructive and irritating dusts such as soot, coal, flour and starch.

It is readily seen that this classification also falls into the grouping of physical action (mechanical and irritating) namely 1, 2, and 5, and the chemical action, 3 and 4. It must be borne in mind, however, that dusts act both physically and chemically in some measure on the body.

A more comprehensive classification of dusts according to physical, chemical and physiological effects is that of Sayers.[13]

A) Organic dusts

Organic dusts are those which contain carbon, and were originally supposed to come from organized substances derived from animal or plant life. Thousands of organic substances, are made synthetically by chemical processes, such as dyestuffs, explosives, drugs and similar substances.

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[11] Drinker, *J. Ind. Hyg. Toxicol.*, 18, 524 (1936).
[12] *N. Y. State* Soc. Bull. No. 90, 1918.
[13] Sayers, *U. S. Public Health Repts.*, 53, 217 (1938).

# SUBJECT INDEX