however, both ingestion and skin contact are of relatively minor importance in industrial poisoning insofar as dusts, fumes, and mists are concerned.

Origin and Properties of Particulate Matter

9. The dust normally present in the atmosphere has a beneficial effect in screening out some of the harmful rays of the sun. Inhalation of this dust may not be harmful because either the dust may be nontoxic or body mechanisms capture, remove and eliminate or isolate the small amounts of dust trapped in the lungs. Air pollution, radioactive fallout, pollens, and similar conditions may have an adverse effect on some individuals. Also, when the air breathed contains excessive amounts of dust, the body has difficulty in handling the load and dust may remain in the lungs.

Sources

10. The term *dust* as used in industry is generally applied to air-borne solid particles that range in size from 0.1 micron to 25 microns (one micron = 1/10,000 centimeter = 1/25,000 inch). Process dusts below 0.5 micron in size are rare. Dusts above 5 microns in size usually will not stay air-borne long enough to present an inhalation problem.

11. Dust may enter the air from various sources. It may be dispersed when a dusty material is handled, such as when lead oxide is dumped into a mixer or a product is dusted with talc. Dust may be formed and dispersed when solid materials are reduced to small sizes in processes such as grinding, crushing, blasting, shaking, and drilling. In these processes, the mechanical action of the grinding or shaking device supplies a source of energy to disperse the dust formed (Figure 1).

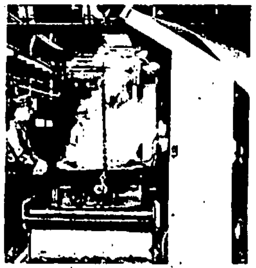

Figure 1. Dust from foundry sand is generated during the shake-out of castings. The mechanical action of the shake-out machine disperses the dust. Path taken by the dust particles as they are drawn into the hood shows the efficiency of the local exhaust system. (Courtesy American Foundrymen's Society)

12. When a solid such as a metal is heated to a temperature high enough to volatilize it, the volatilized matter later condenses in cooler air to form a *fume* (Figure 2). The solid particles that make up a fume are extremely fine, usually less than 0.5 micron in size. In some cases, the hot material reacts with the air to form an oxide. Examples are lead oxide fume from smelting and iron oxide fume from arc welding. Also, a fume can be formed when a material such as magnesium metal is burned or when welding or gas cutting is done on galvanized metal.

13. A *mist* is formed when a finely divided liquid is suspended in air. An example is the oil mist produced during cutting and grinding operations.

14. *Smoke* may be formed by the incomplete combustion of organic materials. Smoke generally contains droplets as well as dry particles. Tobacco, for instance, produces a wet smoke composed of minute tarry droplets. The size of the particles contained in tobacco smoke is about 0.25 micron.

15. Radioactive dust may be dispersed in the same ways as other industrial dusts. Radium, thorium, and other radioactive elements are present in extremely minute amounts in the atmosphere.

Magnitude of particles

16. When a solid is broken into finely divided particles, its surface area is increased many times. For example, 1 cubic centimeter (0.061 cubic inch) of quartz in the form of a cube when crushed into 1-micron cubes will give 10^{12} (1,000,000,000,000 or one trillion) particles with a total surface area of 6 square meters (9,300 square inches), as compared with 6 square centimeters (0.930 square inch) for the original cube.

17. When a solid is broken into finely divided particles, the volume occupied by the mass is also increased because of the voids between the particles. A dust concentration of 50 million particles per cubic foot of air (mppcf), resulting from 1 cubic centimeter of material reduced to particles 1 cubic micron in size, will occupy an air space of 20,000 cubic feet.

18. Even smaller amounts of toxic dusts, fumes, and mists, will make a workroom atmosphere hazardous. For example, the threshold limit value for lead, as adopted by the American Conference of Governmental Industrial Hygienists, is 0.2 milligram per cubic meter of air (mg/cu m), which is 0.0000002 ounce per cubic foot. Therefore, the dispersion of only 0.002 ounce of lead will be enough to give the threshold limit value of 0.2 mg/cu m of dust or fume in an air space of 10,000 cubic feet (280 cubic meters). The concentrations that may be present in the workroom without harm to health are different for different substances.

19. A person with normal eyesight can detect dust particles as small as 50 microns in diameter. Smaller air-borne particles can be detected individually by the naked eye only when strong light is reflected from them. Dust of respirable size (below 10 microns) cannot be seen without the aid of a microscope.

20. Most industrial dusts consist of particles that vary widely in size, with the small particles greatly outnumbering the large ones. Consequently, with few exceptions, when dust is noticeable in the air around an operation, probably more invisible dust particles than visible ones are present.

Separation in air-borne dust

21. Dust in the air may or may not have the same composition as its parent material. The determining factors are the particle size and density of each component in the original mixture, and the hardness of the materials (hard materials will resist the pulverizing action of a mechanical device.)

22. For example, foundry molding sand contains a large percentage of free silica (quartz) with a lower percentage of clays. Most of the clays consist of fine particles that can be air-borne, but most of the quartz particles are too large to be air-borne. The air-borne dust, therefore, as compared with the original mixture, may contain a much higher percentage of clays and a much lower percentage of free silica.

23. Dust particles are, of course, attracted by gravity. Their settling rate through still air will vary with their size, density, and shape. Microscopically small particles settle out more slowly than larger particles because of their relatively minor density and because of their being influenced by Brownian movement. Mineral particles larger than 10 microns will settle out relatively fast. The estimated settling rates for silica dusts in still air are given in Table I.

TABLE I. SETTLING RATES FOR SILICA DUSTS

Size in Microns	Time to Fall 1 Foot (minutes)
0.25	590.0
0.50	187.0
1.00	54.0
2.00	14.5
5.00	2.5

24. Most of the particles in air-borne industrial dusts are small. Because of air currents, the fine particles in dust clouds at an operation will remain suspended in the workroom air for relatively long periods of time. The smaller dust particles, moreover, will travel farther away from their point of origin than will the larger particles so that the farther dust is from its source, the greater the percentage of small particles it contains.

Inhalation of Dusts, Fumes, and Mists

25. With the exception of such fibrous materials as asbestos, dust particles must usually be smaller than 5 microns in order to enter the alveoli or inner recesses of the lungs. Although a few particles up to 10 microns in size may enter the lungs occasionally, nearly all the larger particles are trapped in the nasal passages, throat, larynx, trachea, and bronchi, from which they are expectorated or swallowed into the digestive tract.

26. When larger particles of certain toxic dusts are trapped in the upper respiratory passages, they can be absorbed by the body fluids in the nasal passages and in the digestive tract before they are eliminated. Hence the final toxic effects of larger dust particles may be delayed. The larger particles of irritant dusts can cause immediate effects in the upper respiratory system.

27. Ragweed pollen, which varies from 18 to 25 microns in diameter can cause hay fever from its action in the upper respiratory system. This type of dust and other allergenic types, as well as bacterial and irritant dusts, can cause difficulty even in the larger air-borne sizes.

28. When dust-laden air is inhaled, some of the larger particles are trapped by the hairs in the nose. Other dust particles are removed from the air as it passes over the moist mucous membranes of the nose, throat, and other portions of the upper respiratory system.

29. The bronchi and other respiratory passages are covered with a large number of tiny, hairlike *cilia* or microscopic whiplashes, which aid in the removal of dust trapped on these moist surfaces. The cilia, all bending in one direction, make a fast stroke toward the mouth and a slower return stroke. This action tends to push mucous and deposited dust upward to the mouth so that the particles can be expectorated or swallowed.

Retention of dust

30. Many studies have been made in an effort to determine the amount of dust that is retained in the lungs, but there is no simple answer to this question. It has been shown that the size of the dust particles, the rate of respiration, the density of the dust in the air, the efficiency of the dust-catching mechanism, and probably many other factors are involved.

Sizes of particles inhaled

31. Although an occasional dust particle of larger size will enter the lungs, particles less than 3 microns in diameter are the most likely to do so and thus have the greatest opportunity to cause a physiological reaction. In silicotic lungs, for example, dust particles under 3 microns greatly outnumber larger ones, and many particles are less than 1 micron.

32. In the case of very fine fibrous asbestos dust, an exception occurs in the size of particles inhaled. Many fibers up to 100 microns long have been found in the lungs of asbestos workers at autopsy. A typical fibrosis caused by asbestos is produced by fibers ranging from 20 to 50 microns in length, but only a few microns wide.

Figure 2. Metal volatilized by the heat of welding later condenses to form a fume. On this bench-welding installation, fumes are removed at their point of origin by a properly located local exhaust installation. (Courtesy American Foundrymen's Society)

Physiological effects

33. The physiological reactions caused by the inhalation of air-borne particulate matter will vary with different types of dusts, fumes, and mists. The reactions include:

a. The cardiopulmonary reaction which consists of the pneumoconioses, such as *silicosis* and *asbestosis*. In certain cases, specific types of lung pathology result, and the heart may be affected (cor pulmonale) when the fibrosis is advanced. In other cases, there is mainly just an accumulation of a relatively inert dust in the lungs.

b. The systemic reactions which are caused by toxic dusts of such elements as lead, manganese, cadmium, and mercury, by their compounds, and by certain organic compounds.

c. Metal fume fever which results from the inhalation of finely divided and freshly generated fume of zinc or possibly of magnesium or of their oxides. This is a transient condition.

d. Allergic and sensitization reactions which may be caused by inhalation of, or skin contact with, such materials as organic dusts from flour, grains, and some woods and dusts of a few organic and inorganic chemicals.

e. Bacterial and fungus infections which occur from inhalation of dusts containing active organisms, such as wool or fur dust contain-