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1. The amount and kind of dust inhaled.
2. The percentage of free silica contained in the dust.
3. The form of the silica.
4. The size of the particles inhaled.
5. The duration of the exposure.
6. The powers of resistance of the individual concerned.
7. The presence or absence of a complicating process such as infection.

Many theories have been advanced over the years to explain why crystalline free silica acts as it does in the lungs. It is now believed that the fibrosis produced is caused not by the hardness or sharpness of the particles, but by a combination of slight solubility with a physiochemical effect and an immunological effect—but no one is certain of the exact mechanism of the disease. Experimental work on the reasons for the development of silicosis is still going on in various parts of the world. If the precise mechanism of silicosis could be determined, better medical preventive measures might be developed and possibly a cure could be found.

Amorphous free silica differs from crystalline free silica in physical structure and in physiological effects. In the amorphous state, molecules of silica are randomly oriented and may be naturally converted to opal and diatomaceous earth (kieselguhr) or artificially converted into such forms as silica gel, silica fume, and fused silica or quartz.

If amorphous silica is heated to a high temperature, as in calcining, forms of crystalline free silica called cristobalite and tridymite result, intermediate forms of amorphous silica are known as crypto-crystalline (ultra-microcrystalline). Inhalation of these crystalline forms can readily cause diatomite pneumoconiosis.

When diatomaceous earth is calcined, particularly in the presence of a trace of alkaline flux, appreciable quantities are converted to cristobalite. As a result of studies made by the U.S. Public Health Service, it has been recommended that the threshold limit value for crude or amorphous diatomite be placed at 20 mppcf (million particles per cubic foot), but that the atmospheric concentration for dust containing cristobalite be kept under 5 mppcf.

Various commercial products containing particles of silica under 1μ in size are available. The physiological effects of these products have not been well defined. Until more experience with human beings is available, exposure to these products should be kept to a minimum through the use of appropriate control measures.

Free silica is uncombined silicon dioxide (SiO_2). Silicates contain silicon and oxygen combined with other elements in more complex molecules. The SiO_2 reported in chemical analyses for mineral and geological reports is the *total* of the silicon dioxide present, both the free silica (if present), and the silica combined in the mineral. Such analyses are not reliable indications of the silicosis potential of the material, because it is the uncombined or free silica that is most important in industrial dust exposure. So that an exposure can be properly evaluated, the percentage of uncombined silica must be determined by petrographic analysis using a polarizing microscope or, preferably, by X-ray diffraction analyses and special analytical chemical procedures.

With the exception of asbestos and some talcs, the silicate dusts do not ordinarily cause a serious disabling lung condition such as is produced by free silica. Much higher levels of silicate dusts than of free silica dust can be tolerated. In many industries, men have worked with silicate dusts that contained no free silica without development of disability or of nodulation in the lungs. The X ray may show shadows indicating dust deposits in the lungs, but the pneumoconiosis is essentially harmless. However, partially disabling pneumoconioses have been reported where men have worked for long periods of time in very high concentrations of certain silicate dusts. Disabling pneumoconioses from exposure to abnormally high concentrations of mica, tremolite talc, and kaolin dusts have been described in the literature. The clinical signs are not the same for these silicate dusts as for free silica, but the symptoms can be marked.

Asbestosis. Several minerals having a fibrous character are classed as "asbestos"—hydrated silicates of magnesium with variable amounts of iron, calcium, sodium, potassium, and aluminum present as impurities. The fine airborne fibers of asbestos can pass through the upper respiratory tract to the lower parts of the lungs to cause irritation and to form "asbestos bodies" where the fibers are encapsulated. This diffuse fibrosis probably begins as a "collar" about the terminal bronchioles. There is evidence that other minerals having a fibrous character (except glass fiber) can produce a reaction similar to that of asbestos.

A number of investigators in recent years have reported an association between exposure to asbestos in industry and urban atmosphere and a rise in certain types of lung cancer. As a result of these reported findings, the Division of Occupational Health of the U.S. Public Health Service has undertaken an epidemiological study of the asbestos products industry to: (*a*) refine and update earlier work done in this industry in relation to asbestosis; and (*b*) appraise the relationship of asbestos to the carcinogenic properties suggested by these investigators.

Miscellaneous pneumoconioses. Even though a dust is classified as harmless, amounts above the TLV can lead to trouble by causing a pneumoconiosis, mechanically irritating the walls of the respiratory system, or interfering with ordinary lung processes. Mica dust and kaolin dust are two good examples of dusts that ordinarily are considered benign but amounts above the TLV can cause a troublesome pneumoconiosis. Mica pneumoconiosis has been observed in grinding operations where mica dust, but no free silica was present. There were marked changes in the X-ray pictures of the lungs and some disability. The cases occurred where the dust exposures were massive over many years.

Industrially important metals and their compounds that can have a toxic effect when the dust or fumes are inhaled include arsenic, antimony, cadmium, chromium, lead, manganese, mercury, selenium, tellurium, thallium, uranium, and a few others.

The effect of some metals, such as magnesium and zinc, appears to be transient. Only limited data are available on the exotic and rare earth metals.

Although the dusts and fumes from metals with low toxcity do not need as much attention as the dusts and fumes from highly toxic metals, they should not be neglected or disregarded. The metals with low toxicity are more readily controlled because greater amounts can be tolerated, but their dusts and fumes should be kept at reasonable levels since excessive amounts of any of them can be harmful.

Inhalation of the dust of lead compounds is the most common mode of entry of lead into the system, and ingestion of lead compounds can add to the problem if personal hygiene is poor. Workers therefore should be encouraged to wash thoroughly before eating, and lunchrooms should be set apart from work areas. Smoking should be prohibited in work areas. Work clothes and street clothes should be stored separately.

Lead is a normal constituent of plants and animals, and people ingest and excrete it daily even though they are not exposed to excessive lead in their daily work. When intake rates exceed the normal excretion rates, however, lead builds up in the body. When the accumulation reaches a sufficient level, symptoms of poisoning or intoxication appear. The concentration of airborne lead should therefore be kept below the threshold limit because of lead's high toxicity and its tendency to accumulate in the human system.

Beryllium intoxication is a severe systemic disease that can result from the *inhalation* of the dust or fume of metallic beryllium, beryllium oxide, and soluble beryllium compounds. (There is no evidence of intoxication from the *ingestion* of insoluble compounds.) Only the inhalation of the beryllium-bearing dusts or fumes produces systemic disease. Accordingly, control of such dusts and fumes to keep them below the concentration specified by ACGIH (American Conference of Governmental Industrial Hygienists) threshold limit values is a basic protective measure.

When the soluble salts of beryllium, especially beryllium flouride, contact cuts or abrasions on the skin, deep ulcers may be formed which heal very slowly, and complete surgical excision of the ulcer is sometimes required to effect healing.

Metal fume fever is an acute condition caused by a brief high exposure to the freshly

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See Industrial Data Sheet 499 and *Hygienic Guide*.

Arsine (arsenic hydride). Severe and acute industrial poisonings with arsenic are likely to be the result of inhalation of arsine, often produced accidentally when hydrogen is generated in the presence of a material which contains arsenic. The gas has been reported in the acid cleaning of filter plates, in the handling of wet dross from a light metals plant, in the cleaning of tank cars which have held sulfuric and hydrochloric acids, in the cleaning of pipes with an acid contaminated with arsenic, in the precipitation of cadmium with metallic zinc, and in other operations.

Arsine rapidly destroys the red cells. After it has been inhaled, the first signs are those of lack of oxygen. After some time the body begins to excrete the damaged red cells, which appear as a dark or bloody urine. The kidneys may then become too clogged to operate at all. Arsine, in very small amounts, is also capable of producing a chronic type of poisoning, but it is more typically a source of acute episodes.

The possibility of arsine formation should always be considered when there is freshly formed hydrogen around ores of the heavy metals, since arsenic is widely distributed in small amounts and only a trace of it is required to produce enough arsine to be troublesome.

One of the more common sources of arsine incidents in recent years has been the handling of dross from the aluminum refining of metals. Probably the most significant observation about these cases, aside from the fact that the moisture in the atmosphere is enough to form arsine is the fact that the people involved in them have not been aware of the garlic-like odor which is supposed to be a warning of the presence of arsine.

See *Hygienic Guide*.

Asbestos is a hydrated magnesium silicate found in the minerals chrysotile, amosite, crocidolite, and tremolite. Practically all the commercial asbestos used in this country is chrysotile. It is used almost exclusively for heat insulation or for textiles which must resist high temperature, such as heat-resistant clothing and brake linings.

Inhalation of excessive quantities of asbestos fiber can produce a fibrosis in the lungs similar to that found in silicosis but somewhat milder and usually not so rapidly progressive. Like silicosis, the condition develops and advances slowly and is equally resistant to treatment. There is also good evidence that inhaled asbestos causes lung cancer.

See *Hygienic Guide*.

Asphalt. Although asphalt itself is considered to be substantially nontoxic, it may cause inflammation or dermatitis on contact in some individuals. Careful supervision of worker's personal cleanliness is essential in the prevention of dermatitis or other ill effects. Skin contact with the asphalt should be avoided—individuals working with asphalt should wear suitable protective equipment, including goggles to protect the eyes. The effect of exposure to vapors from liquid or cutback asphalt depends on the particular solvent added to the asphalt. Steps should be taken to hold the solvent vapor concentration in the breathing zone below its threshold limit value. Where operations require heating or grinding asphalt inside a building, suitable ventilation should be provided. See N.S.C. Data Sheet 215.

Barium, in the form of its soluble salts, is toxic on both ingestion and inhalation and highly caustic when applied to the skin. The carbonate and sulfide are sufficiently soluble to be toxic, although not very caustic. The sulfate, which is used as a contrast medium in X-ray work, is too insoluble to show any toxicity, and soluble sulfates are specific antidotes for ingested barium salts.

Since these salts produce violent stimulation of all muscle, upon ingestion they produce severe disturbances of the digestive system. After absorption, the barium salts increase blood pressure by constriction of the arterial muscle, slow down heart beat by an action similar to that of digitalis, and first excite and then paralyze the central nervous system. In spite of the high inherent toxicity, there are few cases of industrial poisoning with barium.

Barium is a heavy metal, and the dust of the insoluble salts will collect in the lungs and give rise to the condition known as baritosis. Its nodular appearance on X-ray film

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See *Hygienic Guid...*

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Free silica is uncombined silicon dioxide (SiO_2). Silicates contain silicon and oxygen combined with other elements in more complex molecules. The SiO_2 reported in chemical analyses for mineral and geological reports is the *total* of the silicon dioxide present, both the free silica (if present), and the silica combined in the mineral. Such analyses are not reliable indications of the silicosis potential of the material, because it is the uncombined or free silica that is most important in industrial dust exposure. So that an exposure can be properly evaluated, the percentage of uncombined silica must be determined by petrographic analysis using a polarizing microscope or, preferably, by X-ray diffraction analyses and special analytical chemical procedures.

There has been some experimental evidence that some dusts may tend to inhibit the action of silica on the body, but this inhibiting action is so slight and uncertain that it must be discounted in practice. In fact, there is also evidence that the nonsiliceous components of a dust mixture containing free silica may provoke a disabling condition more severe than that caused by the silica acting alone.

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Following a study by the U.S. Public Health Service of the asbestos textile industry,* it was recommended that the dust concentration be kept at less than 5 mppcf to prevent asbestosis. Evaluation of an exposure to asbestos dust is based on the *total* amount of dust, since the concentration of injurious fibers will be kept within safe limits if the fine dust is kept below the suggested threshold limit.

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Toxic dusts and fumes

Systemic reactions are caused by toxic dusts and fumes of various elements and their compounds and by certain organic compounds. All metallic fumes are irritating, especially when freshly generated. Industrially important metals and their compounds that can have a toxic effect when the dust or fumes are inhaled include arsenic, antimony, cadmium, chromium, lead, manganese, mercury, selenium, tellurium, thallium, uranium, and a few others.

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*U.S. Public health Service, Washington, D.C. "A Study of Asbestosis in the Asbestos Textile Industry." Bulletin No. 241. 1938.