physiological effects of these products have not been well defined. Until more experience with human beings is available, it is believed these products should be handled with care.

57. *Free silica and silicates.* Free silica is uncombined silicon dioxide (SiO_2). Silicates contain silicon and oxygen combined with other elements in a more complex molecule. Analyses of minerals, particularly in geological reports, are sometimes reported as percentages of oxides, which may include SiO_2, Al_2O_3, K_2O, Fe_2O_3. The SiO_2 reported in such chemical analyses 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.

58. It is 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.

59. 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 also is 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.

60. 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.

61. 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.

62. 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.

63. The body does not have adequate defense against indiscriminate amounts of dust of any kind. Therefore, although specific symptoms have not been described for many mineral dusts, the general experience would indicate that dust levels should be kept within threshold limit values or below (Table II).

Asbestosis

64. Asbestos is a general term applied to several minerals having a fibrous character. These asbestos minerals are hydrated silicates of magnesium with variable amounts of *iron, calcium, sodium, potassium,* and aluminum present as impurities.

65. Asbestos when inhaled produces fibrous tissue in the lungs of both men and animals. It has been shown that fibers of asbestos must be present for the production of *asbestosis*. Other silicate minerals of the same chemical composition but nonfibrous in form produce no reaction or a relatively mild reaction, but not the severe reaction of fibrous asbestos dust.

66. These facts lead to the conclusion that asbestosis is mainly the result of physical irritation of the lung tisssue and not of a chemical action, which is thought to be one of the causes of silicosis. It is suspected that lung cancer may be induced by asbestos. However, there is no impressive amount of evidence to support this assumption.

67. The fine air-borne 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 can produce a reaction similar to that of asbestos. Fiber glass, however, does not produce such a reaction.

68. 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 abestos dust is based on the *total* amount of dust because it has proved out in practice that if the fine dust is kept below the suggested threshold limit, the concentration of injurious fibers will also be kept within safe limits.

Talcosis

69. As used in industry, "talc" is a very general term. To the geologist, talc is a hydrous magnesium silicate, which may be a relatively pure mineral or may be mixed with tremolite or with dolomite depending upon where it is mined. The term "talc" is applied commercially to carbonate mixtures that have the same general feel and physical properties; it also is applied to pyrophyllite, a hydrous aluminum silicate, which frequently is mixed with a high percentage of quartz. The free silica generally found with pyrophyllite can cause silicosis. It is therefore essential to know which talc is being used in order to evaluate a specific dust exposure.

70. *Talcosis* is usually associated with tremolite talc. This disease produces changes in the lungs and symptoms similar to those of asbestosis.

Anthracosilicosis

71. *Anthracosilicosis*, a complex form of pneumoconiosis, is a chronic disease caused by breathing air containing dust that has free silica as one of its components and that is generated in the various processes involved in mining and preparing anthracite (hard coal)** and, to a lesser degree, bituminous coal.

72. The disease is characterized anatomically by generalized fibrotic changes throughout both lungs and by the presence of excessive amounts of carbonaceous and siliceous material. Such lungs on autopsy are coal black.

73. Symptoms found in early stages of the disease are shortness of breath, cough with a coal-black sputum, pain in the chest, and in some cases physical weakness. In the advanced stages, there are loss of weight and decreased capacity for work, partly caused by pulmonary infection (frequently bronchitis), and in some cases there may be heart failure.

74. Experiments with animals showed that mixtures of coal and quartz produced more fibrosis than did quartz alone. The harmful effects of coal dust do not come only from the silica in the dust. Coal dust alone in very heavy concentrations over a period of many years can cause breathlessness and ventilatory impairment.

Miscellaneous pneumoconioses

75. Even though a dust is classified as harmless, excessive amounts of it can lead to trouble by causing a pneumoconiosis or simply by mechanically irritating the walls of the respiratory system. Moreover, even though there is no chemical or physical irritation, mechanical plugging of the lungs and interference with their ordinary processes can result. Mica dust and kaolin dust are two good examples of dusts that ordinarily are considered benign but in excessive amounts can cause a troublesome pneumoconiosis:

76. 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.

77. *Kaolinosis* has been described as a condition induced by inhalation of dust released in the grinding and handling of kaolin (china clay). Where the cases occurred, dust levels of several hundred million particles per cubic foot of air were common.

78. Aluminum dust is not considered to be harmful except where exposures are massive. Without adverse effects, aluminum dust inhalation has been used as part of an endeavor to prevent silicosis. Also without adverse effects, extensive exposures to aluminum dust have occurred in the grinding of aluminum parts and castings. It can therefore be concluded that reasonably good control will prevent harm from aluminum dust.

79. Bauxite pneumoconiosis (Shaver's disease) has been found only in workers exposed to fumes containing aluminum oxide and minute or ultramicroscopic silica particles arising from smelting bauxite in the manufacture of corundum, an impure form of aluminum oxide. It is essentially a diffuse interstitial fibrosis and marked associated emphysema, with a complete absence of any nodular fibrosis. It definitely does not occur from the use of corundum grinding wheels or from other forms of aluminum oxide.

80. Some pneumoconioses may show marked shadows on an X-ray film; these shadows, without the necessary information on the exposure of the individual, may be alarming in a general X-ray screening program. On clinical examination of individuals showing the X-ray markings, however, often no disability or symptom can be found.

81. These shadows are frequently encountered when the dusts contain atoms of relatively high molecular weight because the heavier atoms are fairly opaque to X-rays. Insoluble barium dusts and tin oxide dusts, for, example, can show very marked shadows on X-ray films without producing signs of significant pathology (barium dust that is soluble in the body fluids can give a toxic reaction).

82. Iron oxide, particularly excessive fume from welding operations, may produce *siderosis* with a pigmentation of the lungs (black in welders and red in iron ore miners) without disability. The X-ray shadows produced by the iron oxide in the lungs are somewhat similar to the shadows from silicosis. Because of this similarity, differential diagnosis is often difficult, and heavy exposures to iron oxide dust and fume may lead to medicolegal problems. It is therefore important to control iron oxide exposures even though siderosis is not disabling.

83. Limestone, marble, lime, gypsum, and portland cement dusts apparently have no serious effect even after long exposures. Also, many silicates and other minerals have not caused impairment in individuals inhaling the dusts, and the resulting pneumoconioses are generally classed as benign.

Toxic Dusts and Fumes

84. 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 fume is inhaled include arsenic, antimony, cadmium, chromium, lead, manganese, *mercury, selenium, tellurium,* thallium, uranium, and a few others.*

85. 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.

86. Although the dusts and fumes from metals with low toxicity 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 controlled more readily 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 (Table III).

Lead poisoning

87. Although extremely severe cases of lead poisoning are rare in industry today, lead exposures must be controlled to prevent even the moderate symptoms, which can be troublesome. Inhalation of the dust of lead compounds is the most common mode of entry of lead into the system. Ingestion of lead compounds can add to the problem if personal hygiene is poor. Workers should therefore be encouraged to wash thoroughly before eating, and lunchrooms should be segregated from work areas.

88. It should be recognized that lead is a normal constituent of plants and animals. People ingest and excrete lead daily even though they are not exposed to lead in their daily work. The body can handle

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*Dreesen, W. C., Dalla Valle, J. M., Edwards, T. I., Miller, J. W., and Sayers, R. R., *A Study of Asbestosis in the Asbestos Textile Industry*, U. S. Public Health Bulletin No. 241, U. S. Public Health Service, Washington 25, D. C. 1938.

**_Anthracosilicosis among Hard-Coal Miners_, U. S. Public Health Bulletin No. 221, U. S. Public Health Service, Washington 25, D. C., 1935.

*See the following National Safety Council Data Sheets: *Antimony and Its Compounds*, 408; *Arsenic and Its Inorganic Compounds*, 499; *Cadmium*, 312; *Lead*, 443; *Magnesium*, 426; *Manganese*, 306; *Mercury*, 203; *Titanium*, 485; *Zinc and Zinc Oxide*, 267; *Zirconium Powder*, 382.