NIOSH

Current Intelligence Bulletin 36

June 30, 1981

SILICA FLOUR: SILICOSIS
(CRYSTALLINE SILICA)

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

The National Institute for Occupational Safety and Health (NIOSH) Current Intelligence Bulletin is the primary product of the Current Intelligence System. The purpose of the Current Intelligence System is to promptly review, evaluate, and disseminate new information received by NIOSH that may indicate either the existence of an occupational hazard not previously recognized or a greater hazard than generally known. The Current Intelligence System staff within the Division of Criteria Documentation and Standards Development was responsible for the preparation of this Bulletin.

Current Intelligence Bulletins are disseminated to NIOSH staff, other government agencies, and the occupational health community, including labor, industry, academia, and public interest groups. The Bulletins are intended to disseminate new data that may affect prevailing perceptions of occupational hazards. They convey important public health information and recommend voluntary protective measures. Current Intelligence Bulletins do not recommend occupational standards, nor are they intended to have any regulatory significance.

DHHS (NIOSH) Publication No. 81-137

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The National Institute for Occupational Safety and Health (NIOSH) warns producers and users of silica flour that the risk of developing silicosis may be very high for workers exposed to silica flour. NIOSH determined the status of worker health and surveyed airborne silica dust concentrations at two silica flour mills at the request of the Mine Safety and Health Administration (MSHA). Of 61 current and former workers with 1-14 years of exposure to silica dust, 23 (37%) had chest radiographic evidence of silicosis. Of particular concern are the medical evaluations of four of these affected workers who had relatively short-term silica dust exposures (2.5-6 years), indicating rapidly developing silicosis. Usually, about 20 years of exposure to dust containing silica precedes development of silicosis. NIOSH's sampling results agreed with the results from past MSHA inspection samples that showed a large percentage of high silica dust concentrations. On the days of sampling, 61 of 91 samples were above MSHA's exposure limit for silica, and 77 were above NIOSH's recommended exposure limit. In view of the high prevalence of silicosis after relatively short exposures to silica flour in these two mills, and a history of high silica dust exposures in these and 25 other mills, NIOSH believes workers exposed to silica flour are at serious risk of developing silicosis. This concern extends to workers in industries that use silica flour who may also be at increased risk. Therefore, NIOSH recommends control of silica flour exposure and the labelling of products that contain silica flour.

BACKGROUND

Simple, Accelerated, and Acute Silicosis

Silicosis is a debilitating respiratory disease caused by inhalation of fine crystalline silica dust that is retained in the lungs.[1] The amount of dust inhaled, the percentage of free or uncombined silica in the dust, the size of the dust particles, and the length of exposure all affect the onset of silicosis. The inhaled dust deposited in the bronchioles and alveoli reacts within the lung tissue to form silicotic nodules. The nodules appear on chest radiograms as discrete, rounded opacities or shadows. The presence of silicotic nodules and a history of occupational exposure to silica dust are necessary for a positive diagnosis of silicosis. The earliest symptom of silicosis is shortness of breath. As the disease progresses, the silicotic nodules coalesce and form a continuous mass of fibrotic tissue, called progressive massive fibrosis.

Silicosis manifests itself in different ways depending on exposure conditions and individual variations. Researchers have described three forms of the disease. They differ primarily in the length of exposure before the onset of symptoms of the disease and the rate at which the disease then progresses. The common or

simple form of silicosis has been recognized as an occupational disease since antiquity. It may take 20 or more years of exposure before a chest radiogram is positive for silicosis. Usually there is little or no respiratory impairment associated with the early stages of simple silicosis. The silica content of the dust to which workers developing simple silicosis are exposed is often less than 30%.

Accelerated and acute silicosis develop after shorter exposures to respirable silica dust at high concentrations. Accelerated silicosis differs from simple silicosis mainly in the time from first exposure to silica dust until silicotic nodules appear on a chest radiogram. In accelerated silicosis the exposure varies between 5-15 years, the progression of disease development is faster, and often there is progressive massive fibrosis.

Acute silicosis, also termed silicoproteinosis, develops after 1-3 years of exposure and progresses even faster than accelerated silicosis. There is a rapid loss of pulmonary function, invariably followed by death. A distinctive feature in acute silicosis is the presence of a surfactant-like liquid in the alveoli. On a chest radiogram there are few silicotic nodules, and they are rather diffuse.

No effective medical treatment is available for silicosis.

Silica Flour Industries

Silica flour is used industrially as an abrasive cleaner and as an inert filler.[2] Silica flour is found in toothpaste, scouring powder, and metal polish. It is an extender in paint, a wood filler, and a component in road surfacing mixtures. It is also used in some foundry processes. The actual number of workers exposed to silica flour in the United States is not known.

After crystalline silica is mined, it is milled to a fine powder and packaged for shipment. Silica flour is not always labelled as containing crystalline silica, and it may be labelled incorrectly as amorphous silica[3], which is commonly believed to cause little or no fibrosis.[4] More data are appearing which indicate that the fibrogenic potential of amorphous silicas should be reconsidered.[5] A recent report by Groth on the chronic effects of inhaled amorphous silicas in animals identified the fibrogenic potential of certain synthetic amorphous silicas.[6] Thus, workers in industries that use silica flour may be unaware that it is a hazardous material because of either the absence of labelling or the mislabelling of silica flour containers.

Occupational Standards

MSHA's Metal and Nonmetal Mining and Milling standard[7] and the Occupational Safety and Health Administration's standard[8] for respirable crystalline silica (SiO_2) for an 8-hour workshift are expressed by the formula:

$$\frac{10 \text{ mg } SiO_2/m^3}{\% SiO_2 + 2}$$

where: mg SiO_2/m^3 = milligrams of silica per cubic meter of air
% SiO_2 = the percentage of silica in the respirable dust.

For example, the calculated Federal standard for silica flour that is essentially 100% respirable silica is 0.10 mg/m^3.

In 1974 NIOSH recommended that the exposure limit for respirable crystalline silica be 0.05 mg/m^3 averaged over a work shift of up to 10 hours a day, 40 hours a week.[9] NIOSH recommended that silica sand or other materials containing more than 1% free silica be prohibited as an abrasive substance in abrasive blasting or cleaning operations. NIOSH is now preparing an updated review and evaluation of information on crystalline silica that has become available since the criteria document was completed.[10] New data on sampling and analysis, engineering controls, work practices, and toxic effects reported in humans and animals exposed to crystalline silica are described. The new information tends to support the NIOSH-recommended standard. NIOSH's criteria document[9] and literature update[10] should be consulted for further details.

Other Reports

From numerous reports in the literature, two reports were selected to illustrate the occurrence of rapidly developing silicosis in a worker in a silica flour user industry and the ineffectiveness of some respirator programs.

An Australian worker developed symptoms of silicosis after 2 years of exposure to silica flour in the manufacture of metal polish.[11] The workplace concentration of silica was not measured. The silica used was 99.5% silica ground to 200 gauge. About 60 times a year he opened 24 bags of silica flour, poured the powder into a drum, and then emptied the drum slowly into a mixer. The man died 2.5 years after a diagnosis of acute silicosis was made. The authors commented that the silica flour bags had no warning label.

Many cases of silicosis have been reported in sandblasters. Even though whole-grain sand is of larger average size than silica flour, many silica particles are of respirable size (less than 10 μ in diameter). The efficiency of several types of non-air-supplied and air-supplied protective hoods worn by sandblasters was investigated by Samimi and coworkers.[12] They determined the concentrations of respirable silica in the ambient air and inside workers' hoods during short, moderate, and long periods of sandblasting. About one-third of the workers using non-air-supplied hoods did not wear their respirators under their hoods, and the others wore respirators that were not regularly maintained. Some air-supplied hoods worn with properly-fitted respirators did provide adequate protection during the actual periods of sandblasting. However, the sandblasters were not protected from excessive silica dust in the ambient air when they removed their protective equipment during nonsandblasting periods. The authors concluded that most sandblasters wearing various types of protective equipment, even air-supplied hoods with respirators, were exposed to an average level of silica dust several times greater than the standard. The average exposure duration in fatal silicosis in sandblasters was 10 years.

NIOSH INVESTIGATIONS

At the request of MSHA, NIOSH conducted a study at two silica flour mills in 1979. The purpose of the study was to determine the prevalence of silicosis in this workforce and to measure the levels of silica dust exposures. Both mills had a history of exceeding MSHA's standard for respirable crystalline silica dust.

The results of these investigations have been reported.[3,13,14] The medical evaluation consisted of a chest radiogram, spirometry, and a questionnaire emphasizing occupational history and respiratory symptoms. Of 61 current and former workers with 1-14 years of exposure to silica dust, 16 (26%) had chest radiograms indicating simple silicosis and 7 (11%) had progressive massive fibrosis. The average duration of exposure to silica dust for the 16 workers with simple silicosis was 7.7 years (range: 1-9 years). The 7 workers with progressive massive fibrosis had an average exposure duration of 7.1 years (range: 2.5-14 years). One worker, aged 24, had progressive massive fibrosis after only 2.5 years of silica exposure, another after 4 years, and two others after 6 years.

The silica content of the dust from both mills was determined by X-ray diffraction to be approximately 99% free silica. The mean diameters of the dust particles from air sampled at various mill operations were 2.3 - 5.2 μ, which are within the respirable range. Analysis of air samples from both mills on the days of sampling showed that 61 of the 91 dust samples were above MSHA's standard for crystalline silica; 77 were above NIOSH's recommended standard. Some samples were several hundred times over the NIOSH recommendation.

NIOSH considered the situations at both mills at the time of study to be extremely dangerous. There was a significant health hazard present; continued worker exposure at the concentrations measured would cause irreversible harm and shorten life expectancy. Although respiratory protection programs were on record at both facilities, they were ineffective.[14]

NIOSH also reviewed MSHA silica dust sampling results from the 2 mills and 25 other silica flour mills for 1974-79.[14] Altogether, 170 inspections were made, representing 1,350 workers. Of 1,142 samples analyzed for respirable silica, 608 (53%) exceeded MSHA's standard. Only one workplace had no samples in excess of the MSHA standard. There was no significant decline in the number of samples in excess of the standard over the period observed, despite attempts to control the dust at the 26 mills that were not in compliance with the regulation.

NIOSH RECOMMENDATIONS

Worker exposure to silica flour should be controlled to within NIOSH's recommended standard for respirable crystalline silica of 0.05 mg/m^3, averaged over a workshift of up to 10 hours a day, 40 hours a week. Employers and workers should take appropriate actions to reduce silica flour exposure to this limit.

1. Exposure Monitoring

Worker exposure surveys should be made by competent industrial hygiene and engineering personnel. Surveys are necessary to determine the extent of worker exposure and the effectiveness of engineering controls.

A detailed analytical method for free silica (quartz) is in the NIOSH Manual of Analytical Methods, 2nd Ed., Vol. 5, 1979 as method # 259.[15] This method is a revision of the previous NIOSH method.

2. Engineering Controls

The most effective control of airborne concentrations of silica flour is at the source of contamination by enclosure of the operation and/or use of local exhaust ventilation. Guidelines for selected processes and operations can be found in NIOSH's Recommended Industrial Ventilation Guidelines[16] and in the American Conference of Governmental Industrial Hygienist's Industrial Ventilation - A Manual of Recommended Practice.[17]

When enclosing a process or operation, a slight vacuum should be used to create negative pressure so that leakage will result in the flow of external air into the enclosure and minimize contamination of the workplace. This can be accomplished with a well-designed local exhaust ventilation system that physically encloses the process as much as possible, with sufficient capture velocity to keep the contaminant from entering the work atmosphere.

Ventilation equipment should be checked at least every 3 months to ensure adequate performance. System effectiveness should be checked soon after any change in production, process, or control which might result in significant increases in airborne exposure to silica flour.

3. Medical Surveillance

Preplacement and annual medical examinations should be made available to all workers who manufacture, use, or handle silica flour or materials containing silica flour. These examinations should include at least:

a. Comprehensive work and medical histories to evaluate exposure and signs and symptoms of respiratory disease;

b. A 14 x 17 inch posteroanterior chest radiogram, preferably interpreted using the 1971 ILO U/C classification (1980 ILO classification when available);[18] and

c. Pulmonary function tests including forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1), with calculation of the FEV_1/FVC ratio.

Workers with radiographic evidence of silicosis should be given the opportunity to transfer to jobs without silica exposure (defined as exposure at concentrations less than half of the NIOSH-recommended standard).

4. Work Practices

Work practices involve both the design of work procedures and the actions of workers. The following work practices are recommended:

a. Work procedures should be developed so they do not produce dust;

b. Work clothes should be vacuumed before removal;

c. General housekeeping duties should be intensified so that there is no dust accumulation on machinery, beams, corners, and other surfaces. Such accumulations often contain respirable particles which can become airborne when disturbed. Dustless methods of cleaning such as vacuuming or wetting down should be used. Dry sweeping or blowing with compressed air should be avoided; and

d. Emphasis should also be given to cleanup of spills, preventive maintenance, and timely repair of equipment.

5. Personal Protective Equipment

Personal protective equipment is not recommended as a primary means of control. Exposure of workers to airborne silica flour should not be controlled with the use of respirators except:

a. During installation and implementation of engineering or work practice controls;

b. In work situations in which engineering and work practice controls are technically not feasible;

c. During major overhaul and repair of equipment, if exposure to silica flour is possible;

d. In operations that require entry into tanks or closed vessels; or

e. In emergencies.

A list of Respirator Use Conditions from the NIOSH/OSHA Pocket Guide to Chemical Hazards can be found in the Appendix.[19] Only respirators jointly approved by NIOSH and MSHA should be used. Equipment meeting these criteria may be found in the NIOSH Certified Equipment List.[20]

6. Worker Education

Worker education is a vital aspect of a good control program. Workers should be informed of the hazardous nature of silica flour, the results of workplace monitoring and medical tests, and the correct useage and maintenance of respirators.

7. Labelling of Silica Flour Containers

Packaged silica flour should be labelled correctly, and health warnings should be placed on each container to alert users and handlers as well as producers to the hazards of silica flour.

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Acting Director

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19. National Institute for Occupational Safety and Health/Occupational Safety and Health Administration: NIOSH/OSHA Pocket Guide to Chemical Hazards, p. 34. DHEW (NIOSH) Publication No. 78-210 (third printing August 1980).

20. National Institute for Occupational Safety and Health: NIOSH Certified Equipment List as of June 1, 1980, 142 pp. DHHS (NIOSH) Publication No. 80-144 (1980).

APPENDIX

Respirator Use Conditions[19]

NIOSH has recommended respirator use for silica concentrations at 5, 10, 50, and 500 times the standard, defined as a permissible exposure limit (PEL) (see the Occupational Standards section of this bulletin). The degree of respiratory protection for exposure situations is dependent on the type of device that is selected. In the listing below, the first choice (1), offers minimal adequate protection; (2) offers greater protection, etc.

NIOSH recommends respirator use as follows:

5 X PEL mg/m^3:	(1)	Dust mask
10 X PEL mg/m^3:	(1)	Dust mask, except single-use and quarter-mask respirators
	(2)	Fume or high-efficiency particulate respirator
	(3)	Supplied-air respirator
	(4)	Self-contained breathing apparatus
50 X PEL mg/m^3:	(1)	High-efficiency particulate respirator with a full facepiece
	(2)	Supplied-air respirator with a full facepiece, helmet, or hood
	(3)	Self-contained breathing apparatus with a full facepiece
500 X PEL mg/m^3:	(1)	Powered air-purifying respirator with a high-efficiency particulate filter
	(2)	Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode

CUMULATIVE LIST OF NIOSH CURRENT INTELLIGENCE BULLETINS

1.	Chloroprene	- January 20, 1975
2.	Trichloroethylene (TCE)	- June 6, 1975
3.	Ethylene Dibromide (EDB)	- July 7, 1975
4.	Chrome Pigment	- June 24, 1975 - October 7, 1975 - October 8, 1976
5.	Asbestos - Asbestos Exposure during Servicing of Motor Vehicle Brake and Clutch Assemblies	- August 8, 1975
6.	Hexamethylphosphoric Triamide (HMPA)	- October 24, 1975
7.	Polychlorinated Biphenyls (PCBs)	- November 3, 1975 - August 20, 1976
8.	4,4'-Diaminodiphenylmethane (DDM)	- January 30, 1976
9.	Chloroform	- March 15, 1976
10.	Radon Daughters	- May 11, 1976
11.	Dimethylcarbamoyl Chloride (DMCC) Revised	- July 7, 1976
12.	Diethylcarbamoyl Chloride (DECC)	- July 7, 1976
13.	Explosive Azide Hazard	- August 16, 1976
14.	Inorganic Arsenic - Respiratory Protection	- September 27,1976
15.	Nitrosamines in Cutting Fluids	- October 6, 1976
16.	Metabolic Precursors of a Known Human Carcinogen, Beta-Naphthylamine	- December 17,1976
17.	2-Nitropropane	- April 25, 1977
18.	Acrylonitrile	- July 1, 1977
19.	2,4-Diaminoanisole in Hair and Fur Dyes	- January 13, 1978
20.	Tetrachloroethylene (Perchloroethylene)	- January 20, 1978
21.	Trimellitic Anhydride (TMA)	- February 3, 1978
22.	Ethylene Thiourea (ETU)	- April 11, 1978
23.	Ethylene Dibromide and Disulfiram Toxic Interaction	- April 11, 1978
24.	Direct Black 38, Direct Blue 6, and Direct Brown 95 Benzidine Derived Dyes	- April 17, 1978
25.	Ethylene Dichloride (1,2-Dichloroethane)	- April 19, 1978
26.	NIAX® Catalyst ESN	- May 22, 1978
27.	Chloroethanes - Review of Toxicity	- August 21, 1978
28.	Vinyl Halides - Carcinogenicity	- September 21,1978
29.	Glycidyl Ethers	- October 12, 1978
30.	Epichlorohydrin	- October 12, 1978
31.	Adverse Health Effects of Smoking and the Occupational Environment	- February 5, 1979
32.	Arsine (Arsenic Hydride) Poisoning in the Workplace	- August 3, 1979
33.	Radiofrequency (RF) Sealers and Heaters: Potential Health Hazards and Their Prevention	- December 4, 1979
34.	Formaldehyde: Evidence of Carcinogenicity	- April 15, 1981
35.	Ethylene Oxide (EtO): Evidence of Carcinogenicity	- May 22, 1981
36.	Silica Flour: Silicosis	- June 30, 1981

NOTE: Bulletins #1 through #18 and #19 through #30 have been reprinted as NIOSH publications, #78-127 and #79-146 respectively, for the convenience of those that desire a complete series of Current Intelligence Bulletins. Distribution of these publications and single copies of Bulletins #31 and later are available from NIOSH Publications Dissemination, Division of Technical Services, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

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