CDC Workplace Safety and Health

# Evaluation of Exposures at a Pottery Shop

*Lilia Chen, MS*
*Jessica Ramsey, MS*
*Scott Brueck, MS, CIH*

Health Hazard Evaluation Report
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FUNKe Fired Arts (formerly known as Annie's Mud Pie Shop)
Cincinnati, Ohio
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DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
NIOSH National Institute for Occupational Safety and Health

**The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].**

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# Abbreviations

| | |
|---|---|
| ACGIH® | American Conference of Governmental Industrial Hygienists |
| ANSI | American National Standards Institute |
| ASHRAE | American Society of Heating, Refrigerating, and Air Conditioning Engineers |
| cc/min | Cubic centimeters per minute |
| cm | Centimeter |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| °F | Degrees Fahrenheit |
| GFCI | Ground fault circuit interrupter |
| HEPA | High efficiency particulate air |
| HHE | Health hazard evaluation |
| ' | Foot |
| " | Inch |
| IDLH | Immediately dangerous to life or health |
| LEV | Local exhaust ventilation |
| LOD | Limit of detection |
| Lpm | Liters per minute |
| MDC | Minimum detectable concentration |
| MQC | Minimum quantifiable concentration |
| $mg/m^3$ | Milligrams per cubic meter |
| min | Minute |
| mm | Millimeter |
| NAICS | North American Industry Classification System |
| ND | Not detected |
| NIOSH | National Institute for Occupational Safety and Health |
| $NO_2$ | Nitrogen dioxide |
| OEL | Occupational exposure limit |
| OSHA | Occupational Safety and Health Administration |
| PBZ | Personal breathing zone |
| PEL | Permissible exposure limit |
| PPE | Personal protective equipment |
| ppm | Parts per million |
| REL | Recommended exposure limit |
| $SO_2$ | Sulfur dioxide |
| STEL | Short-term exposure limit |
| TLV® | Threshold limit value |
| TWA | Time-weighted average |
| USEPA | United States Environmental Protection Agency |
| VOC | Volatile organic compounds |
| WEEL | Workplace environmental exposure level |
| $\mu g/m^3$ | Micrograms per cubic meter |
| $\mu g/100\ cm^2$ | Micrograms per 100 square centimeters |
| μm | Micrometer |

# Highlights of the NIOSH Health Hazard Evaluation

**The National Institute for Occupational Safety and Health (NIOSH) received a management request for a health hazard evaluation at FUNKe Fired Arts, previously known as Annie's Mud Pie Shop, in Cincinnati, Ohio. Management was concerned about employees' long-term exposure to a variety of substances, although no health symptoms had been reported. These substances included silica from the clay mixing process and elements from the mixing of dry materials used in the glazes. There were also concerns about exposures to volatile organic compounds (VOCs) and gases released during kiln firing. Management also asked for information on the proper use and maintenance of respirators.**

## What NIOSH Did

- We took area and personal breathing zone (PBZ) air samples for respirable particulates and silica.
- We took area air samples for VOCs, carbon monoxide (CO), nitrogen dioxide, and sulfur dioxide during kiln firing.
- We took surface wipe samples for elements.
- We visually inspected the ventilation system and reduction kiln exhaust hood.
- We measured CO levels during forklift use.
- We performed an ergonomic assessment of work practices.
- We gave management information on respiratory protection.

## What NIOSH Found

- We found that one employee had a full-shift, PBZ silica exposure that was at the NIOSH recommended exposure limit of 0.05 milligrams per cubic meter.
- We found that some silica samples collected during high dust-generating tasks exceeded the American Conference of Governmental Industrial Hygienist's excursion limit.
- We found that some employees were not using respirators properly.
- We found that CO levels exceeded the NIOSH ceiling limit of 200 parts per million during forklift use.
- We found that air was not well mixed throughout the facility.

## What Managers Can Do

- Managers should install local exhaust ventilation in areas where high dust-generating tasks are performed.
- Managers should improve the central building ventilation to increase overall air mixing and the number of air changes per hour.
- Managers should start a formal respiratory protection program which should include training employees on correct respirator use.
- Managers should make sure that employees are wearing respirators correctly, especially during high dust-generating tasks.

- Managers should make sure that routine maintenance is performed on the forklift.
- Managers should create a health and safety training program for employees.
- Managers should install ground fault circuit interrupters.
- Managers should fix or replace worn wire insulation jackets on electrical cords.

### What Employees Can Do

- Employees should use respirators when needed.
- Employees should properly store and maintain respirators and other personal protective equipment.
- Employees should wash hands thoroughly before eating to prevent ingesting harmful substances.

# Summary


**Air samples and surface wipe samples for contaminants were collected to evaluate employee exposures at a pottery shop. Although none of the PBZ samples exceeded the OSHA PELs or NIOSH RELs for any of the compounds measured, one employee's full-shift exposure for silica was at the NIOSH REL of 0.05 mg/m³. Some samples collected during high dust-generating tasks exceeded the ACGIH's excursion limit for silica. Employees did not always wear respirators properly when performing these dust-generating tasks. The use of LEV for high dust-generating tasks, improvements to general building ventilation, and a formal respiratory protection program would reduce employee exposure to contaminants.**

On February 2, 2007, NIOSH received a management request for an HHE at FUNKe Fired Arts, previously known as Annie's Mud Pie Shop, in Cincinnati, Ohio. Although no health symptoms were reported, management was concerned about the potential for employees' long-term exposure to a variety of substances while performing duties at the pottery shop. Exposures of concern included silica from the clay mixing process, elements from mixing dry materials used in the glazes, and VOCs and gases during kiln firing. Because management requires the use of respirators during clay and glaze mixing, they also requested information on proper respirator use and maintenance.

On March 21, 2007, NIOSH investigators held an opening conference and toured the facility to review work processes. On April 11, 12, and May 24, 2007, NIOSH investigators collected eight 8-hour PBZ samples and six area air samples for respirable particulates and silica. Six separate PBZ samples were taken while employees performed specific dust-generating tasks. Wipe sampling for elements was conducted throughout the facility. An ergonomic evaluation of the work processes was performed. During the firing of the kilns, area air samples were taken for elements, $NO_2$, $SO_2$, CO, $CO_2$, and VOCs. CO readings were also taken during forklift activities.

None of the PBZ or area air samples exceeded the OSHA PELs or NIOSH RELs for any of the compounds measured, although one employee's exposure for silica was at the NIOSH REL of 0.05 mg/m³. Tasks that created the highest concentrations of respirable silica and particulates included moving bags of raw materials to and from storage and mixing clay. Short-term concentrations of silica were high, reaching 2.0 mg/m³ over 96 minutes of sampling. This exceeded ACGIH's excursion limit of 5 times the TWA TLV. VOCs, $NO_2$, and $SO_2$ concentrations were not detected above the MDC during the kiln-firing process. Although PBZ samples of CO were not taken during the use of the forklift, real-time area CO measurements taken at breathing zone level in the storage room peaked at 204 ppm, exceeding the NIOSH ceiling limit of 200 ppm.

Due to the silica content of the clay and the potential for silica exposures to exceed OELs, we recommend using engineering controls to reduce employee exposures. This includes installing LEV in areas where high dust-generating activities take place and improving general building ventilation to allow adequate intake of outdoor air, mixing of indoor air, and dilution of potential airborne contaminants. Engineering controls are the preferred method over respirator use to reduce exposures to workplace contaminants. However, respirators should be used, and a formal respiratory protection program should be implemented until exposures can be reduced below the NIOSH REL and ACGIH excursion limit for silica. We also recommend establishing a health and safety training program for employees on appropriate equipment use and hazards. We further recommend that employees and students practice good hygiene in the workplace. Regular preventive maintenance for the forklift should be performed, eventually transitioning to a low or no emission forklift, and loading dock doors should be kept open while using the forklift to prevent the build-up of CO.

**Keywords:** NAICS 327112 (Vitreous China, Fine Earthenware, and Other Pottery Product Manufacturing), ceramics, silica, particulate matter, metals, elements, pottery, kilns, dust, clay, respirators, glazes, cobalt oxide, VOCs, $CO_2$, CO, forklifts, ergonomics, refractory ceramic fibers, glass fibers

# Introduction

In February 2007, NIOSH received a management request for an HHE at FUNKe Fired Arts (previously known as Annie's Mud Pie Shop) in Cincinnati, Ohio. Although no health symptoms were reported, the company requested an evaluation of potential hazards to their employees from long-term exposures while performing regular duties in the pottery shop. Management was interested in minimizing exposures to airborne elements and silica when employees transport and mix dry ingredients to make glazes and clays. Concerns were also raised regarding exposures to gases and metal fume emissions from kiln firings. Management also requested information on proper respirator use and maintenance.

FUNKe Fired Arts is a pottery shop that offers classes and sells pottery supplies, including pottery-making tools and raw materials such as clays and glazes. The shop employs four full-time employees who work 8-hour shifts and perform a variety of tasks. It also employs a varying number of part-time employees. The shop, part of a warehouse that previously manufactured thermometers, also houses a laundromat and private offices. The working area is divided into two large spaces containing the shop area and main studio. Specific areas of the shop are sectioned off by shelving or waist-high walls. The main storage area and loading dock, clay mixing/pugger room, glaze kitchen, and a space for a future spray booth are separate rooms that can be closed off by doors from the rest of the studio. Numerous fans have been placed throughout the studio to dry pottery pieces and to keep the area cool during warm weather. The facility contains a ceiling exhaust fan in the middle of the studio that is usually kept off due to the noise it generates. The shop has seven electric kilns and two gas-powered kilns located throughout the facility. Due to ongoing repair work, only one reduction kiln was functioning at the time of the NIOSH evaluation.

Aside from classes, other activities in the studio include receiving bags of supply materials (for sale and pottery shop use) and mixing raw materials to make glazes and clays. Clays are composed of a number of minerals including silica and alumina, while glazes include ingredients such as silica, feldspars, carbonates, borates, and coloring oxides (cobalt, copper, iron, tin, etc.). Clays can have a silica content of 5%–30% by weight. At the time of the evaluation, no LEV was available to control dust generated during the weighing and mixing of dry ingredients for glaze mixing or clay mixing and pugging. Employees were required to wear NIOSH certified elastomeric half-mask respirators with P100 particulate filter cartridges (Micro low profile, MSA, Pittsburg, Pennsylvania) when performing these tasks, but no formal respiratory protection program was in place.

Clay mixing and pugging occur in a dedicated room that is approximately 20'x 30' and is separated from the studio by a sliding door. The mixing process starts with wet waste clay, which is stored in 10-gallon buckets containing water located next to each pottery wheel and collected by the employee prior to the mixing process. The mixer is loaded with waste clay, then dry, powdered clay is added to the mixer until the desired consistency is reached. After the mixing process, the clay is removed from the mixer by hand and placed into a bucket, and is again hand-transferred to the pugger machine. The pugger extracts the air from the clay and pushes it onto a belt where it is cut into logs and stored for use. Although clay is usually mixed as needed, about 8–10 hours of mixing is performed per week in 2-hour time periods by several part-time employees.

Glazes are mixed in the raw materials area, which is partly sectioned off from the administrative and shop areas with storage shelves. The ingredients for the dry glaze powders are stored in plastic bins on and under tables. Glazes are weighed on a scale in 10-gallon buckets, and each ingredient is placed into another mixing bucket by upending one bucket into another and tapping the bottom. Buckets containing the proper mixture of dry ingredients are moved to the sinks where water is added and an electric hand-held mixer is used. Water is continuously added until the desired consistency is reached. Prepared glazes are stored in sealed jars and mixed on an as-needed basis. Employees typically mix approximately 22 glazes over 6 weeks.

During the firing process, shaped clay is placed in kilns and brought to very high temperatures that change its chemical and physical properties. The final characteristics of the pottery depend on the composition and preparation of the clay body, the firing temperature, and type of glazes used. Due to the intense heat used in the firing process and the variety of compounds used in the clays and glazes, health concerns related to fume exposures and the adequacy of the ventilation system were raised.

The gas-powered reduction kilns provide a reducing atmosphere produced by limiting the flow of air into the kiln; they are used mostly for glaze firing. The shop owns two reduction kilns; however, due to ongoing maintenance, only one reduction kiln

## Introduction (continued)

was being used at the time of our site visit. This working kiln has a canopy hood that allows hot emissions to exhaust through the roof. The canopy hood does not have an exhaust fan. We were told that the high temperature from the kiln emissions facilitates removal of contaminated air to the outside. This kiln is located in the corner of the shop space that also contains a kitchenette and is in the same area as the administrative desks. Electric kilns were observed to have individual exhaust systems that exhausted fumes from the bottom of the kiln through a duct and out the building. Kilns are usually fired 9–10 hours on average per firing event and can reach up to 2350°F. Firing frequency depends on the number of items needed to be fired.

Other duties performed in the shop include driving a forklift to shift pallets of 50-pound bags from supply trucks into the store room. Individual bags are moved to other locations or emptied in plastic storage containers to refill raw materials. Wheeled carts are available to move bags from locations within the shop, but stacking and removing individual bags is done by hand.

Students are required to clean their individual work spaces with a wet sponge after each use. However, a major cleaning by the staff is performed at the end of each 6-week class session. Employees use wet sponges to wipe down the tables and floors. During this time, employees wear NIOSH certified elastomeric half-mask respirators with P100 particulate cartridges (Micro low profile, MSA, Pittsburg, Pennsylvania).

## Assessment

NIOSH investigators held an opening conference and toured the facility on March 21, 2007. We collected samples on April 11, 12, and May 24, 2007. On April 11 and 12, area and PBZ air samples were collected to evaluate employee exposures to respirable particulates and silica. Wipe samples of various surfaces were also collected for elemental analysis. Real-time CO and $CO_2$ measurements were taken during the forklift activities and when the reduction kiln was in operation. Bulk samples were taken from thermal insulating material reported by some employees to cause skin irritation to identify its composition. Air samples for mercury were taken to ensure that no health hazard remained from the mercury found in a clogged drain several weeks earlier. A NIOSH ergonomics specialist observed the shop's work processes and spoke with several workers. Digital photos and measurements were taken to document the tasks and worksite layout.

The visit on May 24, 2007, included measurements of CO, $CO_2$, $NO_2$, $SO_2$, temperature, relative humidity, airborne elements, and VOCs during the firing of the reduction and electric kilns. Area samplers were placed next to the reduction kiln and the electric kilns being fired, in the shop area by the glaze mixing area, and in the middle of the studio to measure airborne elements and VOCs. $NO_2$ and $SO_2$ were measured with Draeger® colorimetric detector tubes (Lübeck, Germany) at various times throughout the day and in different locations in the facility. Real-time CO and $CO_2$ measurements were taken next to the reduction kiln and electric kilns. We observed air movement throughout the building with smoke tubes.

Depending on the compound, analysis was conducted in-house or by the NIOSH contract laboratory (Bureau Veritas, Novi, Michigan) according to methods specified in Appendix A. The evaluation criteria and discussion of the health effects of silica, respirable particulates, elements, CO, $CO_2$, $NO_2$, $SO_2$, and VOCs are provided in Appendix B.

A NIOSH medical officer was available for confidential medical interviews on April 11 and 12, 2007.

# RESULTS AND DISCUSSION

## Respirable Particulates and Silica

Silica and respirable particulate air sampling was performed by area, by PBZ, and by task (dust-generating). Twenty PBZ and area samples were taken on April 11 and 12, 2007, and analyzed for respirable particulates and silica. The only form of crystalline silica detected in any of the samples was quartz; cristobalite and tridymite were not detected. Results are listed in Tables 1, 2, and 3.

Table 1 shows that full-shift PBZ respirable particulate results ranged from trace to 0.90 mg/$m^3$, which did not exceed the OSHA PEL (5 mg/$m^3$) or ACGIH TLV (3 mg/$m^3$) for respirable particulates not otherwise regulated or classified; however, one full-shift PBZ sample contained silica. When respirable particulates contain silica, OSHA uses a formula based on the percent of silica contained in the dust to determine the PEL (refer to Appendix B). The calculated PEL for employee A (1.3 mg/$m^3$) on April 11, 2007, was not exceeded, although the full-shift PBZ sample was at the NIOSH REL (0.05 mg/$m^3$) for silica. NIOSH has classified crystalline silica as a potential occupational carcinogen.

Table 1. PBZ Sampling Results for Respirable Particulates and Silica

| Date | Employee | Sampling Time (min) | Respirable Particulates (mg/m³) | Silica (Quartz) (mg/m³) |
|---|---|---|---|---|
| 4/11/2007 | A | 499 | 0.90 | 0.05 |
| 4/11/2007 | B | 362 | 0.42 | ND |
| 4/11/2007 | C | 202 | trace | ND |
| 4/11/2007 | D | 444 | 0.15 | ND |
| 4/12/2007 | A | 561 | 0.19 | ND |
| 4/12/2007 | B | 309 | 0.19 | ND |
| 4/12/2007 | C | 476 | 0.22 | ND |
| 4/12/2007 | D | 280 | 0.34 | ND |
| MDC* | | | 0.05 | 0.01 |
| MQC* | | | 0.15 | 0.02 |

ND = Not detected (concentration is below the MDC).
Trace = Concentration is between the MDC and MQC.
* Calculated using a volume of 600 liters.

Respirable particulates measured in the area samples ranged from 0.12 mg/m³ to 0.49 mg/m³ (Table 2), below the OSHA PEL for respirable particulates. The only sample that contained silica was measured in the clay mixing and pugging room. Based on the silica content of this sample, the measured concentration was less than half the calculated OSHA PEL (1.2 mg/m³).

Table 2. Area Air Sampling Results for Respirable Particulates and Silica

| Date | Location | Sampling Time (min) | Respirable Particulates (mg/m³) | Silica (Quartz) (mg/m³) |
|---|---|---|---|---|
| 4/11/2007 | Employee Studio Glaze Mixing Area | 487 | 0.12 | ND |
| 4/12/2007 | Employee Studio Glaze Mixing Area | 451 | 0.13 | ND |
| 4/11/2007 | Raw Materials Area | 479 | 0.25 | ND |
| 4/12/2007 | Raw Materials Area | 454 | 0.25 | ND |
| 4/11/2007 | Mixing/Pugging Room | 489 | 0.49 | 0.03 |
| 4/12/2007 | Middle of Studio | 447 | 0.12 | ND |
| MDC* | | | 0.04 | 0.004 |
| MQC* | | | 0.11 | 0.025 |

ND = Not detected (concentration is below the MDC).
*Calculated using a volume of 800 liters.

The task of "moving bags of raw materials" had the highest concentrations of both respirable particulates and silica of all tasks performed (Table 3). Because this task was not performed over an 8-hour period, ACGIH excursion limits are an appropriate OEL for comparison. Quantifiable task-based silica concentrations obtained for "clay mixing" and "moving bags of raw materials" exceeded the ACGIH excursion limit of 0.125 mg/m$^3$ (5 times the TWA TLV [0.025 mg/m$^3$]) for silica. The full-shift sample that met the NIOSH REL for silica was obtained for the person who moved bags of raw materials that day. Other samples collected during clay mixing contained trace amounts of silica. These trace samples may have also exceeded the ACGIH excursion limit; however, due to the short sampling times and analytical LOD, we could not reliably quantify those concentrations. These silica concentrations show that a health hazard exists for employees who perform these high dust-generating tasks without appropriate engineering controls in place and without proper respiratory protection use.

Table 3. Task-based Sampling Results for Respirable Particulates and Silica

| Date | Task | Sampling Time (min) | Respirable Particulates (mg/m$^3$) | Silica (Quartz) (mg/m$^3$) |
|---|---|---|---|---|
| 4/11/2007 | Moving Bags of Raw Materials* | 96 | 2.4 | 2.0 |
| 4/12/2007 | Clay Mixing | 72 | 2.0 | trace |
| 4/12/2007 | Clay Mixing | 135 | 1.6 | 1.3 |
| 4/11/2007 | Clay Mixing | 125 | 1.2 | trace |
| 4/11/2007 | Restocking Dry Glaze Ingredients | 67 | 1.1 | ND |
| 4/11/2007 | Dry Glaze Mixing | 180 | 0.43 | ND |
| MDC† | | | 0.15 | 0.02 |
| MQC† | | | 0.45 | 0.10 |

ND = Not detected (concentration is below the MDC).
Trace = Concentration is between the MDC and MQC.
* This task was performed by employee A (Table 1). All other tasks were performed by part-time employees.
† Calculated using a volume of 200 liters.

## Elements

Nine surface wipe samples for elemental analysis were collected throughout the facility, including the working, eating, and administrative areas. The results of the surface sampling are shown in Table C1 in Appendix C. Areas with highest amounts of elements were the corner of the hood of the reduction kiln and the raw materials mixing area. However, elements were also present on eating table surfaces and the refrigerator handle. Lead was found on the eating table in the studio area, and on the conference table, which is sometimes also used as an eating table. Copper, iron, lead, manganese, and strontium were found in almost all of the locations sampled, including the interior lining of a respirator. This indicates that respirators need to be cleaned more thoroughly and more often.

Very few standards define "acceptable" levels of workplace surface contamination. Wipe samples, however, can provide information regarding the effectiveness of housekeeping practices, the potential for exposure to contaminants by other routes such as dermal or ingestion (e.g., surface contamination on a table that is also used for food consumption), the potential for contamination of worker clothing and subsequent transport of the contaminant outside the work place, and the potential for non-process related activities (e.g., sweeping) to generate airborne contaminants.

Area air sampling for elements resulted in concentrations well below the OSHA PELs and NIOSH RELs (refer to Table C2). The highest concentration was zinc, which was found in three locations between 12 and 18 µg/m$^3$ (by the reduction kiln, shop area, and administrative desk), which is well below the NIOSH REL for zinc oxide dust of 5 mg/m$^3$. All other airborne elements were present at concentrations below 5 µg/m$^3$.

## Gases and Bulk Samples

Several weeks before the site visit, management found a ball of mercury the size of a pencil end eraser in the floor drain after clearing a clogged drain. Management had it removed by a hazardous material company and contacted the consulting company who had approved the facility for use as a pottery shop. They stated that the company had previously inspected the facility, except the drain pipe where the mercury was found. NIOSH investigators took two air samples in the area around the drain to detect the presence of mercury. The samples showed no detectable concentrations; the limit of detection was 0.05 mg/m$^3$.

The reduction kiln, which is gas-fired, has a canopy hood positioned above the kiln. The hood has no active exhaust fan pulling air into the hood, but seemed to rely on the buoyancy of the hot air emitted from the kiln, which was then exhausted through the ceiling to the outside (Figure 1). When fired, the reduction kiln emitted a noticeable odor, and a visible plume of smoke was observed escaping the hood canopy. A layer of black residue was observed toward the top of the walls near the reduction kiln, which may be due to the escaping fumes and fume residues. Also, depending on the direction and strength of wind outside the building or air movement in the building near the kiln, it is possible that the passive hood of the reduction kiln may not consistently or effectively vent fumes at all times.

**Figure 1. Reduction kiln with hood**

Air sampling was performed for VOCs, $NO_2$, $SO_2$, $CO_2$, and CO during the firing of the reduction and electric kilns. Five area samples were taken for VOCs throughout the shop in various work areas. Only trace amounts of contaminants (perchloroethylene, trichloroethylene, benzene, and $C_5$–$C_7$ aliphatic hydrocarbons) were detected in any of the samples. Air samples collected using Draeger colorimetric detector tubes at various times during the kiln-firing process throughout the facility showed that $NO_2$ and $SO_2$ were not detectable above the LOD (0.5 ppm).

Real-time measurements for CO, which is emitted during the firing process, were taken near the electric and reduction kilns on April 12 and May 24, 2007, to compare emissions from each of the kilns. A Q-Trak™ Plus Indoor Air Quality Monitor, Model 8554 (TSI Incorporated, Shoreview, Minnesota) was placed next to each working kiln throughout the duration of firing. CO levels ranged from 0.3 ppm to 72 ppm during the reduction kiln firing, and from 0 to 4.7 ppm during the firing of the electric kiln. Average and maximum concentrations are summarized in Table 4. The results showed that the highest calculated CO average concentration was 4 times less than the NIOSH REL, and the peak concentration measured was less than half the 200 ppm ceiling limit. Very low emission levels of CO were seen around the electric kilns; this is probably due to the presence of LEV systems and the use of electricity rather than gas as the energy source.

On the afternoon of April 11 and the morning of April 12, 2007, employees used a propane-powered forklift (Mitsubishi 25 Model

RGC25, Houston, Texas) to pull pallets off high shelves and unload supplies off a supply truck to storage locations. During this time, forklift training was being conducted, and the employee being trained stood in various areas of the storage room observing the use of the forklift. A Q-Trak Plus monitor was placed on a shelf by the wall in the middle of the storage room. CO concentrations are summarized in Table 4. The maximum CO concentration measured during forklift use (204 ppm) exceeded the NIOSH ceiling limit of 200 ppm, a value that should not be exceeded at any time [NIOSH 2005].

Table 4. Real-time CO Concentrations Taken During Kiln Firing and Forklift Use

| Date | Location | Sampling time (min) | CO concentration (ppm) TWA | CO concentration (ppm) Maximum |
|---|---|---|---|---|
| 5/24/2007 | Next to Electric Kiln | 540 | 0.5 | 4.7 |
| 4/12/2007 | Next to Reduction Kiln | 570 | 8.5 | 72 |
| 5/24/2007 | Next to Reduction Kiln | 540 | 7.8 | 29 |
| 4/11/2007 | Storage Room with Forklift | 20 | 150 | 204 |
| 4/12/2007 | Storage Room with Forklift | 40 | 48 | 62 |
| NIOSH REL | | | 35 | 200 (Ceiling) |
| OSHA PEL | | | 50 | |
| ACGIH TLV | | | 25 | |

Smoke tubes were used to observe air movement throughout the facility during various activities. Investigators observed large areas of the studio that had stagnant pockets of air when no fans were turned on, even when windows were open. During reduction kiln firing and when the weather was cold, we observed that only a few windows near the reduction kiln were opened. When the weather was warm, most to all of the windows were opened and fans were turned on to ventilate and cool the building. Open windows change the flow of air movement throughout the building and increase emission migration from the reduction kiln into other areas of the building. This pattern seemed to magnify when the loading dock doors were open.

The bulk samples taken from the fibrous material used to plug the eye hole in the reduction kiln and the insulation board consisted of glass or ceramic fibers. Also present were perlite (non-fibrous glass), cellulose, and minor amounts of mineral fragments and synthetic fibers. No air samples were taken because these materials are only periodically handled, however, due to their friable consistency, the fibers can become airborne and may be inhaled when cleaning or moving the boards.

## Ergonomic Assessment

Bagged and boxed dry clay and glaze materials weighing 50 pounds are stored on pallets on and around shelves (see Figure 2). Lifting from pallets stored on the floor to the shelves requires bending, resulting in the vertical location of the hands ranging from 4" to 32". Accessing materials stored on the shelf requires reaching and lifting above shoulder height. Workers informed us that they occasionally use a forklift truck to pull the pallet off the shelf and position it to a more appropriate height instead of lifting overhead. The pallets on the floor are not height adjustable, and in most cases, workers cannot access them from all sides.


**Figure 2. Bags and boxes of raw material**

The dry clay and glaze materials are prepared for use in large plastic totes (see Figure 3). Due to lack of storage space, half of the boxes are positioned on a raised platform (vertical location = 36" to handle) and the other half are positioned under the platform on dollies (vertical location = 15" to handle).


**Figure 3. Plastic tote storage**

When adding water to the dry materials, workers must transport the bucket to a sink in a different area of the building. Workers either use a cart or carry the bucket to the sink and manually lift the bucket into the basin (see Figure 4). When the appropriate amount of water is added, they must remove the bucket from the basin to transport it to the mixer.

**Figure 4. Sink**

In the mixing/pugging room, the machines are raised on platforms to bring them to a more appropriate level. However, the buckets (see Figure 5) and carts used to transport the material in this area are too low and are not adjustable.

**Figure 5. Buckets used in mixing/pugging room**

Workers not only prepare the materials for the shop, they also use the potter's wheels in the workstations. One setup is shown in Figure 6. Back pain can occur when the throwing surface and seat are not the same height. The workstation measured during the walk-through tour had an approximately 1" difference between the throwing surface and seat, which may cause back discomfort. As a result of back discomfort, one potter had asked that a workstation be modified for working while standing (see Figure 7).


**Figure 6. A typical potter's workstation**


**Figure 7. A modified potter's workstation**

## Other Observations

During the facility tour, NIOSH investigators observed that electrical outlets were not equipped with GFCIs. These devices

## Results and Discussion (continued)

prevent electrocution by constantly monitoring electricity flowing in a circuit to sense any loss of current. If a loss of current does occur, the device quickly switches off power to that circuit to prevent electrocution. Investigators also noticed that the electric cord insulation jackets had pulled away from several of the potter wheel plugs, exposing the intermediate wires. These should be repaired or replaced. Plugs should also be securely inserted into the outlet.

Due to a malfunction in the sliding mechanism, the door of the mixing/pugging room did not close completely, leaving a 4-inch gap in the most closed position. The smoke test used to visualize air flow in this room showed that the old, unused ventilation ducts from the previous business allow random currents of air (perhaps due to wind activity outside) to flow into the room and into the studio area. During the mixing/pugging, and glaze mixing activities, we also observed employees improperly using NIOSH-certified, elastomeric half-mask respirators with P100 particulate cartridges. A copy of the OSHA respiratory protection standard 29 CFR 1910.134 and *(Mandatory) Information for Employees Using Respirators when not Required Under Standrd - 1910.134 Appendix D,* was given to management on April 12, 2007.

Some areas in the administrative and shop areas were carpeted. Carpets may be more difficult to clean than hard-surfaced floors and vacuuming carpets without HEPA filters may introduce particulates back into the air.

No employees participated in confidential medical interviews. They told NIOSH investigators that they had no health concerns at that time.

## Conclusions

On the basis of our investigation, NIOSH investigators determined that employees may be potentially overexposed to silica. One employee's full-shift PBZ sample was at the NIOSH REL. The tasks of "clay mixing" and "moving bags of raw materials" by hand exceeded the ACGIH's excursion limit for silica. Concentrations of airborne elements, $NO_2$, or $SO_2$ did not exceed NIOSH RELs or OSHA PELs. CO concentrations can be high in the immediate vicinity of the forklift, and they exceeded the NIOSH ceiling limit at times. Also, the flow of air throughout the building can vary greatly, and stagnant pockets of air were observed.

## Conclusions (continued)

The best approach for controlling exposure to workplace contaminants is through the hierarchy of controls (refer to the discussion in Appendix B). If a less- or non-hazardous substitution of the hazardous compound cannot be made, then proper engineering controls, such as installing and using LEV in high dust-generating areas and improving general ventilation throughout the building should be considered. Respiratory protection should not be the sole method for controlling exposures below recommended levels. However, until proper engineering controls can be implemented and exposures are documented to be below OELs, a formal respiratory protection program should be established. Because management requires that employees who perform specific tasks (glaze mixing and clay mixing) wear respiratory protection, the respiratory protection program must meet all the requirements of OSHA standard 1910.134 [29 CFR 1910.134], including having a written program and providing training, fit testing, and medical testing.

The main ergonomic design problems that place workers at risk of musculoskeletal disorders are low work heights, non-adjustable workstations/pallets, and lifting heavy boxes/bags. Workers sometimes do not take the time to work as safely as they can, and no training regarding proper lifting is provided.

## Recommendations

Management has already demonstrated a proactive approach to managing occupational health and safety issues. NIOSH investigators support management's plans to work with a ventilation engineer and kiln manufacturer to install active ventilation hoods for the reduction kilns. Due to the age of the building, the shop is exempt from many of the current building codes. NIOSH investigators support management's plan to bring the fire and sprinkler system up to code and to fix exposed wires. NIOSH investigators also recommend the following:

### Ventilation Recommendations

- Install LEV in the mixing/pugging room. The LEV should include a hood, ductwork, a fan, and an exhaust stack. The hood should capture airborne dust as close as possible to the point of generation. Consult a ventilation engineering firm that is familiar with industrial ventilation systems.
- Improve the general ventilation system to allow adequate intake of outdoor air, improve mixing of indoor air, and

facilitate dilution of potential airborne contaminants. Consult a licensed ventilation specialist familiar with designing ventilation systems for ceramic shops. It is important that the ventilation system provide enough make-up air, especially when the LEV is on and kilns are being fired because these processes will be removing air from the building. Fans and windows may supplement, not replace, proper ventilation controls.

- After ventilation controls have been installed, consider taking additional PBZ and area measurements to evaluate the effect of the changes and to ensure that exposures have been reduced to levels below the NIOSH REL and ACGIH excursion limit.
- Minimize the number of bends in the electric kiln exhaust duct. These turns and bends will decrease the efficiency of the system.

## Respirator Recommendations

- Because management requires employees to wear respirators when performing certain tasks, all requirements of OSHA's respiratory protection standard (29 CFR 1910.134) apply, including but not limited to establishing a written respiratory protection program, medical evaluations, fit testing, and employee training on proper respirator use and maintenance (such as shaving facial hair before use and proper placement of straps). Please refer to the document, ***OSHA Small Entity Compliance Guide for the Revised Respiratory Protection Standard*** [OSHA 1998], for more information. You can also access it online [http://www.tsi.com/pages/fittest/secgrev.pdf].
    - For fit testing, medical testing, board certified occupational medicine doctor referrals, and the location of local occupational health clinics, contact the Association of Occupational and Environmental Clinics [http://www.aoec.org/].
- Wear respirators when performing any high dust-generating tasks due to the PBZ concentration found at the REL for silica. This is already required for tasks such as "clay mixing" and "glaze mixing," but should be expanded to include the task of "moving bags of raw materials." Respiratory

protection may not be needed once additional sampling for air contaminants shows that the ventilation changes are consistently effective.

## Forklift Recommendations

- Ensure that employees always wear seatbelts and drive forklifts with forks as close to the ground as possible, regardless of load.
- Provide employees with forklift training in accordance with OSHA standard 1910.178 [29 CFR 1910.178]. OSHA has developed checklists to assist in training on OSHA's powered industrial truck operator standards. Information can be found at [http://www.osha.gov/dcsp/ote/trng-materials/pit/daily_pit_checklist.html].
- Ensure regular forklift tune-ups to reduce unnecessary exhaust emissions and maximize efficiency. For propane or natural gas units, exhaust gas analysis should be periodically performed as part of the preventive maintenance. Consider replacing the current forklift with a low/no emission forklift, such as an electric model, to minimize exhaust gases in the workplace.

## Ergonomic Recommendations

To prevent the occurrence of musculoskeletal disorders in this work environment, NIOSH investigators recommend the following:

- Incorporate a minimum height range of 27.6" to 29.7" and a maximum height range of 51.6" to 56.2" with respect to workstations/worktables, palletized pieces, shelving units, and items on carts to eliminate overhead reaching and bending [Kroemer 1989].
    - Store frequently used materials at waist height; do not store materials at floor level.
    - Use extra pallets to raise the height of cart surfaces to the recommended ranges.
    - Provide scissor lift tables to reduce bending and overhead reaching.

- Use pallet carousels and collapsible carousel stands to allow access to loads from various angles [Chengalur et al. 2004].

- Eliminate lifting and carrying items weighing more than 50 pounds. Always use carts to transport heavy materials long distances.
- Provide a faucet hose extension (see Figure 8) to eliminate lifting buckets into and out of the sink.

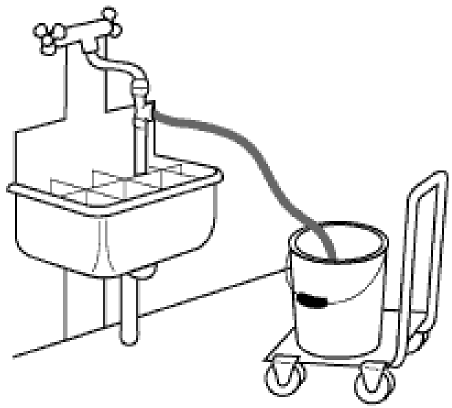

**Figure 8. Recommended hose extension**
[Canadian Centre for Occupational Health and Safety 1998]

- Provide a range of heights for pottery wheels and stools. Make sure these two heights match to eliminate back pain and discomfort.
    - Consider using the leg extension kits that are available for wheels.
    - Look into the variety of sizes of blocks that are available for wheels as seen in Figure 7.
    - Use stools with lumbar support and tilt adjustment.
    - Provide adjustable leg stools for level or tilted seats.
- Do not perform repetitive activities (wedging, throwing, and trimming) in long sessions. Divide these activities into several sessions or shift from one task to another.

## Other Recommendations

- Suppliers of raw materials sometimes glue bags together that are stacked on pallets to prevent them from falling off each other during transit. When stacked bags of raw materials are manually separated and moved, the paper bags sometimes tear due to this glue. We recommend purchasing from suppliers that either use stronger bags that do not tear easily or use suppliers that have an alternative method of keeping the bags on the pallet. In the interim, employees should continue to wear respirators when shifting bags to minimize exposures to respirable particulates containing silica.

- Fix or adjust the door to the mixing/pugging room so that it closes fully. This will also help prevent silica and other particulates from entering the studio.
- Replace disintegrating insulation fiberboard. Minimize aerosolizing the fibers when cleaning the board by using a HEPA vacuum. Although performing this task may not exceed current OELs due to the short time in which tasks are performed, a NIOSH-approved N95 respirator should be worn for additional respiratory protection, and the individual performing the task should be included in the formal respiratory protection program. When handling fibrous materials, minimize skin contact by wearing disposable gloves and long-sleeved clothing.
- Establish a hazardous communication program in accordance with the OSHA Hazard Communication Standard [29 CFR 1910.1200]. The standard addresses issues of evaluating and communicating hazards to workers, including supplying employees with information on hazardous chemicals used in the workplace, and providing training on appropriate work practices, proper use of equipment and PPE, and appropriate hygiene techniques. Guidelines for establishing a hazardous communication program can be found at [http://www.osha.gov/Publications/osha3111.html].
- Designate a separate and dedicated area for eating, drinking, and storing food; encourage both employees and students to use the designated eating area. To prevent ingestion of metals and other contaminants that were found on surfaces, eating, drinking, or storing food should be prohibited outside designated areas.
- Maintain good housekeeping practices to minimize particulate exposures. This includes removing carpeting in areas where particulates accumulate. Ensure that vacuum cleaners have HEPA filters to prevent fine particulates from being released back into the air during vacuuming.
- Install GFCIs throughout the facility. Fix or replace worn wire insulation jackets and periodically check the condition of electrical equipment.

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## Crystalline Silica

All area samples were taken over an 8-hour shift. PBZ samples were taken over approximately 8 hours for full-time employees, and separate PBZ samples were taken during the performance of certain tasks. Specific tasks included activities such as clay mixing, moving bags of raw materials, restocking raw materials, and mixing glazes. Samples taken by task varied from 67 to 180 minutes.

All sampling trains (including those for elements below) were calibrated using a DryCal DC Lite (Bios International, Butler, New Jersey) primary flow calibrator. Calibration was conducted before the sampling trains were placed on the workers and immediately after the work shift ended. Samplers were attached to the employees' clothing (in the employees' breathing zones) and checked throughout the day for correct positioning and to ensure that the sampling pumps functioned correctly.

Sampling for silica was performed using pre-weighed 37-mm polyvinyl chloride filters (5-µm pore size) installed in Dorr-Oliver cyclones. Cyclones remove the non-respirable fraction of particulate so the filter collects only that portion of the dust (<10-µm aerodynamic diameter) that penetrates to the deeper areas of the lung. The sampling pumps were calibrated to a flow rate of 1.7 Lpm. Respirable crystalline silica was analyzed using X-ray diffraction according to NIOSH Method 7500 [NIOSH 2007].

## Respirable Particulates

Prior to analyzing air samples for crystalline silica, the total weight of each air sample was determined gravimetrically according to NIOSH Method 0600 [NIOSH 2007]. Sample mass was determined by weighing the filter used during sampling on an electrobalance and subtracting the weight of the filter taken before sampling.

## Elements: Metal and Minerals

Surface wipe and air sampling analysis for elements was performed in accordance with NIOSH Method 7303 [NIOSH 2007]. Samples were analyzed using a Perkin Elmer Optima 3200XL, inductively coupled plasma atomic emission spectrometer.

### *Surface Wipes*

Ghost Wipe brand wipes were used to collect nine surface wipe samples for elemental analysis from various locations with a high potential for skin contact. The USEPA classifies a surface as high contact if workers routinely touch it, such as computer keyboards. Where the surface was flat, a 10 cm by 10 cm template was used to collect the sample. The sampling process consisted of using a wipe and wiping the surface in an "S" pattern from top to bottom and then from left to right. A template was not used on non-flat surfaces so sample results are only a qualitative indication of surface contamination. The wipes were placed in a sterile container and submitted for laboratory analysis per NIOSH Method 7303 [NIOSH 2007]. A clean template and new pair of gloves was used for each sample and care was taken to use the same technique and wiping pressure to reduce variation in collection efficiency.

### *Airborne Elements*

Five area samples for elements were taken over a full shift. Samplers were placed near the kiln firing area, administrative area, and studio areas. Sampling for airborne elements was conducted using 37-mm mixed-cellulose ester filters (0.8-µm pore size) in plastic filter cassettes. These sampling trains were calibrated to a flow rate of 2 Lpm. Elements were digested in concentrated nitric acid and analyzed per NIOSH Method 7303 [NIOSH 2007].

## VOCs

To screen for VOCs, NIOSH investigators collected area air samples using thermal desorption tubes attached by Tygon® tubing to SKC® Pocket Pumps® calibrated at a flow rate of 0.05 Lpm. The tubes contain three beds of sorbent material. The first section contains Carbopack Y (90 mg), the second section contains Carbopack B (115 mg), and the last section contains Carboxen 1003 (150 mg). Sample tubes were purged with helium at 100 cc/min for 30 minutes prior to analysis to remove moisture. Analysis was done by gas chromatography-mass spectrometry.

## $NO_2$ and $SO_2$

Draeger colorimetric detector tubes (Lübeck, Germany) were used to take spot measurements of $NO_2$ (Serial #: XL-1131) and $SO_2$ (Serial #: XK-0471). A leak check test was done on the pump prior to sampling, and air was pulled through the tubes to observe color change in the tubes. Samples were taken next to the reduction kiln, electric kiln, and in the main studio at the start of firing, and every 2–3 hours thereafter. The detection range of the $NO_2$ detector tubes is 0.5–10 ppm and the range for $SO_2$ detector tubes is 0.5–5 ppm.

## Mercury

To identify the presence of mercury, Draeger colorimetric detector tubes (Serial #: XK-0331; 0.1/b) were used in two locations. One air sample was taken in the mixing/pugging room where the mercury ball was found. The other air sample was taken in the basement. The detection range for these tubes is 0.05–2 $mg/m^3$.

## $CO_2$, CO, Relative Humidity, and Temperature

NIOSH investigators used a Q-Trak Plus Indoor Air Quality Monitor to continuously monitor for CO, $CO_2$, relative humidity, and temperature. On April 11 and 12, 2007, the Q-Trak was used during the forklift driving. It was placed on the center left side of the storage room at approximate breathing level. On May 24, 2007, a Q-Trak was placed next to the reduction kiln and another Q-Trak was placed next to the electric kiln taking measurements throughout the firing process once a minute for 8 hours.

## Bulk Samples

Two bulk samples were collected. One sample was taken from crumbling pieces of a high temperature insulation board. The other sample was taken from the material used to plug the eye hole into the kiln to prevent heat from escaping after the heat source was turned off. The samples were submitted for qualitative analysis by polarized light microscopy. The samples were prepared and analyzed using NIOSH Method 9002 [NIOSH 2007].

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# Appendix B: Evaluation Criteria

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by Federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. However, not all workers will be protected from adverse health effects even if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, which contributes to the individual's overall exposure.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values where health effects are caused by exposures over a short period. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits, while others are recommendations. The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits enforceable in workplaces covered under the Occupational Safety and Health Act. NIOSH RELs are recommendations based on a critical review of the scientific and technical information available on a given hazard and the adequacy of methods to identify and control the hazard. NIOSH RELs can be found in the *NIOSH Pocket Guide to Chemical Hazards* [NIOSH 2005]. NIOSH also recommends different types of risk management practices (e.g., engineering controls, safe work practices, worker education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects from these hazards. Other OELs that are commonly used and cited in the U.S. include the TLVs recommended by ACGIH, a professional organization, and the WEELs recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. They are not consensus standards. ACGIH TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2007]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2007].

Outside the U.S., OELs have been established by various agencies and organizations and include both legal and recommended limits. Since 2006, the Berufsgenossenschaftliches Institut für Arbeitsschutz (German Institute for Occupational Safety and Health) has maintained a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the U.S. [http://www.hvbg.de/e/bia/gestis/limit_values/index.html]. The database contains international limits for over 1250 hazardous substances and is updated annually.

Employers should understand that not all hazardous chemicals have specific OSHA PELs, and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect its employees from hazards even in the absence of a specific OSHA PEL. OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminate or minimize identified workplace hazards. This includes, in order of preference, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting worker health that focuses resources on exposure controls by describing how a risk needs to be managed [http://www.cdc.gov/niosh/topics/ctrlbanding/]. This approach can be applied in situations where OELs have not been established or can be used to supplement the OELs, when available.

## Crystalline Silica

Silica exists in several forms, but only exposure to crystalline (as opposed to amorphous) forms can produce the pulmonary condition called silicosis [Klaassen 2008]. Silicosis is a disabling, progressive, and sometimes fatal pulmonary fibrosis characterized by the development of silica-containing nodules in the lung [NIOSH 1981]. These nodules are thought to be formed by the death of macrophages laden with fine silica. The silica is ingested by new macrophages which are in turn killed, thereby releasing intracellular enzymes to promote further fibrosis; thus, the process becomes progressive even if exposure is terminated [NIOSH 1977]. The exposure conditions can affect the occurrence and/or severity of silicosis. Silicosis usually occurs after 15 or more years of exposure; however, silicosis has developed after only a few years of exposure to high concentrations [NIOSH 1986]. Initially, silicosis may not produce symptoms. However, as the disease progresses, it is characterized by shortness of breath and a reduction in pulmonary function. Individuals with silicosis are also at increased risk of developing tuberculosis.

Quartz is the most common crystalline form of silica. Cristobalite and trydimite, other major forms of crystalline silica, can be formed from quartz under certain temperature and pressure conditions. Cristobalite and trydimite are considered to have greater fibrogenic potential than quartz, and OSHA has set the PEL for the respirable fraction of these substances at one half the value of quartz [29 CFR 1910.1000]. The respirable fraction is considered to be that portion of inhaled particulates that penetrates to the nonciliated portions of the lung. In general, particulates greater than 7–10 µm in diameter are removed in the nasal passages and have little probability of penetrating to the lung. Particulates smaller than this can reach the air-exchange regions (alveoli, respiratory bronchioles) of the lung and are considered more hazardous.

The OSHA PEL for crystalline silica is determined according to the amount of crystalline silica in the dust. The OSHA PEL for respirable dust containing 1% quartz or more in general industry is expressed as an equation [29 CFR 1910.1000]:

$$\text{Respirable PEL} = \frac{10\ \text{mg/m}^3}{\%\ \text{Silica} + 2}$$

If, for example, the dust contains no crystalline silica, the PEL is 5 mg/m$^3$, and if the dust is 100% crystalline silica, the PEL is 0.1 mg/m$^3$, an enforceable standard under the OSHA General Industry Air Contaminants Standard [29 CFR 1910.1000].

The NIOSH REL for respirable silica (all forms), is 0.05 mg/m$^3$ [NIOSH 2005]. The RELs are intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen [NIOSH 1996].

The ACGIH TWA TLV for respirable quartz is 0.025 mg/m$^3$ [ACGIH 2007]. However, for many substances with a TWA OEL, no STEL exists. In these cases, ACGIH recommends applying excursion limits, which state that worker exposure levels may exceed 3 times the TLV TWA for no more than a total of 30 minutes during the work day, and under no circumstances should they exceed 5 times the TLV TWA, provided that the TLV TWA is not exceeded [ACGIH 2007].

## Respirable Particulates (Particulates Not Otherwise Regulated)

Formerly referred to as nuisance dust, airborne particulate that does not have an established occupational health exposure criterion is referred to as particulates not otherwise regulated. These terms encompass general categories of dusts, or mixtures of dusts that do not have substance-specific occupational exposure standards. This category includes all inert or nuisance dusts, whether mineral, inorganic, or organic that are not listed specifically in 29 CFR 1910.1000 [29 CFR 1910.1000].

The OSHA PEL for total particulate is 15.0 mg/m$^3$ for total dust and 5.0 mg/m$^3$ for the respirable fraction, determined as 8-hour averages. These are generic criteria for airborne particulates that do not produce significant organic disease or toxic effects when exposures are kept under reasonable control. If the respirable particulates contain silica, the OEL for respirable particulates would not apply. NIOSH has not established an REL for respirable particulates, not otherwise classified or regulated.

## Carbon Monoxide

Carbon monoxide is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials such as gasoline or propane fuel. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea; symptoms advance to vomiting, loss of consciousness, and collapse with prolonged or high exposures. If the exposure level is high, loss of consciousness may occur without other symptoms. Coma or death may occur if high exposures continue. The display of symptoms varies widely from individual to individual, and may occur sooner in susceptible individuals such as young or aged people, people with preexisting lung or heart disease, or those living at high altitudes.

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm, which should not be exceeded [NIOSH 2005]. The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure [29 CFR 1910.1000]. The ACGIH TLV is 25 ppm for an 8-hour TWA. The IDLH is 1200 ppm. The IDLH exposure condition poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment.

## Volatile Organic Compounds

This is a large class of organic chemicals (i.e., containing carbon) that have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state at room temperature. VOCs are emitted in varying concentrations from numerous indoor sources including carpeting, fabrics, adhesives, resins, solvents, paints, cleaners, waxes, cigarettes, and combustion sources.

Indoor environmental quality studies have measured wide ranges of VOC concentrations in indoor air as well as differences in the mixtures of chemicals that are present. Research also suggests that the irritant potency of these VOC mixtures can vary. Some researchers have compared levels of VOCs with human responses (such as headache and irritative symptoms of the eyes, nose, and throat). However, neither NIOSH nor OSHA currently have specific exposure criteria for VOC mixtures in the non-industrial environment. Research conducted in Europe suggests that complaints by building occupants may be more likely to occur when total VOC concentrations increase [Molhave et al. 1986]. It should be emphasized that the highly variable nature of these complex VOC mixtures can greatly affect their irritancy potential.

## Elements on Surfaces

No standards defining “acceptable” levels of workplace surface contamination have been established for most substances. Exposures to elements can manifest a variety of human health effects and are influenced by many factors including the dose and the route of exposure (e.g., manganese has a very low order of toxicity when ingested, but is much more toxic when inhaled as a fume). Toxicity can also be influenced by the state of the element (e.g., methyl mercury is much more toxic by ingestion than the elemental form).

Metals comprise the majority of the known elements and have widespread natural occurrence in the environment.

Elements have a wide range of properties, uses, and toxicity. Some elements are essential for life while others have no known biologic function. Other metals are capable of producing disease. Some metals that are essential nutrients can be toxic at higher concentrations. Allowable daily intake (food), maximum contaminant level (drinking water), and industrial exposure (e.g., NIOSH RELs) guidelines and regulations have been established for a number of metals. Inhalation is usually the exposure pathway of concern in industry. However, some metals (e.g., nickel, beryllium, arsenic) can cause skin effects. If the metal is in a certain form (e.g., alkyl lead), it can be absorbed through the skin [Klaassen 2008].

The toxicity of a metal and its mode of toxicity are influenced significantly by the metal's chemical state. The elemental form of a metal, for instance, rarely interacts with biologic systems. Metal hydrides (e.g., arsine) are generally far more acutely toxic than other forms. Soluble salts of metals are usually more readily absorbed and are possibly more hazardous. The toxic properties of methyl mercury are very different from inorganic mercury. Despite these differences, some toxicologic similarities exist among the group of metals. Many absorbed metals accumulate in the kidneys and the bones, and many have long half-lives [Clayton and Clayton 2008]. Inhalation of high concentrations of metals is irritating and may result in severe respiratory tract damage, including bronchitis, chemical pneumonitis, and pulmonary edema.

## Ergonomics

Overexertion injuries and musculoskeletal disorders, such as low back pain, tendonitis, and carpal tunnel syndrome are often associated with job tasks that include: (1) repetitive, stereotyped movement about the joints; (2) forceful manual exertions; (3) lifting; (4) awkward and/or static work postures; (5) direct pressure on nerves and soft tissues; (6) work in cold environments; or (7) exposure to whole-body or segmental vibration [Armstrong et al. 1986; Gerr et al. 1991; Rempel et al. 1992; NIOSH 1997]. The risk of injury appears to increase as the intensity and duration of exposures to these factors increases and the recovery time is reduced [Moore and Garg 1995]. Although personal factors (e.g., age, gender, weight, fitness) may affect an individual's susceptibility to overexertion injuries/disorders, studies conducted in high-risk industries show that the risk associated with personal factors is small compared to that associated with occupational exposures [Armstrong et al. 1993].

In all cases, the preferred method for preventing and controlling work-related musculoskeletal disorders is to design jobs, work stations, tools, and other equipment to match the physiological, anatomical, and psychological characteristics and capabilities of the worker. Under these conditions, exposures to task factors considered potentially hazardous will be reduced or eliminated.

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Table C1. Surface Wipe Sampling Results for Elements Taken on April 11, 2007

| Element | Raw Materials Mixing Table | Kiln Hood Corner* | Table in Studio | Refrig-erator Door Handle* | Glaze Dipping Table | Interior Surface of Respirator* | Electric Kiln Lid | Confer-ence Table | Office Desk Surface | LOD | LOQ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Location (µg/100 cm²) | | | | | | | | | (µg/sample) | |
| Barium | 21 | 2.7 | 1 | 0.8 | 2 | 1 | 4.2 | 1.2 | 0.17 | 0.05 | 0.16 |
| Cadmium | trace | 0.39 | trace | trace | trace | trace | trace | trace | trace | 0.07 | 0.24 |
| Cobalt | 250 | trace | ND | trace | 9.2 | trace | 2 | trace | ND | 0.6 | 2.0 |
| Copper | 1400 | 26 | 11 | 26 | 45 | 11 | 15 | 24 | 5.5 | 0.2 | 1.0 |
| Iron | 300 | 600 | 29 | 36 | 23 | 29 | 430 | 140 | 11 | 0.4 | 2.0 |
| Lead | 5.5 | 11 | 0.71 | 0.61 | 1 | 0.71 | 2.6 | 0.9 | ND | 0.6 | NA |
| Magnesium | 310 | 190 | 120 | 120 | 120 | 120 | 170 | 140 | 100 | 10 | 42 |
| Manganese | 87 | 8.8 | 1.9 | 1.5 | 1.4 | 1.9 | 7.1 | 90 | 0.34 | 0.09 | 0.29 |
| Zinc | 310 | 8100 | trace | 40 | trace | trace | 44 | trace | trace | 0.3 | 20 |

Trace = element was detected, but at levels too low to be quantified (between the LOD and LOQ).
ND = Not detected (below the LOD).
* Templates were not used on non-flat surfaces, so sample results are an estimate of a 100 cm² area and results should be considered as a qualitative indication of surface contamination.

Table C2. Area Air Sampling Results for Elements Taken Over an 8-Hour Shift, May 24, 2007

| Element | Reduction Kiln | Office Area | Front Studio Area | Back Studio Area | MDC | MQC | NIOSH REL† | OSHA PEL† | ACGIH TLV† |
|---|---|---|---|---|---|---|---|---|---|
| | Location* Concentration (µg/m³) | | | | (µg/m³) | | | | |
| Barium | 0.07 | 0.08 | trace | trace | 0.02 | 0.06 | 500 | 500 | 500 |
| Cadmium | 0.20 | 0.28 | 0.30 | trace | 0.02 | 0.07 | Ca | 5 | 2‡ |
| Cobalt | trace | 0.41 | 0.17 | trace | 0.05 | 0.17 | 50 | 100 | 20 |
| Copper | 0.48 | 1.0 | 0.70 | trace | 0.06 | 0.22 | 1000 | 1000 | 1000 |
| Lead | trace | trace | 1.2 | trace | 0.31 | 1.0 | 50 | 50 | 50 |
| Manganese | 0.47 | 1.5 | 0.47 | trace | 0.02 | 0.07 | 1000 | 5000§ | 200 |
| Tin (tin oxide) | 2.7 | 3.7 | 4.5 | trace | 0.52 | 1.6 | 2000 | none | 2000 |
| Titanium (titanium dioxide) | 0.08 | 0.13 | 0.07 | trace | 0.02 | 0.07 | Ca | 15000 | 10000 |
| Zinc (zinc oxide) | 12 | 17 | 18 | 1.3 | 0.21 | 1.0 | 5000 | 5000‡ | 2000‡ |

Trace = element was detected, but at levels too low to be reliably quantified (between MDC and MQC).
Ca = potential occupational carcinogen. NIOSH recommends exposures should be limited to the lowest feasible concentration.
* All results from the 5th location were trace values or below the limit of detection.
† Given as a TWA.
‡ As respirable dust.
§ Ceiling limit.

# Acknowledgments and Availability of Report

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

This report was prepared by Lilia Chen, Jessica Ramsey, and Scott Brueck of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. Medical field assistance was provided by Ayodele Adebayo. Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway. Health communication assistance was provided by Stefanie Evans.

Copies of this report have been sent to employee and management representatives at FUNKe Fired Arts and the OSHA regional office.  The report may be viewed and printed from the following internet address: http://www.cdc.gov/niosh/hhe. Copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161.

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