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Worker Exposure to Airborne Contaminates when using
Waste Foundry Sand in the Construction of Road Embankments

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16. Abstract <p>A section of road was constructed in Northeastern Indiana in the summer of 1996 using waste foundry sand as the embankment construction material. Initial testing on the waste sand had determined no detrimental health effects. However, it was observed during construction that once the sand had dried, tire-road interaction raised copious clouds of black dust. This led to worker concern regarding airborne silica and silicosis. This study aimed at determining whether the threat of overexposure to airborne crystalline silica existed in regard to Occupation Health and Safety Administration's (OSHA) Permissible Exposure Limit (PEL).</p> <p>Experiments carried out at the Auburn Foundry waste sand monofill in the summer of 1998 in which clouds of dust were purposefully generated and sampled by both respirable personal samplers and high volume area samplers showed that respirable crystalline silica dust did not overexpose the workers relative to the OSHA PEL. The negative findings of crystalline silica in the respirable samples were confirmed in the area samples by an second, independent laboratory.</p> <p>Calculations show that up to an average of 20% by weight of respirable size dust such as baghouse hopper dust can be allowed in the waste foundry sand. Specifying this amount of fine dust for waste foundry sand will provide a worker exposure safety factor of about 2.0 for protection against overexposure to crystalline silica dust.</p> <p>Removing the baghouse hopper dust material from the waste sand would reduce dust generation considerably. Recommended methods of dust abatement include watering down the dust during transportation, dumping, and compacting and keeping the sand wet during construction.</p>					
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Introduction

Sand is a major waste product of the foundry industry. For many years, foundries have advocated the use of waste sand for civil engineering purposes. One such use is in the construction of roadway embankments. It seems to be an ideal solution, one which rids the industry of the protracted problem of dumping the sand on the plant site or at a monofill site and fulfills the Occupational and Safety Health Administration's (OSHA) specifications for limiting worker exposure. It also makes good business sense to "recycle" waste products.

The waste foundry sand is a mixture coming from different processes in the foundry. It can range in size from large coarse waste sand from broken and crushed castings and molding to much finer particulate matter accumulated and captured in baghouses, a device used for air pollution control. These various sand wastes are mixed in order to prevent the finer sand particles from becoming airborne and posing a dust problem either at the plant or the sand monofill.

In 1996, waste sand was used to in the construction of a roadway embankment in northeastern Indiana. Previous investigations of the sand had found that it was safe to use as a construction material and had no detrimental effects. However, several days after the laying and compaction of the sand, tire interaction with the compacted and now dried sand caused the generation of copious black dust clouds that coated the backs of the construction vehicles in a layer of fine black dust.

Concern expressed by the workers breathing the dust is the driving force behind this research. The workers concern in breathing the waste sand dust, knowing it is composed mainly of silica, is silicosis. Thus the aim of this research was to determine whether worker exposure is greater than the current OSHA Permissible Exposure Limit (PEL) for silica and to specify a mixture percentage of fine dust for waste sand that can be used for embankment construction.

Findings

The field experiments took place at the Auburn foundry waste sand monofill during the summer of 1998. Large black dust clouds were generated by moving the sand around on the sand monofill under dry conditions. Area sampling was done using a High Volume Andersen Cascade Impactor, a PM-10 sampler and a Total Suspended Particulate (TSP) sampler. Personal cyclone respirable samplers were worn by personnel at the site to measure worker exposure.

Overall, over 20 samples were taken from the various samplers over two days of sampling. Aerodynamic size distribution and percentage silica content among particles ranging up to 3.3 microns was found using results from the Andersen Impactor. The air sampling showed that a large fraction of the collected dust contained particles within the respirable range of 0.5 to 5.0 microns and indicated that most of the silica obtained was from quartz, with very small amounts of cristobalite and non-detectable levels

of tridymite. The PM-10 sampler measured particles equal to or less than 10 microns in diameter and cumulatively indicated quartz to be the major phase of silica present at approximately 12% by weight. Total dust concentration values obtained from the PM-10 sampler also yielded high values. The total suspended particulate (TSP) sampler measured particles equal to or less than 40 microns in diameter and was used to determine the concentration of sand dust and the silica content for this wider range of particle sizes. Results from the TSP sampler results were similar to those given by the PM-10 sampler. Comparison

of the total dust concentration results from the different field samplers showed good agreement. The low percentage of cristobalite and the more dangerous tridymite was constant throughout the samplers. Quartz emerged as the main component of silica present in the dust. Data from the personal cyclone respirable samplers showed that overexposure will not occur during an 8 hour work shift using the waste foundry sand in road embankment construction. Up to an average of 20% by weight of respirable dust such as baghouse hopper dust can be contained in the waste sand and still provide a margin of safety of 2.0 with respect to the OSHA PEL.

Implementation

The recommendations reached in this research indicate that a waste foundry sand material specification would allow up to an average of 20% by weight of respirable dust in the waste sand. Standard safety precautions

should be used during the road-laying, including wetting the sand before dumping and compacting, regular wetting of the compacted sand, and initial worker testing using personal respirable samplers to check for overexposure.

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1. INTRODUCTION

1.1 Background

1.1.1. Material Re-use

Sand is a major waste product of the foundry industry. For many years, foundries have advocated the use of waste sand for civil engineering purposes. One such use is in the construction of roadway embankments. It seems to be an ideal solution, one which rids the industry of the protracted problem of dumping the sand on the plant site or at a monofill site and fulfills the Occupational and Safety Health Administration's (OSHA) specifications for limiting worker exposure. It also makes good business sense to "recycle" waste products.

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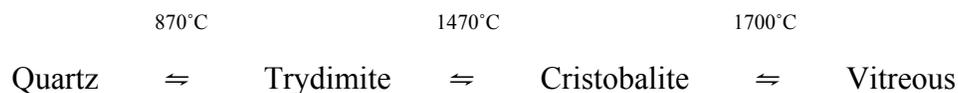
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1.1.2. Silica

Silica is a compound composed of silicon and oxygen, with a constant elemental composition expressed by the chemical formula SiO_2 (USDL/NIOSH, 1996). It is the second most common mineral in the earth's crust and is a major component of sand, rock and mineral ores. Yet much remains to be learned of its chemistry and, in particular, its behavior as a dust.

Silica exists in eight known principal phases: quartz, cristobalite, tridymites (M and S), coesite, keatite, stishovite, and silica W. According to Sosman (1965), quartz, cristobalite and the tridymite varieties are of particular importance in terms of human health and safety as the other phases are producible only under high pressure and are presumably barically stranded under atmospheric pressure. Thus, these are also the most common crystalline forms of silica encountered in the industry.

Quartz, the most common phase found in nature, ranges from huge crystals, to amorphous-looking powders a few microns in size, to shapeless masses of chalcedony agate. It is a silicon dioxide polymorph with a composition of 46.7% Si and 53.3% O crystallized in a hexagonal system. The transformations between the three common forms and vitreous silica are as follows:



1.1.3 Silicosis

Silica dust has long been recognized as a major occupational hazard, causing disability and deaths worldwide among workers in several industries such as mining and quarrying, refractory materials industry, potteries and foundries. It causes silicosis, which is a disabling, nonreversible and sometimes fatal lung disease caused by over exposure to respirable silica (CDC/NIOSH, 1992). It occurs due to tiny particles of the silica being absorbed by cells deep within the lung. These cells become impaired and digest themselves, causing lung damage and scarring known as fibrosis. Eventually the capacity to breathe is reduced leading to fatigue, loss of appetite, severe cough, chest pains and fever. Markowitz and Roaner (1995) found that particle size, dust concentration, and

duration of dust exposure are important factors in determining the attack rate, latency period, incidence, rate of progression and outcome of the disease. Hence these factors also play an important part in the setting of standards and limits for exposure. In addition to silicosis, inhalation of crystalline particles has been associated with other diseases such as bronchitis and tuberculosis as the body becomes more susceptible to these illnesses.

A careful study was made by King et al. (1964) on the effects of quartz, cristobalite, tridymite and fused silica glass all of the same particle size (generally 1 – 4 microns) and specific area. All the silicas caused pulmonary silicosis. However, health effects from the amorphous (fused) form were least severe. Quartz and cristobalite were similar in that both caused typical symptoms of silicosis. But tridymite was the most potent, causing much more rapid and severe symptoms. Further testing concluded that the particularly hazardous particles are those of solid crystalline in the 0.5 – 5.0 micron range.

The National Institute for Occupational Safety and Health (NIOSH) has classified three types of silicosis, depending upon the airborne concentration of crystalline silica to which a worker has been exposed (USDH/NIOSH, 1992):

1. Chronic Silicosis : Usually occurs after 10 or more years of overexposure.
2. Accelerated Silicosis : Results from higher exposures and develops after 5 to 10 years overexposure.
3. Acute Silicosis : Occurs where exposures are the highest and can cause symptoms to develop within a few weeks or up to 5 yrs after exposure.

1.1.4 Silicosis and Cancer Risk

The profound and often extensive lesions caused by exposure to crystalline silica in the lung naturally leads to the question of whether these lesions also favor the occurrence of lung cancer. A number of early studies, mostly based on autopsy material, gave a negative answer to this question and the view that exposure to silica does not increase the risk of lung cancer became widely accepted.

It is only in the last decade that this issue has been taken up again, using more powerful epidemiological methodology than was used in previous investigations, such as

the study carried out by Goldsmith et al. (1982). As a result, associations are now documented between work involving exposure to silica dust and cancer of the lung. A study by Simonato et al. (1989) concluded that the potential carcinogenic effect of silica dust is characterized by three main findings:

1. Silica is carcinogenic in experimental systems.
2. Lung cancer risk is increased among workers exposed to silica and not exclusively among those exposed to known carcinogens.
3. When investigated separately, the lung cancer risk is concentrated among the sub- population of exposed workers who develop silicosis.

In 1992, in its Sixth Annual Report on Carcinogens, the National Toxicology Program (NTP) of the U.S. Department of Health and Human Services listed respirable crystalline silica among the substances which may be reasonably anticipated to be carcinogens. This classification was retained in the NTP's Seventh Annual Report (NTP, 1994)

In 1997, a working group of the International Agency for Research on Cancer (IARC) published a monograph classifying inhaled crystalline silica from occupational sources as carcinogenic to humans, and categorized it as an IARC Group 1 agent (WHO, 1997). The publication followed by ten years IARC's 1987 classification of crystalline silica as Group 2A (WHO, 1987).

Objective

The main objective of this work was to investigate worker exposure and subsequent safety issues related to airborne contaminants when handling waste foundry sand for road construction. The waste foundry sand used in this research was a mixture of used sand and baghouse dust. Baghouse dust particles typically range from 10 microns down to 0.25 micron and as such, the majority of them are in the respirable range of 0.5 – 5.0 microns. Thus, it is vital that it be ascertained whether the worker exposure is greater than the current OSHA permissible exposure limit (PEL) for silica.

2. LITERATURE REVIEW

According to the National Institute for Occupational Safety and Health (NIOSH) and the U.S. Department of Labor (1996), every year more than 250 American workers die from silicosis, hundreds are disabled, and more than one million U.S. workers are exposed to crystalline silica. Bang et al. (1995) report that, in the U.S., from 1968 through 1990 the total number of deaths where silicosis was reported anywhere on the death certificate was 13,744. Of these, approximately 6,322 listed silicosis as the underlying cause of death. By industry, construction accounted for 10% of the total silicosis-related deaths.

2.1 Silica Dust in Industrial Processes

Silica, in its many forms, is used extensively throughout many major industrial groups (maritime, agriculture, construction, and general industry). The Standard Industrial Classification (SIC) Codes are used to classify businesses by the type of activity in which they are engaged. OSHA has used the SIC Codes to classify and identify industries where overexposure to crystalline silica was found and where it was not found. Industries where overexposure was found include heavy construction, bridge, tunnel and elevated highway construction, foundries, clay refractories and masonry and other stonework. Industries where sampling was conducted for crystalline silica dust and overexposures were not found include highway and street construction, concrete work, excavation work, wrecking and demolition, and cut stone and stone products. The tables included in Appendix A, prepared from OSHA's Integrated Management Information Systems (IMIS), give a more complete list of the SIC Codes.

Though much work and research has been done regarding crystalline silica dust in industrial processes, it was interesting to note that the recycling of waste material for purposes not associated with the same process which generated the waste has not received any attention. The following are a few of the jobs in which workers are involved in environments similar to the environment in a typical road-laying site, where the dust clouds emanate from the dumping and handling of the waste sand and from the interaction between the waste sand and the construction vehicle tires.

2.1.1 Silicosis in Sand Blasting Workers

According to Shaman (1983), of the more than one million U.S. workers at risk of developing silicosis, more than 100,000 of these workers are employed as sandblasters. Approximately 59,000 of the one million workers exposed to crystalline silica will eventually develop silicosis. No published estimates indicate the number of sandblasters who will develop silicosis, but in a study in England, Merewether (1936) reported that 5.4% of a population of sandblasters died from silicosis or silicosis with tuberculosis in a 3.5 year period.

Acute silicosis is less common today than it was in the 1930's because engineering controls are used to reduce exposure to respirable crystalline silica and because of the use of alternate abrasives (NIOSH, 1992). However, data indicate that most abrasive blasters continue to work without adequate respiratory protection (NIOSH, 1974). In addition, NIOSH (1990) found that workers adjacent to abrasive blasting operations often wear no respiratory protection at all. Samimi et al. (1974) found that even in short-term sandblasting operations (less than 2 ½ hours in an 8-hour workday), the average concentration of crystalline silica was 764 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$), with average silica content of 25.5%. This average dust concentration was twice the 1974 OSHA standard.

2.1.2 Silicosis in Rock Drillers

Silicosis has long been recognized as a danger among rock drillers. Burns et al. (1962) reported it as a danger among highway and dam construction rock drillers, Sacharov et al. (1971) among slate quarry workers, Chernaik (1989) among tunnel construction rock drillers, and Guenel et al. (1989) among rock quarry workers. Although rock drillers in underground coal mines have developed silicosis, those in surface coal mines have not historically been considered at significant risk (Fairman et al., 1977). However, recent studies by Goodman et al. (1992) suggest that surface drilling presents a serious respiratory hazard to drillers and drill helpers because most of the recent case reports on silicosis involve surface drillers.

2.1.3 Silicosis in Construction Workers

Construction activities in which crystalline silica dust may be present in the air include abrasive blasting of concrete, chipping, hammering, and drilling of rock, and crushing, loading, hauling and dumping of rock (NIOSH, 1996). Thus, the threat of silica dust among construction workers arises not from sand but from rock dust. The hauling and dumping of rock associated with highway construction has been shown not to be dangerous for worker health as, according to OSHA IMIS data, no exposure to crystalline silica has been found. However, that classification does not take into account the use of waste foundry sand in place of “clean” sand.

2.2 Exposure Limits

OSHA has established Permissible Exposure Limits (PEL) for many substances, including airborne crystalline silica. The OSHA PEL for crystalline silica in general industry is listed in the Code of Federal Regulations, 29 CFR 1910.1000, “Air Contaminates”, under Table Z-3 of mineral dusts (CFR, 1997). It is a time-weighted average that cannot be legally exceeded for an 8-hour shift during a 40-hour week. OSHA has published general industry PELs for three different forms of crystalline silica: quartz, cristobalite and tridymite. The current OSHA PEL for crystalline silica is $10 \text{ mg}/\text{m}^3$ divided by the percentage of silica in the dust (respirable) + 2 (for quartz). The same formula applies for cristobalite and tridymite, divided by 2. The formula used for a mixture and which is used in this research is:

$$\text{PEL}_{\text{mixture}} = \frac{10 \text{ mg} / \text{m}^3}{(\% \text{quartz} + 2(\% \text{cristobalite}) + 2(\% \text{tridymite}) + 2)}$$

A recent study of gold miners by Steenland et al. (1995) concluded that a 45-year exposure equal to the current OSHA standard for silica would lead to a lifetime risk of silicosis of 35% to 47%. In light of this and other such studies, NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH) have recommended stricter limits. Though NIOSH can recommend limits to OSHA, OSHA is responsible for establishing health and safety regulations and any NIOSH recommendations are not

mandatory. NIOSH's recommendation is $0.05\text{mg}/\text{m}^3$ and its position is that crystalline silica dust is a carcinogen. ACGIH's recommendations include $0.05\text{ mg}/\text{m}^3$ for cristobalite, $0.1\text{ mg}/\text{m}^3$ for quartz, and $0.05\text{ mg}/\text{m}^3$ for tridymite.

2.3 Work Place Safety

An important part of this research deals with the recommendation of remedial or precautionary measures should our field measurements program reveal a threat of overexposure to airborne crystalline silica when using waste foundry sand in road construction. Hence it is vital to review and be aware of the standard safety precautions and measures.

In silica-hazardous workplaces, safety and health programs, policies and procedures must be implemented and enforced. They must be designed to fit the specific needs of the workplace in order to keep exposure to airborne silica below the PEL. They can be carried out in several ways that are detailed in the following paragraphs.

2.3.1 Workplace Dust Sampling

A program for periodic sampling for airborne crystalline silica dust must be followed. Sampling and analysis of respirable crystalline silica are conducted in accordance with NIOSH Method No. 7500 and 7602 (NIOSH, 1984) or their equivalent, for "silica, crystalline respirable". Appropriate places for sampling can be determined with the help of an industrial hygienist. This sampling program must include both personal sampling of workers in the course of their jobs and area sampling.

2.3.2 Medical Surveillance Programs

According to NIOSH (1992) a respiratory medical surveillance program designed by a physician experienced in occupational or pulmonary medicine should be set up. Such examinations should take place before job placement and at least every three years thereafter (NIOSH, 1974). At the minimum, the program should include:

- A medical and occupational history to collect data on worker exposure to crystalline silica and signs and symptoms of respiratory disease.

- Periodic chest X-ray interpreted by a physician certified by NIOSH as a B reader with demonstrated proficiency in the classification of silicosis.
- Respiratory symptom questionnaire.
- Evaluation by a physician with special attention to the lungs.

2.3.3 OSHA Hazard Communication Standard

Every employer has the obligation to warn, protect, and train workers about workplace hazards and to provide a safe workplace. The OSHA Hazard Communication Standard, 29 CFR 1910.1200, requires employers to warn and train employees concerning workplace hazards.

2.3.4 Administration and Engineering Controls

Engineering, administrative, and housekeeping controls need to be used to reduce worker exposure. These controls consist of new or modified equipment to reduce airborne silica, industrial ventilation, washing down surfaces, vacuuming and limiting the time spent by a worker in a silica-hazardous area. The most common and economical control in the field involves the use of water to wet the surface and prevent fugitive dust generation.

2.3.5 Respiratory Protection Equipment

When a work area exceeds the PEL, appropriate respiratory protective equipment must be worn. OSHA regulations for this equipment can be found in 29 CFR 1910.134. Respiratory protection programs are outlined in the NIOSH Guide to Industrial Respiratory Protection, Publication No. 8.

2.4 Special Emphasis Program (SEP) for Silicosis

The threat of silica dust has motivated the implementation of an OSHA-wide Special Emphasis Program (SEP) to reduce and eliminate the workplace incidence of

silicosis from the exposure to crystalline silica. It is based on the wide-spread occurrence and use of crystalline silica across the major industrial groups such as maritime, agriculture, construction, and general industry, as a result of the number of reported silicosis related deaths, the NIOSH estimates for the number of exposed workers, and the health effects of crystalline silica dust exposure.

SEP has set forth a policy, that covers most SIC Codes where an overexposure to crystalline silica may exist. SEP includes procedures for the initiation, scheduling, and conducting of inspections in these areas. Administration and area directors ensure that these procedures are adhered to in the scheduling of programmed inspections.

It can be gathered from the literature review that worker concern of overexposure to crystalline silica dust is justified. However, it has also been seen that this will depend upon several significant factors including dust concentration, silica content, and the duration of exposure. Other important factors that must be looked at include aerodynamic particle size distribution and the waste sand mixture with particular attention to the presence of baghouse dust within the waste foundry sand.

3.0 FIELD EXPERIMENTS

Equipment

Calibration of the air pollution monitoring equipment to be used at the waste sand monofill site at Auburn Foundry was the first initiative. The equipment that was used for field-testing included a Total Suspended Particulate sampler (TSP), a PM-10 sampler, a High-Volume Anderson Sampler, and typical OSHA personal cyclonic samplers (refer to Figure 3.1). With a cut-off equivalent particulate diameter of 40 microns, the TSP sampler was used to determine total suspended particulate dust concentration and the silica content within the dust. The PM-10 sampler selectively determined the dust concentration for particles 10 microns and less in diameter and subsequent analysis yielded the silica content. Both the TSP and the PM-10 were used as area samplers. The High-Volume Anderson was used specifically for aerodynamic particle size distribution

as well as to determine the content of silica and its various phases among the smaller size particles. The driver of the vehicle

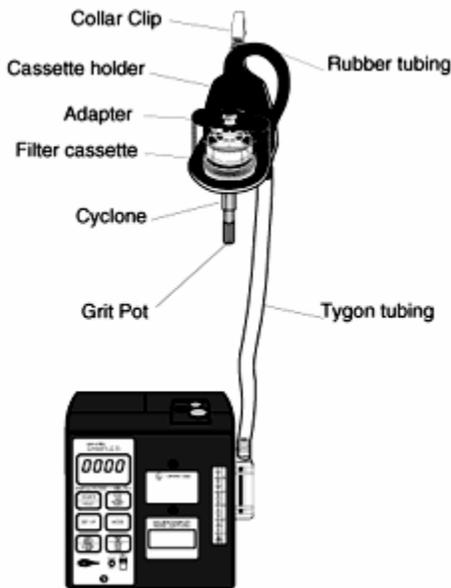


Figure 3.1 : Personal Sampling Train - SKC 224-PCXR8 Universal sampler and filter assembly (Source - SKC web site)

and other persons present at the sampling site, to simulate worker exposure at a typical road construction site, wore personal cyclone samplers as well.

Site Selection and Sampling

For actual site sampling, simulation of a road-laying environment was of utmost importance. As no new road is planned to be constructed any time in the near future using waste foundry sand as embankment material, all experiments were conducted at the Auburn foundry waste sand monofill site located 5 miles south of Auburn, IN just east of I-69. The equipment was driven up to the Auburn foundry but sampling had to wait until a period of dry weather long enough so that dust clouds at the site could be generated with ease.



Figure 3.2. : Equipment set-up at Auburn sampling site.

The equipment was set-up in a flat, level area in the middle of the monofill to simulate the level area at a road laying and construction site. As seen in Figure 3.2, all three area samplers were kept in close proximity of each other so that their results could later be compared and correlated. A steady wind with fluctuating direction blew on both days air sampling was conducted. The samplers were placed such that the plume of dust from the manipulated waste foundry sand always traveled directly to the samplers.



Figure 3.3 : Worst case scenario dust generation at the sampling site.

To create a road-laying environment and a relative worst case scenario, a bulldozer, front end loader and dump truck were used to move waste sand around the monofill and to raise and dump sand loads. This generated copious dust clouds that rolled across the samplers as seen in Figure 3.3.

A front-end loader generated dust clouds throughout the sampling period by working piles of sand as well as dropping front-end bucket loads of sand upwind of the area samplers, refer to Figure 3.3. The operator in this front-end loader also wore a personal respirable dust sampler. Two additional personal samplers were worn, one by Waseem Afzal and the other by Steve Miller (INDOT) for one hour. Both remained in and around the dust clouds simulating worker exposure as can be seen in Figure 3.4. At times, the dust clouds generated were so dense that both “workers” disappeared in black dust clouds. An interesting observation was the amount of particulate matter that settled on their clothing, hair, eyebrows, and cheeks showing that a large amount of the dust seemed to be particles greater than 40 microns, which settle readily under the influence of gravity. Both of the personal samplers were translocated near the other air sampling equipment at a height of approximately 3 to 4 feet from the ground, for the remaining sampling time.



Figure 3.4: Simulation of worker exposure at the sampling site.

The personal samplers were run for a 2-hour period. Four sets of filters were changed on the TSP and the PM-10, and three sets of samples were taken with the High-Volume Anderson Sampler on the first day of sampling. Additional samples were obtained during the second day of sampling.

4.0 Results and Discussion

4.1 Personal Samples

Worker personal air monitoring samplers used respirable dust cyclones in combination with 3-piece, 5micron PVC cassettes for the MSA[®] units operating at a flow rate of 1.7 LPM and a 2-piece cassette for the SKC[®] units operating at a flow rate of 1.9 LPM in accordance with the manufacturers specifications. These samplers collected respirable dust only with a mass median diameter of about 4 to 5 micons. Sampling was

carried out in accordance to NIOSH method 7601 for crystalline silica. The personal samples were collected as indicated in section 3.0 and were sent to Kemper Laboratories for analysis of quartz, cristobalite and tridymite. Kemper Laboratories is an independent lab certified by the American Industrial Hygiene Association.

Since the personal sampling was carried out for a time period shorter than the typical 8-hour work shift, the permissible exposure level (PEL) and severity calculations were performed as specified by OSHA procedures to take into account the reduced sampling time. Table 4.1 contains the results of the personal samples as analyzed for quartz, tridymite and cristobalite.

Table 4.1 Personal Sample Results for Exposure and Severity

Sample No.	Exposure Mg/m ³	Severity	Comment
1	0.488	0.58	<1.0 no overexposure
2	0.368	0.76	<1.0 no overexposure
3	0.534	0.40	<1.0 no overexposure
4	1.031	0.86	<1.0 no overexposure

As can be seen from Table 4.1, the exposure to the mixture of quartz, cristobalite and tridymite as adjusted for severity and the reduced sampling time period resulted in no worker overexposure to crystalline silica. Specifically, the Kemper lab found no tridymite in the personal respirable samples, very little cristobalite and quartz ranging from 4 to 12 % by weight. These results are significant in that the experiments as shown in section 3.0 were very severe as the air samplers and the personal samples were well immersed in the plume of dust coming directly from the manipulated waste foundry sand at the Auburn sand monofill. Moreover, the experiment also quantified the total dust concentration with the PM10 and the TSP high volume samplers. The total dust concentration measured was far above what would be expected to exist at a road construction work site over an 8 hour period.

4.2 Area Samples

The area samples taken with the PM10, TSP and Andersen High Volume Impactor samplers were sent to a different laboratory for analysis of crystalline silica. This was done to obtain a second laboratory result for the waste foundry sand dust for confirmation of the Kemper lab findings of no tridymite and very little cristobalite in the personal samples. The laboratory chosen was the Wausau laboratory in Wausau Wisconsin. This lab, like the Kemper lab, is certified by the American Industrial Hygiene Association. The additional eleven samples were delivered to the Wausau by Dr. Jacko in his airplane immediately after sampling was completed. The results of the Wausau lab were very similar to that of the Kemper lab. Wausau lab found no tridymite in the eleven additional samples. Also, while Kemper found very little cristobalite, Wausau laboratory found none. The quartz fraction found by the Wausau lab ranged from about 7 to 20% by weight which was slightly higher than the Kemper samples. However, keep in mind that the area samples (sent to Wausau lab) encompass a much broader range of particle sizes than do the personal samples (sent to Kemper lab). Recall also that the personal samples are all respirable samples being about 5 microns in diameter and less. This broader particle size range of the area samples probably explains the slightly higher quartz percentages in these samples as analyzed by the Wausau lab.

4.3 Material Specification for Waste Foundry Sand

The question of what a reasonable material specification would be for waste foundry sand to be used in road construction will be addressed in this section. Since the waste foundry sand used in these experiments contained very fine baghouse dust mixed in with the much larger size waste sand from the molding operations at the foundry, it would seem reasonable to develop a specification calling for zero baghouse dust. With zero baghouse dust, the respirable fraction of particles in waste foundry sand would be much lower and therefore there would be much less chance of overexposing workers to

silica dust in the respirable size ranges. However, a material specification calling for zero baghouse dust (or a similar fine fraction of dust) may be too restrictive. In order to find a reasonable level of fine dust that a waste foundry sand may contain and still be used for road embankment fill, a calculation can be performed using some assumptions along with the OSHA PEL concept.

If a severity level of 0.5 results from an OSHA exposure calculation for crystalline silica, then there is implied a factor of safety of 2.0 in the amount of crystalline silica the worker is exposed to. If we use this assumed severity level of 0.5, we can calculate the allowable percentage of respirable dust in a waste foundry sand material. Using the four personal respirable samples as analyzed by Kemper Laboratory for crystalline silica along with their respective total sample weights, respirable sample weights, PEL mixture concentrations and a severity level of 0.5 the allowable respirable dust percentage was calculated. The results indicated that a waste foundry sand could contain a weight percentage of respirable dust ranging from 15% to 30% with an allowable average of 20%. Therefore, from worker personal samples taken at the Auburn Foundry sand monofill, while vigorously handling their waste sand to purposely generate airborne dust, it appears that a reasonable waste sand specification would call for no more than 20% by weight of particles less than 5 microns.

4.4 Summary and Conclusions

A series of worker personal and area air samples taken at the Auburn Foundry waste sand monofill while the sand was being handled to purposely generate high dust concentrations indicates that crystalline silica in the air breathed by workers does not pose a significant silicosis threat. Personal samples of respirable dust analyzed for quartz, cristobalite and tridymite as analyzed by the Kemper Industrial Hygiene Laboratory of Long Grove, IL showed quartz ranging from 4 to 12% by weight, very little cristobalite and no tridymite. Additionally, these respirable personal samples did not exceed the OSHA PEL standard, and therefore workers would not be overexposed to crystalline silica dust.

The area samples were hand-carried to Wausau Industrial Hygiene Laboratory in Wausau, Wisconsin for confirmation of the crystalline silica content found by the Kemper labs. The Wausau lab results confirmed the results of the Kemper lab. While quartz was higher and ranged from 7 to 20% by weight probably due to the wider range of particle sizes captured by the area samplers, the cristobalite and tridymite were in non-detectable amounts. This second opinion by the Wausau laboratory confirmed the very low cristobalite and non-detectable tridymite found in the respirable samples by the Kemper laboratory.

A calculation using an OSHA severity factor of 0.5 indicated that waste foundry sand can contain up to an average of 20% by weight respirable size dust such as baghouse hopper dust. This specification for respirable fine dust in waste foundry sand will keep worker exposures to crystalline silica below maximum allowable values.

4.5 Epilogue

The field experiments in this research project were carried out during the summer of 1998 at the Auburn Foundry waste sand monofill located just south of Auburn, Indiana. Originally there were plans to continue this field measurements program at the monofill in order to gather additional data. However, a severe company worker strike followed by a complete change of personnel in the subsequent years following the summer of 1998 prevented additional samples from being taken. Attempts were made to find a section of roadway that was being constructed using waste foundry sand somewhere in the State of Indiana but to no avail. Therefore, no additional field samples were taken. The conclusions reached in this paper regarding worker exposure to crystalline silica dust, therefore, must stand on the field experiments performed in the summer of 1998. Keep in mind that the simulated road construction activity using waste foundry sand at the Auburn Foundry monofill, generated very severe airborne dust conditions which were much worse than would be expected in a typical road construction situation. As such, the Principal Investigator of this research considers the results described herein to be very conservative.

APPENDIX A : SIC CODES FOR EXPOSURE TO CRYSTALLINE SILICA

SIC Codes where overexposure to crystalline silica dust have been found and documented:

<u>SIC Code</u>	<u>Industry Type</u>
0732	Crop preparation services for market
1542	Non-residential construction
1622	Bridge, tunnel, and elevated highway construction
1629	Heavy construction
1721	Painting and paper hanging
1741	Masonry and other stonework
1799	Special trades contractors
3255	Clay refractories
3321-2	Foundries
3325	Foundries
3365	Foundries
3441	Fabricated structural metal
3443	Fabricated plate work
3479	Metal coating and engraving and allied services
3543	Industrial patterns
3731	Shipbuilding and repair

SIC Codes for where sampling has been conducted for crystalline silica dust during the previous three years and no overexposures were found:

<u>SIC Code</u>	<u>Industry Type</u>
1389	Oil and gas field services not elsewhere classified
1611	Highway and street construction
1771	Concrete work
1793	Glass and glazing work
1794	Excavation work
1795	Wrecking and demolition
2851	Paints, varnishes, lacquers, enamels and allied products
2951	Asphalt paving mixtures and blocks
3088	Plastics plumbing fixtures
3089	Plastics products not elsewhere classified
3251	Brick and structural clay and tile
3281	Cut stone and stone products
3264	Porcelain electrical supplies
3272	Concrete products except brick and blocks
3297	Nonclay refractories
3324	Steel investment foundries
3363	Aluminum die castings
3364	Non-ferrous die castings

3366	Copper foundries
3369	Nonferrous foundries
3431	Enameled iron and metal sanitary ware
3444	Sheet metal works
3492	Fluid power valves and hose fittings
3498	Fabricated pipe and pipe fittings
3523	Farm machinery and equipment
3533	Oil and gas field machinery and equipment
3561	Pumps and pumping equipment
3569	General industry machinery and equipment
3599	Industrial and commercial machinery and equipment not elsewhere classified
3648	Lighting equipment not elsewhere classified
3715	Truck trailers
3823	Industrial instruments for measurement
4789	Transportation Services
5199	Nondurable goods
7261	Funeral services and crematories
7363	Help supply services
7538/9	General automobile repair shops
7699	Repair shops and related services

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