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EXPOSURE ASSESSMENT TO RESPIRABLE CRYSTALLINE SILICA PARTICLES DURING AIRFIELD MAINTNENANCE CONCRETE OPERATIONS

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by

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Abstract

Crystalline silica is found in naturally occurring and manmade materials. According to OSHA, approximately 2.2 million people are exposed to silica each year (OSHA, 2002). These individuals are at an increased risk of silicosis, an incurable disease that is often fatal. The objective of this project was to determine if airport maintenance workers are exposed to crystalline silica over the current permissible exposure limit. Two days of sampling was conducted and it was determined that there was some exposure to the Airfield Paint Crew exceeding the action level. The highest employee exposure was at 0.362 mg/m^3 with a corresponding PEL measured to be 0.455 mg/m^3. The severity ratio has a score of 0.797 (any score greater than 1 is an overexposure). As shown by the mortality rates in several studies, there is evidence to suggest workers in the construction industry are at an increased risk of exposure to crystalline silica (NIOSH, 2008). This paper finally concludes that further sampling should be conducted to confirm the sampling results. If the results yield the same exposure, then the workers should be put into a respiratory protection program and engineering controls should be implemented to reduce exposure.

Keywords: Crystalline Silica, Airport Maintenance Operations, Concrete Cutting, Paint Striping

Dedication

To Saranya, Natalie, Nathan, and Natasha, your unbridled support for me throughout my career and education. I couldn't have done it without you!

Acknowledgement

I would like to acknowledge my employer, Salt Lake City Department of Airports for allowing me the time, materials, and financial backing for this project.

I would like to particularly acknowledge Heidi Harward (Airport Safety Manager) for her faith and confidence in me during this time.

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1. Introduction

Silica is a group of minerals composed of Silicon and Oxygen molecules (Figure 1). The word crystalline refers to how the molecules arrange themselves to form a three dimensional lattice structure (USDOI, 1992). The two forms of silica are crystalline (Figure 2) and non-crystalline (amorphous) (Figure 3). Crystalline silica can be found in more than one form (polymorphism). Some of the polymorphic forms of crystalline silica are: alpha quartz, tridymite, and cristobalite. Quartz is often referred to as one of the three forms of crystalline silica (NIOSH, 2002). Quartz is commonly found in stone, brick, concrete, soil, and other natural occurring and manmade materials.

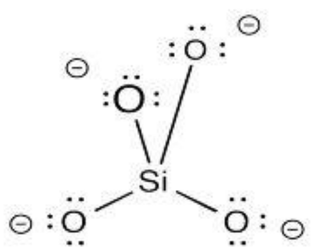

Figure 1 Molecular Structure of Silica **(SBSJ, 2015)**

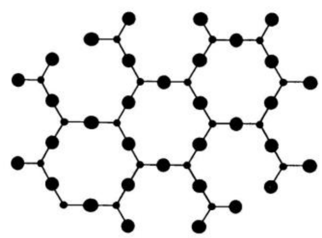

Figure 2 Crystalline Structure of Silica **(Best, 2015)**

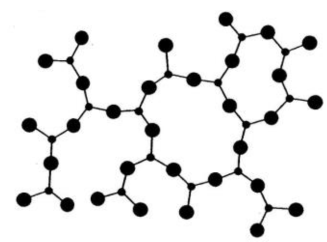

Figure 3 Non-Crystalline Structure of Silica **(Best, 2015)**

2. Background

Salt Lake City International Airport (4227 feet above sea level) is situated in the mountain west of the Western United States. The airport campus covers an area of more than 8000 acres (Figure 4). Much of the area is covered with concrete for the Aircraft Operations Area (AOA) and the Aircraft Movement Area (AMA). This concrete is at least 24" thick in both the AOA and AMA (Figure 5). The airport was constructed on an ancient lake bottom in the Great Salt Lake Basin and is surrounded by wetlands with a subsequently high water table. There is extreme heating and cooling cycles that cause expansion and contraction of the concrete. Cracks in the concrete are a direct result of these cycles. Salt from surface and deicing activities along with the high alkaline content of the ground water enter and cause further chemical stress. The resulting cracking and crumbling requires the need for constant maintenance and repair. Maintenance also includes surface area paint marking, striping and the maintenance of airfield embedded lighting. The Department of Airports has several airfield maintenance crews whose sole job is to repair and maintain the concrete surface area.

Figure 4 International Airport (Google Maps, 2014)

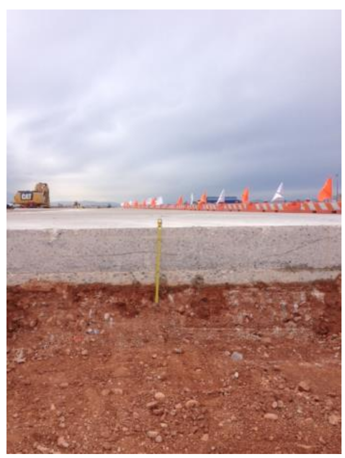

Figure 5 Concrete Depth Taxiway “H” 16L/34R End of Runway Deice Project

Figure 6 Taxiway “H” 16L/34R End of Runway Deice Project

3. Silicosis

Silicosis is a respiratory disease caused by inhaling silica dust. There are three types of silicosis: simple chronic, accelerated, and acute silicosis. Simple chronic silicosis occurs from long term exposure (over 20 years) to low amounts of silica dust. Accelerated silicosis exposure occurs from high levels of silica dust exposure over a shorter period of time (5 – 15 years).

Acute silicosis occurs from a very high exposure to silica dust in a short period of time (NIH, 2015).

3.1 Signs and Symptoms

At its earliest stage, silicosis can be seen as scarring on an x-ray without showing any symptoms. Silicosis is manifested by the presence of lesions in the lungs. In the earliest stage, the lesions form nodules and begin in the bronchioles. The typical lesion of silicosis is a hardened nodule composed of collagen. The nodules are anywhere from 1 – 10 mm in diameter and are found near the blood vessels and in the lymph nodes (NIOSH, 1978). As the disease progresses, the symptoms include frequent dry coughing, shortness of breath, wheezing and increased weakness. These symptoms will become worse in advanced stages until death results from respiratory failure (lungs are no longer able to function), heart failure, pneumonia or other complications (NJDOH, 1989).

4. Route of Exposure

Exposure begins with the inhalation of dust which enters the upper respiratory system commonly referred to as the nasopharyngeal region. The dust particles travel from nasopharyngeal region down through the larynx past the trachea to the primary, secondary, and tertiary bronchi (tracheobronchial region) before finally lodging into the alveolar ducts (pulmonary region). Many standards including NIOSH use the aerodynamic diameter to determine the cut point, which is used to estimate what region of the respiratory tract the particle will affect. The cut point is defined as the size of the particle that will be removed with 50% efficiency. Particles larger than the cut point will be removed with less efficiency and particles smaller than the cut point will be removed with greater efficiency. The pulmonary region is impacted by particles with an aerodynamic diameter of 4 µm or less (respirable fraction, as defined occupationally by ACGIH), 10 µm aerodynamic diameter for the tracheobronchial region, and 100 µm aerodynamic diameter for the pharyngeal region or the inhalable fraction (OEHHA, 2005).

5. Mechanism of Toxicity

The main target for respirable crystalline silica is the respiratory system, primarily the lungs. There is some research that indicates the kidneys and the immune system may be deleteriously affected. Research conducted by Ghahramani (2010) discusses several potential mechanisms for nephrotoxicity. The toxicity is thought to be through biopersistence from the direct exposure to silica, as well as silica-induced autoimmune diseases such as scleroderma and systemic lupus erythematosus (Ghahramani, 2010). There is still much research needed to determine if occupational exposure to crystalline silica is related to renal disease.

5.1 Lungs

The respirable crystalline silica is inhaled through the nasopharynx or the oropharynx where it will travel through the larynx passing the trachea and into the bronchioles where it will finally settle into the alveoli. Particles deposited in the conducting airways will be cleared by mucociliary clearance, where the particles will be carried to the surface of the glottis and will be swallowed within one day. Particles deposited in the alveoli section, will undergo phagocytosis. The mucociliary clearance can be impacted by smoking, drugs or other environmental exposure (Lippmann et al, 1980). Incomplete phagocytosis leads to production of fibronectin, an alveolar macrophage-derived growth factor. Since silica particles cannot be digested by the macrophage, the inflammatory process becomes chronic (frustrated phagocytosis). An increased silica burden leads to more inflammation, nodule formation, fibrosis and scar tissue (OEHHA, 2005). The scar tissue causes decrease production of surfactant, which lead to diminished gas exchange in the alveoli sacs.

5.2 Kidneys

The mechanism for the toxicity of silica as a nephrotoxin is not fully understood, but it is believed to be manifest in two different ways. First, the absorption of silica from the blood stream via the upper respiratory tract and the subsequent disposition of silica in the parenchyma of the kidney are believed to cause glomerulonephritis. The second possible way is from an autoimmune response due to activation of macrophages through which the kidneys are affected. The silica causes saturation of macrophages that subsequently release factors to which lead to an increase of biosynthesis by fibroblasts. According to the article *Silica Nephropathy* published by the International Journal of Occupational and Environmental Medicine (IJOEM) there is serological data confirming this mechanism (IJOEM, 2010).

5.3 Chronic Toxicity

Silicosis is the disease most associated with exposure to crystalline silica. Several studies have shown an exposure relationship with crystalline silica and lung disease, renal failure, and autoimmune disorders. Silica is slightly soluble in blood and has been shown to lead to renal failure by several mechanisms. One study (Chen et al., 2014) have shown high-dose mesoporous silica nanoparticle to be associated with renal interstitial fibrosis. Inhalation of silica in the lungs initially causes irritation and inflammatory reaction in the lungs eventually leading to interstitial fibrosis. Chronic exposure to low amounts of silica has been shown to cause obstructed airways and a lower lung capacity as measured by the pulmonary function test (OEHHA, 2005).

One retrospective cohort study of 2,342 workers exposed to diatomaceous earth from a mine and processing facility shows a proportional increase in mortality rates based on cumulative years and exposure levels (Checkoway et al, 1997). Another study demonstrates an increase incidence of lung tumors with laboratory rodents from exposure to respirable crystalline silica (Rice, 2000).

There was also a cohort study of 17,644 porcelain workers from Germany which found a link from exposure of crystalline silica to silicosis. This study however, did not show a correlation to renal disease, lung cancer or other diseases (Birk et al, 2009). Although there is some research that shows a link between exposures to crystalline silica and renal failure. One study by Wyndham et al. (1986) demonstrated that exposure to silica showed an increased incidence in chronic nephritis (Wyndham et al., 1986). The association of crystalline silica and autoimmune disorders has shown a positive relationship with rheumatoid arthritis and scleroderma. Rheumatoid arthritis may be associated more as a work related musculoskeletal disorder due to the use of hand tools to the exposed workers (OSHA, 2010).

5.4 Factors Influencing Toxicity

There are many physiochemical properties associated with the toxicity they include: form, crystallinity, surface reactivity, free radical generation, and the solubility of the biological fluids. The amorphous form of silica is less toxic than the crystalline form. Sharp edges of silica may lodge further into tissue subsequently resulting in biopersistance. Fractured surfaces can cause the particles to become charged and will react with toxins such polyaromatic hydrocarbons (PAH). When mineral dust comes in contact with biological fluids, free radical generation can occur resulting in damage of cell membranes and cellular functions. Clearance of dust is related to the hydrophilicity of the mineral and may result in greater biopersistance of the mineral. Biopersistance can lead to activation of macrophage and subsequent phagocytosis (Fubini, Fenolglio, 2007).

5.5 Elimination

Elimination of respirable crystalline silica can occur when the particles are impacted in the upper respiratory tract and expelled via the mucociliray clearance. When the particles are deposited in the respirable region, elimination by mucociliray clearance is unlikely to occur. The body will then attempt to remove particles by specialized cells called the alveolar macrophage. The macrophage will quickly engulf the particle in an attempt to clear to particle from the region. Many other environmental toxins such as cigarette smoke from smoking have shown to reduce the activity of cilia and therefore reduce the clearance. The results from a study of smokers and non-smokers suggest that chronic smoking may induce an increased number of abnormal cilia which could participate in impairment of tracheobronchial clearance (Fernando et el, 1995).

5.6 Exposure Diagnostic Strategies

X-ray imagery is usually used in determining late stages of silicosis. The pulmonary function test can be used to determine diminished lung capacity due from exposure to respirable crystalline silica. Utilizing the FEV1/FVC ratio (Forced expiratory volume in 1 second and the forced vital capacity) can also be used for baseline medical monitoring.

6. Controls

NIOSH has made the following recommendations to help mitigate exposure to crystalline silica (NIOSH, 1996):

- Recognize when silica dust may be generated and plan ahead to eliminate or control the dust at the source.
- Substitute less hazardous materials for abrasive blasting materials
- Use engineering controls such as wet sawing of silica-containing materials to control the hazard and protect adjacent workers from exposure
- Routinely clean and maintain dust control systems to keep them in good working order
- Practice good personal hygiene to avoid unnecessary exposure
- Wear disposable or washable protective clothes at the work site
- Shower and change into clean clothes before leaving the work site to prevent contamination of cars, homes, and other work areas
- Conduct occasional air monitoring to measure worker exposures and ensure that controls are providing adequate protection for workers
- Use adequate respiratory protection when source controls cannot keep silica exposures below the permissible exposure limit
- Provide periodic medical examinations for all workers who may be exposed to silica
- Provide workers with training that includes information about health effects, work practices, and protective equipment for respirable crystalline silica

There should be the integration of engineering, administrative, and personal protective equipment controls used. The best controls for the airport maintenance workers would be to use less hazardous blasting materials, utilization of wet methods and integration of local exhaust ventilation. It was noted from observations in figure 8 that although, the wet method of dust control was being used, there was still a significant plume of dust. The engineering controls should be monitored to ensure they are being properly integrated or used.

7. Current Regulatory Efforts

OSHA currently has two forms of regulatory standards for respirable crystalline silica. One is for the construction and shipping industry and one is for general industry. The concrete operation for the Airport is considered general industry. The current OSHA PEL for crystalline silica is difficult to understand and calculate. The standard was adopted using exposure data from the 1960's (OSHA, 2013). The OSHA permissible exposure limit is determined by both a gravitational method and by x-ray diffraction. These methods are also known as the NIOSH Manual Analytical Method (NMAM) 0600 (used to determine respirable dust exposure) and by x-ray diffraction NMAM 7500 (used to determine the percentage of silica). The resulting PEL is then calculated by using an OSHA formula (Appendix B, Equation 1), which results in the concentration of the respirable fraction of crystalline silica.

(Equation 1): **PEL = 10 mg/m3/(2 + % Quartz + 2x % Tridmyte + 2 x % Cristobalite)**

8. Proposed Regulatory Efforts

OSHA's current permissible exposure limit was established in 1971 and is outdated, doesn't adequately protect workers from exposure and is difficult to understand. OSHA has proposed a new rule that is expected to prevent thousands of workers from exposure and will make the PEL for all industries the same at 0.05 mg/m^3. The proposed rule will also limit workers access to areas where exposures are known to be high, provide medical exams for workers routinely exposed, require effective methods to be used for control of the hazards, provide training for workers about the hazards of silica and how to reduce exposure (OSHA, 2002). According to the Federal Register for the proposed rule, percent crystalline silica will include quartz, cristobalite, and tridymite as a combined percentage. The NMAM 7500 (Crystalline Silica) and 0600 (Respirable Dust) would continue to be used but the respective minerals would be treated equally as a combined percentage (Federal Register, 2013).

9. Occupational Exposure

According to OSHA, exposures occur when workers cut, grind, crush or drill silica containing materials (OSHA, 2002). Exposure to silica is associated with silicosis, lung cancer, and pulmonary tuberculosis. Exposure is also related to autoimmune disease and renal failure (NIOSH, 2002).

Recent trends show that mortality rate from silicosis has been decreasing from over 1000 deaths annually in the 1960's to just under 200 deaths annually in 2004 (NIOSH, 2008). Although the numbers are looking better, people are still suffering and dying. According to NIOSH, the construction industry has one of the highest mortality rates of all industries for silicosis. The mortality rate between 1990 and 1999 was at 13.4% (NIOSH, 2008).

In one study of the construction industry by KD Linch (2002), sand blasting, grinding, drilling, and cutting were shown to have up to 280 times the NIOSH recommended exposure limit (0.05 mg/m^3) for silica (Linch, 2002). Another study by Akbar-Khanzadeh (2001) for exposure to concrete finishing (using a grinder) found a median exposure without local exhaust ventilation (LEV) of 27 mg/m^3. This was substantially reduced by using LEV (median subtotal of 4.68 mg/m^3). Akbar's study was to determine if there was a difference in exposure with LEV versus without LEV. His study showed there to be a significant difference in exposure (Akbar, Brillhart, 2002).

10. Environmental Exposure

There is a risk of exposure to the environment and the general public. Although silicosis is greatest for individuals exposed to high dust levels for a prolonged period, there is still a public concern for environmental exposure. Environmental exposure is common in regions of the world where there is a high background level of silica and where dust storms are common such as the Gobi desert in China and the Sahara desert in Africa (AMJRCCM, 1997).

Figure 7 shows a fumigating plume due to a contractor saw cutting for the airport "end of runway deice project". The plume was observed traveling over the airport terminals. Figure 8 shows another plume from a contractor saw cutting.

Figure 7 Environmental Exposure

Figure 8 Environmental Exposure

11. Similar Exposure Groups

The similar exposure groups studied were the Airfield Paint Crew and the Airfield Concrete Crew.

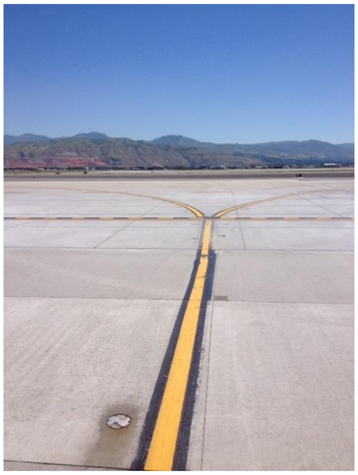

Figure 9 Air Paint Markings

Figure 10 Airfield Concrete Repair

11.1 Airfield Maintenance Paint Crew

The paint crew's duties are to maintain the painted marking on the aircraft operations area and the aircraft movement area (Figure 9). These operations include preparing the concrete surfaces for directional concrete markings. There surface preparation includes bead blasting (Figure 11) and grinding (Figures 12-14) to remove the old paint marking. The crew can spend as much as entire shift grinding or blasting the concrete. The exposure for this group occurs when they are grinding, blasting, sweeping (Figure 14), and cleaning their equipment (Figures 14 and 15). Cleaning of the equipment entails the use of a broom, air hose or a leaf blower.

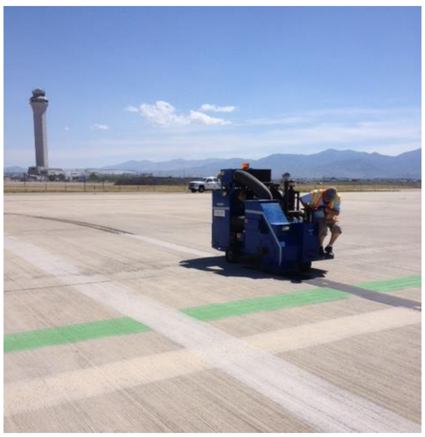

Figure 11 Bead Blaster

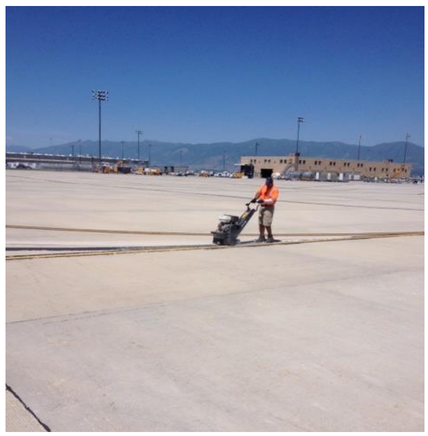

Figure 12 Paint Grinder

Figure 13 Paint Grinder

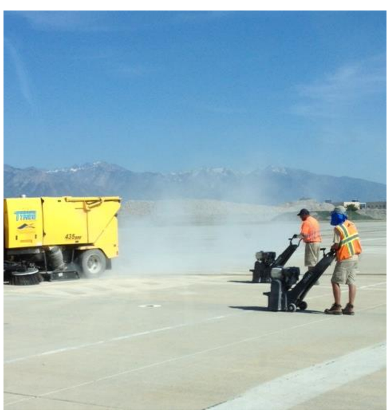

Figure 14 Sweeper

Figure 15 Equipment Cleaning

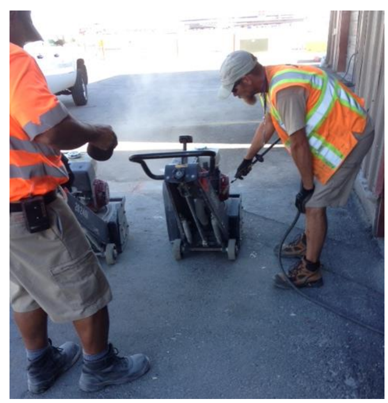

Figure 16 Equipment Cleaning

11.2 The Airfield Maintenance Concrete Crew

The concrete crew is responsible for sealing cracks and removal and replacement of failing sections of concrete in the Aircraft Operations and Movement Areas (Figure 10 & 17). The concrete crew spends much of their time waiting for their repairs to cure (Figure 20) before they can move to the next job. The actual time cutting the concrete can be as little as ten minutes, but the crew may need to wait a minimum of one hour for their epoxy to cure before allowing the area to be reopened for operations. Their exposure includes cutting (Figure 18), jack hammering (Figure 19), vacuuming (Figure 20), and sweeping of the concrete.

Figure 17 Concrete Crack

Figure 18 Concrete Cutting

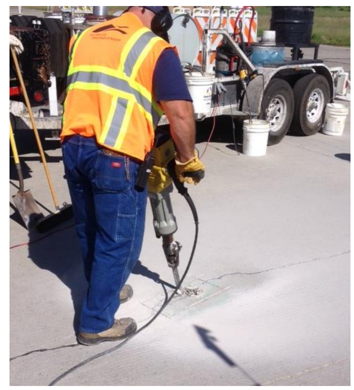

Figure 19 Jack Hammer

Figure 20 Preparing for concrete

Figure 21 Mixing Epoxy

Figure 22 Curing Epoxy

12. Sampling Methods

The airfield maintenance crews were informed of the plan to observe and sample their concrete cutting operations, paint blasting and grinding operations. This process was to run over the course of a week to ensure that there would be adequate time to conduct sampling operations. The plan was to place a personal pump on three individuals from both SEGs. Thirty minutes before the shift begun, the sample pumps were pre-calibrated. The pumps were affixed to the workers belt via a clip. The sample cyclone and cassette was clipped to the shoulder of each of the workers. The pumps were started at the beginning of the workers shift. After the collection of the samples, a post calibration of the pumps was conducted to document any flow rate drift. The samples were sent to ALS Laboratories in Salt Lake City, Utah (an AIHA certified laboratory) for analysis by NMAM 7500/0600.

12.1 Sample Train

The SKC Sidekick pumps were used with the GS-3 Respirable Dust Cyclone and calibrated with the SKC Defender utilizing a 37mm sample cassette and 5-µm PVC membrane filter (Appendix A, Table 1). The pumps were rented from the ALS laboratories and pre-calibrated by the lab prior to pick up to a flow rate of 2.75 L/min (as determined by the cyclone specifications). ALS provided a secondary rotometer to ensure that any drift in the pump flow rates would be documented. The rotometer can only be used to measure in tenths of L/min and therefore can only be confidently used to ensure the flow rate is between 2.7 and 2.8 L/min. The rotometer will be used to determine if the rates are within the primary standard calibration flow rate.

12.2 *Airfield Maintenance Concrete Crew*

Day 1

Sampling was conducted on two consecutive days for the concrete crew, beginning on June 15th and 16th (see Appendix A, table 2). The crews work the swing shifts from 2:00 – 10:30. On Monday June 15th, the three sample pump flow rates were confirmed to be within primary standards utilizing the rotometer. The SKC Sidekick pumps were placed on the concrete crew at 3:30 pm. Due to high winds, thunderstorm warnings, and severe weather, the concrete crew was forced to cancel their repair work orders. The pumps were subsequently removed at 7:15 pm from the crew without any cutting operations or work orders performed.

Day 2 - Taxiway “H”

On Tuesday June 16th, three sample pumps were pre-calibrated and observed to be within the primary standard calibration flow rate. The pumps were placed on the concrete crew at 2:15 pm. The crew was able to begin work on taxiway “H” directly adjacent to an open (34R/16L) runway. The taxiway is a high speed runway exit and had to be closed for one and a half hours. It took less than 10 minutes for the crew to stage, 10 minutes to make the cut, and 10 minutes to jack hammer the cut and prepare the area for the placement of the epoxy patch. The epoxy patch was placed and took one hour for the patch to cure. Finally at 4:15 pm the taxiway was re-opened for aircraft use. It is critical that the crew complete their operations as soon as possible so as not to impact air traffic.

Day 2 – Taxiway “S”

The next repair was made on taxiway “S”. This taxiway connects two major runways from the airport terminals. During this work, the taxiway had to be closed for another one and half hours. Beginning at 4:30 pm the crew setup, cut, jack hammered, poured the patch, and waited for the patch to cure. The taxiway was finally opened at 6:00 pm. The crew broke for lunch at 6:15 until 6:45.

Day 2 – Concluding Operations

At 6:45, the crew attempted to make a repair on taxiway "M" but it was determined there was a mistake and that the work order had been repaired on a previous date. The next attempt was to close Spot 4 (adjacent and opposite to several major carrier gates). It was determined that the crew was not going to be able to make these repairs until another date. At this point the crew indicated their work orders for concrete cutting were done for the evening and would be spending the rest of the shift filling in cracks with concrete epoxy caulk. The pumps were removed at 7:15 pm. The pump flow rates were post-calibrated utilizing the secondary rotometer. The flow rates were observed to be within the primary standard calibration flow rate.

12.3 Airfield Maintenance Paint Crew

Day 3 – North Cargo Paint Removal

On Wednesday June 17th, the pumps were placed on the paint crew to monitor the bead blasting and grinding for concrete paint marking removal. The pumps were pre-calibrated and observed to be within the primary standard calibration flow rate. The pumps were placed on the crew at 2:15 pm and began the work order to remove paint markings on the North Cargo ramp at 2:30 pm. Two of the crew members utilized the grinders (Pump Serial Number 0310 and 0295) and the third member (Pump Serial Number 0562) used the bead blaster. The paint removal operations are quite labor intensive and apparent dust emissions were visible during these operations. It took the crew nearly four hours to remove a paint swath of 2 feet by 200 feet. Once the removal was finished, the crew had to clean off their equipment, creating more visible dust emissions. The paint crew completed the paint removal operations and the pumps were removed at 6:15 pm. The pumps flow rates were post-calibrated utilizing the secondary rotometer. The flow rates were within the accuracy of the primary standard.

Day 4 – Return Pumps and Samples to the Laboratory

On Thursday June 18th, the samples were hand delivered to ALS Laboratories. The pumps were post-calibrated with the primary standard calibrator at the lab and a final flow rate was determined to be an average of 2.735 L/min. The lab coordinator indicated that the flow rate of 2.75 L/min would be acceptable as the final flow rate in determination of the sample volumes.

12.4 Confounding Factors

Many factors including: wind, air traffic flow, work orders, ambient temperature, and precipitation made the sampling events difficult and interfered with the sampling plan.

13. Laboratory Analysis

The methods used for the analysis of crystalline silica is commonly called the NMAM 7500 for Silica, Crystalline by XRD and NMAM 0600 for Particulates Not Otherwise Regulated, Respirable. The NMAM 0600 is gravimetric analytical method which utilizes a cyclone and filter for measuring the mass concentrations of any non-volatile respirable dust. The NMAM 7500 will determine the respirable percentages of quartz, tridymite, and cristobalite in a sample by X-ray powder diffraction. The gravimetric mass values for the respirable dust will then be used with the percentage of the respective silica forms to determine the exposure and the OSHA permissible exposure limit (PEL) by using an OSHA formula (OSHA 1910.1000 Table Z-3).

14. Results

The sample results are presented in Appendix A, tables 3 – 7.

14.1 Airfield Concrete Crew

The laboratory data reveals that there is no significant exposure to the Airfield Concrete Crew for respirable dust and significant crystalline silica. The concentration of respirable dust in one sample was below the laboratory reporting limit (RL) of 0.020 mg/sample (see Appendix A, table 3). There were two samples that the percentage of crystalline silica was below the limit of detection for all three of the analyte (Appendix A, table 4). Finally, only one sample had a detectable exposure at 0.069 mg/m^3 with a calculated PEL of 0.435 mg/m^3 and a corresponding severity of 0.160 (Appendix A, table 5). The severity ratio is determined by the exposure from the respirable dust divided by the PEL (Appendix B, equation 4). Any severity greater than 1 is an overexposure. In comparison to the proposed OSHA PEL of 0.050 mg/m^3, (presuming the percent crystalline silica – quartz, cristobalite, and tridymite would be multiplied by the total dust sample) the severity level would nearly double to 0.28.

14.2 Airfield Paint Crew

The laboratory data indicates there is some exposure exceeding the OSHA action level (action level is half the PEL) to the Airfield Paint Crew for respirable dust and crystalline silica but, there was no exposure above the PEL. The concentration of respirable dust was measured at 0.362, 0.298, and 0.524 mg/m^3, as can been seen from Appendix A, table 6. The highest dust exposure was from the bead blaster (serial # 0562). The bead blaster had a percentage of quartz at 10% but a lower PEL as compared to the grinders. Both of the grinders had a similar percentage of quartz (average near 20%) (Appendix A, table 7). The highest severity ratio is 0.797 (Appendix A, table 8) was from one of the grinders (serial # 0310). In comparison to the proposed OSHA PEL of 0.050 mg/m^3, (presuming the percent crystalline silica – quartz, cristobalite, and tridymite would be multiplied by the total dust sample) the severity level on the highest exposure would almost double and become 1.45 (grinder), 1.01 (grinder), and 1.05 (bead blaster). This would show a significant increase and result in over exposure in all samples.

14.3 Sampling Concentrations

The samples collected and the corresponding concentrations were based on the presumption that the results would be representative of the respective operations and not of an 8 hour shift. The sampling include preparation time, breaks, and periods of inactivity. The formula used to determine the exposure concentrations was the average TWA: TWA = Sum (C_i x T_1) / Sum T_i (Appendix B, equation 5). The alternate calculation is for an entire 8 hour work shift sampling period, where the TWA = Sum (C_i x T_1) / 8 Hours (Appendix B, equation 6). The entire 8 work shift was not used to calculate the exposure.

14.4 Limitations

The limitations of the sampling events are the sample costs, equipment availability, worker cooperation, and sample duration. The cost associated with the sampling was $75 per sample. The primary standard calibrator could be available for rental price of $250 per week. In order for the sampling events to be successful there needs to be full cooperation of the workers. The workers did give full support with this sampling event. The maximum and minimum sample volume must consider flow rate for the particular cyclone sampler and the respective method. These values dictate the time sampled for the shift.

15. Conclusion and Recommendation

After a two days of sampling it was determined that there is an exposure approaching the PEL for the paint crew. Although the concrete crew was not significantly exposed to crystalline silica or dust on these particular sampling events, more exposure sampling should be conducted. In addition, technologies such as wet cutting and equipment with local exhaust devices should be utilized.

If the additional air monitoring yields similar results, then the paint crew should be placed in a respiratory protection program. It was observed that the bead blaster had a lower exposure to silica (10%) than the grinders. It is recommended to phase out the use of the grinders in paint removal operations and utilize non-silica based blasting media.

It is also recommended that a primary standard calibrator be used for any additional sampling. The results from this sampling event are a more of qualitative demonstration of exposure rather than a quantitative. The volume can be significantly impacted due to atmospheric changes during the sampling operations. The best way to accurately quantify this is with a primary standard calibrator.

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Appendix A Data

Table 1 Instruments Used

Instrument Make and Model	Serial Number
SKC Sidekick Pump 2.75 L / min	0310
SKC Sidekick Pump 2.75 L / min	0295
SKC Sidekick Pump 2.75 L / min	0562
SKC Defender Calibrator	

Table 2 Concrete Operations

Sampled	Discription	Activity	Duration (hours)	Notes
Concrete Crew	Concrete Repair	Taxiway "H"	1.5	Completed
Concrete Crew	Concrete Repair	Taxiway "S"	1.5	Completed
Concrete Crew	Concrete Repair	Taxiway "M"	0	No work. Work order already completed
Concrete Crew	Concrete Repair	Spot 4	0	Had to wait for an additional day
Paint Crew	Paint Removal	North Cargo	4	Completed

Table 3 NMAM 0600 Respirable Dust - Concrete Crew

Pump Serial No	Sample	Sample Period (min)	Total Volume (L)	Respirable Weight (mg)	Average TWA Respirable Exposure (mg/m3)
0295	113589	320	880	<0.023	NA
0310	113563	316	869	0.035	0.040
0562	113567	324	891	0.062	0.069

Table 4 NMAN 7500 Percent Crystalline Silica - Concrete Crew

Pump Serial No	Sample	(%) Quartz	(%) Tridymite	(%) Cristobalite
0295	113589	0.010	0.020	0.020
0310	113563	<33	<66	<66
0562	113567	21	<36	<36

Table 5 OSHA Calculated PEL - Concrete Crew

Pump Serial No	Date Sampled	Sample	PEL (mg/m3)	Severity
0295	6/16/2015	113589	NA	NA
0310	6/16/2015	113563	NA	NA
0562	6/16/2015	113567	0.435	0.160

Table 6 NMAM 0600 Respirable Dust - Paint Crew

Pump Serial No	Sample	Sample Period (min)	Total Volume (L)	Respirable Weight (mg)	Average TWA Respirable Exposure (mg/m3)
0310	113573	231	635	0.23	0.362
0295	113588	232	638	0.19	0.298
0562	113544	222	611	0.32	0.524

Table 7 NMAM 7500 Percent Crystalline Silica - Paint Crew

Pump Serial No	Sample	(%) Quartz	(%) Tridymite	(%) Cristobalite
0310	113573	20	<14	<14
0295	113588	17	<16	<16
0562	113544	10	<10	<10

Table 8 OSHA Calculated PEL - Paint Crew

Pump Serial No	Date Sampled	Sample	PEL (mg/m3)	Severity
0310	6/17/2015	113573	0.455	0.797
0295	6/17/2015	113588	0.526	0.566
0562	6/17/2015	113544	0.833	0.628

Appendix B Equations

Equation 1 OSHA Permissible Exposure Limit

PEL = 10 mg/m3/(2 + % Quartz + 2x % Tridmyte + 2 x % Cristobalite)

Equation 2 Volume

Volume (m3) = 1L / 1000

Equation 3 Respirable Exposure

Respirable Exposure (mg/m3) = sample weigth (mg) / Volume (m3)

Equation 4 Severity Ratio

Severity Ratio = Respirable Exposure (mg/m3) / Permissible Exposure Limit (mg /m3)

Equation 5 Actual TWA

TWA = Sum (C_i x T_1) / Sum T_i

Equation 6 8-Hour TWA

8-Hour TWA = Sum (C_i x T_1) / 8 Hours