

Particle Composition and Respirable Crystalline Silica Concentrations in Sand Mining and Processing Facilities

Joe Oster, Junyi Zhang, Callie Fischer Mentor: Dr. Patricia Cleary | Department of Chemistry, UW-Eau Claire

Introduction

In the last 10 years, hydro fracturing has completely transformed the sand mining industry. In Wisconsin, the nation's leading sand producer, the number of industrial sand facilities has grown from just 8 in 2008¹ to 129 as of September 1, 2015². Crystalline silica is one of the main compounds that makes up the earth's crust.³ It is not inherently dangerous until it is ground up into fine dust that can penetrate deep into the lungs.

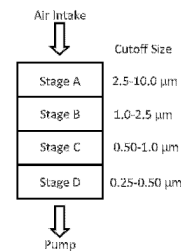
Respirable crystalline silica is the common name for silica particles that are small enough to become airborne and pose an inhalation hazard.

The particle size at which this becomes a concern is PM10, when the particles diameter is less than 10 microns. At PM10, particles can enter your lungs, but at PM4, diameter less than 4 microns, the particles can travel to the deepest, most sensitive parts of the lungs. Respirable crystalline silica is especially dangerous because the body cannot dissolve it. When crystalline silica is absorbed by the lungs, it causes irreversible damage to the lungs and leaves scar tissue, which over time has been proven to cause shortness of breath, poor oxygen/carbon dioxide exchange within the lungs, fatigue, and in extreme cases, respiratory failure.⁴

Methods

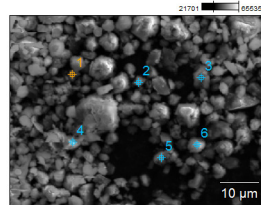
SAMPLE ACQUISITION

A Sioutas Personal Cascade Impactor was loaded with four 25mm, 2.0- μ m PTFE filters to collect the airborne particles from the sand mining facility. The four sampling filters and one field blank filter, the same type as the sampling filters, were weighed before and after sampling to the nearest 0.01mg a minimum of three times until a variability of less than 0.1% was attained. This allows for the determination of how much particle mass was collected on the filters over the 24 hour sampling period.



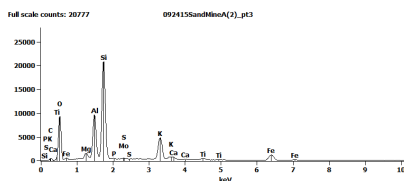
The cascade impactor collects and separates airborne particles.

SEM/EDS ANALYSIS

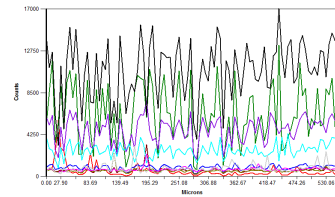


Each point in the point-and-shoot technique is picked individually and each produces a unique spectrum.

The sample filters were then analyzed using scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) to analyze the elemental character of the sample. The point-and-shoot technique provided an elemental analysis for a chosen spot on the display. 30 data points were obtained from each filter analyzed using this method. The SEM can perform an elemental analysis to an area down to 1/2 micron so this technique was used to determine the elemental composition of the filter stage with only the largest particle size, stage A. The three remaining stages, B-D, were analyzed using the X-ray linescan technique, which analyzes 100 points along a line and will produce a spectrum similar to the one shown below on the right. This technique allows for the analysis of a larger sample of particles. 1200 data points were obtained from each filter analyzed using this technique.



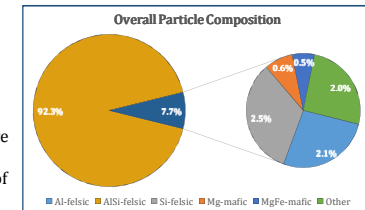
A spectrum produced from a single point of the point-and-shoot method.



A linescan spectrum samples 100 locations on a sample.

Results

Three samples, with four filters each, were collected and analyzed from an active sand processing facility. The samples were analyzed and the particles were categorized into one of five groups based on their geologic composition according to the conditions listed below.⁵ The particles were sorted based on atomic % of elements. The largest of the five categories was the AlSi-felsic group making up 92.3% of the 3500 data points collected.



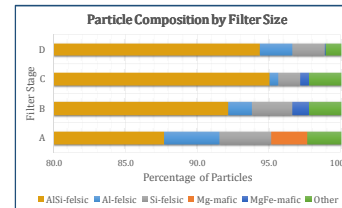
AlSi-felsic: $Si / (Al+Mg+Fe+Si) > 50\%$; $Mg+Fe < 25\%$; $Al < 25\%$; $Al/Si > 0.2$

Al-felsic: $Al / (Al+Mg+Fe+Si) > 25\%$

Si-felsic (Silica): $Si > 50\%$; $Si+O > 85\%$; $Mg+Fe < 25\%$; $Al < 25\%$; $Al/Si < 0.2$

Mg-mafic: $Mg / (Al+Mg+Fe+Si) > 25\%$; $Al < 25\%$

MgFe-mafic: $(Mg+Fe) / (Al+Mg+Fe+Si) > 25\%$; $Mg < 25\%$ $Al < 25\%$

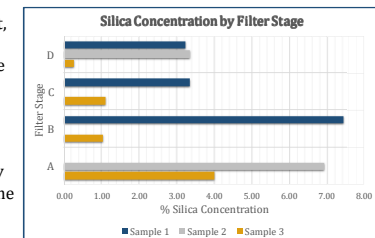


The fact that there are more particles categorized as non-AlSi-felsic in the stages with the larger SEM particle size is most likely due to the limitations of the SEM to target individual particles in the stages with the smaller particle sizes. In the stages B-D, every time a particle is analyzed, elemental data is collected from a group of particles, both around and under the particle. A high percentage of the particles sampled are likely to be AlSi-felsic so they would mask the signal being given off by any different particle.

Conclusions

The AlSi-felsic category most likely represents the cement, specifically potassium feldspar, holding the silica sand particles together. At the processing facility, the sandstone containing the silica sand is crushed and broken apart, destroying the cement in the process, which explains the abundance of this cement found in the air. The mafic categories are most likely impurities found in the sandstone such as iron-rich hematite. The 'other' category is comprised of the particles that were unidentifiable. Some of which contained large amounts of sulfur, phosphorus, and trace amounts of transition metals such as titanium, molybdenum, and scandium.

While inhalation of large amounts of small particles has been shown to be harmful, respirable crystalline silica is the biggest hazard in sand mining facilities. The NIOSH Reference Exposure Level (REL) for respirable crystalline silica is $50\mu\text{g}/\text{m}^3$ for a 10 hour period. With the mass of particles typically collected on the filters during a 24 hour period, about 2mg, it would take a silica percentage of 32% to exceed the REL. It seems as if the silica concentrations that are being observed are well below the REL. Respirable crystalline silica exposure, even in low amounts has still been proven to have the ability to cause irreparable damage to the lungs, which could lead to more chronic problems. We are continuing to collect data from active sand mining and processing facilities to gain a better understanding of the composition of the airborne dust present and its silica content.



CITATIONS

- (1) Pregaman, K. (2012). Frac sand boom creates thousands of jobs.
- (2) Wisconsin Department of Natural Resources. (n.d.).
- (3) Richards, J.; Brozell, T. Air Control Techniques, P.C., *Ambient PM4 Crystalline Silica Sampling*, March 31, 2014
- (4) OSHA *Crystalline Silica Exposure Health Hazard Information* 2002
- (5) Moreno, T et al. *Atmospheric Environment* 2003, 37, 4265-4276

ACKNOWLEDGMENTS

We are pleased to acknowledge the financial support of this project by the University of Wisconsin Eau Claire Office of Research and Sponsored Programs.