Characterization of Sand Processed for Use in Hydraulic Fracture Mining

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Background

Hydraulic fracturing wells may use up to 5,000 tons of proppant during their operational lifetime. Sand with 95-99% silica (SiO_2) content is highly desirable due to its durability and tendency to form spherical grains.

When sand is processed for use as a proppant, fine particles (<105 um) are removed. However, a 2013 study conducted by NIOSH revealed 68.5% of workers at hydraulic fracturing wells were exposed to respirable crystalline silica (RCS) at concentrations above the OSHA PEL.

Railways are the primary form of transport for proppant traveling long distances. Whether proppant travels by rail or by truck, the material is exposed to low-frequency vibration.

Objectives

(1) Compare exposure risk to respirable crystalline silica between freshly mined (or "raw") sand and proppant.

(2) Characterize differences in silica composition between bulk samples of raw and proppant sand.

(3) Characterize changes in exposure to respirable crystalline silica when processed sand undergoes vibrational stress.

Methods

(1) Sand was aerosolized into a chamber in a controlled environment. Respirable dust samples were collected from five different types of sand:

- Raw Sand
- Proppant Sand
  - 20/40 Proppant
  - 30/50 Proppant
  - 40/70 Proppant
  - 100M Proppant

(2) Samples of raw and proppant sand underwent x-ray diffraction analysis for silica content. A scanning electron microscope (SEM) was used to conduct an energy dispersive x-ray spectroscopy analysis. The SEM was used to identify the mineral type of individual aerosolized particles.

(3) Samples of 20/40 proppant were subjected to low-frequency vibration (35 Hz) for 15 or 30 minutes before being aerosolized. Respirable dust samples were collected after sample vibration.

Results

Objective 1: Raw sand vs. Proppant

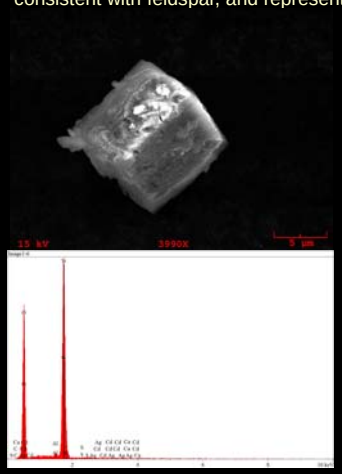
	Arithmetic Mean of Respirable Dust Concentrations (mg/m^3)	Silica Composition (%)
Raw (n=5)	4.06 (SD = 2.20)	5.7 (SD = 4.2)
Proppant (n=7)	0.22 (SD = 0.17)	19.0 (SD = 6.7)

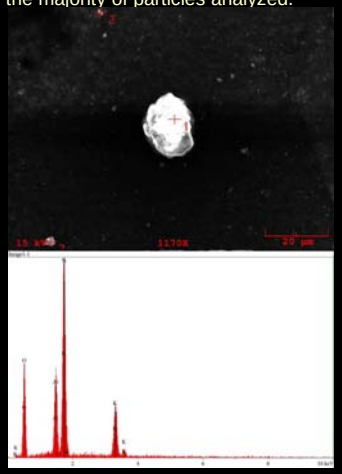
Mined sand (1mm)

Proppant sand (1mm)

Objective 2: Mineral Composition

Both bulk samples of raw and proppant sand had crystalline silica content ranging from 59-88%. Analysis of respirable dust samples resulted in crystalline silica content ranging from 5-19%. This indicates that other minerals in the sand may be responsible for generating the majority of respirable dust particles. Two spectroscopy profiles were seen with the SEM. The profile on the right represents a pure SiO_2 particle, while the mineral composition on the right is consistent with feldspar, and represented the majority of particles analyzed.

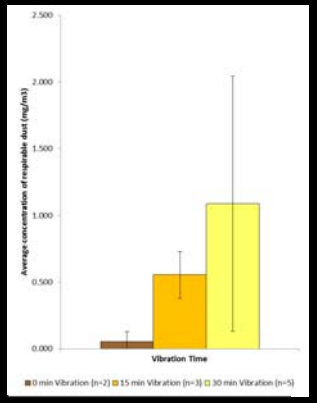




Results (cont.)

Objective 3: Vibrational Energy

Samples were vibrated for 0, 15, or 30 minutes prior to being aerosolized. Respirable dust concentrations tended to increase as vibration time increased, however the range in sample results also increased. The error bars in the graph on the left represent the standard deviation in sample results.



Exposure Risk Ratios

In order to compare the risk of exposure to RCS between samples with different silica contents, the respirable dust concentration was divided by the Permissible Exposure Limit PEL as calculated by the Mining Safety and Health Administration (MSHA).

$$\text{Exposure Risk Ratio} = (\text{Sample Concentration}) / \left(\frac{10^{\,mg/m^3}}{\%SiO_2 + 2}\right)$$

	Concentration (mg/m^3)	% Silica	MSHA PEL	Exposure Ratio
Raw sand	4.06 (SD = 2.20)	5.7 (SD = 4.2)	1.30	3.2
Proppant	0.22 (SD = 0.17)	19.0 (SD = 6.7)	0.48	0.5
Vibrated (15 min)	0.56 (SD = 0.18)	19.0 (SD = 6.7)	0.48	1.2
Vibrated (30 min)	1.09 (SD = 0.96)	19.0 (SD = 6.7)	0.48	2.3

Conclusions

Aerosolization of raw sand produced the highest concentrations of respirable dust, but contained the lowest percentage of silica. Proppant produced the lowest concentrations of respirable dust, but had silica percentages that averaged four times higher than that of raw sand. When proppant was exposed to low-frequency vibration, concentrations of respirable dust tended to increase.

When an exposure risk ratio is calculated to normalize respirable dust concetrations based on silica content, the highest ratio was seen in raw sand, despite the low SiO_2 content (5%). As vibration time prior to aerosolization increased, the risk ratio also increased.

Acknowledgements

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