ENFORM The Safety Association for Canada's Upstream Oil and Gas Industry

Managing Chemical Hazards

Silica

PROCESS DOCUMENT GS 003

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An Industry Product
This guidance sheet was developed by industry for industry! Working collaboratively, Enform led cross-industry representatives in developing a guidance sheet that meets the industry's needs. Canada's leading oil and gas industry trade associations support the use of guidance sheets to help companies of all sizes improve performance.

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What is Silica?

Silica (silicon dioxide) is a naturally occurring solid abundant in most rock types, sand, gravel and soils. It occurs in crystalline and amorphous forms. Quartz and cristobalite, are all naturally occurring forms of crystalline silica. Silica gel, diatomaceous earth and vitreous silica are examples of amorphous silica.

Where is it Found?

Any material that contains naturally occurring rock, sand, gravel or soil is likely to contain crystalline silica. Examples common in the oil and gas industry include: sand used for hydraulic fracturing operations, road crush, gravel, drilling mud components, silica used for sandblasting, concrete and refractory materials, and dust produced as a result of drilling and exploration activity.

The Risks:

Health Effects

The effects on your health depend on how much silica you are exposed to, and for how long. It also depends on the size of dust particles and type of silica. Health effects of inhaling crystalline silica dust include silicosis, lung cancer, chronic obstructive pulmonary disease and emphysema. Amorphous silica is not known to cause these effects but under certain conditions (very high temperature) may be converted into the crystalline form. In order for silica to have an effect it must be inhaled into the lung. Larges particles do not pose a risk of lung damage because they cannot be inhaled.

Silicosis is the development of scar tissue in the lung resulting in permanently reduced lung function. Both lung cancer and silicosis typically develop after years of overexposure (chronic) and are often fatal diseases; however acute (immediate) and sub-chronic forms of silicosis are possible with extreme exposures. Workers with silicosis may at first have no symptoms. As the disease progresses, coughing develops and breathing becomes difficult. Persons with silicosis have an increased risk of contracting respiratory infections such as pneumonia and tuberculosis. They also have greater difficulty in recovering from respiratory infections because of reduced lung function.

Both crystalline and amorphous silica can cause irritation of the eyes and skin as a result of mechanical action of the dust grinding on tissue.

Primary Routes of Exposure

Silica can be produce effects in your body:

- if you breathe in air containing silica dust;
- if it contacts skin or eyes.

Actions:

Steps to Evaluate Risk

The risk to worker health increases with length of time exposed to silica, the concentration in workplace materials and the amount of worker contact with materials containing silica. It is important to know how much silica is present before you begin work and the likelihood of it becoming airborne. This information can usually be estimated from information found on the Safety Data Sheet and from previous chemical analysis done of cuttings from the same production field or area. The type of work done will also have an impact on worker exposure and risk to health. Grinding, drilling, mixing and blasting with or on silica containing materials all increase the risk dust becoming airborne. Keeping materials wet decreases the risk of materials becoming airborne. Crystalline silica has a very low legislated occupational exposure limit (OEL) because of its potential to cause disease. This low OEL results in an increased need for strict workplace controls and increases the chance of exceeding these limits. The Managing Chemical Hazards System is designed to help you use this basic information to define the procedures and control approaches you need to follow to protect worker health and safety. Go to www.enform.ca to develop a specific Safety Protocol for Chemical Management to control silica exposures for your specific operation.

Procedures

- Consider using crystalline silica free materials or processes when possible (e.g. silica free barite clay for drilling mud, soda blasting instead of sand blasting).
- Whenever possible, enclose operations (e.g. mixing and transfer) as much as possible to prevent release of dust.
- Use water sprays to keep silica materials wet when they cannot be contained (e.g. transporting on conveyors, when drilling or cutting rock or concrete, sweeping or spreading of silica containing materials).
- Install and use local exhaust ventilation and dust suppression equipment where necessary to prevent dust release into the workplace.
- If local exhaust ventilation or dust suppression equipment is not available use P100 respirators when working with dry silica containing materials (see GS 401 - Respiratory Protection, Appendix A).
- Reduce the need for people to be there by using automated systems to monitor the processes.
- Time dusty operations (e.g. blending operations) for a time when less people will be present.

Control Approaches

In order of preference there are four basic hazard control approaches: elimination/substitution; engineering controls (e.g. enclosing/containing the material or ventilation); administrative controls (e.g. safe work procedures); and personal protective equipment (See GS 401 Respiratory Protection and GS 405 PPE). All or just some of the approaches may be required to control worker exposure to silica. The Managing Chemical Hazards System is designed to help you use basic information to define the procedures and control approaches you need to follow to protect worker health and safety. Go to www.enform.ca to develop a gain assistance with controlling silica exposures for your specific operation (see GS 300 Control Approaches).

Facilities:

Provide clean facilities: a washroom, showers, storage for clean and contaminated work clothing and a refreshment area.

Information Training and Supervision:

Employer responsibilities

- Provide information on the silica containing materials that will be present at the workplace (i.e. Safety Data Sheets, previous analysis of samples from the same or similar production fields)
- Consider elimination or substitution for a less hazardous substance (e.g. using silica gel instead of crystalline silica).
- Installation of local ventilation hoods, enclosures around work processes and use of automatic systems to move silica or substances containing silica from storage containers to process containers
- Use the Chemical Hazards Management System to define the required Safety Protocol for Chemical Management for the work you wish completed.
- Provide medical monitoring for workers exposed to silica.

Supervisor responsibilities

- Ensure the availability of the Guidance Sheets required for Chemical Management.
- Organize the work to limit the time workers are exposed to silica
- Educating workers about the hazards of silica for Chemical Management.
- Implementing good hygiene practices
- Implementing use and maintenance policies
- Implementing storage polices regarding hazardous materials
- Ensuring that unprotected workers are not in areas where products containing silica are used
- Implementing spill response policies including the use of appropriate protective equipment and clothing.
- Ensuring the availability and use of personal protective equipment and ventilation equipment.

Worker responsibilities

- Workers must participate in training and monitoring programs in the workplace
- Workers must use and maintain all controls and equipment used to reduce exposure properly
- Workers must clean up of spills quickly and properly by first wetting and then sweeping, using appropriate protective equipment and clothing.
- Do not use compressed air for cleaning.
- Workers must keep product containers tightly sealed when they are not in use.
- Workers must maintain and wear required personal protective equipment.
- Undergo medical monitoring.

PRECAUTIONS YOU SHOULD TAKE:

- ❒ Ask your employer about the risks, what precautions to take and what to do in an emergency;
- ❒ Follow the safe working procedures laid down by your employer;
- ❒ Avoid breathing in dust containing silica;
- ❒ Always wet down silica containing materials before sweeping or handling;
- ❒ Use the ventilation, dust suppression and personal protective equipment provided, i.e. gloves, respirators, goggles (see GS 405 PPE).
- ❒ Report to your employer or safety representative any damaged or defective ventilation systems, dust suppression or protective equipment.
- ❒ Cooperate with health surveillance.
- ❒ Keep upwind of dust clouds.

Further Reading and References

1. http://www.enform.ca/cms-assets/documents/57636-88930.ib1101.pdf Working With Safely with Silica
2. http://employment.alberta.ca/documents/WHS/WHS-PUB_ch059.pdf Crystalline Silica in the Workplace
3. http://www2.worksafebc.com/publications/posters.asp?reportID=35498 The Dangers of breathing Silica Dust
4. http://www2.worksafebc.com/Publications/Multimedia/Videos.asp?ReportID=36018 Silica Exposure Video
5. http://www.worksafebc.com/publications/health_and_safety/by_topic/assets/word/developing_a_silica_ECP_final.doc Developing a Silica Exposure Control Plan

Appendix A: Areas and Tasks Known to Produce High Exposures to Crystalline Silica

Area / Task	Respiratory protection must be worn unless adequate local exhaust ventilation or dust suppression (e.g. wetting) is provided when completing these tasks.
Plant Sites	
Abrasive Blasting	When using silica containing products during abrasive blasting
A variety of controlled products such as process additives.	When utilizing products that contain silica in spill response procedures
Maintenance Activities / Demobilization	When working with refractory brick (ceramic fibre). Crystalline silica can be formed in refractory brick when used as an insulator at operating temperatures above 1000 deg C.
Cementing Operations - plant operations	When dry products containing silica are mixed or added and there is worker exposure. Or when existing concrete is cut or broken up for removal.
Drilling	
Dry Product Additives	When the dry products contain quartz and are added to drilling fluids. In particular when bags are opened, when product is handled, mixed or added into the hopper or when dumping through grate of mud tank
Produced Dry Product - maintenance of shale dryers	When the dry particulate (fine dust) from Shale dryers is scooped, shoveled, handled or mixed.
Cementing Operations - field operations	When dry product containing silica is exposed to the workers during transportation, loading / unloading and mixing
Seismic Drilling Rigs	
Air Hammer Drills	When air hammer drills are used in a dry hole environment and workers are exposed to silica dust
Hydraulic Fracturing	
Transporting Storage of sand	When sand being brought to site contains silica and workers are exposed during unloading / loading or storage.
Movement of Sand	When sand containing silica is moving to/from site sand castles, on conveyors, on conveyors, augers etc. to blend trucks or hoppers and workers situated around equipment.
Other	
Road dust	When workers are being exposed to silica due to excessive road dust containing silica.
Sweeping/Moving sand/crush	When workers are being exposed to silica while sweeping or moving sand/crush containing silica (primarily during spring clean-up)

Silica Exposure Control Plan (ECP) Template

Background

This Silica Exposure Control Plan (ECP) template has been developed for the upstream oil and gas industry to assist in managing silica exposures. Silica is an emerging exposure concern in oil and gas operations. This ECP has been developed to enable the oil and gas industry to manage these silica exposures in a proactive manner. Sector-specific guidance sheets, such as completions (hydraulic fracturing) have been created to work in conjunction with this ECP. In addition, several related guidance sheets from Enform's Controlling Chemical Hazards Guideline are referenced where appropriate. Exposures are grouped into tiers based on anticipated airborne levels. These tiers are based on the 12-hour adjusted Occupational Exposure Limit and as such may be overprotective for 8-hour exposures or jurisdictions where adjustment for extended work shifts is not required.

Instructions for use

1. Use this Silica ECP along with relevant company and site-specific details, such as in the Silica ECP sections "Company Information" and "Annual Review".

2. Add in the relevant sector-specific guidance sheets to this Silica ECP as indicated in the Silica ECP section entitled "Guidance Sheet Selection and Implementation" (page 12).

3. Conduct the hazard assessment as indicated in the sector-specific hazard assessment guidance sheet. Check off which situations will apply to your work site. Conduct this hazard assessment twice: once as a planner and once as a supervisor. Document and retain these hazard assessment records.

4. Implement controls, as appropriate, determined by the hazard assessment and develop applicable procedures, as indicated in the control guidance sheet.

5. Conduct site inspections to verify that the controls indicated are in use.

6. Validate that the controls are effective by collecting exposure monitoring data.

7. As required, implement additional controls to mitigate risk. Seek also to use engineering or administrative controls in order to reduce dependency on personal protective equipment (PPE).

Company information

[Name]

[Address]

[Contact information - names and phone numbers]

Worksite information

[Project name]

[Address]

Purpose and responsibilities

[Name] are responsible for protecting our workers and other workers on our worksites from overexposure to crystalline silica (herein referred to as silica) in the course of performing their duties. According to the Enform Controlling Chemical Hazards Guideline, silica exposure is ranked as an Extreme risk in industry work sites requiring special controls, including seeking the advice of experts. Studies such as those conducted by National Institute for Occupational Safety and Health (NIOSH)[1] and Alberta Jobs, Skills, Training and Labour[2,3] show that a variety of oil and gas activities generate airborne contaminants in excess of occupational exposure limits. Effective controls are available to protect workers from harmful exposure.

A combination of control measures are required to protect workers from silica exposure. [Name] commit to being diligent in our efforts to select the most effective control methods (or combination of controls) available, and to ensure that the best practices, as described in this exposure control plan (ECP), are followed at our work sites.

Procedures established will not only protect our workers, but also any other workers onsite who are not involved in these operations.

This ECP applies to the site prime contractor, the site owner, service providers such as the driller, the hydraulic fracturing company, the trucking company, and their employees, as well as any other service providers and their employees when at risk as determined by a hazard assessment.

This document applies only to exposure to silica; we acknowledge that this is not the only chemical hazard at our work sites and will ensure that these hazards are appropriately assessed and controlled, as required.

Employers are responsible for the following:

- Ensure that, at a minimum, the ECP meets or exceeds provincial regulatory requirements.
- Ensure that the materials (for example, tools, equipment, and personal protective equipment [PPE]) and other resources (for example, worker training) required to fully implement and maintain this ECP are readily available.

[1] Esswein EJ, Breitenstein M, Snawder J, Kiefer M, Sieber WK. Occupational exposure to respirable crystalline silica during hydraulic fracturing. J Occup Environ Hyg 2013;10:347–56.

[2] Radnoff D, Todor M, Beach J. Exposure to Crystalline Silica at Alberta Work Sites: Review of Controls. J Occup Environ Hyg 2015: 12,6:393-403

[3] Radnoff D, Todor M, Beach J. Occupational Exposure to Crystalline Silica at Alberta Work Sites. J Occup Environ Hyg 2014: 11, 9:557-570

- Provide required materials and documentation to comply with applicable health and safety legislation (e.g. safety data sheets). A copy of this plan, or a similar one, must be present on every oil and gas site where at-risk activities are underway.
- Ensure supervisors and workers are educated and trained in the hazards of silica exposure and work procedures and controls to work safely with silica.
- Maintain written records of training (e.g. proper use of respirators), respirator fit-test results, crew talks, exposure monitoring results, and inspections (of equipment, PPE, and work methods and practices).
- Conduct exposure monitoring as required and ensure that workers are informed of exposure measurements.
- Ensure that health assessments are performed in accordance with applicable health and safety legislation requirements.
- Conduct an annual review (or more often if conditions change) of the ECP's effectiveness. This includes a review of controls to ensure they are selected and used when required.
- Coordinate work with other employers to ensure a healthy and safe work environment.

Prime Contractors and their site personnel need to ensure that an exposure control plan is present on site and enforce compliance. Prime Contractors need to select a service provider based on which available control strategies, like engineering controls, it employs to minimize exposures.

Supervisors are responsible for the following:

- Provide adequate training and instruction to workers on the hazards of silica exposure associated with their respective oil and gas activities and the work procedures and controls to protect them.
- Select and implement the appropriate control measures.
- Ensure that workers using respirators have been properly trained and fit-tested, and that the results are recorded.
- Ensure that control equipment, including respirators and other PPE, is maintained in accordance with manufacturer specifications.
- Make sure that work is conducted in a manner that minimizes and adequately controls the risk to workers and others. This includes ensuring workers use the available engineering controls and administrative controls. PPE should only be worn as the last line of defense.
- Making sure that workers have been educated and trained in this exposure control plan. They must ensure that workers understand the plan's expectations and enforce it on the work site.

Workers are responsible for the following:

- Read, understand, and comply with the controls and procedures set out in this exposure control plan.
- Complete the training provided by the employer.
- Ensure their safety and the safety of other workers at the work site.

- Use the assigned protective equipment in an effective and safe manner in accordance with work site procedures developed by their employer. For example, if workers are required to use a respirator that's effectiveness depends on a tight facial seal, the workers must be clean-shaven where a respirator seals with the worker's face.
- Follow established work procedures and use controls as directed by the supervisor.
- Report any unsafe conditions or equipment to the supervisor.
- Report any exposure incidents.
- Confirm that they understand the ECP's requirements prior to commencing their work activities.

Health hazards from silica exposure

Silica exposure usually results from the inhalation of airborne crystalline silica dust. Quartz is the most common form of crystalline silica; however, cristobalite does exist in certain materials. It is the respirable fraction of the dust, which is small enough to get deep into the lung that is of concern.

Crystalline silica dust can cause a disabling, sometimes fatal disease called silicosis. The fine particles are deposited in the lungs, causing thickening and scarring of the lung tissue. The scar tissue restricts the lungs' ability to extract oxygen from the air. This damage is permanent, but symptoms of the disease may not appear for many years.

A worker may develop any of three types of silicosis, depending on the airborne levels of silica dust encountered and the duration of exposure:

- Chronic silicosis—develops after 10 or more years of exposure to crystalline silica at relatively low airborne levels
- Accelerated silicosis—develops 5 to 10 years after initial exposure to crystalline silica at high airborne levels
- Acute silicosis—develops within a few weeks to a few years, after exposure to very high airborne levels of crystalline silica[4]

Initially, workers with silicosis may have no symptoms; however, as the disease progresses, a worker may experience:

- Shortness of breath
- Severe cough
- Weakness

These symptoms can worsen over time and lead to death.

Exposure to silica has also been linked to other diseases, including bronchitis, tuberculosis, chronic obstructive pulmonary disease (COPD), kidney disease, and lung cancer.

[4] Buchanan D, Miller BG, and Soutar CA. (2003). Quantitative relations between exposure to respirable quartz and risk of silicosis, Occup Environ Med 6-:159-164. http://oem.bmj.com/content/60/3/159.full.pdf+html?sid=5259c728-aeef-4511-97a3-3e5af842dea6

Silica is classified as a human carcinogen (Group I) by the International Agency for Research on Cancer (IARC).

Other hazardous materials may be present in the silica-containing materials or involved in the process such as heavy metals or NORM that have additional health effects. Examples of this include abrasive blasting dust, refractory brick removal or bauxite-based ceramic proppants.

Risk identification

When silica containing materials (generally greater than or equal to 0.1% by weight) are disturbed, moved, or handled, airborne dust can be generated and silica exposure can occur. Worker exposure is primarily from inhalation, but dust on skin, hair, clothing and PPE can also become airborne and inhaled by the worker or other workers. Airborne dust containing silica may also cause mechanical abrasion to the eye or respiratory tract when airborne levels are very elevated.

Inhalation exposure to silica can occur as a function of:

- the work location
- the activity (task); and
- the occurrence of unplanned events

The nature of the hazard

Silica dust is not ordinary dust and exposure to silica in the oil and gas industry can occur during a variety of dust generating activities. For a list of many silica exposures please refer to Guidance Sheet 003. The hazardous component of silica dust is the respirable fraction: this means the very small particles that can penetrate deep into the lung. Different types and sources of silica may have different size ranges. For example, dust generated from hydraulic fracturing may consist of a large portion of respirable particles. In contrast, silica dust generated while cutting concrete generally has a wider range of particle sizes. Airborne levels above the occupational exposure limit (OEL) of respirable silica may not be visible, because the particles do not significantly block, scatter, and reflect light. The net result is that with many silica hazards, by the time it is visible, the airborne silica levels are well above what would be considered acceptable risk.

The absence of visible dust may not mean the absence of an airborne silica hazard!

Silica dust generated from sand can come from existing fines in the dust, or it can come from breaking the sand grains apart during handling.

Airborne exposure limits

Crystalline silica, such as quartz and cristobalite, has exposure limits described below in Table 1. When other hazards such as heavy metals or NORM are present, those occupational exposure limits (OEL) need to be considered as well.

Table 1 - Silica occupational exposure limits (OEL)

Jurisdiction	8-Hour OEL (respirable)	12-Hour adjusted OEL (respirable)
ACGIH TLV[5]	0.025	0.0125
Alberta[6]	0.025	0.025
British Columbia	0.025	0.0125
Saskatchewan	0.05	0.05
Manitoba	0.025	0.0125

Note. Occupational exposure limits are subject to change by the agencies that set them. Excursion limits also exist for silica such as the derived 30-minute time weighted average and derived ceiling, which are 3 times the full-shift OEL and 5 times the full-shift OEL respectively.[7]

The 8-hour OEL of 0.025 mg/m^3 is recommended to standardize risk management across the western provinces. This is based on this value being adopted by three of the four western provinces and the risks of silicosis, lung cancer, and other disease being markedly elevated at levels above 0.025 mg/m^3.

The current understanding of the risk of silicosis disease over 45 years of exposure at 0.025 mg/m^3 is between 5 to 40 cases of silicosis per 1,000 workers versus 20 to 170 cases per 1,000 workers at 0.050 mg/m^3. At the older 2006 ACGIH TLV of 0.1 mg/m^3 the silicosis risk ranged from 60 to 773 cases per 1,000 workers.[8] The range is a reflection of different industries and different studies and therefore may not be appropriate for all types of silica exposures.

Skin and ingestion

Skin and ingestion exposure to silica is generally not thought to be a concern in and of itself; however, the re-entrainment of silica back into the air creates an airborne hazard that warrants attention. As a result, good hygiene practices, gloves, body protection (coveralls), and proper hand washing is required. In general, workers should limit skin contact with silica whenever possible.

Hazard assessment

Exposure to silica has been recognized as a concern in several industries, including the oil and gas industry. NIOSH and Alberta OH&S have conducted and published independent studies of silica exposures in select oil and gas activities and identified exposures of concern.

[5] 12-hour adjusted OEL's are calculated from published 8-hour OEL's by multiplying the 8-hour OEL's by a conversion factor (usually 0.5). Please see legislation for particular details.

[6] Alberta OH&S intends to not adjust silica for extended shifts such as shift lengths greater than 8 hours or more work hours equivalent to a typical 40-hour work week.

[7] Excursion OEL's are based on statistical relationships that exist between exceeding these values and increased likelihood of exceeding the full-shift OEL. The ACGIH defines processes that exceed excursion limits as out of control.

[8] OSHA. (2010). Occupational Exposure to Respirable Crystalline Silica – Review of Health Effects Literature and Preliminary Quantitative Risk Assessment, Docket OSHA-2010-0034-0306. Page 351. https://www.osha.gov/silica/Combined_Background.pdf.

WorkSafeBC has created a variety of silica awareness campaigns, templates, and training videos. Links to these are provided in the Resources section of this ECP template.

While many assessments have been completed within industry, individual site variations, configurations, and activities, as well as other site-specific conditions, may affect the exposure risk.

Factors of exposure risk

A variety of factors impact the degree of exposure risk on site. Some factors that commonly apply to the majority of silica exposures are detailed below. An understanding of these factors can assist in selecting controls.

- **Time** – How long is the duration of the exposure? Cumulative exposure is a better predictor of silica disease. As such, OEL's are full-shift time-weighted averages (TWA) like the 8-hour OEL. Some task-based exposures may last only minutes, while others may last the entire work shift. It is important to remember that excursion OEL's also exist and require compliance; one example is the 30-minute TWA, which is 3 times the full-shift EL.
- **Proximity** – How close are you to the emission source? The closer you are to the emission source, the higher the airborne silica concentration is likely to be.
- **Relative Dustiness** – How dusty is the material or process? The dustier the material is, the more airborne dust may be generated. It is important to recognize that the manner in which the material is disturbed can impact the dustiness. For example, a product that is not dusty, such as clean sand, can generate dust when it is ground to make silica flour or used in abrasive blasting. Relative dustiness is grouped into three categories – low, medium, and high – in accordance with Enform's Controlling Chemical Hazards Guideline.
- **Energy** – Is energy being imparted into the silica-containing material? The more energy, the greater the airborne concentration of silica. Energy can come from the speed of telebelts, the speed of a chop saw blade, the drop distance, the pressure and associated speed of abrasive blasting media coming out of the gun nozzle, the air pressure used to pneumatically convey bulk materials, etc.
- **Quantity in use** – How much is being used? Generally, the more product in use, the greater the airborne hazard created. Quantities are grouped into three categories including grams, kilograms, and tonnes, in accordance with Enform's Controlling Chemical Hazards Guideline.
- **Percentage Silica** – What is the bulk silica percentage? Higher silica concentrations generally result in higher airborne silica levels, especially for pure products rather than mixtures.
- **Ventilation** – Can silica build up in the air? The amount of ventilation can make a significant difference to exposures. Exposures in well-ventilated environments, like wide-open windy outdoor locations, may be less significant than exposures in poorly ventilated indoor environments. Wind can dilute the hazard, but can also take the hazard from one area and make it a hazard for others. This is of particular concern when the concentration is very high, as in hydraulic fracturing and abrasive blasting operations.

Conducting the hazard assessment

Because silica is so toxic, it is categorized in Enform's Controlling Chemical Hazards Guideline and associated web-tool into Hazard Group E. This means that an exposure control plan and Control Approach 4 is required (i.e. seek expert advice). See Guidance sheet GS-304 for more information. This ECP template and its associated silica exposure guidance sheets provide some of that special advice.

Personnel at risk for silica exposure need to:

- conduct hazard assessments for their specific operations as a component of their health and safety program; and
- implement appropriate controls to mitigate hazards to acceptable levels

A series of questions are provided below to assist you in conducting a hazard assessment. Additional guidance is provided in the Controlling Chemical Hazards Guideline.

Step #1: Is Silica Present in Your Worksite? Look at Safety Data Sheets (SDS) and if disturbance of natural silica sources (soil, gravel etc.) are occurring. Involve workers in this process and conduct a worksite tour.

Step #2: If yes, determine who might be at risk.

Step #3: Look at each group of workers and determine specific tasks that they conduct.

Step #4: Determine if any Enform Guidance Sheets apply to the work environment. If so, use the control and hazard information to guide your assessment. If not, prioritize the exposures based on the workers/tasks that are anticipated to be the most elevated and by the number of workers at risk.

Step #5: Implement interim controls where elevated exposures are anticipated such as workers breathing visible dust that is known to contain silica and then conduct representative exposure measurements to determine airborne silica levels.

Step #6: Evaluate monitoring results and existing controls and determine if and what additional controls are required.

Step #7: Document and communicate results and control requirements to workers and management.

Step #8: Conduct inspections and periodic re-assessment or when change occurs. Examples of change may include a new site configuration, wind direction, introduction of new products, new controls, etc.

Exposure measurement

Exposure measurement is used to answer a variety of questions. It is important that one first knows what questions you want to answer and then design your measurement strategy to answer those questions. For more information on exposure measurement, please refer to the Exposure Measurement Guidance Sheet (GS 305).

Specific to silica the generally agreed to best measurement method is NIOSH method 0600 and 7500. Sample pumps with respirable cyclones and filters are attached to workers to measure the amount of respirable dust and respirable quartz in the breathing zone over a set period of time (time weighted average). The filters are weighed and are then ashed (burned) and the resulting residue analyzed by x-ray diffraction for the quantity of silica present in the respirable dust.

In addition to traditional sampling involving filters and pumps, real-time monitoring for respirable dust may be a useful tool to augment air sampling. This type of real-time monitoring can assist in identifying sources and providing real-time feedback on the effectiveness of controls. Additionally, if silica percentages (quartz) are known, it may be possible to make real-time approximate predictions on the respirable silica (e.g. quartz) present in the air.

Airborne hazard categories

Four categories of airborne hazard are detailed below in Table 2.

Table 2 – Airborne hazard categories

Hazard category	Airborne silica level (mg/m^3)[9] (Based on 12-hour adjusted OEL)
Tier 0	<0.0125
Tier I	0.0125 - <0.125
Tier II	0.125 - <0.625
Tier III	≥0.625

Controls

Hazard assessment and evaluations should lead to the implementation of effective exposure controls. Most OHS legislation requires employers to select controls based on the following hierarchy:

- Elimination and Substitution
- Engineering controls (i.e. local exhaust ventilation, barriers)
- Administrative controls (i.e. limiting time workers are in a potentially contaminated area, procedures and signage); and
- Personal protective equipment (i.e. respirators and disposable coveralls)

Because silica exposure may increase the risk of lung cancer, exposure should be maintained as low as reasonably practicable in keeping with the theory that even small exposures may represent a cancer risk.

[9] Mg/m^3 – milligrams of respirable crystalline silica per cubic meter of air collected on a worker for a full work shift; however, excursion limits such as the 30-minute excursion limit of 3 times the full-shift OEL must be considered as well. Exposure ranges are based on respiratory protection factors and the 12-hour adjusted OEL of 0.0125 mg/m^3. A protection factor of 50 is assigned to a full-face respirator in accordance with CSA Z94.4-2011.

Ideally, the hazard should be eliminated or substituted. However, the substitution of non-silica based products is not applicable to many of the silica exposures associated with oil and gas activities, because many of the exposures come from naturally occurring silica such as sand, rock, and soil. One activity where substitution is appropriate is the use of non-silica abrasive blasting media. It is worth noting that contrary to what may be indicated in a product SDS some of these alternative media may still contain low concentrations of silica sufficient to result in airborne silica levels over the OEL. So, engineering (e.g. ventilation), administrative (e.g. work procedures) and personal protective controls (e.g. respirator) may still be needed.

Of these controls, the use of engineering controls is typically the most desirable and effective. Personal protective controls are required when engineering controls and/or administrative controls are either not practical or not effective on their own. The goal should be to apply engineering and administrative controls to Tier III exposures first; so, over time, only Tier 0 exposures remain.

Engineering controls

Engineering controls can offer effective exposure control, because they separate or remove the hazard from the work environment. Engineering controls that are applicable to silica exposure control may include the following:

- Use of water in processes or for dust control
- Dust suppression agents
- Partial or full enclosures (around processes or people such as control rooms)
- Ventilation and filtration on processes or tools; and
- Automation of equipment and remote monitoring systems such as cameras to remove the need for a worker to be present

Implementing change in a process often creates other health and safety risks that require assessment and management. Engineering controls typically require on-going maintenance to be effective. Worker training and other administrative controls are also necessary.

For more information on engineering controls, please refer to the Controlling Chemical Hazards Guidance Sheets GS 300, GS 301, GS 302, and GS 303.

Administrative controls

Personnel on site must follow established practices and procedures to reduce dust and/or limit contact with or exposure to silica. Where engineering controls are in place, procedures for their use and maintenance must also be present and followed.

Signs must indicate that an airborne silica hazard is present and that respiratory protection is required when a Tier I, Tier II or Tier III hazard exists. Restrictive barriers such as banner tape are recommended, when practical.

In general, proximity and duration of exposure can be managed by administrative controls. Examples include procedures limiting access, limiting time in exposure areas, maximizing distance from sources and control zones indicating where personnel are permitted.

Procedures are required for the use of a variety of PPE, including respirators, and for personal decontamination.

(Courtesy of MySafetySign)

Personal protective equipment

Respirators

Different types of silica-generating activities or operations require different levels of respiratory protection. Options range from a half-face air purifying respirator (APR) with an assigned protection factor of 10 to a tight-fitting full-face powered-air purifying respirator (PAPR) that has an assigned protection factor of 1,000. These different respirator types correspond with different exposure risk levels.

Respirators are assigned protection factors. For example, a half-face respirator has a protection factor of 10 meaning that it can reduce the concentration of the contaminant from outside the respirator to inside the respirator by 10 times. Fit testing is required for any respirator that relies on a seal between the mask and the face. As such, filtering face-piece respirators (dust masks) must be fit tested as well.

These protection factors are assigned by the CSA and NIOSH and adopted by the various health and safety regulatory jurisdictions.

Regardless of the type of respiratory protection used, a respiratory protection program must be in place to ensure that workers have been fit-tested and are trained in the use, care, and maintenance of their respirators. Where a facial seal is required for protection the worker must either be clean shaven or use respiratory protection that does not rely on a seal. Respirators will be used, cleaned, and stored in accordance with the respiratory protection program. For more information on a respiratory program please refer to GS 401 and the Alberta requirements for a Respiratory Code of Practice.

The presence of other chemical hazards may require a higher level or different type of respiratory protection.

Table 3 describes equipment and configurations necessary for certain situations. This list is not exhaustive, please refer to the CSA Standard for a complete list of respiratory protection and assigned protection factors.

Table 3 – Hazard categories and respirator types

Hazard category	Required protection factor[10]	Respirator type and filter
Tier 0	NONE	No protection required
Tier I	10	Half-face with N95 or better filters[11]
Tier II	50	Full-face with P100 filters
Tier III	1,000	Tight-fitting full-face PAPR & P100 filters or Supply Air[12]

Respirators are only effective if they are worn properly and consistently 100% of the time!

The use of tight-fitting full-face PAPRs instead of full-face respirators for work situations that require full-shift use should be considered to increase comfort, reduce stress on the worker, and improve adherence to proper use. PAPRs are not recommended for Tier III exposures that are sustained, because the main limitation on use is filter dust loading. This requires the filter to be changed numerous times in a day. A recommended filter change-out schedule is provided in Table 4; however, the filters should be changed whenever it becomes hard to breathe.

Table 4 - Respirator filter change-out schedule

Respirator	Duration of use	Change-out frequency[13]
Half-face APR (Tier I)	12-hour Shift	Daily
	<2 hours	Weekly
Full-face APR (Tier II)	Any	Daily
Tight-fitting Full-face PAPR[14] (Tier III)	Any	~Variable (Calculation Required)

[10] Protection factor of 50 is assigned to a full-face respirator in accordance with CSA Z94.4-2011. Exposure ranges are based on the 12-hour adjusted OEL of 0.0125 mg/m^3. Assumes quantitative fit testing.

[11] Half-face includes elastomeric and filtering facepiece respirators.

[12] For any work situation requiring the use of a 1,000 protection factor respirator the use of full-body disposable coveralls is highly recommended.

[13] Calculations are based on the following: a 200 mg maximum loading per filter, an inhalation rate of 85 L/min, a PAPR flow rate of 115 lpm and the protection factor (PF) required based on 0.0125 mg/m^3. A dust factor (DF) is required to account for non-quartz respirable dust loading as well as non-respirable dust loading provided that silica is the driving hazard. A dust factor of 10 is recommended for hydraulic fracturing. T(min) =(200 mg*# Filters*1000 L/m^3)/(0.0125 mg/m^3*PF*DF*Flow Rate L/min).

[14] The use of tight-fitting PAPR for Tier III exposures is not recommended because of the impractical change-out schedule.

Coveralls

Decontamination is an integral component of exposure control. The goal is to remove contamination of skin and personal protective equipment to prevent the potential inadvertent secondary inhalation of contaminants.

Coveralls such as FR coveralls must not be worn off site and must be laundered on a regular basis. Inadvertent secondary inhalation may occur when silica dust that is present on PPE, skin or head hair is disturbed, re-entraining the silica into the air.

Disposable coveralls worn over FR coveralls are highly recommended when working with uncontained bulk silica dust (powder) such as found in engineering control filters or ventilation systems and for Tier III (PAPR or Supply Air) exposure hazards.

Coveralls should be sized and worn in a manner to limit exposed skin such as at the arms, ankles and neck. For more information on coverall selection, please refer to GS 400 and GS 403.

Gloves

Gloves suited for the physical hazards of the task are recommended, but not required, for protection against silica. It is not generally considered a skin hazard. For more information on glove selection and use please refer to GS 404.

Guidance sheet selection and implementation

This is the most important part of this ECP. It is where you determine which category of hazard applies to your work site, implement controls to protect workers' health, and comply with the law.

An assortment of hazard assessment and control guidelines have been prepared. Take the guidance sheets that are applicable to your work site and check off the various hazards and control strategies that apply. Then, implement them on the work site. If guidance sheets are not available for your worksite you will need to add the relevant site-specific information here and indicate what controls are required for each group of workers and tasks.

Insert guidance sheets here as per Table 5.

Table 5 – Guidance sheets to be inserted into ECP

Industry sector	Guidance sheets
Completions (hydraulic fracturing)	*GS 407 Sources of Exposure*, *GS 408 Controls* and *GS 409 Hazard Assessment*
Other sectors	Coming soon.

Hygiene facilities and decontamination procedures

In order to protect workers, decontamination is an integral component of exposure control. The goal is to remove contamination of skin and personal protective equipment to prevent inadvertent secondary inhalation of contaminants. Inadvertent secondary inhalation may occur when silica dust that is present on PPE, skin, or hair is disturbed, which reintroduces the silica into the air.

Prior to eating, drinking, and leaving the worksite, workers should thoroughly wash their face and hands with a mild detergent solution. Adequate washing facilities must be provided on site to enable worker decontamination. Eating and drinking is restricted to no exposure areas and authorized areas only.

Adequate washing facilities must be provided on site to enable worker decontamination. A shower is not required, but may be advisable for those working with bulk silica dust and Tier III exposures.

(Courtesy of MySafetySign)

Decontamination should be conducted in the following order:

1. Remove disposable coveralls (if applicable) and place in waste receptacle
2. Remove FR coveralls and place in laundry receptacle
3. Wash hands, face, head and respirator
   (respirator should be wet wiped prior to removal)
4. Remove respiratory protection
5. Inspect respirator, replace cartridges and store properly

Contaminated coveralls must be laundered or disposed of in a controlled manner to prevent exposure to those handling or worker near the contaminated coveralls.

Health monitoring

A program of monitoring and evaluating worker health is recommended and is required in some jurisdictions. Lung spirometry is recommended to detect changes in lung function and the onset of lung disease for anyone who works in an environment that is at or above the OEL (full-shift TWA) for 30 days in a calendar year. This is an Alberta OHS Code requirement that is tied to the definition of an “exposed worker”. Additionally, chest x-rays are a requirement of Alberta and Saskatchewan legislation.

Lung spirometry must be conducted by competent medical health professionals. Please consult OHS legislation for your applicable jurisdiction in regards to the specific health monitoring requirements.

Supervisors must address health and wellness issues with their employees. Discussion should include general fit for work expectations, ability to wear a respirator, and other related components, such as respirator fit testing. These are elements of the health and safety program.

Training

Training must be performed by the employer or the employer's designate. Records of attendance, dates of training, and training material must be documented and retained.

Training topics

- Roles and responsibilities
- Health hazards of silica exposure
- Operations that can produce silica exposure
- Engineering controls and safe work practices used to protect workers
- The importance of proper equipment control and maintenance
- Housekeeping procedures
- Proper use of respirators and the respirator program
- Personal hygiene decontamination procedures to reduce exposures
- Review the details of the exposure control program for silica.

As with all hazard controls, training is paramount to the success of any program and is a legislated requirement.

Annual review

This ECP will be reviewed at least annually and updated as necessary by the employer, in consultation with the workplace health and safety committee or the worker health and safety representative. This review should take into account any voluntary certification programs (i.e., COR Audit) in place, as well as any changes in regulatory requirements. Substitution and control technologies are evolving quickly and must be considered in the annual review. Proposed changes to this practice can be directed to the _________.

Definitions and abbreviations

ACGIH - American Conference of Governmental Industrial Hygienists

APR - Air Purifying Respirator

CSA - Canadian Standards Association

DOP Testing – DOP or Dioctyl Phthalate is an aerosol that is used to test HEPA filters and the seal of the filter to the housing of a vacuum or negative air unit. It is recommended that this testing occur at least yearly.

ECP - Exposure Control Plan. A term referenced in WorkSafe BC legislation, but generally considered synonymous with the Code of Practice requirements of the Alberta OH&S legislation.

Occupational Exposure Level - the maximum allowable exposure to a chemical or other agent or hazard. It is often expressed as an average over eight hours or 15 minutes or as a ceiling above which no exposure is permitted at any time. Exposures longer than eight hours are often adjusted to account for extended exposure and reduced recovery time. Occupational exposure levels can also be referred to as permissible exposure levels (PEL).

Heavy Metals - general a term used to describe metals with high atomic weights that are very toxic such as mercury, cadmium, lead, arsenic, manganese, chromium, etc.

IARC - International Agency for Research on Cancer

Mist - the presence of liquid droplets suspended in the air

SDS - Safety Data Sheet as a component of WHMIS 2015

NIOSH - National Institute of Occupational Safety and Health – a federal department of the Centre for Disease (CDC) Control in the United States of America. NIOSH is responsible for conducting research and making recommendations for the prevention of work-related disease and injury. They also certify respirators.

NORM - Naturally occurring radioactive materials. These are typically decay products of thorium and uranium such as radium-226, radium-228, radon-222 and lead-210. NORM may be concentrated in oil and gas process equipment in the form of gas, sludge, scales and films. Certain products such as refractory brick insulation may naturally contain NORM.

PAPR – Powered Air Purifying Respirator. A respirator that is equipped with a filter and a blower motor such that a slight positive pressure within the face piece is created. PAPR's can be either tight-fitting or loose-fitting.

Respirable - Delineates a specific size of airborne particles small enough to access the lower regions of the lung where gas exchange takes place. Generally this includes airborne particulate that has a diameter of less than 10 micrometers with a cut-point of 4 microns.

Service Provider - A company selected to perform a service for an owner or prime contractor such as pressure pumping or drilling.

Silica (Quartz or Cristobalite) - an abundant crystal form of silica that can be present in many dry products, present in refractory brick insulation, and present in naturally occurring products such as sand, cement and soil and rock. It is highly toxic and can cause serious disease and lung cancer.

Silicosis - A progressive and often fatal lung disease that is caused by the inhalation of respirable crystalline silica such as quartz or cristobalite. Silicosis is an auto-immune disease where the body reacts to the presence of the silica in the lung with the formation of scar tissue that leads to difficulty in breathing and reduced gas exchange in the lungs.

Spirometry - tests that measure pulmonary lung function (PFT) in order to diagnose a variety of lung diseases. Often includes the forced vital capacity (FEV) and forced expiratory volume in one second (FEV(1)) tests.

WHMIS - Workplace Hazardous Materials Information System

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Managing chemical hazards

Silica on hydraulic fracturing sites – sources of exposure

PROCESS DOCUMENT **GS 407**

BACKGROUND

This document is part of the Silica Exposure Control Plan (ECP) template. The template provides general silica information. Please refer to Guidance Sheets GS 408 and GS 409 to understand controls and conduct a hazard assessment on hydraulic fracturing sites.

Hydraulic fracturing involves the use of water, proppant, chemicals and pressure to fracture the formation and hold it open so petroleum resources may be extracted.

One of the most common proppants is sand. Sand typically contains 30-100 percent quartz silica, one of the most abundant minerals on the planet. In addition to sand, some ceramic proppants are used that contain other forms of silica such as cristobalite.

Elevated respirable crystalline silica exposures associated with hydraulic fracturing – herein referred to as fracking – are a serious emerging concern, because silica can cause serious lung disease. The amount of sand used in fracking operations has changed in recent years. Current operations use significantly more sand than earlier ones did. The amount of proppant moved down hole in any given work shift has increased from a few tonnes to as much as a 1,000 tonnes. In addition, advances in the ability to measure silica and more scientific evidence of the toxicity of silica have resulted in a reduction of the silica exposure level by several times.

Silica exposure levels on frack sites vary widely in concentration from <0.0125 to 10.0 mg/m^3 compared to the respirable quartz 12-hour occupational exposure limit of 0.0125 mg/m^3 as identified by NIOSH[3] and Alberta Jobs, Skills, Training and Labour[4,5]. Sources of these exposures and a variety of exposure factors exist that differentiate one situation from another.

SOURCES OF SILICA EXPOSURE ON FRACK SITES

A variety of sources of exposure can exist on a fracking site. They may include the following, which are listed from highest to lowest airborne concentration:

- Thief and vent hatches during loading of proppant, either by way of conveyor belts or pneumatic conveyance (use of air)
- Any uncovered fill nozzles on vertical or horizontal sand storage
- Hopper
- Handling of bulk silica frack dust (powder), such as from local exhaust ventilation engineering controls or in air filters
- Conveyor junction points
- Sand tent loading and un-loading
- Top of blend truck auger
- Truck end-dump or bottom-dump locations
- Contaminated coveralls
- Soil, rock and clay ground cover

SPECIFIC FACTORS OF EXPOSURE

In addition to the general determinates of exposure discussed in the Silica ECP, please see the following additional determinates and information provided specific to fracking.

Quantity in use: For workers in close proximity to silica sources the more sand moved down hole in a 12-hour period the more elevated the silica levels will be. For example, the "ball drop" method minimizes the downtime between frack stages. Thus, more proppant is moved down hole in a 12-hour period when compared to the "plug and perforate" technique.

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Relative dustiness: Not all sands are created equal: Mesh size and ceramic proppant all impact dust levels. In addition, the use of sand with reduced fines (smaller diameter particles that are more likely to become airborne) will reduce the exposures. However, it is also important to remember that it does not eliminate the risk, because of the dust that is generated when the sand is moved. Dust suppressants may be used to reduce the silica dust generated from moving the sand.

Sand comes in different sizes with small sand grains having a higher mesh size. Higher mesh size sand typically generates more dust. For example, 100 mesh sand may generate several times more dust than 40/70 mesh sand. Therefore, the higher mesh number of sand that is used the more elevated the exposures may be. Often higher mesh sands are used at the front end of the frack followed by lower mesh sand (larger sand) for the majority of the sand in that stage. In general, as the ratio of 100 mesh to 40/70 mesh increases, so do the exposures.

Ceramic proppant is manmade, contains less silica, and may be less dusty. As a result, silica exposures associated with ceramic proppant are generally significantly less. Ceramic proppant is used based on formation requirements, is significantly more expensive than frack sand and is not as widely available.

Bulk silica frack dust (powder) is the collected or settled airborne silica dust such as in filter socks affixed to pneumatic air hoses or thief hatches. This material is extremely dusty and may result in very elevated exposures.

Energy: The more energy that is incorporated into the sand, the more dust that is created at junction and drop points. Wide and deep conveyor belts moving slower can deliver the same volume of sand as a flat and narrow belt moving several times faster.

Sand can be stored onsite using horizontal or vertical containers. Horizontal storage containers are equipped with a conveyor while vertical storage containers are typically gravity feed either directly into the hopper or onto a conveyor. Offsite sand storage could be a sand tent or building with conveyors and augers.

Proppant can be moved to the work site in a variety of ways, such as:

- the use of end dump trucks on very small fracks
- the use of bottom dump trucks that drop the sand into augers or conveyors to move it into site sand storage
- pneumatic conveyance

Pneumatic conveyance is one of the most visible – and significantly elevated – silica frack dust sources. As the sand moves through the metal pipes and hoses, friction creates new fractures in the sand. The pneumatic air now contains silica dust and in the absence of engineering controls, this dust is released from the sand storage equipment into the air of the work site. When pneumatic in-loading is conducted on an on-going basis while pumping is occurring, referred to as “Hot Loading”, additional risk is created because of increased personnel in the area and duration of exposure. Depending on the type of sand storage equipment, site layout, and prevailing winds, adjacent workers may be at risk from exposure.

As a result, the use of PPE controls alone for adjacent workers can be very challenging and often not effective. Therefore, a variety of controls are required to reduce silica dust at the source; examples include engineering controls and administrative controls. These, and other controls, are discussed in Guidance Sheet GS 408. For work sites with lower tonnages, exceeding the full-shift exposure level and associated full-face respirator protection factor is unlikely. However, it is important to recognize that exceeding other exposure limits, like the 30-minute derived TWA (3 X full-shift TWA) and associated respirator protection factor, is very likely. This is due to the high energy involved at the sources. This is particularly true for those personnel in close proximity to the silica dust sources such as within 1 meter.

SOURCES OF EXPOSURE

☐ Thief hatches

☐ Uncovered fill nozzles

☐ Hopper

☐ Handling filters or uncontained bulk silica frack dust (powder)

☐ Conveyor junctions

☐ Blender auger

☐ Sand storage (tents)

☐ Ground cover

FACTORS OF EXPOSURE

☐ Energy

☐ Relative Dustiness

☐ Quantity in use

☐ Percentage silica

☐ Proximity

☐ Time

☐ Ventilation

Further Reading and References

1. Enform’s Silica Exposure Control Plan
2. Enform’s Silica Information website: Enform.ca
3. Esswein EJ, Breitenstein M, Snawder J, Kiefer M, Sieber WK. Occupational exposure to respirable crystalline silica during hydraulic fracturing. J Occup Environ Hyg 2013;10:347–56.
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Managing chemical hazards

Silica on hydraulic fracturing sites – controls

PROCESS DOCUMENT **GS 408**

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BACKGROUND

This document is part of the Silica Exposure Control Plan (ECP) template. The template provides general silica information. Please refer to Guidance Sheets GS 407 and GS 409 to understand sources of exposure and conduct a hazard assessment on hydraulic fracturing sites.

ELIMINATION

Eliminate the use of proppant that contains silica. Some formations do not need proppant.

SUBSTITUTION

Use sand that is clean of dust whenever possible. Substitute out higher energy equipment for lower energy equipment: examples include lower energy belts, conveyor or auger in-loading instead of pneumatic conveyance, etc.

ENGINEERING CONTROLS

The following preventative engineering controls are available below:

- Minimize vertical drop height at conveyor junctions and into the hopper.
- Use equipment that minimizes the amount of energy put into the proppant. For example, wider, deeper belts with lower belt speeds generate less dust. Tie conveyor belt speed to hopper auger speed to avoid using unnecessary speed and spilling of proppant.
- Enclose junction points such as with tarps to minimize dust. (Do not put workers under tarps).
- Positively pressurize with HEPA-filtered air in the cabs of adjacent occupied vehicles, such as the blender on a frack site or a front-end loader in a sand tent.
- Use dust suppressants where compatibility and chemical risk management allows.
- Use filter bags/socks, water filtration systems, and local exhaust ventilation to capture dust emissions from pneumatic in-loading.
- Minimize the pneumatic air pressure used during pneumatic in-loading.
- Use HEPA-filtered vacuum cleaners (DOP tested) or wet mopping to decontaminate indoor workspaces.
- Use temporary ground covers such as matting, ground wetting and wind barriers like noise walls in order to minimize soil and clay dust generation.
- Install remote monitoring equipment such as video cameras so that workers are not required to be in close proximity to emission sources on an ongoing basis.

The use of pneumatic in-loading in the absence of engineering controls such as dust suppressants or local exhaust ventilation is not recommended because of the risk to adjacent personnel.

Dust suppressants: Dust suppressants are now available that can help reduce the formation of new fractures in proppant and the resulting dust by 10 or more times, depending on the suppressant and its application. Dust suppressants have another advantage; they can reduce exposures at various points along the supply chain if they are applied, for example, at the mine site. Dust suppressants must be chemically compatible and meet or exceed responsible chemical product programs. Dust suppressants, combined with other controls, may be able to decrease the number of people that have to wear a respirator.

Collected dust must be contained. It is not permitted to be discharged or dumped onto the ground.

Local exhaust ventilation: In order for it to be effective it should be set up as follows:

- 16 inch ducts should be used from the system, and should branch to 8 to 10 inch ducts to the tops of the sand storage. Use of smaller diameter lines before branching will dramatically reduce suction.
- Smooth-bore (internal surface) flexible ducting is required to reduce turbulence and increase suction rather than corrugated ducts.
- Use long sweep-style elbows rather than 90 degree angle branches to minimize turbulent flow.
- Branches should have blast gates or throttle valves so that ducts that are not in use can be closed.
- Setup ducting to minimize the length of ducting so that significant pressure drops do not occur.
- One 20,000 CFM unit is sufficient for 3 to 6 trucks pneumatically in-loading at a time. Reduce in-loading pneumatic pressure where feasible to align with ventilation unit capacity.
- Ventilation controls must discharge dust into impervious air-tight bags or containers that have WHMIS labels.
- Ventilation controls at the hopper can be effective provided they are combined with an air-tight enclosure.

ADMINISTRATIVE CONTROLS

Activity-specific procedures that must be in place to minimize exposure include:

- Handling dust filters or collected bulk silica dust (powder)
- Conducting maintenance of ventilation units
- Opening and closing blast gates on ventilation units in accordance with the bins that are being filled
- The prevention and clean-up of sand following a screen-off

Signage: Signage indicating that a respiratory hazard is present must be located at least 10 meters[4] from frack silica sources. Proppant storage equipment should include WHMIS workplace labels.

Time and distance: Maintain as much distance as possible between workers and silica sources and minimize the time workers spend in those areas. Rotate workers in and out of the work areas particularly when the work conditions are demanding (high exertion, temperature extremes, etc.). Design site equipment and site layout so sand personnel are not required to be directly adjacent to hopper. Alternatively, install transparent wall barriers between sources and workers. Design site layout so that adjacent personnel are kept upwind at least 10 meters from silica sources and farther in the absence of engineering controls or as site conditions dictate such as wind.

Other controls: Wait for the conveyor arm to completely lower prior to moving sand into the hopper and minimize belt speeds where feasible. When feasible, conduct in-loading when fewer personnel are in the vicinity of the sand moving equipment. This could be in the early morning or evening when less people are on site. Instead of sweeping conduct wet mopping or HEPA vacuuming of occupied interior equipment structures like lunch rooms, as well as of adjacent vehicles or equipment.

Training: Any person who comes to a frack site or proppant storage site must be made aware of the potential silica hazard. A review of the Silica ECP and these guidance sheets can meet this requirement. This must be included in the site orientation. The orientation should address where personnel can and cannot go. It should also detail which form of personal protective equipment, including respirators, is required in each of those areas.

PERSONAL PROTECTIVE EQUIPMENT

Respiratory protection is required when present in visible frack dust or within 10 meters of silica frack dust sources. Full-face respirators are required at least when within 3 meters of silica dust sources. Disposable coveralls are highly recommended for Tier III exposures and for those handling uncontained bulk silica frack dust (powder). Please refer to the Silica ECP for more information on respirators.

SUBSTITUTION:

- ☐ Use low dust proppants.
- ☐ Substitute out high energy equipment.

ENGINEERING CONTROLS:

- ☐ Use dust suppressants.
- ☐ Use ventilation or filter controls when pneumatically in-loading.
- ☐ Use HEPA-filtered ventilation for vehicle cabs.
- ☐ Enclose junction points. (Do not put workers under enclosures).

ADMINISTRATIVE CONTROLS:

- ☐ Train workers on the hazards of silica dust.
- ☐ Maximize distance from silica sources; stay at least one meter away from silica sources at all times.
- ☐ Keep upwind of dust clouds.
- ☐ Reduce time in dusty areas.
- ☐ Install silica signs at least 10 meters from major sources.

PPE CONTROLS:

- ☐ Properly use controls provided.
- ☐ Wear respirators consistently when present in silica frack dust.

Further Reading and References

1. Enform's Silica Exposure Control Plan
2. Enform's Silica Information website: Enform.ca
3. Photograph courtesy of Industrial Vacuum Equipment Corp.
4. The selection of 1 meter, 3 meter and 10 meter distances are based on exponential dust reductions as a function of distance from source combined with a pragmatic approach. 10 meters is the approximate length of horizontal sand storage equipment.

Managing chemical hazards

Silica on hydraulic fracturing sites - hazard assessment

PROCESS DOCUMENT **GS 409**

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BACKGROUND

This document is part of the Silica Exposure Control Plan (ECP) template. The template provides general silica information including details of the health effects of silica exposure. Please refer to Guidance Sheets GS 407 and GS 408 to understand the sources of exposure and controls on hydraulic fracturing sites.

WHO IS AT RISK?

Based on a review of existing industry data the following personnel are currently at risk:

- frack sand personnel e.g. blender and sand attendants
- sand truck personnel
- adjacent frack personnel e.g. chemical unit and local exhaust ventilation personnel
- adjacent non-frack personnel e.g. water storage personnel
- anyone who handles bulk silica dust (powder) e.g. in a filter or a ventilation system
- sand storage and transfer personnel e.g. sand tent and rail-loading attendants
- anyone who works in visible silica frack dust
  (hazard is invisible at the exposure level, others may be at risk)

Pneumatic in-loading may create a silica dust cloud that migrates across the site resulting in exposure risk to adjacent personnel.

EXPOSURE HAZARD ASSESSMENT

All site personnel including producers, pumping companies, truckers and third-party service providers should meet or exceed the requirements detailed below unless they have representative exposure measurement data that indicate to the contrary. The categorization of exposures into tiers is based on a review of industry data and should be protective under most circumstances; however, is not a replacement for on-going hazard assessment and exposure monitoring.

The following tables summarize acceptable control recommendations and requirements when working with frack proppant. Review the tables and look for the work site situations that are appropriate for your work site. These tables should be used by planners, supervisors, and workers.

Planners: As a planner, look for ways to move from higher Tier exposures to lower Tier exposures by adding controls or changing the design of the frack. Check the exposure categories that apply to the work site and communicate these controls to the supervisors, so that appropriate arrangements can be made for controls and personal protective equipment (PPE).

Following the implementation, conduct exposure measurements to verify that the controls are adequate. Your health and safety personnel may be able to assist in this regard. If a lot of the categories require data collection, prioritize the categories by starting at Tier III and working towards Tier 0.

Supervisors: As a supervisor, check to see that controls indicated are in place, actively used, and regularly inspected. Document the inspections. Fix any deficiencies identified. Communicate any challenges to the control strategies in use to the Planners so that subsequent jobs can be improved. Conduct periodic follow-up inspections.

Workers: Use and maintain engineering controls, follow procedures, and use PPE such as respirators. Remember, taking off your respirator in a control zone – even for only a few minutes – can result in a significant exposure, particularly for higher Tier exposure situations. Identify challenges and other exposure concerns and communicate to your supervisor.

EXPOSURE HAZARD ASSESSMENT – HYDRAULIC FRACTURING

The list of work site situations is not exhaustive; some tasks, such as equipment maintenance, are likely needed. Review the tables and look for the work site situations that are applicable to your work site. Implement the associated controls. For Tier I or higher work situations, evaluate how often the work situation occurs and conduct regular exposure measurements to ensure controls are working. If the work situation occurs 30 or more days in a calendar year, implement periodic health surveillance.

Tier 0 – No respiratory protection required
(Includes standard controls such as signs and training on the hazards of silica)

Applies on work site (check all that apply)	Tier 0 (<0.0125 mg/m^3) Based on 12-hour adjusted OEL	Other control considerations	Monitoring data collected?
☐	At least 10 meters from any emission sources, not present in visible frack dust at any time and if pneumatic in-loading is being conducted engineering controls are in use such as dust suppressants, ventilation, etc.		☐
☐	Personnel inside cab of blender that is positively pressurized with HEPA-filtered heated/cooled air and with air-tight doors and windows that remain closed	Half-face respirator required to exit cab provided you remain 3 meters from sources	☐

Tier 1 – Half-face respirator with at least N95 or better filters
(Includes standard controls such as signs, training on respirators and silica. Medically cleared to wear a respirator and fit tested)

Applies on work site (check all that apply)	Tier I (0.0125 - <0.125 mg/m^3) Based on 12-hour adjusted OEL	Other control considerations	Monitoring data collected?
☐	Hopper attendant on frack site or sand tent where proppant is dumped from an end dump truck directly into hopper		☐
☐	Between 3 and 10 meters from any emission sources and present in visible frack dust occasionally	Use engineering controls, as adjacent personnel on site may be at risk of overexposure	☐
☐	Personnel inside cab of blender that is NOT positively pressurized with HEPA-filtered heated/cooled air and with air-tight doors or when dust suppressant not in use	Half-face respirator required to exit cab	☐
☐	Trucking personnel conducting loading or unloading	Consider keeping truckers restricted to cab of truck for conveyor or auger loading/unloading	☐
☐	Personnel within 1-3 meters of hopper or conveyor junctions with dust suppressant or ceramic proppant in use	Keep personnel at least 1 meter away from edge of source equipment to manage excursion limits	☐
☐	Personnel within 3 meters of Vertical Sand Storage discharged directly (no drop) into Hopper with dust suppressant or ceramic proppant in use		☐
☐	Personnel handling used silica-contaminated coveralls or HEPA vacuuming contaminated buildings etc.	Vacuum must be HEPA-filtered, consider wetting coveralls prior to handling	☐

ARE YOU AT RISK?

Conduct a hazard assessment in the design of work, in the implementation of the work and in the execution of the work

PLANNER?

- ☐ Design the site and equipment so that exposures are minimized
- ☐ Communicate your control strategies to site supervisor
- ☐ Organize exposure monitoring to verify

SUPERVISOR?

- ☐ Conduct a hazard assessment of site and implement controls
- ☐ Check that controls are being used and effective and make changes if required
- ☐ Communicate learnings back to the planners

WORKER?

- ☐ Properly use controls provided
- ☐ Stay as far away from silica sources as practical
- ☐ Communicate concerns to supervisor

Further Reading and References

1. Enform's Silica Exposure Control Plan
2. Enform's Silica Information website: Enform.ca

Tier II – Full-face respirator with P100 filters

(Includes standard controls such as signs, training on respirators and silica. Medically cleared to wear a respirator and fit tested)

Applies on work site (check all that apply)	Tier II ($0.125 – <0.625\ mg/m^3$) Based on 12-hour adjusted OEL	Other control considerations	Monitoring data collected?
☐	Personnel on-top of Horizontal Sand Storage during in-loading by conveyor with no engineering controls	Keep personnel at least 1 meter away from source equipment to manage excursion limits	☐
☐	Personnel within 3 meters of Vertical Sand Storage discharged directly (no drop) into Hopper or within > 1-3 meters of hopper or conveyor junctions	Providing that if pneumatic in-loading is conducted, engineering controls are present	☐
☐	Pressure washing bulk silica frack dust from equipment such as pumper radiators	Keep adjacent unprotected personnel back 10 meters, use a Rubber Apron	☐
☐	Personnel handling ≤ 1 kg of free bulk silica frack dust (powder)	Disposable coveralls. Collected materials should be stored in an airtight container that has WHMIS labels	☐
☐	Personnel in sand storage tents during loading or unloading of sand or when visible dust is present	Consider ventilation fans >10 air changes per hour with dust capture	☐
☐	Personnel conducting dry sweeping of sand or silica dust in an enclosed setting (change room)	Consider wet methods or HEPA vacuuming	☐

Tier III – Supply Air or full-face tightfitting PAPR

(Includes standard controls such as signs, training on respirators and silica. The use of disposable coveralls is highly recommended for Tier III exposures. Medically cleared to wear a respirator and fit tested.)

Applies on work site (check all that apply)	Tier III ($\geq 0.625\ mg/m^3$) Based on 12-hour adjusted OEL	Other control considerations	Monitoring data collected?
☐	Personnel immediately adjacent (≤1 meter) to conveyor junctions, conveyor-hopper junction or Horizontal Sand Storage thief hatch (during pneumatic in-loading) for frack with no engineering controls	Implement engineering controls. Keep workers at least 1 meter away from source equipment.	☐
☐	Pneumatic in-loading with personnel adjacent (≤1 meter) to uncovered fill nozzles and down tube vents (vertical sand storage) with no engineering controls	Implement engineering controls. Unacceptable risk to adjacent personnel	☐
☐	Personnel viewing the sand levels with breathing zone at thief hatch during active pneumatic in-loading	Other ways to estimate bin volume should be engineered	☐
☐	Personnel emptying silica frack dust sock filters or handling > 1 kg of free bulk silica frack dust (powder)	Collected materials should be stored in an airtight container that has WHMIS labels.	☐
☐	Personnel underneath a tarp covering hopper or conveyor	Working alone requirements	☐

ARE YOU AT RISK?

Conduct a hazard assessment in the design of the work, in the implementation of the work and in the execution of the work

PLANNER?

- ☐ Design the site and equipment so that exposures are minimized
- ☐ Communicate your control strategies to site supervisor
- ☐ Organize exposure monitoring to verify

SUPERVISOR?

- ☐ Conduct a hazard assessment of site and implement controls
- ☐ Check that controls are being used and effective and make changes if required
- ☐ Communicate learnings back to the planners

WORKER?

- ☐ Properly use controls provided
- ☐ Stay as far away from silica sources as practical
- ☐ Communicate concerns to supervisor