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Silica dust control in small-scale building/structure demolition operations using good work practice guidance

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Abstract. Work practices can influence exposure, especially in small-scale operations conducted by mobile work crews. This study evaluated the use of information on good work practice in control guidance sheets adapted from UK Silica Essentials guidance sheets by trained workers and supervisors employed in small-scale concrete and masonry demolition operations. A one-page employee silica task-based control guidance sheet for each of four demolition tasks and multiple-page silica control guidance for supervisors were developed. Interactive, hands-on worker training on these task-based good work practice controls was developed. Training was presented to 26 participants from two demolition crews. Feedback on the training and task-based good work practice control guidance sheets was elicited. Observations of work practices were made before and after training. Participants indicated gains in knowledge and checklists were used to document skill attainment. The quality of the training and usefulness of the material/skills was rated high by trainees. Increased use of water to suppress dust and wet cleaning methods on the job were documented following the training. Additional follow-up after training is required to determine long-term impact on sustained changes in work practices, and to evaluate the need for refresher training.

1. Introduction

Small-scale demolition of concrete and masonry structures is a ubiquitous activity that precedes building renovations, remodelling, reconstruction or larger demolition operations. Various researchers have identified demolition of concrete or masonry structures as one of the construction activities with very high exposures to respirable crystalline silica [1]. There is consistency among various professionals that total elimination or substitution of silica from the construction process may not be a feasible option [2]. The use of wet methods, such as sprinkling systems, local exhaust ventilation and high efficiency particulate air (HEPA) filtration systems attached to work tools or equipment, worker's isolation from dust generating sources by tenting off or use of other physical barriers, respiratory protection and work practices may significantly reduce silica dust in many construction activities [3]; however, these controls when used separately or incompletely may fail to reduce exposure to less than established occupational exposure limits [4].

In the late 1990s the Center for Construction Research and Training, responding to the challenge of assessing and controlling occupational health hazards in the construction industry associated with its dynamic nature (highly mobile workforce and perpetually changing worksite, very high exposures for a short working time period, outdoors versus indoors, etc), developed a task-based exposure assessment model. In the model, the task was viewed as a primary building block of an exposure assessment framework. Susi and Schneider, (1995), and Susi et al., (2000) provided detailed description of the model [5]. However, the results are not widely used to control worker exposures. The United Kingdom Health and Safety Executive (UK HSE) developed Control of Substances Hazardous to Health (COSHH) Essentials – a step-by-step occupational risk assessment and risk management tool to provide advice on adequate control measures for supplied chemicals; a number of sector specific and task-based guidance sheets are also provided such as Silica Essentials [6]. Partially as a result of this experience, the European Union (EU) multi-sectorial Negotiation Platform on Silica (NEPSI) developed a Good Practice Guide and detailed task control guidance sheets; these toolkits are widely used in the UK and Europe [7].

Our previous research on silica dust exposure control strategies in small-scale concrete and masonry demolition operations evaluated the usability of the UK HSE Silica Essentials, and the European Union Negotiation Platform on Silica – Good Practice Guide. The results indicated constraints of language differences (English to native languages in industrializing nations), recommended resources could not be accessed (e.g. no Internet access) and absence of exposure controls including local exhaust ventilation, water suppression systems, and respiratory protection [8]. Also, the control guidance sheets included extensive text and technical information on both hazard and controls that may limit their usability by workers and some supervisors as a result of lack of time and literacy. These toolkits were considered valuable resources to address silica hazard prevention and control, but needed adaptation to local working conditions in industrializing countries [7].

The work presented evaluated the implementation of short, task-based good work practice control guidance sheets by employees and supervisors in small-scale concrete and masonry demolition operations to reduce exposure to silica following a training program. Exposure measurements for respirable crystalline silica dust were made. These results will be reported separately.

2. Materials and Methods

Task-based good work practice control guidance sheets were developed to be used by construction supervisors and employees during small-scale demolition of concrete and masonry structures or buildings. To evaluate the effectiveness of the task-based control guidance sheets plus training, data on work practices were collected before and after the training. Human subject review and approval was provided by the University of Cincinnati Institutional Review Board (IRB) and the Social and Behavioral Sciences and the Ethics Committee of the Eduardo Mondlane University, Maputo, Mozambique.

2.1. Development of task-based good work practice control guidance sheets

Task-based good work practice control guidance sheets were developed for four demolition tasks: (i) breaking or dismantling concrete and masonry structure, (ii) segregating, concentrating and stockpiling the debris and scraps and, (iii) removing, transferring or transporting debris for disposal, re-use or recycling and iv) cleaning-up the worksite. The exposure reduction strategy in each guidance sheet was based on the use of:

- wet methods to suppress dust (spray, sprinkle or mop);
- HEPA filtered vacuum cleaner to remove dust;
- natural ventilation by working at an upstream position of the dust generating source and allowing free air circulation through opening doors and windows when appropriate;
- basic personal protective equipment, and,
- basic hygiene and sanitation practice.

Special attention was given to clarity of language and brevity [9].

2.2. Work practice controls walkthrough survey

A walkthrough survey guide was developed for data collectors to document use of work practice controls while workers performed demolition tasks. The walkthrough survey guide was composed of a complete description of the good work practice categories presented on the task-based control guidance sheets plus worksite description, equipment, tools and material used by the demolition crew. A checklist was developed to capture observations on the use of various work practices.

2.3. Training of observers/data collectors

In order to control for information and observation bias [10], two observers were trained to observe and record work practices. They assessed worker training performance by observing participants and completing a performance checklist.

The observers were trained and calibrated by one author (CM) to obtain accurate observations. The calibration was done at the worksite, and at the end of the shift the results were compared. At a random time during each shift the author (CM) visited the worksite and recorded observations for later comparison.

2.4. Worker training

Interactive, hands-on training was developed for the supervision and employees in separate programs so supervisors and workers could learn to use information on the task-based good work practice control guidance sheets to reduce exposure.

The supervisor training was based on structured dialogue [11] in a round table type and at the demolition worksite. The supervisors were challenged to explain a step-by-step small-scale demolition process, tools and material used and details of their work practices/habits. This discussion was followed by a field demonstration of how the small-scale demolition is done, and the names and functions of the tools/equipment. During the training, the supervisors reviewed and provided their feedback on the task-based good work practice control guidance.

The training for crew workers included: (i) silica dust health hazard information, (ii) pre-planning and procedures for applying good work practice controls while performing each task and (iii) step-by-step small-scale demolition processes and reinforcement of key points. Photographic pictures of typical tasks of small-scale concrete and masonry demolition operations in Mozambique and a small-scale concrete and hands-on demolition simulation exercise were used.

The worker training covered the following work practice categories:

- Pre-planning and post self performance evaluation on use of good work practice control guidance
- Use of water to suppress dust (spray, sprinkle until moistened but not wet)
- Use of a high efficiency particulate air (HEPA) filtered vacuum to remove silica dust
- Use of natural ventilation by instructing workers to stay upwind/upstream of the silica dust generating source while performing the task, and allowing free air circulation by opening doors and windows if suitable
- Availability and practice of basic hygiene (hand washing, cleaning working tools and PPE after finishing the work, changing clothes before reaching home) and sanitation (availability of potable water and toilets)
- Availability and usage of basic PPE for the construction industry (hard hat, safety glasses, ear plugs, work gloves, work shoes).

Participant performance was evaluated. The evaluation was composed of two parts. To assess knowledge a three item pre-and-post test was conducted with the group. Participants were asked to raise their hands if they had knowledge in the following areas: 1. What are the hazards of dust in demolition or construction activities? 2. How do dusts generate hazards of silica exposure? 3. How do

you keep dust exposure as low as possible during your work? The data were tabulated and the proportions of participants reporting knowledge before training and after training were compared [12]. Secondly, to assess the trainees' skills, performance checklists were completed by the data collectors during a simulation exercise. Any incorrect procedure was discussed with the participants and repeated until correctly performed; thus all participants successfully demonstrated use of skills on the guidance sheets.

2.5. Participant feedback on the training

Written feedback was requested from all participants to better understand whether the training was considered effective and useful. Items on the quality of the training presentation were rated using a four-point Likert scale: 1-strongly disagree, 2-disagree, 3-agree, and 4-strongly agree. The usefulness of the various work practice control methods to reduce dust was rated with a similar scale: 1-not useful at all, 2-somewhat useful, 3-useful, 4-very useful. Participants rated satisfaction with the guidance sheet on a four-point scale: 1-not satisfied at all, 2-somewhat satisfied, 3-satisfied, 4-very satisfied [9].

2.6. Post-training walkthrough survey at worksites

After the training, walkthrough survey observations of work practices were performed by the observers using the same checklist. Work practice changes were obtained by comparing pre-and-post intervention walkthrough survey results for each demolition crew. Pre- and post-training comparisons were made in tabular form, noting the presence or absence of a practice by the crew.

3. Results

3.1. Development of task-based good work practice control guidance sheets

The final version of task-based good work practice control guidance sheets were modification of previous models [8] and all information was captured on a single page for workers, and multiple pages for supervisors. Figure 1 illustrates the Guidance Sheet for Breaking Concrete and Masonry Structures for workers. The supervisor guidance sheet (not shown) included information on: (i) why be concerned about silica dust exposures (regulation compliance requirements, health hazard information and business and economic point of view), (ii) access and premises, (iii) design and equipment, (iv) maintenance, (v) examination and testing, (vi) personal protective equipment, (vii) cleaning, housekeeping and personal hygiene practice, (viii) training and supervision, (ix) further information on control methods for silica dust exposures and useful links.

During the preliminary walkthrough and input from supervisors, three tasks were determined to be relevant for small-scale demolition operations at the participant sites: (i) breaking concrete and masonry structures (walls, floors or ceilings), (ii) cleaning, concentration and removal of demolition debris and scraps, and (iii) transferring and transporting the debris or scraps for salvage and disposal. Therefore, the fourth sheet on cleanup was not used.

Figure 1. Task-based control guidance sheet: Breaking up concrete/masonry structures.

Task-Based Silica Control Guidance Sheet for Small-scale Manual Demolition
Task 1: Breaking concrete and masonry structures (walls, ceilings or floors)

Control Approach: Good Work Practices

IMPORTANT MESSAGE FOR EMPLOYEES

Dust resulting from demolition and other construction activities can be deadly.
 The harm from dust depends on:

- What it is made of
- What size it is
- How much is in the air
- How long you breathe it

If you are exposed to dust with silica, **its very fine particles can penetrate deep into your lungs.** If a lot of silica is in the air and you breathe it for a long time you can develop disabling and fatal diseases such as:

- **silicosis**
- **lung cancer**
- **silico-tuberculosis**

The following actions well done will lower silica dust exposure and decrease the risk of diseases.

Preventive actions to reduce silica dust exposures with good work practices	Answers	
	Yes	No ^a
I take few minutes to pre-plan and assure compliance with good work practices		
I use water to suppress dust (spray, sprinkle or damp cloth)		
- water hose spray		
- sprinkling with my hand or other appropriate resources		
- wet wiping		
I maximize the use of natural ventilation		
- by allowing free air circulation (doors and windows open if possible)		
- working upwind or upstream of the dust-generating source		
I exercise personal hygiene practices by		
- Washing hands before eating, drinking or smoking		
- cleaning and checking working tools after finishing the work		
- I clean my PPE after I finish my work		
- I change clothes before I reach home		
Basic sanitation practice		
- I use the available potable water if needed		
- I use appropriately the available toilet		
I take a few minutes after I perform my task to examine my performance or compliance with these good work practices		

^aA check mark on “No” needs immediate solution before the task is performed

3.2. Observer training

Comparison of the recorded observations by one of the authors (CM) with the observers during random checks showed complete agreement during all three activities—pre-training, training and post-training. For data analysis, only the recordings made by the observers were used.

3.3. Pre-training work practice observations

Two demolition crews doing renovations in a university setting in Maputo, Mozambique participated in the research. Each crew and its work organization is described below.

3.3.1. *Crew 1.* This crew was composed of four supervisors, four masons and six assistant masons employed by the university. Their daily duties included renovations, remodelling and maintenance of university infra-structures and buildings. Their construction projects always involve some demolition operations of concrete and masonry structures. The crew worked on two sites before the training, and three sites following training. Tools used prior to the training were: sledge hammers, chisels, scrapers, shovels, buckets, pickup truck, wheel barrow and their hands to remove debris. Tools were selected for the task as the work progressed. First, the area to be demolished was marked with a pencil and then the crew used hand tools for demolition, followed by breaking up with a sledge hammer. The cleaning and removal task was conducted to concentrate the debris in one area and the debris was transferred to a container and carried to a disposal or salvage point.

3.3.2. *Crew 2.* This crew was composed of two supervisors, five masons and seven assistant masons employed by an external contractor. The two on-site supervisors were foreign to Mozambique and had limited Portuguese language proficiency. They could communicate with their Mozambican fellows, but not with the trainer; thus, the supervisors did not participate in the training. During the study the crew worked on the same renovation project, which involved some demolition operations before and after training. The crew used the following tools: sledge hammers, chisels, scrapers, circular saw and shovel. They used their hands, push broom, and buckets for debris removal. Tools were selected for the task as the work progressed. This crew worked in teams. One team marked the area with white chalk and used a circular saw to initiate the demolition, another team was assigned to breaking up the concrete and masonry structure with chisel and hammer or sledge hammer, and another team worked on cleaning and removing the debris to a designated point.

3.4. Worker training

Interactive, hands-on worker training on the use of information in the task-based silica good work practice control guidance was delivered to 22 workers and four supervisors, for a total of 26 participants. The evaluation of workers' knowledge of silica dust exposure prevention and controls showed a substantial increase. Prior to training, three of 26 (11.5%) indicated some knowledge on one or more question; following training, 25 of 26 (96%) indicated some knowledge on one or more of the questions. These proportions are significantly different, $p < 0.001$. Skills performance checklists of observations during the simulation of demolition activities showed that all participants (100%) mastered work preplanning, pre-work compliance with good work practices, use of water, maximizing use of natural ventilation, good personal hygiene, no use of compressed air or other dry method to remove dust from clothing and post work review of work practices. No training was conducted using high efficiency particulate air filtered vacuums, as these were not commercially available in the area.

3.5. Participant feedback on the training

Fourteen of the 26 participants (54%) provided some feedback on the training evaluation instruments. This represents 100% of Crew 1. The Crew 2 feedback was not accomplished because of communication difficulties with supervisors and limited time. Twelve of 14 rating the quality of the

presentation agreed or strongly agreed that it was at an understandable level. All respondents scored agreement or strong agreement with: Helped me think about solutions to problems in the workplace (n=12) and Encouraged active participation (n=14). Five respondents noted lower scores for following the agenda and remaining flexible to unplanned issues during a session. All scores for feedback from the instructor (n=14) were at the level of agree or strongly agree. All participants completing the evaluation item on effectiveness of the training rated it as effective or very effective overall (n=12).

At the end of training, 13 of 14 participants rated use of water as useful or very useful in suppressing dust at the worksite; only 1 participant rated it as somewhat useful. Supervisors (n=4) and masons (n=4) rated the use of natural ventilation as useful or very useful in reducing dust exposures; assistant masons rated the open windows as useful or very useful (5 of 6) but did not report high confidence in being able to work upstream of a dust source; 3 of 6 rated this approach as not useful.

Participants' overall evaluation of the information in task-based control guidance sheet information to help reduce exposure was very high. Thirteen of 14 (93%) participants reported being very satisfied with the tool; the other participant was satisfied with the tool.

3.6. Post-training work practice observations

Following training, changes in work practices were observed. Table 1 shows components of good work practices used for both crews before and after training. Both crews implemented aspects of the task-based control guidance Sheets. Some differences in the materials used between the crews were observed; for example, crew 1 used plastic sheet to cover dusty materials, acquired a drum to store water, garden hose and watering can to suppress dust, and hand truck for transporting debris. Crew 2 acquired a wet sponge or cloth to clean surfaces and tools, a concrete water tank, plastic bucket and used hands to sprinkle water on surfaces and walls; they used empty cement sacs to manually transport demolition debris from the working site to disposal or salvage point. Neither crew used HEPA filter vacuums, long sleeves and pants, containment/isolation, or local or general exhaust. Vacuum and ventilation is generally not available commercially. High temperatures and high levels of physical exertion influence clothing decisions. Containment and isolation may be useful in some applications; however, these are often coupled with ventilation for best effectiveness.

Table 1: Pre-and-post good work practice controls for crews 1 and crew 2 indicated with – if not used and + if used.

#	Components of good work practice control guidance sheets	Before		After	
		Crew 1	Crew 2	Crew 1	Crew 2
1	Pre-planning	-	-	+	+
	Warning signs, checking if all tools and supplies are available and functioning well	-	-	+	+
2	Water for dust suppression	-	-	+	+
	Water hose spray	-	-	+	-
	Sprinkling by hand or other appropriate resources	-	-	+	+
	Wet wiping	-	-	+	+
3	High efficiency particulate air (HEPA) filter vacuum	-	-	-	-
4	Natural ventilation				
	Free air circulation (doors and windows open if possible)	-	-	+	+
	Working upwind/upstream of the dust-generating source	-	-	+	+
5	Basic personal protective equipment (PPE)				
	Safety glasses with side shields	-	-	+	+
	Hard hat	-	-	+	+
	Safety shoes (boots or steel toe shoes)	-	-	-	-
	Work gloves	-	-	+	+
	Hearing protection	-	-	+	+
	Long sleeves and long pants	-	-	-	-
6	Personal hygiene practices				
	Hand washing facilities	-	-	+	+
	Water for cleaning tools and PPE	-	-	+	+
	Separated space for eating and drinking	-	-	+	+
7	Basic sanitation practice				
	Potable water	+	+	+	+
	Toilet	+	+	+	+
8	Self post-performance evaluation	-	-	+	+
9	Other control measures				
	Containment or isolation	-	-	-	-
	Local exhaust ventilation	-	-	-	-
	General mechanical ventilation	-	-	-	-
	Respiratory protection equipment (N95 mask)	-	-	+	+

4. Discussion

Small scale demolition processes frequently involve generation of dusts. These operations are conducted for short durations of time at temporary work sites. Previous observations showed that the types of engineering controls recommended for dust control generally are not available. More attention to work practices was identified as a method that might be introduced to reduce exposures. This work reported here is part of a larger evaluation of the use of task-based good work practice control guidance sheets with worker training developed especially for small scale demolition operations.

The guidance sheet format presented for each task is much shorter than other models such as the COSHH Essentials. This is appropriate, given the narrowly defined activity of demolition workers. For each task, it is possible to be more limited in the nature of controls in the checklist. Four sheets were

developed initially, based on previous work. However, it was found that cleaning and removal was always done at the same time and was followed by transferring and transport. This sequence excludes segregation, concentration and stockpiling of debris which is only done on rare occasions as separated task by the participating crews. This work organization was reported by the supervisors and verified during the completion of initial walkthroughs. It is not known if this combination of tasks is unique to the crews participating in this work, or is now the more usual work organization. In the future, a range of task-specific sheets may be needed for demolition activities. A training program could be structured to include the selection of relevant tasks by the participants. The full complement of sheets would be available, and could be a resource for the participants at future work sites, where work organization might vary.

The observers recorded data consistent with the author during random checks; therefore, inter-observer variability was not relevant. As the data were collected over a four week period, we did not evaluate trends in recording over time.

The work was conducted at one employment site in Mozambique. As English is not the native language, all materials were first developed in English and then translated into Portuguese. Crew 2 had immigrant supervisors who did not read Portuguese and did not participate in the training. The constraint of communicating with supervisors and limited time prevented the trained employees from Crew 2 from completing the training feedback evaluation instruments; their understanding of the goals of the training is demonstrated by the changes implemented by the crew. More time was needed to talk with contractor management who could understand either Portuguese or English and be able to transmit the request to the supervisors in their language and provide time for employees to complete feedback evaluations. If resources were available, an onsite interpreter would be hired to facilitate communication with supervisors. The short time period available to conduct this project prevented long durations between interactions. However, overall, the training program delivery was well-received by participants in the native crew. Time for special training alternatives should be considered.

Knowledge gain was documented by participants raising their hands. Raising hands provided the number of people reporting knowledge before and after training. The assumption was that any worker who would not raise his /her hand, did not have the required knowledge. The instructor asked those who raised their hands to provide a verbal response that was recorded on flipchart. These responses were generally consistent with knowledge of the topic. Although the knowledge gain was assessed using this crude measure it was consistent with the participatory approach. Both employees and supervisors provided very important details throughout the training regarding exposure determinants, tasks generating high dust exposures and measures to reduce exposures while performing demolition task, indicating a high level of engagement. These reports were consistent with previous research that used a task-based exposure assessment model to comprehensively understand tasks, the nature of work, conditions causing or exacerbating exposures and controls that realistically can reduce exposures in construction industry [13]. Alternative knowledge gain assessment methods are the use of a pre-and-post written test or retrospective pre-test [14]. The ability to apply the methods in the task-based control guidance sheets was the main goal and was more rigorously evaluated using observations during simulation exercises and work activities after training.

Before the training, tools and equipment used for small-scale demolition operation included sledge hammers, hammers, chisels, a circular saw, hand scrapers, shovels, and handheld push broom or sweeper, wheelbarrows, use of hands and buckets. After the training, more tools and equipment were added such as the use of water, use of wet/humid clothes or a sponge to remove dust, water reservoir or source (drum or tap water), use of plastic sheet to cover the debris and the use of a hand trailer to transfer the debris from the demolition site to the disposal or salvage point. The workers in these two crews demonstrated high motivation and interest to implement work practice controls. They found sources of water and utilized wet methods and demonstrated awareness for the use of natural ventilation to reduce exposure. Efforts are needed to increase the availability of HEPA vacuum equipment to demolition work crews in this area.

Longer follow-up is needed to determine if changes in work practices can be sustained by the crew members and supervisors at this location, and as they move to other work sites. Refresher training may also be needed, if the implementation of good work practices is documented to decline over time.

5. Conclusions

A program was developed and implemented to train workers in the use of a short Work Practice Control Guidance Sheet to improve work practices that would reduce exposures to dust in small scale demolition. Observations document changes in work practices after training, including preplanning, use of wet methods and end-of-task review.

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