Case Study to Identify Barriers and Incentives to Implementing an Engineering Control for Concrete Grinding Dust

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Abstract: Research has indicated that respirable crystalline silica dust exposure is a serious health hazard in the construction industry. One source of this hazard is the dust generated by drilling, sawing, chipping, and grinding concrete. There are several options for controlling this hazard, one of which is the use of local exhaust ventilation (LEV) directly attached to the cutting tool. Implementing an engineering control presents a challenge on the construction work site where it is often difficult to determine who will take the initiative for introducing an innovative strategy. This study examines the implementation of an LEV system on an overhead grinder illustrating the roles that various members of the construction team played. The results of the case study found that key factors that affected implementation were: (1) a cooperative relationship between individuals employed by the general contractor and the concrete subcontractor; (2) the effect of high airborne dust levels on scheduling the work of other subcontractors; (3) the public relations effects of high dust levels in a downtown area; and (4) the concrete subcontractor perceived benefits that exceeded the short-term cost of the intervention.

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Background

The construction industry lags behind manufacturing in the use of engineering controls to eliminate worker exposures to occupational health hazards. Research is needed to identify the influences within the construction industry that assist or impede the implementation of engineering interventions to reduce health hazards from silica dust exposures in particular. To ensure the successful introduction of controls, health professionals and construction managers must understand the incentives and barriers to the implementation of these controls. This qualitative case study identifies the barriers and incentives that influenced one subcontractor's (SC) decision to implement a specific dust control device. It is part of a larger intervention research study evaluating the efficacy and implementation of dust controls for concrete cutting drilling and chipping in construction.

The focus on dust controls for construction or demolition work on cured concrete is based on studies that find overexposure to silica while cutting concrete (Lofgren 1993; Linch 1997, 2002; Nash and Williams 2000; Akbar-Khanzadeh and Brillhart 2002; Croteau et al. 2002; Rappaport et al. 2003; Tjoe Nij et al. 2003a; Yasui et al. 2003; Flanagan et al. 2006). In addition exposures may occur not only to the person operating the dust-producing tool but also other bystander workers in the area (Woskie et al. 2002).

Good industrial hygiene practice uses a hierarchy of controls with substitution of less hazardous materials or processes as the ideal approach. However, replacing concrete as a building material is not feasible at this time. With a rise in the price of steel, buildings are being constructed with even more concrete. Concrete is also being promoted as a sustainable building material (Portland Cement Association 2006) creating new markets in the homebuilding sector. The aggregate, particularly granite, used in concrete is the primary source of the respirable crystalline silica exposure during concrete cutting, demolition or finishing operations.

Through focused improvements in design and construction planning, it may be possible to reduce some of the concrete cutting that takes place after concrete is put into place. Such improvements would require a specific commitment to planning, scheduling, and integration by all the parties involved in the construction project (European Construction Institute 1995; Hecker and Gambatese 2003). In most situations, this level of planning remains an unrealized goal for the construction industry. The use of personal protective equipment is considered the least desirable approach to controlling construction health hazards. However respiratory protection (RP) is the primary, though still relatively uncommon, dust exposure reduction method currently used in construction. Studies have indicated that RP equipment is often not available or worn and that it may not provide sufficient pro-

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tection from respirable crystalline silica for many tasks (Tjoe Nij et al. 2003b; Flanagan et al. 2006). Engineering controls could eliminate the need for RP and the accompanying mandatory RP program. The Occupational Safety and Health Administration (OSHA) (U.S. Department of Labor) requires an engineering controls approach before instituting the use of personal protective equipment. In previous work, in a controlled field study (Shepherd et al. 2009), we showed that a local exhaust ventilation (LEV) control (shroud and vacuum cleaner) for a hammer drill reduced airborne dust levels below the 2003 American Conference of Governmental Industrial Hygienists threshold limit value for respirable crystalline silica.

An "intervention" can be defined as an attempt to change how things are done in order to make an improvement (Robson et al. 2001). In this study the writers are documenting the attempt to introduce a LEV control for a concrete cutting tool in order to reduce airborne dust.

For a dust control device to be an effective intervention it not only has to remove dust, but it also must be used regularly, maintained and become part of the normal work process. Engineering controls require ongoing management support and worker acceptance to be effective. Goldenhar and Schulte (1994) reviewed health and safety interventions described in the literature between 1988 and 1993. They acknowledge that evaluating interventions is often complex, involving not only the performance of the engineering control but the organizational issues surrounding implementation. They state: "Such complexity may also mean that intervention research should focus more on the process and milieu of an intervention as well as the outcomes."

Studies examining the barriers and incentives for the implementation of interventions to improve occupational health in construction are few. Some (Akbar-Khanzadeh et al. 2007; Flynn and Susi 2003; Hess et al. 2004; Meeker et al. 2007; Neitzel and Seixas 2005; Rempel et al. 2010; Young-Corbett and Nussbaum 2009) focus on the efficacy of the intervention rather than the implementation process. Others focus on health behaviors within the occupational context, such as interventions to increase construction workers' use of hearing protection (Lusk et al. 1997, 1998, 1999) or RP (White et al. 1988). Albers et al. (2005) reported on a construction stakeholder meeting examining the extent of ergonomic interventions within the industry. Participants discussed potential barriers to using these interventions, but not the specifics of implementing them on actual construction sites. Likewise van der Molen et al. (2005) interviews stakeholders in the bricklaying industry to understand the phases of behavioral changes in the process of adopting ergonomic interventions. Lingard and Holmes (2001) offered interesting and useful data on the understanding of risk control in small construction companies, but not about the implementation of an engineering control in particular. Thus the literature examining engineering controls for health improvement in the construction industry is limited but increasing, particularly in the area of ergonomics.

Intervention Framework

Macroergonomics and other sociotechnical systems analysis frameworks (Hendrick and Kleiner 2001; Haro and Kleiner 2008) are used to analyze work environment systems. These models have been used to examine and improve the design of whole work organizations through understanding key factors within the organization. Within construction, the factors influencing the decision to implement and support workplace health interventions are complicated. To capture this complexity a theoretical framework was developed using similar categories to those in macroergonomics. This framework is more restricted in breadth than macroergonomics yet it provided a guide to the collection and interpretation of the qualitative case study data.

The following general categories were the focus of the evaluation of the acceptance and ongoing support given to an intervention and are described in more detail below:

1. Individual actions;
2. Technical and equipment;
3. Organizational environment; and
4. External environment.

Individual Actions

Individual actions include actions by workers, foremen, superintendents, safety officers, and others to employ or reject an intervention on a worksite. Examples are when a worker takes the time to find a longer electrical cord needed to use the control equipment or when a foreman decides a job is too short to use the crane to hoist the right equipment. Personal experience and judgment, along with competing agendas such as productivity, safety, and quality, are considered by the individual in the decision process. Researchers have examined these personal decisions within the realm of cognitive science looking at how the beliefs, attitudes, and perceptions of individuals influence the decisions (Lusk et al. 1997). Although we acknowledge the role of these personal characteristics in decision making, we do not focus on the psychological motivation behind the decision to use a dust control device. Rather, this study takes a socioecological approach, viewing individuals primarily as members of a group whose actions occur within a social context. This approach leads to examining how the social context can be altered in order to stimulate actions by individuals, rather than examining how to change the way individuals act in spite of their social context.

The introduction of engineering controls in the manufacturing setting is often used to replace or reduce the discretion of individual work practices that affect exposures. These controls remove the hazard "automatically" and require little or no decision on the part of workers to use the control (Corn 1984). In construction, however, there is no fixed workplace; no opportunity to install a control and have it become part of a work process in a permanent way. Workers continually make individual choices about how a job or task will be done within a catalog of acceptable practices. Implementing an engineering control intervention is about how the intervention becomes integrated into that framework of ordinary work practices as the workers build the workplace. "In contrast to an industrial setting, where the tasks are often repetitive and controlled by the location of machinery, the construction site allows and requires extensive movement by the worker from moment to moment. This means that the worker is much more responsible for self-protection" (Ringen et al. 2000).

Technical and Equipment

Technical and equipment factors reflect the machine-situation interaction. The control technology must first of all reduce the dust exposures to an acceptable level, either the occupational health standard if the focus is worker exposures or less than the particulate matter (PM) 10 and 2.5 standards if community exposure is the focus. Ease of use and maintenance are key concerns. Equipment maintenance should not be beyond the technical sophistication and financial ability of the contractor. Workers must be able to use the equipment properly and safely without an unusual

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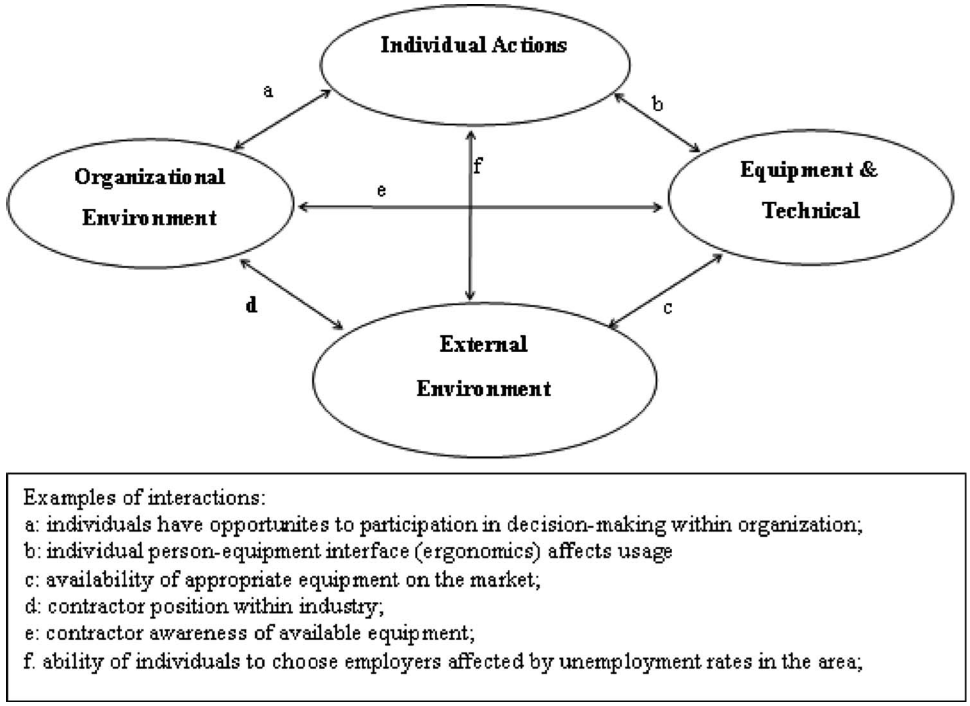

Fig. 1. Intervention framework

amount of training or technical background. The equipment must fit into the environment where it will be used and not create ergonomic or physical hazards during use.

The quality of the finished product and productivity are also considerations. Heitbrink and Collingwood (2005) reported that when using shrouds on tuck-point grinders, the dust collector is most effective when working in one particular grinding direction. Workers were therefore forced to adapt their work practices to assist the dust control. Although one contractor has been using the ventilated grinder for several years, this may prove to be a barrier for others.

Organizational Environment

Organizational environment factors reflect the manner in which the construction industry operates through layers of management and separation of trades and how this reflects on day-to-day work practices. There are many examples of this on every level of the industry. A common example in health and safety is lack of coordination between two trades working in proximity where one trade, equipped with personal protective equipment, is generating a hazardous dust while another trade works in the same area with no protection at all. Often, the choice for the second group may be between not working in the area thus losing productivity or being exposed to the hazardous dust. This bystander exposure is common in construction. The two trades are often employees of different SCs working on their own schedules. The general contractor, who may be responsible for scheduling, may be too far removed from the hour-by-hour workings on the site to have effective control of these situations. These negotiations are often left to the workers on the site, with some intervention by foremen and/or union stewards (Moir 2004).

"Construction has not been the subject of much intervention research, largely because of the complexity of the industry. It is marked by diffuse control, small-employer firms, temporary worksites, multiemployer worksites, temporary employment, and numerous crafts." (Ringen et al. 1995). In the United States, this complex management structure is recognized by OSHA through their multiemployer policy (U.S. Department of Labor 1999) for citations. Employers on the site have a stake in the control of hazards and may be cited for violations based on whether they have created the hazard, have employees exposed to the hazard, or are in control of the site. The financial cost, or the perceived cost, of an intervention is included here as a factor within the organizational environment because the true cost of an item is often evaluated within the context of its value to the organization.

External Environment

The external environment reflects the milieu in which health and safety decisions are made by all parties. Regulatory enforcement, local unemployment rates and the general economic health of the construction industry in the area are all such factors (Levenstein et al. 1997). As workers' compensation premiums have increased over the years in the construction industry, more general contractors and construction management companies have looked to "prequalify" SCs based on their safety records and injury and illness experience (Hinze et al. 1995) causing more attention to be directed to this area.

A regulatory incentive for dust control arose when OSHA implemented a Silica Special Emphasis Program in 1996 (Dear 1996). This policy resulted in citations under the General Duty clause for overexposure to respirable crystalline silica (U.S. Department of Labor 2004a,b).

Interaction of These Factors

In reality, the elements contained in these categories interact in various ways (Fig. 1). That is the essence of a socioecological model. Individuals respond to their organizational environment. The organization may promote or dampen individual initiative, for example, and the response may be that individuals will be more able to use their talents and participate in decision making. Organizationally, some contractors may keep more full-time regu-

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lar employees developing their talents and in return the individual employees have more of a stake in that organization and will therefore take actions that benefit the contractor.

The organization in turn is also affected by an external environment that it often cannot control, such as regulatory agencies, prices of building materials, and the financial markets and be forced to change its focus and structure in response. Some organizations will be structured to respond better than others.

Equipment and technical expertise may not be available to fill the needs of the organization to accomplish its goals, or the organization may not be prepared to adopt new technologies. The external environment affects technological innovation by providing incentives through regulation or efficiency requirements. A recent example is the development of low gas mileage vehicles in response to increasing oil prices. An organization also may not have the technically competent individuals in place to take advantage of a new technology. Thus, the interactions of these factors should be considered when attempting a workplace intervention (Goldenhar and Schulte 1994).

Methods

A qualitative case study method was used to document the barriers and incentives to implementing an engineering control on a construction site for the control of respirable crystalline silica while cutting concrete. The efficacy of such a control on a hammer drill was established in a prior study under controlled drilling conditions (Shepherd et al. 2009). The goal of this phase of the research was to implement a similar control on the site of a willing contractor and document the success or failure of the control in the field and the process of implementing the control.

A contractor was recruited through contacts within the construction industry acquainted with the University of Massachusetts Lowell Construction Occupational Health Project (COHP), including instructors at the New England Laborers Training Center, corporate safety representatives from the Associated General Contractors, the Labor-Management Construction Safety Alliance, and local OSHA compliance officers. A contractor was chosen based on several factors: (1) use of hammer drills as a significant portion of their work; (2) employment of union construction laborers; and (3) willingness to participate.

After the contractor was recruited, the plan was that one of the hammer drills used on a regular basis would be retrofitted with a cowl similar to those that had been previously shown to be effective at removing dust. Using the contractor's own tool eliminated the barrier of trying to use a hammer drill that itself was not appropriate to the work. This allowed the research to concentrate on barriers to the LEV system specifically.

Data Collection

Sources of data were open-ended interviews, participant observation, and document reviews. The field notes and results were discussed with the participants during the data collection phase. Several open-ended unstructured interviews took place on the construction site where the workers were available. Workers were interviewed in order to explain or elaborate on an observation made by the researcher on the site. All field observations, interviews and discussions with participants were written up as field notes and included in the project database created within NVivo software (NVivo 2.0, QSR International). Signed informed consent forms approved by the University of Massachusetts Lowell Institutional Review Board were obtained by the interviewer from all participants.

The content of the field interview questions included questions about the site, the workers and their tasks on the site, the use of personal protective equipment and what training on silica had been done. Field observation guidelines included noting work practices, trades, exposures and controls, work organization, and the observed barriers on-site to the use of LEV. The project database consisted of notes from 14 field observation visits and five individual or group informal field interviews which included 10 workers, pictures of the equipment, manufacturers' data sheets for the equipment, publicly available OSHA inspection records for the contractors, and the Dodge report for the building site.

In addition, one formal group interview, similar to a focus group, was held at the field office near the construction site. This interview lasted almost 2 h and included a safety officer and superintendent from the concrete SC and the safety manager (SM) from the general contactor (GC). The interview questions centered on the particular intervention that had been implemented. Four questions were used as triggers for the discussion: Why did you implement this dust control? Why didn't you do it before? Are other contractors doing this and if not, why not? What changes have you seen as a result of using this? This interview was taped and transcribed for data analysis. No participants were paid or given other incentives as a part of this study.

Data Analysis

All text and pictures from the data collection were imported into a qualitative research software program (NVivo 2.0, QSR International) for coding. Thematic analysis was developed in concert with a codebook including 40 topic codes based on earlier research on the implementation of interventions in construction (Moir 2004; Fulmer et al. 2006). In qualitative research the process of data analysis is interwoven with data collection (Stake 1995). Therefore, common topics discussed in earlier interviews were also used to guide the direction of the data collection in later interviews. As the text was coded, it was evaluated as either a specific example of an a priori topic or a new topic. The topic codes were then grouped or regrouped based on common themes. The qualitative data analysis did not simply consist of listing whatever topics arose in the collected data, but finding relevant meaning in the relationships between the topics that were discussed. One approach to interpreting the data was to organize the coded topics within the proposed intervention framework (Fig. 1) to determine if the framework themes adequately covered all of the material collected in the interviews. The validity of resulting thematic interpretation was tested through triangulation with other sources, such as follow-up discussions with the contractors and other workers.

Intervention #1 (Provided by Researcher)

This study took place over 2 years. The SM of the GC on a large downtown building construction project agreed to participate and aided in contacting the concrete SC and with their on-site safety officer (SSO).

The site was visited with the SC's safety officer twice to prepare for the testing. During these visits there were many discussions between the SSO and the researcher about the barriers and

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Fig. 2. Researcher-introduced dust control on hammer drill

incentives for using engineering controls on the site. The testing consisted of using a researcher-provided portable LEV system on a drilling and light chipping task (Fig. 2).

In the field, the study was explained to the participants, a short fact sheet given to each person and informed consent forms were signed. Participants were trained on the proper use of the equipment, and then asked to do their normal work of drilling concrete. The researcher remained with the crew to observe their activities and to sample dust exposures.

Personal dust and silica sampling was completed at this time. When this one test was over, the safety officer for the concrete SC agreed to call when there was more concrete drilling but declined when asked to keep the LEV system on the site. After many researcher-initiated follow-up calls, it was apparent that the SC was not interested in further testing or use of the LEV.

Intervention #2 (Homegrown)

Several months later, the same safety manager for the same general contractor met the researcher at a regional construction safety conference. The safety manager was excited about a "dustless" grinding operation that he and the same concrete SC had put together. He invited the researcher to return to the same construction site to evaluate the new LEV system.

This system was based on an already existing device, a "giraffe" built by the concrete SC used for holding a grinder against the ceiling (Fig. 3). The original giraffe was an ergonomic engineering control. The local exhaust system included an off the shelf grinder with shroud and a portable vacuum cleaner. After two sampling visits to the site during the dustless grinding operation, the researcher reported to the contractors that the LEV system installed by the contractors did reduce the personal dust and silica exposures to below the occupational exposure limit. Data collection as previously mentioned included discussions about the intervention before, during and after the sampling, with the two safety officers for the GC and the concrete SC, as well as the workers operating the grinder, culminating with a longer interview that included the site superintendent for the concrete SC.

Fig. 3. Homegrown dust control on grinder

Results

The data analysis indicated that implementing this homegrown intervention for controlling dust was the result of a number of factors converging at this time and on this construction site. This success was based on or influenced by factors from every category of the intervention framework previously outlined.

These results show that a multifaceted approach must be taken to bring new technology to bear on health problems in construction. It is not enough to find the right equipment, the organization must be able to support the individual managers who are willing and able to work through the initial technical and work process problems and achieve successful results. Also, the benefit of achieving good results must be clear to the organization. In this study, simple OSHA compliance was not the only incentive and perhaps may not be a sufficient incentive to invest in an engineering control. These are the themes that emerged from the data coding and analysis.

Visible Dust Emissions

This particular job included grinding almost every square foot of concrete slab ceiling on 28 floors. Each floor took approximately 2 days to complete. The potential for job-delaying complaints from the community about high dust levels from grinding all the ceilings in an open-sided building in a highly populated downtown business district was a stated incentive for lowering dust levels. The public unacceptability of the dust emissions is an example of the influence of the external environment on changing internal organizational practices.

More Concrete Grinding due to New Forms

During an initial walkthrough of the construction site, the safety officer for the concrete SC discussed that the amount of concrete grinding was increasing on local job sites. More buildings were using concrete as the finished ceiling and therefore required more grinding to create a smooth finish. This architectural feature was popular in other parts of the country and was now becoming more popular in this region as well. The grinder operator advised the researcher that a new system of concrete slab forms had also been introduced that used smaller panels and left more concrete slag on the ceiling. The manufacturers' literature for this formwork system lists several advantages. Each panel is less than 33 lb for quick assembly and disassembly by hand and the girder system allows removing the plates in 1 day after pouring concrete. This system is gaining popularity as it saves considerable time and therefore money. The smaller panels have more seams and the concrete sets into these seams and must be ground to a smooth finish because this is now the finished ceiling. Thus the grinding dust and silica problem was long term and its control was an investment for future projects as well. This is an example of a

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technical innovation in production methods forced by the external market environment that created the dust and silica problem that then needed to be solved.

Required RP for Workers

Once the safety manager decided that the grinder dust might be a problem, he called in the state OSHA consultation service to evaluate the respirable crystalline silica exposures. The results of the sampling indicated potential overexposure and the need for RP. Therefore, the operator of the grinder was required to wear an air-purifying respirator and be enrolled in a RP program. The OSHA-required RP program, includes training, medical evaluation, and fit testing (U.S. Department of Labor).

If other trades were required to work in the area, they too would require similar protection. RP programs are considered a financial burden in the construction industry due to the temporary nature of employment for any individual worker. The assurance that all program components are satisfied falls on each SC-employer even though their activities may not be creating the dust and silica hazard. This issue was also discussed in a separate interview with an electrical contractor on another construction site who sought out dustless drills for overhead work in order to eliminate the requirement for RP. The OSHA requirement for a RP program was a part of the socioeconomic and regulatory environment providing an incentive for an intervention.

Prior Use of a Similar Control

The safety manager for the general contractor knew of other situations where LEV on hand tools had been successful. Painters, using a ventilated drywall sander, the drilling with LEV discussed earlier and a wall grinder with a cowl and vacuum cleaner attachment had been seen or used by people working on the site. Therefore, it was proposed by the GC's safety manager that LEV could be applied to the overhead ceiling grinder. This is an example of individual action based on personal experience to initiate an intervention.

Improved Work Scheduling

Before implementing the dust control for the grinding operation, workers from other subcontracting specialties were not allowed in the area when grinding was done because of high silica levels. This resulted in production delays and an increased need for schedule coordination.

During one discussion the managers alluded to the fact that they could not do the grinding at night on this site. With the dust control intervention in place, the concrete SC saved money by not paying overtime or a night premium to avoid problems for community complaints on dust or exposure of other workers. For the general contractor, scheduling among the SCs was made easier and more productive because there was no need to work around the grinding. This incentive was a result of the particular organizational environment of the construction industry in which the contractors were working.

Adapting the Tool to the Job

The tool equipment salesman played a key role in obtaining the equipment. When asked, he was willing and able to locate and provide several options for grinders combined with dust collectors. For portable tools, these dust collectors consist of a cowl which attaches to the grinder and a portable vacuum cleaner. A hose is used between the cowl and the vacuum cleaner. Much of this equipment is currently sold by European companies but is available in the United States.

The technical barrier to this intervention was fitting the grinder to the particular task of ceiling work. This was centered around two issues: (1) fitting the off-the-shelf grinder with the cowl and LEV onto the already existing homebuilt giraffe device and (2) having sufficient power and ruggedness to grind so much concrete. The previously used grinder had been a powerful floor grinder. The new grinder that came with the vacuum cleaner was smaller and more like a wall grinder.

The superintendent and the safety officer for the SC personally made modifications so that the newly purchased LEV grinder could tilt in both directions in order to stay flat on the ceiling. Overcoming these technical barriers is an example of the interaction of the role of individual actions with technical issues. In many instances the individuals involved may not have the required skills to make the adaptations. In this case, the limitations of the equipment were a barrier that was overcome.

The role of the tool supply salesman exemplifies the interaction of the individual action of the salesman and the organizational relationship between himself and the contractors. It also illustrates the dependence of construction contractors on the tool supply industry for innovation.

Benefits Outweighed Increased Costs

Cost was not an issue when purchasing the intervention or making it work for the specific job. All of the interview participants said that the company would pay whatever necessary to provide a safe and healthy work environment. The new grinder was smaller and the motor would burn out frequently. Two complete systems were set up and if one burned out the other would continue to be used. New grinders were purchased regularly at a cost of around $500 each.

In the proposed intervention framework, cost is considered as part of the organizational environment. In this case, there was an organizational commitment to the end result of controlling the concrete grinding dust and silica, but the intervention may have saved money due to increased productivity, easing scheduling, and eliminating the cost of a RP program due to this contaminant covering employees of all the SCs. Apparently, no formal cost-benefit analysis of the intervention was undertaken.

Increased Demands of GCs in the Bidding Environment

General contractors are demanding more sophisticated health and safety plans from their SCs as well as better safety performance. The SC's superintendent on the worksite was able to name several large general contractors in the area that "have prequalifications on the big jobs."

To prequalify in the area of health and safety, general contractors are looking for safety plans, good record keeping, and low injury rates. There was strong support from the GC safety manager for this SC to improve its safety reputation. He insisted on many other innovations in health and safety, particularly fall protection, on this site. He showed the SC that they could be productive and safe at the same time. He had convinced the SC that this would be to their benefit in the long run, in bidding on other large jobs, illustrating the effect of the socioeconomic environment on this decision.

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Response to the OSHA Silica Emphasis Program

There was mixed message from the participants on the role of regulatory requirements as an incentive for engineering controls. One message was that OSHA had an emphasis program on silica and therefore there had been more enforcement in this area. However, all the participants stated that OSHA had never inspected this site for silica. A related incentive mentioned was that OSHA rules had changed regarding silica and that a silica control program was required. The site superintendent stated "OSHA expects this and so does [the general contracting company]." This had definitely prompted more cooperation from the concrete SC.

The GC safety manager had required the SC to put together a *silica control plan*. The safety officer for the SC was very enthusiastic about how the GC safety officer had helped him put this plan together and had provided templates that he could use on other jobs. It was obvious that this had not happened on previous projects with other GCs.

As a part of the silica control plan, the GC safety officer had called in the state OSHA Consultation Service to do respirable silica sampling. This program operates free of charge and typically targets small businesses who cannot afford industrial hygiene services. After they had implemented the dust control they brought the consultation service back on-site to do follow-up monitoring. This was part of a plan to get "credit" for what they had put in place and to verify that RP was no longer needed.

This result again demonstrates the influence of the external regulatory environment on the decision to implement an intervention. Although there had been no direct enforcement action by OSHA on the site, the regulatory environment was such that it worked as an incentive.

Innovative Practice Brought from Another Company

The safety officer for the SC indicated that the GC safety manager brought the silica control plan, either the actual plan or the idea for it, from a previous general contractor he had worked for in the area. That previous general contractor is very upfront about being innovative and a leader in the industry on health and safety issues and has implemented a number of new practices on building sites. Their safety staff are frequent speakers at local conferences and provide innovative ideas on implementing site safety. The individual action of the GC safety manager diffused a practice from another contractor through his initiative.

Positive Role of Individuals Involved

The three men involved in implementing the dust control agreed that the ability to work together personally was a huge influence on the success they experienced, not only on this intervention, but a number of new safety practices throughout the site. All three men had extensive experience as tradesmen. The site superintendent had been a union carpenter with 16 years experience with the concrete SC. The safety officer for the SC was a carpenter with over 30 years' experience who had personal credibility with the workers. The GC safety manager had been a union piledriver for many years and had acquired his interest in health and safety while an instructor in the union training program. The mechanical ability to actually get the intervention working was important. The GC safety manager had described the site superintendent as someone with "mechanical aptitude and could make it fit."

The GC safety manager raised the issue of increased expectations. Everyone on the job participated in doing new and innovative things all around. The participants from the concrete SC said it was the first time that they had been treated as partners in problem solving around health and safety issues. Everyone on the site started to expect to work safer. This is an example of how individual actions within an organization produce results beyond what the organization might typically demand.

Why Not Intervention #1?

It is interesting to contrast the contractors' differing approaches to the two potential dust control engineering interventions. The researchers carefully examined the data for indications of what was different between the two situations. Neither the GC nor the concrete SC had been interested in using the dust control intervention on the drill proposed by the research industrial hygienist (Intervention #1). They were willing to bring the control on the site and test it, probably as a favor to the researcher. The researcher observed several differences between the "imposed" intervention of the LEV on their hammer drill (#1) and the "homegrown" intervention of the grinder (#2). First, the dust control for the grinder was developed because the GC safety manager perceived a problem with the grinding dust and silica. The problem was not just the health effects of the dust and silica, but also the appearance of a dust problem. Once silica overexposures were identified, there was also the requirement for a RP program and the need to carefully schedule other trades in the area if there were no dust control. On the other hand, the drilling/chipping job was not perceived as a problem, and it was unlikely there were overexposures although it did contribute to the general dust levels on the site.

One reason the grinding was more of a problem than the chipping or drilling was because it was a long-term job that continued for a full-day shift, day after day. The researcher observed that there were three electric hammer drills on the site that could be used for drilling or chipping concrete. One de-facto reason for lack of interest in further testing of the drill LEV was that the foreman could not predict when the drilling/chipping would take place. During the observation of the dust control on the overhead grinder, another laborer came into the area and chipped off some concrete slag around a column using one of the hammer drills. The entire task took less than one minute. This task is performed occasionally, usually for short periods and by different people on the job. On this building construction site there was nobody who just drilled or chipped all day. This is contrasted to the Ted Williams tunnel job observed by the COHP where 14,000 holes (Blute et al. 1999) had to be drilled in the ceiling of the tunnel. Thus the length of time spent on a task within the day seems to be important as to whether a control will be sought to mitigate the perceived hazard. For dust exposures, this may also be related to a perception of the level of hazardous exposure associated with a short-term task. It is likely that a worker chipping concrete for a few minutes a day will not be exposed above the OSHA permissible exposure limit (PEL) which is an 8-h average exposure level. This is in direct contradiction to the idea that they should be wearing RP while chipping, which was consistently stated by all employees. In spite of those statements, the researcher never observed workers wearing RP while chipping concrete.

Only two men were assigned to the overhead grinding. Having only one or two people assigned to a task also aids in the control implementation and equipment maintenance. Although portable, operating this equipment became their "work station" similar to a manufacturing setting. They took some ownership of the dust control equipment and one of the operators had been consistently

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Table 1. Categorizing the Resulting Themes within an Intervention Framework

Individual actions	Prior use of a similar control
	Innovative practice brought from another company
	Positive role of individuals involved
Technical and equipment	Adapting the tool to the job
	More concrete grinding due to new forms
Organizational environment	Benefits outweighed increased costs
	Improved work scheduling
External environment	Visible dust emissions
	Required RP
	Increased demands in the bidding environment
	Response to the OSHA silica emphasis program

improving the giraffe device over time. On the other hand, the three hammer drills on the site traveled from floor to floor on an as-needed basis, creating a "nonownership" situation. For example, when the laborer who participated in the dust control testing with the researcher tried to use the hammer drill for a little chipping job, the chisel did not work. Either it was the wrong chisel for the tool or someone had broken the connection, evidence that no worker in particular was responsible for the maintenance of this tool. When the researcher had proposed leaving the LEV system on-site to be used by the SC, the safety officer replied, "No, someone will steal it." This further illustrates the presumed fate of tools that are not used continuously.

Discussion

The themes that emerged from the data analysis in this limited case study can be categorized within the intervention framework presented earlier (Table 1). Achieving implementation of the engineering control in this case was the result of all the factors working together to produce results.

The safety manager for the GC identified a problem with excessive dust being generated from the overhead grinding operation. Although the grinder operator could be protected through RP, others who needed to work in the area were not protected. Typically, this could be dealt with by moving the grinding operation to a night shift or by scheduling all other work around the grinding. This solution is not optimal from an occupational health and safety perspective or from an economic perspective. Inspired by the downtown location of the job and potential community concerns about the dust/silica, the safety manger for the GC decided that a dust control should be placed on the grinder. He encouraged the site superintendent and safety officer for the SC to find such a solution. Through the assistance of their tool salesman and "trial and error," they were able to put together a working system. Many construction companies face the same external environment at their sites, yet do not have the individuals in place to solve the problem.

The participants in this intervention were able to build and implement the dust control because of a combination of personal traits and positions within their organizations and the particular project they were on. The safety manager for the GC had a solid personal knowledge of health hazards from prior experiences and had fervor for eliminating these hazards where possible. The SC's site superintendent and safety officer were taking a new approach to health and safety on the site because of the leadership from the GC. They might not have taken this direction on their own, but were very willing to "do what they were told." The site superintendent on this project had enough personal sway within his own organization to be heard and his request for financing the dust control was approved. The safety officer for the SC had worked in the trades for many years and was taken seriously by the workers. He was also assigned as a foreman on the job which gave him status within the line organization. The organizational environment was key to empowering individuals to take action.

The construction industry maintains a craft trade system which has its roots in medieval times. There is a strong identification with "craftsmanship," an individual control over how a job gets done and a pride in working with one's hands. Thus there is room for individual actions within construction. Observations on construction sites support the notion that most workers work on their own or in very small crews. There was little instruction or direction that went on in the course of the work. This result is consistent with Eakin's (Eakin 1992) and Gillen's (Gillen et al. 2004) findings in interviews with construction workers. It is through "craftsmanship" that a skilled worker must decide how to get the job done. In this case, the three management individuals were able to use the skills developed over many years in the trades. Due to their management positions in their companies they had access to more resources as well. Given the discretion that construction workers have, it was interesting to find that worker rejection or acceptance of the intervention was not an issue in this case. Management set an example by working to overcome problems with the dust control and supported worker efforts to do the same. Thus the operators were more engaged in the process and happy to be using something that made their jobs healthier.

One government regulation was a direct incentive for engineering controls: the need for a RP program. It is easy for contractors to hand out filtering facepiece dust masks and leave the impression that wearing them is good, but optional. A mandatory RP program involves much more time, and time is money. Reducing dust levels below those which would require RP gave the contractors a bonus of eliminating this burdensome program. This is considered a burden because fit testing, providing, storing and maintaining the correct respirators, training workers, demanding that workers shave off beards, and providing medical evaluation for workers who may be on that particular site for a short period of time is not economical. There is no multicontractor regional system of tracking an individual worker's fitness to wear a respirator and so the process must be replicated by each contractor upon hire even if only for 1 day! Therefore the mobility of construction workers, precipitated by how the industry is organized, may work against the protection of their health.

In a project-based industry such as construction, there is a changing organization on each construction site. The researcher had visited another similar building construction site 2 years earlier and had first observed the overhead grinder without the dust control. The GC on that site was known for their innovative safety procedures and they employed the same concrete SC on the site. In discussions at that time, the grinder operator and other workers could not imagine having a dust control on the overhead grinder. That site had a different safety manager for the GC and a different site superintendent and safety officer for the concrete SC. The

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building was approximately four blocks away from the site where the dust control was eventually implemented. Thus site management appears key in the response to a similar dust exposure challenge.

The management skills of the safety manger were also a key factor in accomplishing the intervention. Building a cooperative environment for problem solving rather than bullying people into doing "safety" falls in line with what Gillen et al. (2004) found when she interviewed workers on characteristics they determined were important for management. They reported that favorable qualities in managers were "excellent administrative and communication skills," and that particularly around safety practices, they wanted management to "treat workers with respect."

Although enforcement of the OSHA silica regulations was not a direct incentive in this intervention, a regulatory environment promoting dust reduction was important. The smaller SC received a message from the large GC that they needed to increase their sophistication in dealing with health and safety hazards. The competitive bidding structure of the construction industry forces SCs to always look for an edge on their competition. Sometimes that is simply a low bid. Other times it is quality or productivity.

Since the construction industry is regional in scope (Finkel 1997) and members know each other through working together on-sites, the unions, or employer organizations, reputation and relationships are often the key to business success. Understanding this and perceiving a shift in expectations from the general contractor, the concrete SC was convinced to develop a health and safety program and to finance a relatively expensive LEV dust control for the grinding operation. In this context, cost was not an issue in the selection and implementation of the dust control. The value of the intervention exceeded the financial outlay for the concrete SC.

The inability of the researchers to implement a dust control for the short-term task of drilling and chipping on this site is indicative of how hard it is for industrial hygienists and safety managers to gain control of silica exposures in construction. In this particular situation one insurmountable barrier was the short-term nature of the drilling/chipping task. There are two types of short-term jobs on construction sites. One type is a task performed by workers regularly employed on the site. The other is performed by SCs who may come onto the site for one task only for a very short period of time, perhaps an hour or less. At a regional meeting of safety mangers, one manager mentioned the difficulty in monitoring dust exposures created by the concrete cutting contractors who come to cut one hole in a floor or wall with expensive specialized equipment. The safety manager may not even know they are there until they have gone. Yet these activities add to the overall airborne dust exposure on the site. More work needs to be done to document the exposures from these types of tasks to see how much they actually contribute to the cumulative dust exposure to all workers on the site. Using that information, the prioritization of engineering controls for these types of short-term tasks might be justified. Also, contractors could include mandatory engineering controls in subcontracts.

A repercussion of the project-based nature of construction is that contractors may have difficulty bringing new skills from one project to the next in an organizationwide fashion. Each project can be like starting over again from scratch (Gann 2000) with new combinations of workers and management. One issue that was addressed by the participants was the ability to bring the intervention to other projects. It was interesting that nobody said they would put this dust control onto other already existing projects for their employers. The SC superintendent said in general that he takes everything he learns to the next project. Because of the success working with this SC in developing and implementing new health and safety procedures, the GC safety manager said that he now had particular requirements for the next concrete SC. Dissemination of this intervention appeared to rest with the key individual people who put together the intervention. It was up to them to bring it with them onto the sites under their control rather than there being a mechanism to inform their peers within the company or the region to do the same. However, the GC safety manager was eager to have a splashy report from the researcher to promote a class on silica and dust controls he would like to give at the local contractors' association. The "credit" for a new health and safety intervention that had positive economic benefits was also a factor for the GC safety officer. This reinforces the possible role of individuals and their particular personalities on dissemination of controls (Rogers 1995) as well as the particular roles of the GC safety manager and the site supervisor which have been noted in another study (Fulmer et al. 2006).

Limitations of the Study

A study of one intervention cannot claim to discover all of the meanings and values associated with the addition of LEV to hammer drills, or even overhead grinders. It is a start in uncovering the issues surrounding health interventions in the construction industry. This information will better enable industrial hygienists, safety officers, and construction managers to respond to the concerns of workers and contractors while addressing the critical issue of silica exposures. Future research should further examine the roles of site supervision in the implementation of health and safety initiatives. This research could specifically examine what role supervisor training in both health and safety and human relations plays in their success.

Conclusions

This case indicates that it is possible to implement engineered controls for the concrete dust exposures produced by hand operated power tools in construction. All aspects of the proposed theoretical framework needed to be considered in order to understand why the intervention was successful.

The need for the intervention must be accepted, if not initiated, by the on-site safety personnel in order to provide the incentive needed to overcome obstacles to implementation. The particular safety personnel involved in this case also had sufficient mechanical ability to make technical improvements to make the control work (individual actions). Equipment must be available through the normal channels, the tool supply company, within a reasonable time. The control equipment must provide good results (technical and equipment). The general contractor and SC must be able to work together and support the intervention with time and financial resources needed (organizational environment). The regulatory climate and bidding environment provided enough of an incentive to force the initiation of the intervention process (external environment).

Industrial hygiene researchers and other engineers can provide technical assistance in the design of equipment that functions effectively but end users must be consulted to understand the practical requirements for a construction site. Collaboration between researchers and site safety personnel could have led to building the dust control system onto the original ceiling grinder which had more power and better designed for the ceiling grinding task.

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This may have saved the contractor some expense from the need to frequently replace the smaller grinders. However, in construction time is money, and it was perceived to be less expensive to buy slightly inadequate equipment off-the-shelf than to wait for research to produce what they needed.

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