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An Assessment of Lead Controls for Torch Cutting and Rivet Removal on Steel Structures

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The use of engineering and work practice controls to protect workers from lead-containing dusts and fumes generated during rehabilitation of steel structures is mandated by the Occupational Safety and Health Administration (OSHA) Lead in Construction Standard (1993). Because the implementation and assessment of controls can be problematic in the rugged and dynamic construction environment, industrial hygienists should understand the effectiveness and limitations of controls adopted. The present investigation assesses the efficacy of two controls to reduce lead exposure: paint removal prior to oxy-acetylene torch cutting of steel, and encapsulation of rivets prior to their removal. A task-based exposure assessment approach was used to evaluate these tasks at three sites. Exposures at one site without controls were compared to exposures at sites with controls. Comparison of the results via an analysis of variance (0.05 significance level) indicates that, for torch cutting, exposures at the control site were not significantly different from those at an uncontrolled site ($p = 0.14$). The results for rivet busting show no significant differences in exposures at the control site compared to the uncontrolled site ($p = 0.08$). Results are also presented from two control sites where work was done in enclosed spaces. Two main difficulties in applying the controls are explored: technical and managerial. Technical problems during torch cutting included the penetration of paint into the steel profile and the configuration of the structures. For rivet busting, working within an enclosure was an important factor. Management problems arose both from a lack of coordination among different contractors, and from a failure to provide day-to-day guidance and assessment of the control. Important components of a program to implement controls are preplanning and coordination of control implementation, frequent testing of control efficacy, and a method for timely intervention to correct deficiencies.

Keywords Lead Exposure, Task-Based Exposure Assessment, Bridge Rehabilitation, Engineering Controls, Work Practice Controls, Construction Industry

In keeping with generally accepted industrial hygiene practice and federal occupational health standards, the Occupational Safety and Health Administration's (OSHA's) Lead in Construction—Interim Final Rule (29 CFR 1926) mandates that the first line of defense for protecting workers from lead exposure should be engineering and work practice controls.[(1)] The control of lead exposure is necessary to reduce well-documented, high concentrations of lead fume and dust generated during the rehabilitation and demolition of bridges and other steel structures coated with lead-based paint.[(2–5)] Such exposure represents a considerable health risk to the approximately 57,000 construction workers engaged in these activities.[(6)] The recent congressional reauthorization of the Intermodal Surface Transportation Efficiency Act, now called TEA-21 (Transportation Equity Act for the 21st century), ensures that road and bridge rehabilitation work will be well funded for several years.[(7)]

Because of the dynamic nature of construction, the implementation and assessment of engineering and work practice controls designed to protect workers present unique challenges. Construction work processes are designed to transform the environment. Whether the process is putting up a building, laying down a road, renovating an office space or bridge, or demolishing a factory, the physical environment is being molded and remolded continuously. The ruggedness of the construction environment—temperature extremes, remoteness of sites, work conducted at heights or depths, frequent movement of personnel, materials, and equipment—can also impede the implementation of controls which might more easily be employed at fixed industrial work sites. The presence of many employers at a given site necessitates cooperation and planning among these subcontractors to complete the project. The responsibilities and oversight for health and safety are often diffused in this environment. Nonetheless, it is of utmost importance that industrial hygienists, construction site safety personnel, and contractors understand both the effectiveness and the limitations of the available control technologies and practices, so that workers are properly protected during all phases of work where exposures to lead potentially exceed occupational exposure limits or may lead to illness among workers.

The assessment of personal exposures to airborne concentrations of contaminants is an important tool for evaluating the efficacy of controls.(8) To date, there are a paucity of peer-reviewed reports which present data on the efficacy of controls to reduce lead exposure during structural steel rehabilitation and demolition. Indeed, for the construction industry as a whole, there is a dearth of research and information in this country about worker exposures to hazardous substances and protection from these exposures.(9,10) Data have been reported for lead exposure and controls, but the reports have been largely in trade journals.(11–13)

This study tests the hypothesis that the controls commonly employed to reduce worker exposure to lead during structural steel rehabilitation work are effective. Exposures during torch cutting after paint has been removed from the surface and during rivet removal ("rivet busting") after the coating on the rivets has been encapsulated were monitored. The data collected during this study are compared to those gathered during a bridge rehabilitation project where controls were largely absent. The results of that study have been presented previously.(14) Results are also presented for controlled exposures of torch cutting and rivet busting tasks that were performed at sites where the conditions were essentially different from those at the controlled and uncontrolled sites used for comparison. In particular, work at these sites was performed within enclosed spaces.

DESCRIPTION OF TASKS

The worker tasks which generate dust and fume during bridge rehabilitation entail the removal of corroded steel beams and their replacement with new steel. Steel plates are also added to structures to strengthen them. The removal of old beams is accomplished either by cutting through them with an oxy-acetylene torch or by mechanically removing the rivets connecting beams with a pneumatically driven chisel/hammer called a "rivet buster." Sometimes a torch or high-temperature lance is used to remove the shaft of a rivet which cannot be removed mechanically by the punching action of the rivet buster. Prior to connecting steel members to each other, all coating and rust must be removed from steel left in place. This is accomplished by pneumatic tools such as finger scalers, grinders, needle guns, or rotopeeners. New beams are connected or "bolted up" with a pneumatic air gun.

By and large, the controls developed to protect workers from lead exposure during torch cutting have been known and applied for some time. To control fume generation during beam removal via torch cutting, paint can be removed from the area where the cut is to be made. To control dust generation during rivet busting, paint can be removed from the surface prior to its being disturbed or paint can be encapsulated with a dust-suppressing coating. Paint removal prior to surface disturbance is generally accomplished by chemical strippers or by pneumatic tools as described previously. If a pneumatic tool is used, it can be equipped with a local exhaust system in the form of a shroud surrounding the tool. If the tool is not fitted with a shroud, exposures can be quite intense. The removal of paint prior to surface disturbance has been a recommended practice for years, and is required by OSHA before welding or cutting on coated surfaces in an enclosed space.(15) According to this standard, at least four inches of paint are to be removed from each side of the proposed cut; that is, an eight-inch strip of paint is to be removed for the torch to cut down the middle.

SETTING

In this study, data were collected at three sites. Two of the sites (referred to as Bridge 1 and Bridge 2) are steel suspension bridges built early in the 20th century. Both are part of major inner-city transportation arteries that carry vehicular and train traffic on two levels. Lack of routine maintenance, particularly in the 1970s, resulted in severe corrosion and compromise of structural integrity to both bridges. The deterioration of these structures necessitated large-scale, multi-year rehabilitation projects.

Exposure assessment at Bridge 1 took place in two phases. The first phase, described in a previously published article, evaluated exposures during a period when controls were largely absent.(14) Most of the iron work during this phase took place from under-bridge platforms constructed solely for the project. Other work locations were at the two anchorages where steel reinforcement plates or frames were added to strengthen the bridge. The work was performed largely in the open (i.e., without any containment). Typically, crews on the platforms consisted of 15 to 20 workers; crews of 8 to 10 worked at the anchorages. With only minor variations, the tasks described were performed repetitively during the period when exposure assessment was conducted. Steel beams were removed by torch cutting and by rivet busting.

During a subsequent, second assessment phase at Bridge 1, the rehabilitation contract called for extensive steel removal, but only by means of rivet busting (i.e., no torch cutting). All of the rivet removal was conducted within a containment consisting of loosely draped, overlapping tarpaulins. Workers worked largely from scissor lifts, from under-bridge platforms, or from small moving platforms, called travelers. The effective work area of the platforms, bounded by the tarpaulins, was approximately 25 feet by 40 feet. Each crew consisted of six to eight ironworkers working in pairs and one laborer, who coated the rivets with encapsulant in advance of the rivet removal work, cleaned the platform, and moved materials. Although torch cutting was prohibited, a small thermal lance (called a "slice torch"), approximately the size of a welding rod, was used to remove (burn out) rivet shafts that were bent and could not be removed with the rivet buster.

At Bridge 2 there was extensive demolition of the concrete roadway and supporting steel. The two main tasks employed in steel demolition were rivet busting and torch cutting. Workers worked in pairs from the existing roadway, from scaffolds or scissor lifts, or from the beams themselves. There was no containment surrounding the work area. To reduce dust generation during rivet busting, an encapsulant was brushed on to the rivets and adjacent steel. Prior to torch cutting, paint was removed by shrouded pneumatic tools (needle guns, rotopeeners).

The third site (referred to here as "Elevators") entailed the demolition via torch cutting of industrial-sized elevators coated with lead-based paint and located in a large commercial structure. Both the steel elevators and the steel lining of the elevator shaft, which rose three levels through the building, were demolished. Sections of the lining were cut and either dropped into the basement for future removal or, when possible, placed on the neighboring floor. The cutting itself was performed either from a floor in the building—sometimes with loosely draped tarps surrounding the work area, sometimes without such tarps—and sometimes from scaffolding located within the elevator shaft. A contractor had been employed to remove eight inches of lead paint prior to torch cutting of the elevators. Table I summarizes the tasks monitored at each of the sites, the controls used, and the site conditions. It also indicates whether a site was used for statistical analysis of controlled versus uncontrolled exposures.

METHODS

The study employed a convenience sampling approach: the days selected for performing personal monitoring of ironworkers were determined largely by the stage of the rehabilitation project, the tasks being performed, and researchers' access to the site. Workers were selected for monitoring based primarily upon task performed (e.g., torch cutting, rivet busting). Given this approach, the same workers were sometimes sampled on different days.

Monitoring was conducted at flow rates of approximately 2 liters/minute with a closed-faced cassette containing a 37-mm mixed cellulose ester filter of 0.8μ nominal pore size. The pumps (MSA Escort Elf) were pre- and post-calibrated in the researcher's laboratory. The cassettes were carried to and from the site in clean ziplocked plastic bags. Field blanks were used for each monitoring episode. Sample analysis was performed according to National Institute for Occupational Safety and Health (NIOSH) method 7082 by a laboratory accredited by the American Industrial Hygiene Association (AIHA). In addition to air samples, bulk samples of paint chips were collected from each site to assess the percent of lead by weight in the paint. Samples were taken from different work locations either by cutting an approximate two-inch-square area with a knife and removing as much of the paint as possible down to bare steel, or by simply tearing off a piece of peeling paint that left no residue on the underlying steel surface.

Every attempt was made to collect full-shift samples of worker exposure during the performance of one task—that is, a task-based approach was employed. This approach has been described in several recent publications, and holds promise as an exposure assessment tool in construction. It is indispensable for comparing monitoring results with and without a control in place, because task is one of the most important determinants of exposure in construction.[14,16,17] It was often not possible to gather full-shift samples for a number of reasons: a worker assigned to a particular task in the morning might be reassigned to another later in the day; the task might be completed in several hours; the task might be one of several for which a worker was responsible. For example, torch cutting might be interspersed with rigging. As a result, the cassette was removed, when possible, from the worker after completion of the targeted task. In addition, to avoid sample overload, cassettes were changed at appropriate intervals throughout the monitoring period (e.g., when observation revealed potential for overloading). Because the primary goal of data collection was not comparison to an occupational exposure limit, but comparison of uncontrolled with controlled exposures, results are presented both for the individual sample (e.g., collected on one filter, over variable time periods), and for longer period samples, representing a time-weighted average (TWA) of concentrations based upon contaminant collected on more than one filter.

TABLE I
Sites and tasks monitored

Site	Tasks monitored (without controls)	Tasks monitored (with controls)	Controls employed
Bridge 1	Rivet busting[A] Torch cutting[A]	Rivet busting (with thermal lance)[B]	Encapsulant
Bridge 2	N/A	Rivet busting[A] Torch cutting[A]	Encapsulant Paint removal
Elevators	N/A	Torch cutting[B]	Paint removal

[A]Used for statistical analysis of control effectiveness.
[B]Not used for statistical analysis.

STATISTICAL APPROACH

Descriptive statistics were calculated to characterize the distribution of airborne lead concentrations for the different controls at all sites. Due to the skewed distribution of lead concentrations, geometric means and standard deviations were computed in addition to their arithmetic counterparts. To compare the mean

TABLE II
Airborne lead concentrations for torch cutting and rivet busting: Uncontrolled vs. controlled exposures

Site	Task	n	AM (μg/m^3)	SD	Range (μg/m^3)	GM (μg/m^3)	GSD	MT (min)	p-values vs. B1(NC) ($p < .05$)
B1(NC)	Torch cut	21	1158	983	63–3746	737	1.1	133	
B2	Torch cut	31	1539	1493	69–5800	975	1.05	188	0.14
B1(NC)	Rivet bust	22	258	322	10–1200	131	1.25	174	
B2	Rivet bust	37	178	250	6–1430	95	1.19	171	0.08

n—number of samples.
AM—arithmetic mean.
SD—standard deviation.
GM—geometric mean.
GSD—geometric standard deviation.
MT—mean sampling time.
B1(NC)—Bridge 1, no controls.
B2—Bridge 2, controls.

TABLE III
Airborne lead concentrations for torch cutting and rivet busting: Enclosed sites

Site	Task	n	AM (μg/m^3)	SD	Range (μg/m^3)	GM (μg/m^3)	GSD	MT (min)
B1(C)	Rivet bust	18	420	346	45–1100	287	0.96	139
E	Torch cut	29	11,103	12,931	81–52,000	4097	1.77	104

B1(C)—Bridge 1 with controls.

concentrations of the samples collected during use of the same control at the test sites, while accounting for the fact that multiple measurements were taken from the same worker, a repeated measures analysis of variance was performed on the log normalized data. Statistical significance was assessed at the 0.05 level.

RESULTS

Bulk sample results from the three sites are comparable with the percent lead by weight at about 36 percent to 40 percent.

Descriptive statistics for the monitoring results for the task “torch cutting” from the two test sites are presented in Table II. Both the arithmetic and geometric mean concentrations as well as their standard deviations are presented. The mean sampling time is also shown. The geometric mean exposure at Bridge 2 is not significantly different from the uncontrolled exposure at Bridge 1(NC) ($p = 0.14$). For rivet busting, the exposure at Bridge 2 is not significantly lower than the uncontrolled exposure at Bridge 1(NC) ($p = 0.08$) for the same task.

The results of exposure monitoring at the enclosed sites are presented in Table III. The mean concentration of exposure for rivet busting is 420 μg/m^3. The mean exposure at the Elevators is greater than 11,000 μg/m^3. Table IV presents the results for all individual samples at Bridge 1(C) where “lancing” was the only task performed.

TABLE IV
Airborne lead concentrations for lancing

Sample no.	Time monitored (min)	Lead concentration (μg/m^3)
1	49	1500
2	60	5000
3	77	5900
4	30	7200
5	72	9500
6	50	12,000
Mean		6850

DISCUSSION

The efficacy of controls commonly employed to reduce worker exposure during the rehabilitation of bridges and other steel structures was evaluated by a task-based exposure assessment approach, that is, by assessing and comparing personal exposures during performance of the same task with and without controls in place. The results indicate that the controls had a limited effect in reducing worker exposure to lead. At the control site for torch cutting, the mean exposure was not significantly different from that for the uncontrolled exposure. For rivet busting, the controlled exposure was not significantly less than the uncontrolled exposure. However, the difference between the two approaches statistical significance ($p = 0.08$), and must be considered in light of the small sample size and the standard deviation of the measurements.

These results negate the hypothesis that the controls evaluated significantly reduce worker exposures. In fact, the results are counterintuitive: it is a reasonable assumption that removal of paint from a surface should eliminate or at least minimize the generation of lead fume when a hot torch is used to cut through the surface from which the paint has been removed. In fact, paint removal prior to torch cutting is a commonly recommended control.[6,18] Similarly, applying a dust-suppressing coating to a painted rivet should minimize the generation of dust when the rivet is removed with an impact chisel.

The exposures measured during torch cutting and rivet busting at the enclosed sites were high. At the Elevators, the mean exposure of 11,103 $\mu g/m^3$ is over 250 times the OSHA Permissible Exposure Limit (PEL) of 50 $\mu g/m^3$. The arithmetic mean exposure for rivet busting of 420 $\mu g/m^3$ at Bridge 1 is greater than eight times the OSHA PEL. We can draw only limited and tentative inferences about control efficacy at these two enclosed sites. The torch cutting performed at the Elevators was indoors and in an enclosed space, while at Bridge 1(C) rivet busting was done within a containment constructed around the work. The effect on exposure of these environmental factors was not measured, and therefore, their contribution to exposure is unknown. On the one hand, concentrations of airborne contaminants can be greatly magnified when generated in an enclosed environment which mitigates against the dispersive effect of natural ventilation. On the other hand, the fact that exposures were found that were at least as great as those measured in uncontrolled conditions, indicates that the controls did not remove lead from the work site.

The data presented suggest that the control methods evaluated were largely unsuccessful at the sites monitored. The data do not suggest that the controls could never minimize exposures. Nonetheless, the results have implications beyond the three study sites. The sites surveyed are representative of bridge and steel rehabilitation and demolition work performed on massive, aging steel structures coated with many layers of paint containing large quantities of lead. Such bridges are common throughout many regions of the United States, and many are undergoing, or are scheduled for, similar rehabilitation.[19] In addition, the contractors at the sites were experienced in conducting structural steel bridge rehabilitation, and, at the controlled sites, were working under Department of Transportation specifications which mandated, and reimbursed expenses for, the control methods applied. As described elsewhere, the contractor at Bridge 1 made great efforts to control lead exposures and successfully reduced blood lead levels of ironworkers.[20] The contractor at Bridge 2 also took great pains to control worker blood lead levels, and, among other protective measures, monitored these levels monthly—twice as frequently as mandated by the OSHA standard (and not reimbursed by the Department of Transportation).[1]

The amount of lead by weight in paint at the three sites was comparable. Variability in the lead content at each site is presumed to be due largely to the fact that all parts of the structures were not painted at the same time or with the same batch of paint, and paint formulations were not always consistent as to the percent of the individual components, including lead.

Although the data presented allow only for general conclusions about the efficacy of the controls to reduce airborne lead exposures (i.e., that the controls did or did not significantly reduce exposures), observations of the steel surfaces from which paint was removed, as well as of work procedures and practices, point to difficulties in control implementation. There were two kinds of difficulties encountered: technical and managerial.

There were several technical difficulties encountered during paint removal prior to torch cutting. At two of the sites (Bridge 2 and the Elevators), paint was removed by mechanical means—pneumatically driven, shrouded needle guns and rotopeeners. At Bridge 2, paint removal from the designated areas was often incomplete due to the configuration of the beams which obscured or covered parts of painted surfaces, reducing their accessibility to the paint stripping tool. Secondly, red lead primer—typically the first coat used on steel surfaces in the past—was at times visible on the steel surfaces after paint removal. Over time, the primer had penetrated into the profile of the steel plate. Such difficulties have been reported previously in relation to welding on a bridge from which paint had been removed previously.[21]

The technical difficulties at the Elevators were related to the fact that the steel surfaces were covered with many layers of heavy grease, which obscured the coating on the metal and made paint removal very difficult. In some areas, paint removal was incomplete. The exposure to lead fume that resulted from cutting through partially painted areas was intensified by the fact that some of the work was done in the enclosed space of an elevator shaft where air currents produced a flue effect: air laden with lead fume moved as a plume from the bottom of the shaft to the top, past the breathing zone of workers in its path. These factors resulted in extremely high exposures to lead, although, as indicated previously, the data are inconclusive as to the relative contribution to exposure of the environment and failure of the control.

The fact that such technical difficulties in paint removal were encountered is underlined by inspections made of beams and other surfaces after the paint had been removed. It was estimated that at least some paint remained on the steel surface about 75 percent of the time. In about 10 percent of the cases a great deal of paint was visible. However rough these estimates are, the monitoring results are a clear indication that lead was present on the steel. To date, there have been no scientific studies that correlate the quantity of leaded paint on a steel surface with airborne lead levels generated when the surface is torch cut or welded. Intuitively, there is no compelling reason to doubt that, under certain conditions (enclosed space, little air movement), a small quantity of highly leaded paint ($>$ 35% by weight) on a surface could create a high exposure when heated with a torch.

The second difficulty, that of management of control implementation, also led to problems at both sites. At Bridge 2, two subcontractors working with different trades and crews (painters and ironworkers) were responsible for different tasks. The painting contractor was responsible for removing the paint, whereas the ironwork contractor was responsible for removing the beams (torch cutting). From the point of view of control implementation, the work was not well coordinated. As specified by contract, the paint was removed four inches on either side of the cut line, which had been marked previously by a project engineer. During torch cutting, however, the ironworkers did not always cut straight down the middle of the eight-inch strip, but, instead, cut diagonally from the top corner to the bottom corner. It is not at all unusual for the cut to be made in this fashion: a diagonal cut minimizes the binding of the steel when the beam is hoisted. At the Elevators, too, different subcontractors were responsible for paint removal and elevator demolition. Again, the work was poorly coordinated: the paint removal contractor did not anticipate or did not know where the torch cutters would be cutting the steel. During the actual work, torch cutters routinely cut outside of the area from which paint had been removed. Often, the steel section that had to be cut did not correspond to the areas from which paint had been stripped.

The data for rivet busting (Table II) indicate that the exposure at Bridge 2, although not significantly lower than those measured during uncontrolled rivet busting at Bridge 1(NC), did approach statistical significance. Conditions during uncontrolled rivet busting at Bridge 1 were similar to conditions during rivet busting with encapsulant at Bridge 2 in one very important way: at both sites the work was performed without containment. Because conditions were similar, some of the reduction in exposure can reasonably be attributed to use of the encapsulant.

The exposures at Bridge 1(C) for controlled rivet busting did not allow for statistical comparison to uncontrolled exposures at the same site because of the different exposure conditions. Nonetheless, the mean exposure at this site is well above the OSHA PEL. Three possible contributions to the excessive exposures at Bridge 1(C) can be postulated, although the relative contribution of any one factor has not been quantitatively explored. For one, the rivet busting at this site was done within a containment approximately 25 feet by 40 feet. Consequently, the dust and debris generated during rivet busting remained in the workers' immediate environment. Because this task creates a great deal of vibration of the steel beams and work surfaces, and because there is considerable air exhausted from the pneumatic tool, settled dust is easily and frequently reentrained into the workers' breathing zones.

Another contributor to exposures at Bridge 1(C) was the occasional use of a lance. Like a cutting torch, the lance burns at a very high temperature and generates lead fume. The lance was generally used for several minutes at a time at random intervals by a worker who was using the rivet buster as the main tool. Under these circumstances, it was difficult to isolate exposures caused by the lance. There were occasions, however, when one worker used the lance for a more extended period, approximately one hour. At such times, it was possible to measure the exposures generated by the lance alone. The results (Table IV) indicate high exposures which, when combined with those of rivet busting (as was the case for many samples), would elevate the levels above those expected from rivet busting alone. The fact that the task rivet busting sometimes entails the short-term use of heat is acknowledged in the discussion of the data presented in the preamble to the OSHA Lead in Construction Standard—Interim Final Rule.[1] Whatever its effectiveness in suppressing the generation and dispersal of dust, the encapsulant is useless as a protection against fume generation. The encapsulant is simply vaporized along with the paint. In fact, a possible third contributor to the elevated controlled exposures at Bridge 1(C) is the encapsulant used or, more precisely, its ineffectiveness. The encapsulant used at Bridge 2 contained an elastomeric compound specifically formulated for its anti-cracking properties. It could not be ascertained whether the encapsulant used at Bridge 1(C) contained such a compound, but observation of the work suggested that it was not designed to withstand the high impact of a rivet buster. The encapsulant cracked, chipped, and generated dust when subjected to the high impact of the pneumatic hammer.

As was the case with torch cutting, the management of controlled rivet busting had significant shortcomings. With attentive day-to-day management focused on health and safety, the problems with control implementation could have been identified, and simple interventions designed. For instance, more frequent cleaning of the platform would have reduced the amount of lead in the work environment. Monitoring of the performance of the encapsulant might have led to the introduction of one better suited for the job.

During the period when evaluation of the controls was being conducted at the three sites described, workers' blood lead levels were monitored, usually on a monthly basis. Results of the blood lead monitoring at Bridge 1(NC) have been reported elsewhere.[20] Ongoing analysis of the results of blood lead monitoring at all sites, which will be the subject of a future study, has shown that levels have remained by and large below 30 micrograms/deciliter. It is believed that these results were achieved largely by the use of personal protective equipment (principally respirators and work clothing), and by the availability of hygiene facilities at the sites where workers could wash before eating and at the end of the shift.

CONCLUSIONS AND RECOMMENDATIONS

The introduction of engineering and work practice controls to minimize exposures to hazardous substances is of relatively recent vintage in the construction industry. The ever-changing conditions of construction work present a particular challenge to the industrial hygienist and site safety professionals to monitor and supervise closely the efficacy of controls being used. The challenge is renewed at the start of every project, and during every new phase of a project.

This study has shown that the implementation of controls designed to protect workers from lead exposure during the rehabilitation of bridges and other steel structures has potential technical and managerial pitfalls which, if not considered, can undermine control efficacy. For the two tasks studied at these three sites, the results are not very encouraging.

The implementation of controls in construction is not as simple as selecting a control and using it. The efficacy of controls is not automatic, even when conditions are favorable, as they were at the study sites, which had experienced contractors, large contracts, and specifications which mandated and paid for the controls used. In addition, external conditions influenced positive contractor behavior: OSHA enforcement activities, insurance carrier initiatives, union involvement, a trained workforce. In spite of these conditions, the use of control technologies and work practices to protect workers was not integrated into the planning and day-to-day managment of the project. For this to happen in the complex construction environment, where the health endeavor is relatively new, a concerted effort at collaboration is necessary among management, engineers, industrial hygienists, suppliers, unions, and workers. Integration of control measures with the work process throughout the life of the project is critical. Before controls are activated, both management and workers should be trained so that they understand the rationale behind the controls and proper operating procedures. Without such training, recognition of problems in control implementation, and correction of these, are less likely to occur.

A basic tenet of industrial hygiene control philosophy is that a process can be controlled best when the control is designed into the process from its inception, at the blueprint stage. In the construction industry, owners and managers are challenged to collaborate with industrial hygienists and engineers to foster the use, and the correct use, of protective technologies from the beginning of planning a project, and throughout its duration, from blueprints, specifications and contracts, to project completion.

This study has identified important components of a viable plan to implement worker protection controls. These components include: (1) preplanning and coordination of control implementation among all responsible contractors and their work crews; (2) testing control efficacy via task-based exposure assessment, especially during the early phases of control implementation; (3) timely intervention when exposure assessment reveals that controls are not working effectively, combined with day-to-day management of the control implementation. The goal of the controls is to lower exposures and protect workers. In the rugged and dynamic construction environment, close attention must be paid to ensure that controls do the job for which they are designed.

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REFERENCES

1. Occupational Safety and Health Administration (OSHA), U.S. Department of Labor: 29 CFR Part 1926: Lead Exposure in Construction; Interim Final Rule. Fed Reg 58, (84): Tuesday, May 4, 1993. Washington, DC (1993).
2. Fischbein, A.; Leeds, M.; Solomon, S.: Lead Exposure Among Iron Workers in New York City: A Continuing Occupational Hazard in the 1980s. NY State J Med 84:445–448 (1984).
3. Spee, T.; Zwennis, W.: Lead Exposure During Demolition of a Steel Structure Coated with Lead-Based Paints. Scand J Environ Health 13:52–55 (1987).
4. Holness, D.L.; Nethercott, J.R.: Acute Lead Intoxication in a Group of Demolition Workers. Appl Ind Hyg 3(12):338–341 (1988).
5. Marino, P.E.; Franzblau, A.; Lilis, R.; Landrigan, P.I.: Acute Lead Poisoning in Construction Workers: The Failure of Current Protective Standards. Arch Environ Health 44(3):140–145 (1989).
6. National Institute for Occupational Safety and Health: NIOSH Alert: Request for Assistance in Preventing Lead Poisoning in Construction Workers. DHHS (NIOSH) Pub. No. 91-116a. NIOSH, Cincinnati, OH (1992).
7. Department of Transportation: Transportation Equity Act for the 21st Century (PL 105-178). U.S. Government Printing Office 869-036-00025-1. DOT (FHWA), Washington, DC (1998).
8. Hawkins, N.C.; Norwood, S.K.; Rock, J.C.: A Strategy for Occupational Exposure Assessment. American Industrial Hygiene Association (AIHA), Akron, OH (1991).
9. Ringen, K.; Englund, A.; Seegal, J.: Safety and Health in the Construction Industry. Ann Rev Public Health 16:165–188 (1995).
10. Weeks, J.L.; McVittie, D.J.: Construction Injury Hazards in Construction. Occup Med: State of the Art Rev 10(2):395–405 (1995).
11. King, W.R.: The Cost of Lead-Paint Removal. Cost Engineer 38(9):31–32 (1996).
12. Elliot, B.; Zanoni, P.; Ralle, E.; Fuller, B.: Lead Removal Project Uses Power Tools to Eliminate Containment Structure. Ind Hyg News Nov.: 22–23 (1997).
13. Valenti, J.; Wallace, D.E.: Tearing Down the Lead Monster: The Safe Demolition of the Williamsburg Bridge South Roadways. J Prot Coat Lin 15(1):46–57 (1998).
14. Goldberg, M.; Levin, S.M.; Doucette, J.T.; Griffin, G.: A Task-Based Approach to Assessing Lead Exposure Among Iron Workers Engaged in Bridge Rehabilitation. Am J Ind Med 31:310–318 (1997).
15. U.S. Code of Federal Regulations. Title 29, Part 1926, Section 354 (1996).
16. Greenspan, C.A.; Moure-Eraso, R.; Wegman, D.H.; Oliver, C.L.: Occupational Hygiene Characterization of a Highway Construction Project: A Pilot Study. Appl Occup Environ Hyg 10:50–57 (1995).
17. Susi, P.; Schneider, S.: Database Needs for a Task-Based Exposure Assessment Model for Construction. Appl Occup Environ Hyg 10:394–399 (1995).

18. U.S. Department of Labor, Occupational Safety and Health Administration: OSHA Instruction CPL 2-2.58-December 13, 1993. Office of Health Compliance Assistance, Washington, DC (1993).
19. Department of Transportation (FHWA): The Status of the Nation's Highway Bridges. Washington, DC, U.S. Government Printing Office (June 1995).
20. Levin, S.M.; Goldberg, M.; Doucette, J.T.: The Effect of the OSHA Lead Exposure in Construction Standard on Blood Lead Levels Among Iron Workers Employed in Bridge Rehabilitation. Am J Ind Med 31:303–309 (1997).
21. Reynolds, S.J.; Fuortes, L.J.; Garrels, R.L.; et al.: Lead Poisoning Among Construction Workers Renovating a Previously Deleaded Bridge. Am J Ind Med 31:319–323 (1997).
22. Engström, K.; Engström, B.; Henriks-Eckerman, M.: Evaluation of Exposures During the Welding or Flame-Cutting of Painted Steel. Scand J Environ Health 14(suppl. 1):33–34 (1988).