Environmental and Biological Monitoring for Lead Exposure in California Workplaces

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Abstract: Patterns of environmental and biological monitoring for lead exposure were surveyed in lead-using industries in California. Employer self-reporting indicates a large proportion of potentially lead-exposed workers have never participated in a monitoring program. Only 2.6 percent of facilities have done environmental monitoring for lead, and only 1.4 percent have routine biological monitoring programs. Monitoring practices vary by size of facility, with higher proportions in industries in which larger facilities predominate. Almost 80 percent of battery manufacturing employees work in job classifications which have been monitored, versus only 1 percent of radiator-repair workers. These findings suggest that laboratory-based surveillance for occupational lead poisoning may seriously underestimate the true number of lead poisoned workers and raise serious questions regarding compliance with key elements of the OSHA Lead Standard. (*Am J Public Health* 1990; 80:921–925.)

Introduction

The United States Public Health Service goals for 1990 include the virtual elimination of occupational heavy metal poisoning.[1] Ability to assess the extent to which occupational health programs are effective in achieving this goal rests on the existence of an adequate surveillance system.[2] Adult lead poisoning is virtually always associated with work and is due to a single causative agent. Because early lead toxicity is reversible, and patients may be asymptomatic or have vague symptoms, biological monitoring for lead by analysis of blood lead levels is particularly useful.[3] Biological and environmental monitoring for lead are well-established, and required by the California and federal Occupational Safety and Health Administration (OSHA) Lead Standards.[4] California now requires laboratories to report elevated blood lead levels to the State Department of Health Services.[5]

However, little is known regarding what proportion of workers at risk of lead exposure participate in a biological monitoring program that would allow them to be identified through a laboratory-based surveillance system. Although index cases could be identified if even a small proportion of workers were monitored, a laboratory-based system with low sensitivity would reduce the ability to evaluate the true magnitude of the problem, identify trends, and/or properly target or evaluate interventions. An estimate of the sensitivity—or ability to identify workers with elevated blood levels—of such a laboratory-based system is important, if registry data are to be used for monitoring trends or targeting interventions.

The goals of the survey herein reported were to assess monitoring practices for lead exposure in California work sites, and to evaluate the extent to which a laboratory-based occupational lead poisoning surveillance system would fulfill surveillance functions.

Methods

Selection of Sample

Four pre-existing data bases were used to identify 505 unique four-digit Standard Industrial Codes (S/C) with potential for lead use: the National Institute for Occupational Safety and Health (NIOSH) National Occupational Hazard Survey 1972–74 (NOHS)[6]; federal OSHA inspections, 1979–82, provided by Dr. John Froines (UCLA) from federal OSHA Management Information Service Data; Cal/OSHA Lead Standard violators, 1979–85, provided by the California Department of Industrial Relations; and the New York Heavy Metals Registry, 1981–85.[7] A list of employers in California in these SIC codes was obtained from the California State Employment Development Department[8]; these 236,564 reporting facilities, employing 5,837,156 individuals, comprised the sampling frame for the survey.

A weighted sampling scheme, designed to be free of systematic bias, was used to enrich the survey sample with lead-using industries[9]: seven SIC codes were selected as "special interest" industries based on past evidence of high levels of ambient lead and high proportions of workers exposed. The remaining codes were categorized into 165 "high" and 333 "low" exposure groups, based on either federal OSHA inspection data, or judgment of experienced industrial hygienists. Facilities were stratified by total number of employees. The predicted number of lead-exposed workers at each facility was estimated, based on NOHS data on the proportion of exposed workers in each SIC code. Sampling with probability proportional to size[10] was conducted, using predicted numbers of lead-exposed workers as the measure of size.

Survey of Employers

Information was obtained from employers through two questionnaires administered by mail and telephone interview. The initial questionnaire was designed to identify the presence or absence of lead use, the total number of employees at the facility, and a contact name for the second questionnaire. The second questionnaire was administered only to those employers reporting lead use, and requested a list of all processes involving lead use at the facility, the number of workers involved in each process, and information about environmental and biological monitoring practices at the facility.

Categorizing Survey Responses

Lead-using processes described by employers were categorized into 12 specific processes, and three more general exposure categories (high/medium/low) based on anticipated level and frequency of exposure as judged by eight experienced industrial hygienists. It should be noted that the exposure categories utilized in the analysis were *independent*

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of the SIC categories in the initial sampling scheme. Responses were also categorized by facility size and unionization.

Analysis

The statistical analysis incorporated information on the weighted sampling scheme to produce valid and unbiased statewide estimates of numbers and percentages.[11] The standard errors for each estimate reflect the variability that arose from taking a sample; estimation of small numbers frequently leads to large relative standard errors.

Results

Response Rates

Of the 1,165 unique facilities in the initial sample, 1,089 (93.5 percent) completed the first questionnaire. Of these, 539 employers reported using lead or lead-containing materials and 521 (96.7 percent) of this group completed the second questionnaire.

Occupational Lead Exposure

In California, 52,700 facilities (7.7 percent of all facilities) were estimated to use lead. An estimated 230,000 employees work in positions in which their employers report a lead-using process. This represents almost 2 percent of California's total work force.

Environmental Monitoring

Only 2.6 percent of facilities engaged in lead-using processes were estimated to have ever done any environmental monitoring for lead. These facilities employed an estimated 205,000 workers, 10.7 percent of California workers exposed to lead. The proportion of facilities with environmental monitoring varies directly with the number of employees (Table 1).

The percent of potentially exposed employees in positions which have had environmental monitoring performed varies according to lead-using process (Table 2). For example, less than 1 percent of workers soldering pipes or painting with lead-based paints worked in monitored positions, in contrast to 80 percent of battery manufacturing workers.

In general, the proportions of employees in monitored positions are higher in unionized than non-unionized facilities; this was not true in the 100–499 employee size category, perhaps due to the large number of monitored non-unionized electronics industry solderers in this size category (data available on request to author).

TABLE 1—Estimated Number of Facilities with Lead Use in California, and Estimated Number with any Environmental Monitoring of Exposure to Lead, by Facility Size

Facility Size	Facilities with lead use N	Facilities with any environmental monitoring N	Facilities with any environmental monitoring % (SE)
1–19 employees	33,410	32	0.10 (0.04)
20–99 employees	12,753	292	2.29 (1.23)
100–499 employees	4,112	405	9.85 (4.10)
500 or more employees	2,402	630	26.22 (7.12)
Total	52,677	1,359	2.58

Of those workers with high/daily exposures, 37 percent work in positions which had been monitored, versus only 2.6 percent in positions with high/weekly exposures. Radiator repair was the most commonly reported process with high/daily exposures for which environmental monitoring had never been performed.

The characteristics of process, size, and unionization appear to be interrelated. For example, an estimated 88 percent of radiator repair employees work in small (1–19 employees) facilities, while 87 percent of battery manufacture workers are employed in larger (100–499 employees) facilities. Less than .6 percent of the smallest facilities' workers are unionized, versus nearly 50 percent of those at the largest size facilities. A significant proportion of environmental monitoring appears to be done by company-employed industrial hygienists. At large facilities, this was true for 80 percent of monitored workers. For the smallest companies, about 57 percent of monitoring was conducted by private contractor, 19.7 percent by insurance companies, and 23.2 percent by Cal-OSHA (compliance or consultation). Less than one-half of monitored positions had been evaluated in the year preceding the survey; in over 17 percent, monitoring was most recently performed in 1980.

Biological Monitoring

Only 1.4 percent of facilities engaged in lead-using processes, and about 2.6 percent of potentially lead-exposed workers were estimated to have routine biological monitoring programs. Marked variation in biological monitoring practices was noted among the seven "special interest" SIC groups (Table 3). Fifty-three percent of the blood lead analyses performed as part of routine biological monitoring programs are performed by California laboratories, with the rest being done by out-of-state laboratories. The proportion of employees receiving biological monitoring varies with size of facility and potential for high lead exposures (Table 4).

Discussion

There are several possible limitations in the methodology employed in this survey. Results were based exclusively on data from employer self-reporting of lead use, number of workers exposed, and monitoring practices. No attempts were made to validate the information received from employers.

It is possible that some employers did not report actual use of lead on the first survey, and were subsequently excluded; this should not have led to an underestimate of the proportion of workers monitored.

Workers conducting different job activities may have been lumped together as "monitored", even if only one activity in an area has actually been assessed. Also, full- and part-time workers may have been lumped together. Some battery manufacturers included clerical workers among those potentially exposed. In several facilities, these employees received biological monitoring, but none of their positions were environmentally monitored. This may explain discrepancies between environmental and biological monitoring prevalence (e.g., 79 percent of battery workers are in environmentally monitored positions, while 95 percent are biologically monitored).

In the absence of actual exposure data for each work site, the extent to which monitoring actually should be conducted in the sampled facilities cannot be determined. It is possible that monitoring was not done because exposures are below those levels that warrant it. Although our survey

TABLE 2—Estimated Number of Lead-exposed Employees, by Occurrence of Environmental Monitoring at any Time in the Past by Type of Lead-using Process

Lead-using Process	Employee working in position where environmental monitoring ever done? Yes N	Yes % (SE)	No N	No % (SE)	Total employees exposed to lead N
Soldering, except pipes and sheets	18,931	16.59 (3.98)	95,169	83.41 (3.98)	114,100
Dispensing leaded gasoline	129	0.42 (.42)	30,829	99.58 (0.43)	30,958
Soldering pipes and sheets	116	0.52 (0.31)	22,234	99.48 (0.31)	22,350
Cable cutting and splicing	374	2.72 (3.52)	13,393	97.28 (3.52)	13,767
Painting with lead-based paint	92	0.72 (0.53)	12,601	99.28 (0.53)	12,693
Painting with lead-based inks	0	0	7,496	100.00	7,496
Casting or melting lead or jointing	975	21.71 (7.86)	3,517	78.29 (7.86)	4,492
Radiator repair[a]	49	1.14 (0.79)	4,271	98.86 (0.79)	4,320
Welding metal alloys or surfaces painted with lead based paints	280	6.79 (2.55)	3,844	93.21 (2.55)	4,124
Machining, grinding or sanding surfaces painted with leaded paints	254	7.92 (7.23)	2,954	92.08 (7.23)	3,208
Battery manufacture	1,477	79.62 (8.65)	378	20.38 (8.65)	1,855
Other process with lead use	1,814	18.01 (6.41)	8,258	81.99 (6.41)	10,072
Total	24,491	10.67	204,944	89.33	229,435

[a]Includes workers in SICs 7528 and 7539

instrument did not directly assess this possibility, it seems unlikely that this would be true in the "high" exposure categories. There is no evidence that workers in smaller facilities are likely to have lower exposure than those in larger plants, suggesting that the lack of monitoring in small facilities is due to factors other than lack of exposure.

Few other data on biological and environmental monitoring are available. Ratcliff, Halperin, *et al.*[12] utilized data from NOHS to demonstrate that there is no consistent evidence that workers potentially exposed to chemical hazards are more likely to receive screening than other workers, but that such screening is more likely in large facilities. This is consistent with the results of the current survey.

However, the NIOSH study estimated that almost 25 percent of lead-exposed workers receive periodic monitoring, and that 18 percent receive blood tests—a substantially higher proportion than seen in this survey. The NOHS survey was done prior to promulgation of the OSHA Lead Standard; it asks about any blood test, without reference to specific biological monitoring for a particular substance. Also, the NOHS appears to have counted all employees as receiving blood tests if any did.[6] In contrast, the current study asked about monitoring in workers specifically identified as working in lead-using jobs. Therefore, the results reported here are likely to constitute a more accurate assessment of monitoring for lead in lead-exposed workers.

The lack of environmental or biological monitoring in a majority of potentially lead-exposed workers may result in inability to identify workers or work sites where interventions could prevent cases of occupational lead poisoning. The widespread lack of monitoring makes surveillance for trends, assessment of the true magnitude of the problem, or evaluation of the efficacy of interventions virtually impossible. A laboratory-based surveillance system for lead over-exposure would be limited to the identification of two categories of workers: those with overt clinical signs of lead poisoning for whom an alert clinician has ordered a blood lead test, and the small minority of workers who participate in a routine monitoring program. These categories are likely to represent two extremes: the very worst cases, and those who are likely to have more access to medical and industrial hygiene services by virtue of being enrolled in a monitoring program. The large majority of lead-exposed workers remain excluded, and thus inaccessible to the surveillance system.

These limitations do not undercut the ability of a laboratory-based surveillance system to identify important index cases of lead poisoning.[13]

Our data imply a significant lack of compliance with the monitoring provisions of the OSHA Lead Standard, which were constructed specifically to facilitate timely interventions. The relatively high prevalence of monitoring in battery manufacture may be attributable to past California OSHA compliance efforts specifically directed at biological monitoring activities in this industry.* Implementation of recommendations[14] that would require employers to report results of medical examinations and exposure monitoring to OSHA could complement laboratory-based surveillance and assist OSHA in identifying industries and employers who appear to be out of compliance with monitoring requirement.

*Personal communication, J. Simonowitz, RN, Cal/OSHA Medical Unit.

TABLE 3—Estimated Number of Employees Who are Receiving Routine Biological Monitoring by SIC Code

Lead-using SIC Codes	Employees potentially exposed to lead[a] N	Employees receiving routine biological monitoring N	Employees receiving routine biological monitoring % of exposed (SE)
Estimated exposure below action level[b]	107,322	997	0.93 (0.46)
Estimated exposure above action level, excl. below[b]	88,262	2,475	2.80 (1.08)
1711: Plumbing, heating and air conditioning	22,742	0	0
3341: Secondary smelting non-ferrous metals	393	132	33.59 (12.84)
3691: Storage battery manufacture	1,850	1,762	95.25 (3.68)
3731: Shipbuilding and repair	1,089	477	(43.79) (28.07)
7538: Automotive repair shops	6,561	1	0.02 (0.02)
7539: Radiator repair shops[c]	903	70	7.95 (3.95)
7692: Welding repair	312	0	0
Total	229,434	59,142	2.58

[a]Based on employer survey report.
[b]Based on industrial measurements from fed/OHSA or judgment of industrial hygienist.[9]
[c]Companies in this SIC without "radiator" in the name excluded.

Approximately 12 percent of potentially lead-exposed individuals are in construction jobs which are not covered by the Lead Standard.** In this segment, monitoring is extremely limited—for example, no plumbing employees were reported to have biological monitoring for lead, and less than 1 percent of those painting with lead-based paints worked in environmentally monitored positions. Yet reports indicate a serious continued potential for lead poisoning in the construction industry.[13]

Our findings suggest a need for new strategies for enforcement and enhanced compliance with the existing occupational lead standard, as well as a need for expansion of the standard to cover construction workers. Increased employer and worker education regarding lead and the lead standard are also warranted. Education and targeted compliance may be particularly important in small and non-unionized shops.

In conclusion, only a small proportion of the large number of potentially lead-exposed workers in California work in positions which have ever had industrial hygiene monitoring; an even smaller proportion participate in a routine biological monitoring program. Workers in small and non-unionized facilities are especially unlikely to participate in any type of monitoring program. The failure of employers to establish legally mandated environmental and biological monitoring programs severely limits the ability of laboratory-based surveillance programs to adequately fulfill critical functions of occupational disease or exposure surveillance. This, in turn, severely impedes our progress in the prevention and ultimate elimination of occupational lead poisoning.

TABLE 4—Estimated Percent of Lead-exposed Employees Receiving Routine Biological Monitoring by Highest Level of Potential Exposure Reported at Their Workplace and by Facility Size

Level of exposure	Number of employees at facility 1–19	20–99	100–499	>500	All facilities
High	0.52	9.90	48.99	15.90	16.34
Moderate	0	0	8.38	1.01	1.16
Low	0	0	0.24	0.10	0.05
All facilities	0.06	0.55	11.27	4.09	2.58

**The construction industry is required to meet other OSHA standards limiting lead exposure to 200μg/m³, but is not required to provide air or blood monitoring.

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Accelerated Nursing Program at JHU Quadruples Enrollment in 2nd Year

The shortage of nurses in the United States will be eased by former park rangers, Peace Corps volunteers, teachers, flight attendants, and even an ex-circus clown, according to word received from the Johns Hopkins Medical Institutions. Enrollment in an accelerated nursing program there has quadrupled during its second year.

The program, initiated last year in response to the nationwide need for high quality nurses, allows individuals who already hold a bachelor's degree in some other field to earn a bachelor's in nursing in just 15 months—nearly half the time it ordinarily takes to become a registered nurse.

The accelerated program was established to attract a new pool of bright students into the nursing profession by providing an intensified curriculum that responds to their academic and clinical needs. While 13 in the current class have just graduated from college, the majority of students are choosing nursing after working at a previous career, such as those listed above.

The current class of 60 future nurses at JHU includes 10 men. Students range in age from 20–51 years, come from 17 different states, and hold degrees from Stanford, Duke, Antioch, Smith, the University of Virginia and the University of Chicago, among other institutions. Ten members of the new class hold master's degrees.

More than one in every 10 budgeted positions for registered nurses in US hospitals is vacant at the present time, and as many as one in five budgeted nursing home positions is empty. It has been estimated that it would take about 130,000 full-time registered nurses to fill vacant positions in hospitals and nursing homes across the nation.

For further information, contact Johns Hopkins Medical Institutions, Office of Public Affairs, 550 North Broadway, Suite 1100, Baltimore, MD 21205. Tel: (301) 955-6680.