Lead Exposure in Mexican Radiator Repair Workers

Ronald Dykeman,[1] Guadalupe Aguilar-Madrid,[2,3] Tom Smith,[1] Cuauhtemoc Arturo Juárez-Pérez,[2] Gregory M. Piacitelli,[4] Howard Hu, MD,[1,5]* and Mauricio Hernandez-Avila[2,6]

Background *Lead exposure was investigated among 73 Mexican radiator repair workers (RRWs), 12 members of their family (4 children and 8 wives), and 36 working controls. RRWs were employed at 4 radiator repair shops in Mexico City and 27 shops in Cuernavaca and surrounding areas.*

Methods *Exposure was assessed directly through the use of personal air sampling and hand wipe samples. In addition, industrial hygiene inspections were performed and detailed questionnaires were administered. Blood lead levels were measured by graphite furnace atomic absorption spectroscopy (AAS).*

Results *The mean (SD) values for blood lead of the RRWs, 35.5 (13.5) μg/dl, was significantly greater than the same values for the working controls, 13.6 (8.7) μg/dl; $P < 001$. After excluding a single outlier (247 μg/m^3), air lead levels ranged from 0 to 99 μg/m^3 with a mean (SD) value of 19 (23) μg/m^3 (median = 7.9 μg/m^3). In a final multivariate regression model of elevated blood lead levels, the strongest predictors were smoking (vs. non-smoking), the number of radiators repaired per day on average, and the use (vs. non-use) of a uniform while at work, which were associated with blood lead elevations of 11.4 μg/dl, 1.95 μg/dl/radiator/day, and 16.4 μg/dl, respectively (all $P < .05$). Uniform use was probably a risk factor because they were not laundered regularly and consequently served as reservoir of contamination on which RRWs frequently wiped their hands.*

Conclusions *Lead exposure is a significant problem of radiator repair work, a small industry that is abundant in Mexico and other developing countries.* Am. J. Ind. Med. 41:179–187, 2002. *© 2002 Wiley-Liss, Inc.*

KEY WORDS: lead; radiator repair; industrial hygiene; occupational disease

INTRODUCTION

In the mid- to late 1980s, radiator repair in the US was identified as an occupation associated with high lead exposure and blood lead levels in radiator repair workers (RRWs) [Goldman et al., 1987]. Subsequent studies have confirmed these findings [Lussenhop et al., 1989; Maizlish et al., 1990; Bellows and Rudolph, 1993; Nunez et al., 1993; Dalton et al., 1997] and demonstrated that many RRWs have blood leads in excess of the US OSHA standard of 40 μg/dl. Blood lead levels of this magnitude place RRWs at increased risk for the adverse health effects of lead.

Despite efforts to police the industry in the US, smaller shops that are in violation of the OSHA standard are not

[1]Occupational Health Program, Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts
[2]Center for Population Research, National Institute of Public Health, Cuernavaca, Morelos, Mexico
[3]Mexican Institute of Social Security, Office for Work and Health, Mexico City
[4]Division of Surveillance, Hazard Evaluations and Field Studies, National Institute for Occupational Safety and Health, Cincinnati, Ohio
[5]Channing Laboratory, Department of Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts
[6]Division of Occupational and Environmental Health, Rollins School of Public Health, Emory University, Atlanta, Georgia
Contract grant sponsor: NIOSH Education and Research Center; Contract grant sponsor: NIEHS Center; Contract grant number: ES0002.
*Correspondence to: Howard Hu, MD, Channing Laboratory, Department of Medicine, Brigham and Women's Hospital, Harvard Medical School, 181 Longwood Avenue, Boston, MA 02115. E-mail: howard.hu@channing.harvard.edu

Accepted 10 September 2001

DOI 10.1002/ajim.10044

easy to identify. Radiator repair is often a family enterprise or in an area not well serviced by public health surveillance. As recently as 1997, Dalton et al. [1997] reported blood lead levels as high as 94 μg/dl with a median of 29 μg/dl among 63 RRWs in Colorado (8 of whom were not directly involved in repair). The California State Department of Public Health has been proactive in terms of surveillance in higher risk lead exposure industries. Through their early reporting programs, radiator repair was identified as the highest risk lead exposure occupation compared to all others in the state. A special effort to encourage shop participation in a surveillance program was launched and is felt to have been successful [Bellows and Rudolph, 1993].

As described by Dalton et al. [1997], the process of radiator repair involves heating lead solder to its melting point (upwards of 300°C depending on the solder type). Solder is essentially the lead-containing adhesive used to link up new sections of radiator in damaged sections and to patch small holes. The process of soldering volatilizes lead into lead fume, thereby providing an opportunity for inhalation. Particle sizes of 0.5 μm or smaller can be efficiently absorbed directly through the lung while larger particles can be cleared from the respiratory tract and swallowed [Klaasen et al., 1996].

The use of grinders and metal brushes generates and disseminate lead dusts. Such dusts contaminate surfaces and clothing, facilitating ingestion through hand-to-mouth activity. Contamination of the home environment may occur as a result of bringing lead home on clothes as noted in the construction industry [Piacitelli et al., 1997].

Mexico is a country in which the used car and car repair market create a large demand for radiator repair and radiator reconditioning. However, to date there have been no studies of this industry in Mexico and the health and working conditions of Mexican RRWs remains unknown.

This study was undertaken to characterize lead exposure in Mexican RRWs. Outcomes that were studied included levels of lead in blood, air, and hand wipe samples. We also collected information on work and personal habits, conducted multivariate analyses to identify the most important correlates of elevated blood lead levels in RRWs, and collected blood lead levels or associated family members and working controls. All protocols were approved by the Institutional Review Board of the National Institute of Public Health of Mexico.

METHODS

Subject Selection

Radiator repair shops were identified randomly through visual spotting while driving and walking through the automotive repair areas of Mexico City as well as Morelos, a small state within 1 hr driving distance of Mexico City comprising the cities of Cuernavaca, Jiutepec, Ocotepec, and Cuautla. Owners of radiator repair shops and mechanical garages were asked if they knew of other radiator repair shops in the vicinity. As this business is dependent on referral from auto repair garages, radiator repair shops were relatively easy to locate. Every shop that was identified in this manner was approached with the exception of those in Mexico City, where there were more sites than we had resources to sample; here, we concentrated only on large shops.

It was explained to all shop owners and workers that the nature of the study was to determine lead exposure related to the use of lead solder in the course of their work. We also expressed our interest in the amount of lead to which their families were exposed. Participation was voluntary and all results were kept confidential.

In the Cuernavaca area, 30 shops were identified, of which 27 of the shop owners agreed to participate and 3 refused stating "they did not have time." In Mexico City, 8 were identified, of which 4 of the shop owners agreed to participate and the others refused stating lack of interest or fear of legal actions.

Over the following 12 weeks, our team revisited the shops (often on several occasions), interviewing employees, drawing blood, and conducting environmental measurements. A total of 73 RRWs, whose primary function in the workplace was to fix radiators, were included in the study. Fifteen workers located at the same site in proximity to radiator repair but who did not directly repair radiators were identified and were included as a separate group. Samples were also collected from four children and eight wives. A control group was identified including 36 maintenance workers (electricians, and building maintenance personnel) at the National Institute of Public Health in Mexico (located in Cuernavaca) and the nearby campus of the National Autonomous University of Mexico (UNAM). Controls underwent blood sample collection, hand wipe, and questionnaire measurements.

Data Collection

Venous blood samples were obtained from workers and family members wishing to participate. Subjects were informed of the nature of the study and the reason why blood collection was necessary. Consent was obtained. A detailed washing protocol was employed prior to blood collection. Workers were told to wash initially with tap water to remove any large debris. They were then scrubbed down twice using antibacterial soap and rinsed with bottled water purchased at local supermarkets. Bottled water was used in efforts to minimize potential lead contamination from the water supply at the shops. The site was then prepared with alcohol prior to phlebotomy. For children, sites were prepared in a similar fashion and butterflies with 25 gauge needles were used. Samples were collected from 73 RRWs, 36 controls, 8 spouses, and 4 children.

Five personal air samplers were used to collect individual measurements "AMETEK MG 4" personal air pumps (Ametek, Station Square, Paoli, PA). A steel ball rotameter (Matheson 603) was used as the field calibration instrument. The rotameter was calibrated for the altitudes at which sampling was conducted. Findings were standardized to 70°F and 760 mmHg.

Sampling protocols for measurement of inorganic lead in air were utilized as described in NIOSH methods 7105 (1994). Flow was calibrated to between 2 and 4 L/min (target 2.5). Nitrocellulose filters of 37-mm width and 8-μm pour size were used as the collection medium. These filters came pre-loaded into plastic cassettes (Sample Collection Media [SKC], Inc). A second flow reading was recorded following sampling. The two readings were averaged to yield the final flow rate to compensate for any drift (there was a $<5\%$ difference between pre- and post-sampling flow rates with the exception of two pairs of values which differed by 6 and 11%). Field blanks were collected by handling filters in the same fashion as the filters used for sampling i.e., capping and recapping, then were stored and transported with the samples until final analyses was performed. Sampling times ranged from 75 to 557 min depending on each worker's workload and availability to participate. A total of 60 useable samples were collected, of which 51 were from RRWs. Air samples were analyzed for lead by flame atomic absorption spectroscopy (AAS) using NIOSH Method 7082 (1994) by an AIHA-accredited laboratory (DataChem, Inc., Salt Lake City, Utah). If a sample result was below the analytical limit of detection (LOD) for Method 7082 (nominally 3 μg), then the sample was re-analyzed by graphic furnace AAS using NIOSH Method 7105 which has a lower LOD (nominally .05 μg). The LOD was calculated individually for each batch of samples and therefore varied over time and by the type of sample.

Hand wipe samples were obtained mid-day pre- and post-washing just prior to eating. The method employed for collection was the NIOSH method 9100 (1994) for surface wipe samples modified for hand measurements. Individually wrapped Wash & Dry toilettes were passed to each worker by pulling the tab and exposing the corner of the toilette. The worker unfolded the toilette placing it flat out in his or her palm. The subject would then begin wiping each hand while personnel demonstrated the technique, wiping the palmar, dorsal, digit, inter digit areas, and mid wrist crease (right hand then the left) allowing 30 sec for each hand. The sample was folded and deposited in a ziplock bag. A tracing of the hand to the wrist was collected to estimate surface area. The worker was instructed to wash their hands with soap and water as they normally would and a second wipe was collected in the same manner as the first. Fifty-five pairs of worker samples, 13 pairs of area worker samples, and 23 pairs of control samples were collected. This sampling preceded the preparation required for phlebotomy.

Field blanks were collected by opening the package in the same locations as the sample collection and dropping the wipe into the ziplock container without any further skin contact. Handwipe samples were analyzed by the same laboratory that analyzed the air samples and using the same methods (NIOSH Methods # 7082 and # 7105).

Responses to questions addressing occupational and home exposures, hygiene, demographics, and family behaviors were collected. Sixty-two RRWs and 37 controls completed the questionnaire. Inspections that focused on a general checklist of ventilation, personal protective equipment (PPE), general hygiene, children in the work place, evidence of food, hand-washing station etc. were also conducted at each of the 24 shops.

All subjects who participated in this study received their blood lead results with proper health counseling.

Data analysis

Data were entered twice to minimize errors using Epi Info and then transferred to STATA (Version 6.0). Twelve items on the questionnaire regarding demographics, personal hygiene habits, frequency of radiator repair, and use of glazed pottery at home were selected as potential determinants of blood lead levels for further analysis. Univariate analyses was performed to generate descriptive statistics. Relationships between blood lead levels and potential determinants were explored using *t*-tests, analysis of variance, and multivariate regression models.

RESULTS

Walk Through Inspections

Results of the walk through inspections are summarized in Table I. All of the shops surveyed had openings to the out-of-doors. There were no local exhaust ventilation systems over workstations in any of the shops. Cooling or pedestal fans were present in many shops, but they were often non-functioning or used primarily for blowing air across the workers to increase cooling rather than for removal of contaminants from the air. There were wide variations in the layout from shop to shop, making them difficult to group by configuration. The larger shops in Mexico City were out-of-doors but partially under canopies. Smaller shops were located in small buildings opening to the street, while others were located in the backyards of the workers' homes, and some were attached to the primary family dwelling.

Children and or other family were present in 45.8% of the shops. Hand wash stations were present in 58.3% of the shops; however, it was obvious that many were not being used and workers tended to wash in the lead-contaminated water of the cooling baths where radiators are submerged to check for leaks. Eating or evidence of eating was noted in

TABLE I. Results of Walk Through Inspections in 24 Mexican Radiator Repair Shops

Ventilation	Present (%)
Passive ventilation windows/doors	24 (100)
Local exhaust ventilation	0 (0)
General ventilation	3 (12)
Other protection	
Respiratory protection	3 (12)
Skin protection uniform	3 (12)
Evidence of eating at work site	21 (87)
Children present	11 (45)
Other family present	11 (45)
Hand wash station	14 (58)
Tobacco smoking on site	8 (33)

87.5% of the shops. Only one out of the 24 shops evaluated provided PPE. This included aprons and gloves worn by some of the workers, the use of which may have been influenced by our presence.

Blood Lead Levels

A comparison of blood lead levels among study participants (Table II and Fig. 1) revealed that the 73 RRWs had mean (SD) values for blood lead of 35.5 (13.6) μg/dl, which was significantly higher than the same value for the controls [13.6 (8.7) μg/dl; $P < .0001$], the RRW wives, 13.6 (3.4) μg/dl, and the RRW children 20.5 (13.3) μg/dl.

Of the 73 RRWs, we had some questionnaire data on 59 subjects and complete questionnaire information on 47. There was no significant difference between the mean (SD) value for blood lead of these 47 individuals, 35.6 (13.4) μg/dl, and the mean (SD) value for blood lead of the 26 workers who did not have complete information on the questionnaire or who did not fill one out, 35.2 (14.2) μg/dl.

In bivariate analyses (Table III), blood lead levels were higher by an at least marginally significant amount ($P < .15$) in smokers (vs. non-smokers), subjects repairing ≥ 5 radiators/day (vs. subjects who repaired 1–4 radiators/day), subjects who washed their hands < 5 times/day (vs. subjects who washed their hands ≥ 5 times/day), subjects who used a uniform (vs. subjects who did not use a uniform), and subjects who reported washing their faces before lunch (vs. subjects who did not report such activity).

In a multivariate model that included all five of these covariates and then eliminated covariates with P-values $> .05$ (Table IV), a greater number of radiators repaired/day, smoking, and use of a uniform emerged as the most important correlates of higher blood lead levels. Including age into the models resulted in no meaningful change.

Air Lead

With respect to the air lead measurements, after excluding an extreme outlier (247 μg/m^3), the remaining values ranged from 0 to 99 μg/m^3 with a mean of 19.1 μg/m^3, median of 7.9 μg/m^3, and a geometric mean of 9.2 μg/m^3. The measurements were taken when the subjects were engaged in repairing between 0 and 7 radiators on the day of measurement.

The log transformed values of air lead had a roughly linear relationship with the number of radiators repaired over the air-sampling interval (Fig. 2). The regression relationship for natural logarithm of air lead versus radiators repaired per day was $\ln(\text{air}) = 1.33 + 0.426$ number/day. A worker repairing greater than three radiators/day would be expected to have a TWA exposure of greater than 30 μg/m^3, placing them above the limit requiring surveillance by the US OSHA standards. A workload of four radiators per day would place their TWA above 50 μg/m^3, which would mandate the use of respirators in the US.

Hand Wipe Results

Results from the hand wipe study are tabulated in Table V. Using non-parametric methods (Wilcoxon Rank

TABLE II. Age and Blood Lead Levels Among Mexican RRWs, Control Subjects, Spouses and Children of RRWs, and Other Workers in the Immediate Area not Repairing Radiators

	Age (years)		Blood lead levels (μg/dl)		
Study subgroup	N	Mean (SD)	Mean (SD)	Median	Range
RRWs Mexico	73	33.2 (11.7)	35.5 (13.5)[a]	34.2	6.7–79.4
Controls	36	35.8 (9.6)	13.6 (8.7)	10.7	4.0–38.5
Other area workers	16	39.5 (12.2)	20.7 (16)	16	5.4–60.1
Children	4	n/a	20.5 (13.3)	15.7	10.8–39.8
Wives	8	n/a	13.6 (3.4)	14.1	8.8–18.4

[a] $P < 0.0001$ in comparing mean blood lead of RRWs to each of the other groups.

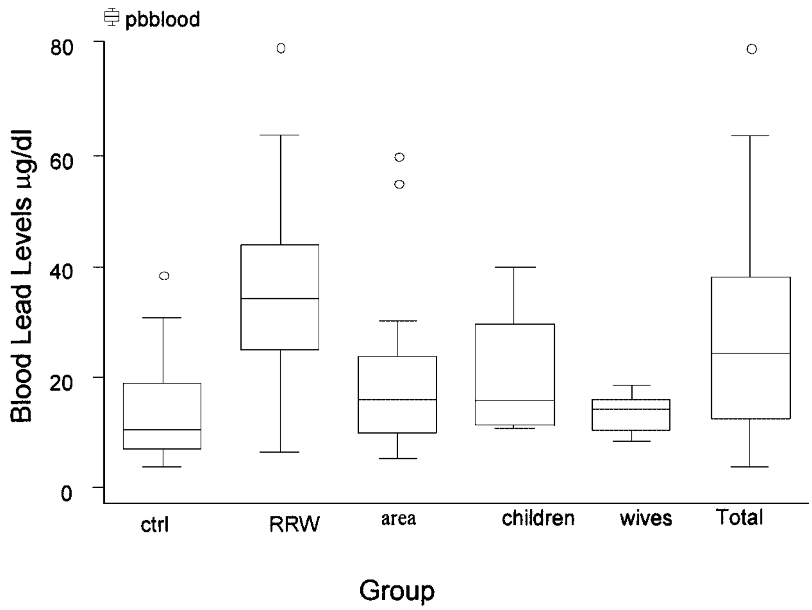

FIGURE 1. Blood leads among Mexican radiator workers, controls, other workers in the area of radiator repair, children, and wives.

Sum Test) the median lead contamination measured in 55 RRWs (490 µg/Towellet) was significantly greater than that of the other 13 area workers who had a median of 190 µg/Towellet ($P < .05$). Both the RRWs and the area workers had higher hand lead burdens compared to controls ($P < .001$ and $P < .0001$, respectively).

The percent of lead contamination removed through hand washing as determined by the difference in the amount of lead present on the second wipe (post-wash) compared to the first (pre-wash) did not differ across all groups. The data suggest that hand washing consistently reduces the amount of lead extractable by a second towellet by ~70–80%, with the median value for RRWs decreasing from 490 to 80 µg/Towellet after washing.

DISCUSSION

Compared to other studies summarized in Table VI the blood lead levels among Mexican RRWs appear similar over all to those observed in US RRWs. Bellows and Rudolph [1993] felt that lower blood lead levels in California RRWs compared to other geographical locations studied in the US may be a result of good natural ventilation as the climate in Los Angeles County was favorable enough to leave doors and windows open. This may be true for Mexico as well, although the effect may be offset by higher background environmental lead levels from the known, albeit declining, combustion of leaded gasoline in Mexico. Dalton et al. [1997] reported that the median number of radiators repaired per day in shops they surveyed was six. The comparable figure in our study was four; however, Mexican RRWs may be getting the same or possibly more lead exposure from fixing fewer radiators due to their technique or shop conditions.

Thirty-eight percent of the 73 RRWs we studied had blood leads over the US OSHA standard of 40 µg/dl and 4% were above the US OSHA criterion of 60 µg/dl that mandates immediate removal from the workplace. Also of concern is that the mean blood lead of the four children (aged 3–12 years) was 20.5 µg/dl, with all values exceeding the US CDC recommended limit of 10 µg/dl. Despite the small sample size this finding has prompted a new study currently underway that is designed to explore in more detail the impact of radiator repair work on families. Background studies report lead levels in children of this age group to be currently 8 µg/dl in Mexico City [Rothenberg et al., 1998]. Additional efforts made to revisit some of the shops where parents were initially reluctant to subject their children to venipuncture were not successful.

The predictors of blood lead we found in our multivariate analyses are similar to those of Nunez et al. [1993], demonstrating that numbers of radiators repaired per day and smoking are important. The finding that job classification, i.e., area worker compared to RRW, is also important is consistent with their findings. Our identification of the use of a uniform as being associated with high blood lead levels is informative. We observed that the uniforms worn tended to be extremely soiled and workers wearing them would frequently wipe their hands on them. Thus, these uniforms were likely acting as reservoirs for lead accumulation and a source of hand lead contamination and subsequent hand to mouth exposure. Our findings suggest that although the intention of wearing a uniform is to minimize the transport on clothing of lead from the workplace to the home, the

TABLE III. Blood Leads Across Categories of Interest Among RRWs Who Answered the Questionnaire (n = 59)

Questionnaire variables	Blood lead levels (μg/dl) N	Mean	SD	Range	*P*-value[a]
Smoke					
Yes	29	40.4	14.9	13.9–79.4	0.02
No	30	32.3	10.7	14.6–56.9	
Info not available	0				
Radiators repaired per day					
1–4	30	32.6	9.9	14.6–55.1	0.03
≥ 5	23	40.6	16.0	17.2–79.4	
Info not available	6	38.1	15.3	13.9–59.9	
Number of hand-washes/day					
1–5	41	37.4	13.9	13.9–79.4	0.13
≥ 5	12	30.6	11.1	17.8–55.1	
Info not available	6	40.2	13.8	20.8–56.9	
Change clothes after work					
Yes	54	36.0	13.4	14.6–79.4	0.55
No	5	40.0	15.7	13.9–55.1	
Use a uniform at work					
Yes	9	50.5	12.5	39.7–79.4	0.0003
No	50	33.8	12.1	13.9–63.4	
Wash face before eating lunch					
Yes	20	40.8	12.7	17.7–63.4	0.067
No	39	34.0	13.4	13.9–79.4	
Use glazed pottery at home					
Yes	22	38.4	13.3	17.7–63.4	0.368
No	37	35.1	13.6	13.9–79.4	
Shower at the end of work shift					
Yes	35	37.6	13.8	14.6–79.4	0.3694
No	24	34.4	13.0	13.9–63.4	
Store your work clothes in a locker					
Yes	31	37.6	14.2	13.9–79.4	0.44
No	28	34.9	12.7	17.7–63.4	
Drink alcohol presently					
Yes	38	36.5	13.5	13.9–79.4	0.86
No	21	35.9	13.7	14.6–63.4	
Eat in the work place					
Yes	50	36.0	14.1	13.9–79.4	0.66
No	9	38.1	9.9	20.6–55.1	
Age					
11–17	3	22.9	6.5	17.8–30.2	0.44
18–25	19	36.3	12.6	17.7–56.9	
26–40	31	36.2	12.7	15.0–17.4	
40+	20	35.4	16.2	6.7–63.4	

[a] *t*-test or analysis of variance.

uniform itself might comprise a hazard to the worker if not properly maintained.

Air lead measurements as high as 500 μg/m^3 have been reported in small shops in the US [Gunter and Pryor, 1980]. Our observations also ranged widely, reflecting the great variation in exposure among repair jobs. Some radiators are large, some are small, and the extent of work required to repair each radiator may vary a great deal. There may also

TABLE IV. Multivariate Regression Models of Determinate of Blood Lead Among Mexican RRWs

Independent variable	Regression coefficient	Standard error	*P*-value	95% CI
Saturated model* (N = 47, Adj $R^2 = .35$)				
#Radiators repaired/day	1.71	0.89	0.061	−0.08, 3.50
#Hand washes/day	−0.56	0.82	0.5	−2.22, 1.10
Smoking status (yes vs. no)	9.23	3.29	0.008	2.59, 15.87
Facewash before eating	0.955	3.86	0.81	−6.83, 8.75
Uses a uniform	16.0	4.92	0.002	6.10, 26.0
Final model (N = 53, Adj $R^2 = .39$)				
#Radiators repaired/day	1.95	0.75	0.012	0.44,3.46
Smoking status (yes vs. no)	11.4	2.86	< 0.001	5.63, 17.1
Uses a uniform	16.4	4.52	0.001	7.34, 25.5

*Using all covariates that had significant ($P \leq 0.15$) differences in blood lead levels across categories in bivariate comparisons (see Table III).

be other jobs that RRWs perform, i.e., gas tank repair or other random odd jobs requiring soldering. From our experience in the shops during operations, however, it appears that bulk of the activity involved radiators from small to midsize cars.

A study in the battery industry addressed the issue of which of two pathways constitutes the largest exposure to lead, i.e., airborne versus hand to mouth [Lai et al., 1997]; however, it was unable to offer a clear answer. We quantified the relationship between air lead and number of radiators repaired in our study group and confirmed that the number of radiators fixed per day on average is a strong predictor of blood lead. We cannot clearly compare the amount that air lead contributes to final dose compared to the hand to mouth pathway, however.

Among the most important limitations in our study were its cross-sectional design and sample size of only 73 RRWs. Only Bellows and Rudolph [1993] had a much larger sample size (n = 273) compared to ours; however, they made no attempt to quantify predictors of lead exposure or blood lead levels in the families. Another limitation is that our study provided only one exposure data point for each subject. Re-sampling at various intervals would have been useful to provide a time profile of exposure to take into account variations in seasonal environmental conditions or seasonal changes in productivity.

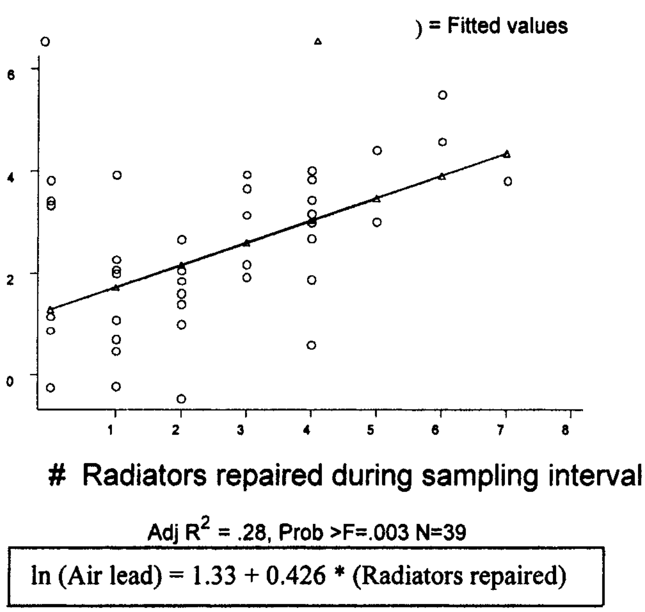

FIGURE 2. Air lead levels (log transformed) in relation to number of radiators repaired during the sampling interval.

CONCLUSIONS

Our results clearly indicate that this group of Mexican RRWs has significantly elevated blood leads compared to the working controls. Many of the blood levels exceed US OSHA standards, placing the workers at risk of the health effects of lead. The levels do not appear to exceed the levels documented in similar US studies, however, particularly when considering higher Mexican background ambient air lead levels.

TABLE V. Hand Wipe Lead Levels Among Subject Groups

Hand wipe analyses	N	Mean	SD	Median
RRW	55	652.2	648.7	490
Area workers	13	432	687.2	190
Controls[a]	22	14.32	16.3	9.8

[a]Summary of the lead contamination extracted from the hands of each study group, measured in µg/towellet (see section on data collection for methods).

TABLE VI. Summary of Selected Studies of Blood Lead Levels Among RRWs

	Shops	Number of workers tested	Median productivity	Mean Pb Bld µg/dl	Median Pb Bld µg/dl	SD	% RRW > 20 µg/dl	% > 25	% > 40	% > 50	% > 60	% > 80
Dykeman et al. [2002] Mexico	31/38	73	4 radiators/day*	35.5	34.2	14	86.7	76	37	*	4	0
Dalton et al. [1993] Colorado	42/43	55	6 radiators/day** (production records)	*	29	*	62	*	22	*	10	*
Bellows and Rudolph [1993] California	148	246	*	*	28	*	*	60	22	*	6	1
Goldman [1987] Massachusetts	27/41	56	*	37.1	35	13	*	*	22	9	4	*
Nunez et al. [1993] New York	28/61	62	*	34	*	*	*	68	39	*	*	*
Lussenhop et al. [1986] Minneapolis	30/35	53	*	*	*	*	*	*	28	*	*	*

*Questionnaire.
**Production records.

Nevertheless, this subject urgently needs interventions. Little attention is being paid in these work settings to exposure prevention considering both engineering controls and behavior. Behaviors such as lack of hand washing and changing overalls or clothes not only places workers at risk but also their families. Further worker education should be conducted focusing on the most basic interventions, i.e., hygiene practices and smoking, and regular surveillance of blood lead levels should be initiated. There is also a great need for the surveillance and implementation of engineering controls such as improved local ventilation units; however, such measures are more costly than behavioral changes and may be thus more difficult to implement.

ACKNOWLEDGMENTS

The authors thank Jill Morris, Sc.D. for assistance with data analyses and database management, Mike Wolfson for technical assistance with the air monitoring equipment; Sid Atwood, Philippe Jacob, and Ribika Mohapatra for computer assistance; and the subjects of this study for their cooperation. This research was supported, in part, by a NIOSH Education and Research Center grant at the Harvard School of Public Health, and NIEHS Center.

REFERENCES

Abudhaise BA, Alzoubi MA, Rabi AZ, Alwash R. 1994. Lead exposure in Indoor Firing Ranges: Environmental impact and risk to the range users. Int J Occup Med Environ Health 9:323–329.

Askin DP, Volkmann M. 1997. Effect of personal hygiene on blood lead levels of workers at a lead processing facility. Am Ind Hyg Assoc J 58:752–753.

Bellows J, Rudolph L. 1993. The initial impact of a workplace lead-poisoning prevention program. Am J Public Health 83:406–409.

Chavalitnitkul C, Levin L, Chen LC. 1984. Study and models of total lead exposures of battery workers. Am Ind Hyg Assoc J 45:802–808.

Dalton CB, McCammon JB, Hoffman RE, Barron RC. 1997. Blood lead levels in radiator repair workers in Colorado. J Occup Environ Med 39:58–62.

Goldman RH, Baker EL, Hannan M, Kamerow DB. 1987. Lead poisoning in automobile radiator mechanics. N Engl J Med 317:214–218.

Gunter BJ, Pryor RD. 1980. NIOSH, health hazard evaluation report HETA 80-89-723. Cincinnati: US Department of Health and Human Services, Public Health Service, CDC.

Klaasen CD, editor, Amdur MO, Doull J, editors emeriti. 1996. Casarett and Doull's toxicology: The basic science of poisons. 5th Edn. New York: McGraw-Hill.

Lai JS, Wu TN, Liou SH, Shen CY, Guu CF, KO KN, Chi HY, Chang PY. 1997. A study of the relationship between ambient lead and blood lead among lead battery workers. Int Arch Environ Health 69:295–300.

Lussenhop DH, Parker DL, Barklind A, McJilton C. 1989. Lead exposure and radiator repair work. Am J Public Health 79(11):158–160.

Maizlish N, Rudolph L, Sutton P, Jones JR, Kizer KW. 1990. Elevated blood leads in California adults, 1987; results of a statewide surveillance program based on laboratory reports. Am J Public Health 80:931–934.

MMWR. 1991. Control of excessive lead exposure in radiator repair workers. MMWR Morb Mortal Wkly Rep March 1, 1991. 40:139–141.

National Institute for Occupational Safety and Health: 1994. Lead by HGAAS—Method 7105. In: Eller PM, editor. NIOSH manual of analytical methods. 4th Edn. (DHHS/NIOSH Pub. No. 94-113). OH: Cincinnati.

National Institute for Occupational Safety and Health. 1994. Lead by Flame AAS—Method 7082. In: Eller PM, editor. NIOSH manual of analytical methods, 4th Edn. (DHHS/NIOSH Pub. No. 94-113). OH: Cincinnati.

National Institute for Occupational Safety and Health. 1994. Lead in Surface Wipes—Method 9100. In: Eller PM, editor. NIOSH manual analytical methods. 4th Edn. (DHHS/NIOSH Pub. No. 94-113). OH: Cincinnati.

Nelson NA, Kaufman JD. 1998. Employees exposed to lead in Washington State non-construction workplaces: A starting place for hazard surveillance. Am Ind Hyg Assoc J 59:269–277.

Nunez CM, Hlitzman S, Goodman A. 1993. Lead exposure among automobile radiator repair workers and their children in New York City. Am J Ind Med 23:763–777.

Orlando P, Perdelli F, Cristina ML, Oberto C, Viglione D, Palmieri S, Vari A, di Bello F. 1994. Blood lead levels in shop keepers and car traffic pollution in Liguria, Italy. Eur J Epidemiol 10:381–385.

Piacitelli GM, Whelan EA, Sieber WK, Gerwel B. 1997. Elevated lead contamination in homes of construction workers. Am Ind Hyg Assoc J 58:447–454.

Romieu I, Carreon T, Lopez L, Palazuelos E, Rios C, Manuel Y, Hernandez-Avila M. 1995. Environmental urban lead exposure and blood lead levels in children of Mexico City. Environ Health Perspect 103:1036–1040.

Rothenberg SJ, Schnaas L, Perrani E, Hernandez RM, Karchmer S. 1998. Secular trend in blood lead levels in a cohort of Mexico City children. Arch Environ Health 53:231–235.

Trebel RG, Thompson TS, Morton DN. 1997. Elevated blood lead levels from exposure via a radiator workshop. Environ Res 77:62–65.

Watanabe H, Hu H, Rotnitsky A. 1994. Correlates of bone and blood lead levels in carpenters. Am J Ind Med 26:255–264.