



## Patterns and predictors of personal protection compliance and workplace hygiene behaviors among workers with elevated blood lead levels in New York State

Vivian Nwudu, Alicia M. Fletcher & Michael Bauer

To cite this article: Vivian Nwudu, Alicia M. Fletcher & Michael Bauer (2018) Patterns and predictors of personal protection compliance and workplace hygiene behaviors among workers with elevated blood lead levels in New York State, Journal of Occupational and Environmental Hygiene, 15:9, 654-663, DOI: [10.1080/15459624.2018.1487066](https://doi.org/10.1080/15459624.2018.1487066)

To link to this article: <https://doi.org/10.1080/15459624.2018.1487066>



Accepted author version posted online: 06 Aug 2018.  
Published online: 04 Oct 2018.



Submit your article to this journal [↗](#)



Article views: 37



View Crossmark data [↗](#)



## Patterns and predictors of personal protection compliance and workplace hygiene behaviors among workers with elevated blood lead levels in New York State

Vivian Nwudu, Alicia M. Fletcher, and Michael Bauer

New York State Department of Health, Bureau of Occupational Health and Injury Prevention, Albany, New York

### ABSTRACT

Despite increasing awareness and significant progress in reducing lead exposure among workers, elevated blood lead levels (BLLs) continue to be an occupational health problem. Little is currently known about the extent of personal protective equipment (PPE) use among lead-exposed workers. We examined the patterns and predictors of consistent PPE use and workplace hygiene behaviors among workers with elevated BLLs using a survey of 1,459 workers with an occupational lead exposure in New York State (NYS). Routine availability of respirators was commonplace, however only approximately half of workers consistently wore PPE while working with lead. Regular access to showers was reported by 41% of workers, but less than a quarter took showers and subsequently changed into clean clothing before leaving work site. Significant predictors of consistent PPE use and good hygiene behaviors were identified. The findings highlight the need for further educational and policy interventions for lead-exposed employees. Increased employer efforts are also required to provide workplace structures and a culture that supports compliance. These include the provision of routine training and hazard communication, provision of appropriate PPE and hygiene facilities, and enforcing its use where necessary.

### KEYWORDS

Employee hygiene; heavy metal; lead exposed; OSHA; PPE compliance

### Introduction

The hazards of occupational lead exposure have been widely documented and disseminated. The Occupational Safety & Health Administration (OSHA) requires the use of personal protective equipment (PPE) to protect workers when engineering and administrative control measures are inadequate. However, PPE is only effective against lead exposure when worn properly and consistently, in combination with good worker hygiene practices. In the United States, approximately 2 million workers are exposed to lead each year, primarily through inhalation of lead particles and accidental ingestion.<sup>[1]</sup> Regardless of the route of exposure, the health effects of lead are the same. Lead exposure adversely affects the hematological, cardiovascular, nervous, endocrine, reproductive, and renal systems,<sup>[2]</sup> causing intoxication ranging from subclinical to life-threatening. Generally, acute poisoning due to recent exposures are thought to be reversible, and chronic poisoning due to cumulative doses are more likely to be irreversible. Even at low levels of exposures, the cumulative effect of lead may

have the same effect as a short-term, high-level exposure.<sup>[2]</sup> Low-level lead exposures have been found to be associated with an increased risk of all-cause mortality and cardiovascular disease mortality according to a recent study.<sup>[3]</sup> In 2015, based on scientific evidence of adverse health effects associated with low-level lead exposure, the National Institute for Occupational Safety and Health (NIOSH) designated 5 µg/dL (5 micrograms per deciliter) of whole blood, in a venous blood sample, as the reference level, to identify adults with elevated BLL.<sup>[4]</sup>

PPE is any equipment worn by a worker to reduce occupational hazards that may result in injuries or illness. OSHA requires the use of appropriate PPE to safeguard workers from over-exposure to lead when engineering, and administrative controls are inadequate or not feasible.<sup>[5]</sup> Appropriate PPE to minimize lead exposures include proper respiratory protection and clothing such as coveralls and gloves. Employers are also required to provide routine training to employees and continually monitor those exposed above the action level or permissible exposure limit

(PEL).<sup>[5]</sup> In addition to wearing PPE, workers should practice simple personal hygiene to not only ensure effective protection from accidental lead ingestion due to contaminated hands and/or skin, but also to protect family members by reducing “take-home” exposures.

Studies have shown that frequency of wearing appropriate PPE and practice of simple hygiene while working with lead are significant predictors of workers' BLL, even after controlling for airborne lead.<sup>[6–8]</sup> Availability and employee training had strong positive associations with consistent PPE use among nurses and textile workers,<sup>[9,10]</sup> in addition to other factors such as length of employment and shift work.<sup>[10]</sup> Routine employee training and collaboration of management with workers were identified as important factors influencing worker hygiene among battery manufacturing workers.<sup>[11]</sup>

Since even the best PPE will only protect against lead exposure when worn consistently and properly, in addition to good hygiene, the objective of this study was to determine the extent to which workers with elevated BLLs in NYS consistently use PPE and practice good hygiene. We also aimed to identify important predictors of consistent PPE use and good workplace hygiene behaviors among lead-exposed workers with elevated BLL. Findings can be used to inform workplace lead exposure prevention programs and other strategies to improve compliance.

## Methods

The New York State Department of Health (NYSDOH) Heavy Metals Registry (HMR) was established in 1980 under Sections 22.6 and 22.7 of the State Sanitary Code. All clinical laboratories performing a test for lead on individuals residing or employed in NYS must report the results to the NYSDOH. Currently, all blood lead results, regardless of age or level, must be reported.

Once a lead report is received, interviews are conducted for adults with BLLs above the interview threshold to determine the source of exposure. Prior to February 2007, both men and women with BLLs of 25 µg/dL and higher were interviewed. Since women could become pregnant, and the potential exists for exposure to the fetus, the interview criterion for women was lowered from 25 µg/dL to 15 µg/dL in February 2007. In February 2009, the interview criterion was further lowered, from 25 to 15 µg/dL in men and from 15 to 10 µg/dL in women. The New York City Department of Health and Mental Hygiene (NYCDOHMH) conducts the interviews for residents

of Bronx, Kings, New York, Queens, and Richmond counties, and the NYSDOH HMR staff conduct all interviews for residents in the rest of the state. Interviews are conducted in several languages. Information is provided to exposed individuals and employers on ways to reduce hazards and eliminate exposure. Exposed individuals who are reported to the registry more than once are interviewed every 3 years when they meet the interview criteria. Repeat cases with an increase in their BLL of 15 µg/dL or more since their last report are re-interviewed. This study analyzed data from adult lead interviews completed between 2009 and 2016 in NYS. Case interviews with occupational exposures were ordered by identification numbers and data were abstracted such that the final dataset reflected only interviews for each patient's highest blood lead result within the 7-year study period.

The questionnaire contained 20 questions covering employer provision of employee education, personal protection, and hygiene. Self-employed individuals were exempt from responding to questions about employer provisions of personal protection or other resources. From responses to the survey questions “When you are working around lead, how often do you wear a respirator?” and “Do you wear a protective uniform/clothing?” workers were categorized as consistently using PPE if they responded “Always” to both questions. The outcome of interest for worker hygiene was taking a shower immediately after their work shift and subsequently changing out of work clothing before leaving the work site. From responses to the questions “Do you usually shower immediately after your shift at work” and “Do you usually wear your work clothes or shoes home?” workers were categorized as taking showers and changing out of work clothes if they responded “Yes” and “No”, respectively, to both questions. Employee education and certain subsets of questions from personal protection and hygiene were identified as predictors to be included in models for each of the two outcomes. Crude and adjusted odds ratios were estimated with logistic regression.

All analysis was completed using SAS 9.4 (SAS Institute, Cary, NC). Potential confounders were identified from chi-square analyses. Predictor variables were then fitted separately into two bivariate logistic regression models to evaluate the extent of association with consistent PPE use and worker hygiene. Variables shown to be significant in bivariate analyses were included in multivariate analyses using a backward stepwise selection approach, with the final

adjusted model restricted to variables significant at  $p \leq 0.05$ . Demographic variables included in the multivariate analyses were: gender, age, educational attainment, geographic region (NYC vs. upstate NY), and origin (Foreign born vs. Native born). The crude odds ratio (OR) was used to present the bivariate model outputs, while the adjusted OR represents the outputs from the multivariate analyses. Discriminative model performance of the multivariate model was evaluated with the area under the receiver operating characteristic (ROC) curve (AUC), and the Hosmer-Lemeshow (HL) test was conducted for goodness-of-fit. The NYSDOH Human Subjects Review Board determined that the activities of this project were exempt according to 45 CFR 46.101(b) Exemption Category 5(i) – Public Benefit or Service Program.

## Results

A total of 1,459 individuals with an occupational lead exposure had completed an interview between 2009 and 2016 (Table 1). The mean age of the workers was 41 years old and the mean BLL was 21  $\mu\text{g}/\text{dL}$ , (range =10–87  $\mu\text{g}/\text{dL}$ ). Workers were primarily male (95%), white (64%), native born (66%), and had not attended college (64%). Many of the workers were employed in the construction (43%) and manufacturing (13%) industry and more than half (54%) worked in NYS outside of NYC. Approximately half (50%) of respondents were union members. The majority (95%) were employed in small size establishments with less than 50 employees, and 76% reported not having a child below age 7 years at home. Many employees (65%) reported being provided with information about the hazards of working with lead and that they felt they know how to work safely with lead (58%).

### Personal protection

Less than half (44%) of respondents reported consistent use of a respirator together with protective clothing while working with lead (Table 1). A higher proportion of those who reported consistent PPE use were males, native born, middle-aged, had no college education, and resided in NYS outside NYC (Table 1).

Respirators were always made available for the large majority (71%) of workers (Table 2). The most commonly provided respirators were half-face with cartridges (62%; data not shown). More than half of workers (55%) had been fit tested for a respirator and trained on proper use, maintenance and storage in the

year immediately preceding the interview (Table 2). Many workers (55%) reported that respirator use was always required by their employers when working with lead. Eight percent of respondents reported never being required by their employers to wear respirators when working around lead. Of the employees always required to wear respirators on the job ( $n = 801$ ), almost all (87%) consistently wore one when working with lead; whereas those who were sometimes or never required to wear respirators ( $n = 258$ ) only consistently wore respirators 12% of the time (data not shown).

### Employee hygiene

Good employee hygiene was defined as employees always taking a shower immediately after their work shift and changing out of work clothing and shoes before leaving their work site. Less than a quarter (23%) of employees took showers and changed out of work clothes before leaving their work site. Middle-aged, native born, white males, those who had not attended college, and those who lived in NYS outside of NYC, made up the greater proportion of respondents who took showers and changed out of work clothes before leaving work (Table 1).

As shown in Table 2, less than half (41%) of respondents had regular access to showers on the work site; however, regular access to wash facilities was common (70%). Of the 631 workers (43%) who reported changing out of work clothes before heading home, 36% never took showers before doing so (data not shown). Many workers (57%) always had a clean break area away from the site; and 82% did not eat, drink or smoke in the work area. More than half (53%) of respondents had laundered or disposable clothing provided to them (Table 2).

Overall, the proportion of employees with elevated blood lead levels who consistently wore PPE and practiced good personal hygiene has steadily declined over the years (Figure 1). Prevalence of BLLs  $\geq 10$   $\mu\text{g}/\text{dL}$  due to occupational exposures have also generally declined over the years with a high of 1,481 cases reported in 2010 and a low of 971 cases in 2015 (Figure 1).

### Predictors of consistent PPE use

Table 3 shows the results of the bivariate analysis of potential predictors of consistent personal protection use. Employer mandating respirator use and respirator availability were the strongest predictors of consistent

**Table 1.** Characteristics of lead-exposed workers with elevated BLL reported to the NYS Heavy Metals Registry, 2009–2016.

Demographics	Total (N = 1,459) N (%)	Used PPE always (N = 639) N (%)	Used PPE sometimes/ Never/Unknown (N = 820) N (%)	$\chi^2$ (p value)	Took shower and changed into clean clothing (N = 340) N (%)	Did not take shower and change into clean clothing/ Unknown (N = 1,119) N (%)	$\chi^2$ (p value)
Gender							
Male	1,392 (95)	625 (97)	767 (93)	<.001	333 (98)	1,059 (95)	0.01
Female	67 (5)	14 (3)	53 (7)		7 (2)	60 (5)	
Age							
18–39	262 (18)	136 (21)	126 (15)	<.001	66 (19)	196 (18)	0.3
40–59	801 (55)	356 (56)	445 (54)		193 (57)	608 (54)	
60+	396 (27)	147 (23)	249 (31)		81 (24)	315 (28)	
Geographic Location							
NYS excl. NYC	790 (54)	378 (59)	412 (50)	<.0001	236 (69)	554 (50)	<.0001
NYC	585 (40)	196 (31)	389 (48)		57 (17)	528 (47)	
Out of state <sup>a</sup>	84 (6)	65 (10)	19 (2)		47 (14)	37 (3)	
Race/Ethnicity				0.09			0.01
White, non-Hispanic	941 (64)	428 (67)	513 (63)		241 (71)	700 (63)	
Black, non-Hispanic	153 (11)	69 (11)	84 (10)		29 (9)	124 (11)	
Hispanic	263 (18)	108 (17)	155 (19)		61 (16)	202 (18)	
Other	102 (7)	34 (5)	68 (8)		9 (4)	93 (8)	
Educational attainment				<.0001			<.01
High school or less	763 (52)	378 (59)	385 (47)		190 (56)	573 (51)	
Some College/Associate's	379 (26)	162 (25)	217 (27)		100 (30)	279 (25)	
Bachelor's or higher	170 (12)	44 (7)	126 (15)		32 (9)	138 (12)	
Unknown	147 (10)	55 (9)	63 (11)		18 (5)	129 (12)	
Origin				<.001			<.001
Native born	962 (66)	452 (71)	510 (62)		257 (73)	705 (63)	
Foreign born	463 (32)	177 (28)	286 (35)		77 (26)	386 (34)	
Unknown	34 (2)	10 (1)	24 (3)		6 (1)	28 (3)	
Union member				<.0001			<.0001
Yes	735 (50)	412 (65)	323 (39)		219 (64)	516 (46)	
No	524 (36)	182 (28)	342 (42)		98 (28)	426 (38)	
Unknown	200 (14)	45 (7)	155 (19)		23 (7)	177 (16)	
Has child <7 years at home				0.8			0.5
Yes	324 (22)	166 (26)	158 (19)		96 (28)	228 (20)	
No	1,105 (76)	470 (73)	635 (77)		244 (72)	861 (77)	
Unknown	30 (2)	3 (1)	27 (4)		0 (0)	30 (3)	
Size of establishment				<.0001			<.0001
<50 employees	1,390 (95)	607 (95)	783 (95)		320 (94)	1070 (96)	
≥50 employees	66 (4)	31 (5)	35 (4)		19 (6)	47 (3)	
Unknown	3 (1)	1 (0)	2 (1)		1 (0)	2 (1)	
Self-employed				<.0001			<.0001
Yes	107 (7)	8 (1)	99 (12)		8 (2)	99 (9)	
No	1352 (93)	631 (99)	721 (49)		332 (98)	1020 (91)	
Industry of employment							
Administration	76 (5)	40 (6)	36 (4)		25 (7)	51 (5)	
Construction	609 (42)	344 (54)	265 (32)		156 (46)	453 (40)	
Manufacturing	187 (13)	98 (15)	89 (11)		87 (26)	100 (9)	
Public administration	70 (5)	20 (3)	50 (6)		11 (3)	59 (5)	
Wholesale & Retail trade	62 (4)	27 (5)	35 (4)		6 (2)	56 (5)	
Utilities	71 (5)	22 (3)	49 (6)		14 (4)	57 (5)	
Other industry	140 (10)	42 (7)	98 (13)		11 (3)	61 (6)	
Unknown	244 (16)	46 (7)	198 (24)		30 (9)	282 (25)	

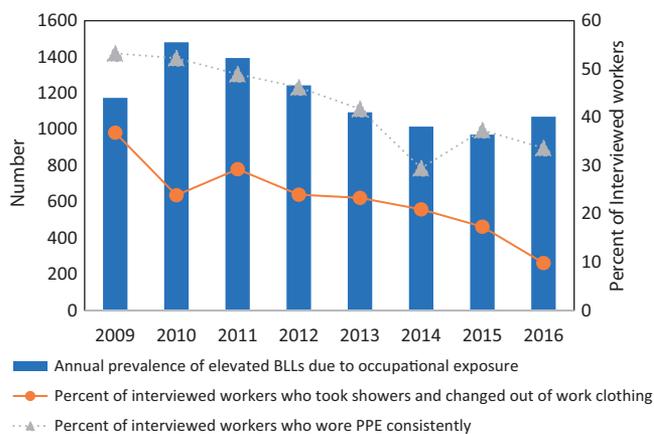
<sup>a</sup>Out of state refers to those participants who do not reside in New York State but are reported to the HMR because they work in New York State.  $\chi^2$  compares whether differences in proportions between outcomes are statistically significant.

**Table 2.** Responses for components of personal protection use and employee hygiene (N = 1,459).

Personal Protection	N	%
Respirators made available for use		
Always	1,030	70.6
Sometimes	101	6.9
Never	141	9.7
Unknown/Refused	187	12.8
Employer require respirator to be worn when working around lead		
Always	801	54.9
Sometimes	136	9.3
Never	123	8.4
Unknown/Refused	399	27.4
How often respirator is worn when working around lead		
Always	738	50.6
Sometimes	278	19.1
Never	76	5.2
Unknown/Refused	367	25.1
Fit tested in past year to wear respirator		
Yes	806	55.2
No	169	11.6
Unknown/Refused	484	33.2
Training provided in past year for proper maintenance, use and storage of respirator		
Yes	804	55.1
No	153	10.5
Unknown/Refused	502	34.4
Wear protective uniform/clothing		
Always	894	61.3
Sometimes	82	5.6
Never	201	13.8
Unknown/Refused	282	19.3
Employee Hygiene	N	%
Wash facilities available on work site		
Yes	1,021	70.0
Sometimes	87	6.0
No	118	8.1
Unknown/Refused	233	15.9
Showers available at work site		
Yes	601	41.2
Sometimes	79	5.4
No	436	29.9
Unknown/Refused	343	23.5
Shower immediately after work shift		
Yes	437	30.0
Sometimes	109	7.5
No	567	38.9
Unknown/Refused	346	23.6
Clean break area provided away from work site		
Yes	837	57.4
Sometime	120	8.2
No	188	12.9
Unknown/Refused	314	21.5
Eat/drink/snack/smoke in work area		
Yes	24	1.6
No	1194	81.8
Unknown/Refused	241	16.5
Employer launders work clothes or provides disposable clothing		
Yes - Launder	361	24.7
Yes - Disposable	355	24.3
Yes - Launder and disposable	65	4.5
No	306	21.0
Unknown/Refused	372	25.5
Wear work clothes/shoes home?		
Yes - clothes	16	1.1
Yes - shoes	64	4.4
Yes - clothes & shoes	357	24.5
No	631	43.2
Unknown/Refused	391	26.8

PPE use in the bivariate model. After adjusting for other co-variates, respirator availability was no longer significant (Table 4). Being employed in the lead industry for less than or equal to 10 years significantly

predicted consistent PPE use in both models. Respondents who had been fit tested for a respirator and trained on its proper use and maintenance in the past year were more likely to use PPE consistently as



**Figure 1.** Annual prevalence of BLL  $\geq 10$   $\mu\text{g}/\text{dL}$  due to occupational exposure by year, 2009–2016.

compared to those who had not been fit tested or trained. This effect remained significant after adjusting for other co-variates (Table 4). Familiarity with potential hazards of working with lead, having a young child at home and belonging to a union emerged as predictors of consistent use of PPE in the bivariate model; however, these effects were no longer significant after adjusting for other co-variates. Employer size and the presence of a pregnant or nursing individual in the household did not significantly predict consistent PPE use in either model. Hosmer-Lemeshow goodness-of-fit test for the final model had a p-value of 0.85. The model had an AUC of 0.8124.

### Predictors of good employee hygiene

In the bivariate model (Table 5), provision of laundered or disposable clothing, clean break areas, and hazard communication were the strongest predictors of taking showers and changing out of work clothes before leaving work site. These effects remained significant in the final adjusted model (Table 6). Union members were significantly more likely to practice good worker hygiene as compared to non-members, even after adjusting for other variables. Having a child below 7 years old at home also emerged to be a significant predictor of good worker hygiene. This effect remained significant in the final adjusted model. Employees who had a pregnant or nursing individual at home did not have a statistically significant increase in likelihood of changing out of work clothes in both models. The Hosmer-Lemeshow goodness-of-fit test for the final model had a p value of 0.74. The model had an AUC of 0.7573.

### Discussion

Given the importance of PPE use and good worker hygiene to minimizing lead exposure among workers, this study examined patterns and predictors of PPE compliance among workers with elevated blood lead levels due to occupational exposure. Current OSHA standards require the use of PPE to supplement engineering and administrative controls where these controls do not reduce employee exposure to or below the PEL.<sup>[5]</sup> Employers are to first conduct hazard assessments before determining whether PPE is required. It is worthy to note that employers may not require PPE or hygiene practices when airborne concentrations of lead are below the PEL, although many workers and family members are being reported to the HMR when airborne concentrations of lead have not exceeded either the PEL or the action level. Because HMR receives cases when exposures were at air concentrations below OSHA's lead standards, widely acknowledged to be outdated,<sup>[12]</sup> NYSDOH industrial hygiene staff recommends that PPE be used and shower/wash facilities be installed at work sites regardless of air monitoring results.

Over the 8-year study period, the proportion of workers with elevated BLL in NYS who consistently used PPE and practiced good employee hygiene on the job steadily declined. Analyses of predictors for consistent PPE use and good hygiene behaviors highlight potential areas for intervention and improvement.

We found that employer enforcement of PPE use, respirator fit testing, and training on proper use of respirator were very strong predictors of consistent PPE use, whereas availability of clean break areas, laundered or disposable work clothing, hazard communication, belonging to a union, and having a child below age 7 at home were key predictors of good worker hygiene.

Our survey did not include questions about air lead monitoring in the workplace, so it is unknown whether airborne concentrations of lead were within permissible limits. Where employees are exposed above the PEL, the employer bears the legal responsibility of ensuring the availability of protective equipment and hygiene facilities, and setting up appropriate workplace policies to ensure compliance. PPE compliance and good worker hygiene behavior do not happen as isolated events; they are implemented on an individual level, as a component of an effective worker protection program.

Employee awareness and training is crucial.<sup>[11,13]</sup> Whether a lead-exposed worker will use PPE or practice good hygiene on the job has a lot to do with their

**Table 3.** Predictors of consistent PPE use: Bivariate model.

Independent Variable	Crude Odds Ratio (OR) (95% Confidence Interval (CI))
Length of employment	
≤10 years	1.50 (1.18–1.92)*
>10 years	ref
Availability of respirators	
Always	24.31 (13.97–42.30)*
Sometimes or never	ref
Employer ever require respirator use when working with lead	
Always	37.21 (23.14–59.85)*
Sometimes or never	Ref
Size of establishment	
≥50	1.14 (0.70–1.87)
<50	ref
Trained on respirator use in past year	
Yes	13.47 (8.59–21.12)*
No	ref
Respirator fitted in past year	
Yes	13.84 (8.96–21.38)*
No	ref
Employer provided lead hazard communication	
Yes	10.33 (6.43–16.60)*
No	ref
Has child <7 years old at home	
Yes	1.42 (1.11–1.82)*
No	ref
Anyone in the house pregnant/trying to conceive	
Yes	1.14 (0.65–2.02)
No	ref
Union member	
Yes	2.40 (1.90–3.02)*
No	ref

\*Significant at  $p$  value < 0.05

perceived risk inherent in that occupation, as noted by a previous meta-analysis<sup>[14]</sup> which showed a positive association between risk perception and health behavior. Risk perception has also been shown to be strongly dependent upon a worker's level of awareness, as seen in a study among construction workers where "not knowing that PPE was necessary at the time" was one of the reasons identified by workers who did not wear PPE.<sup>[15]</sup> In our study, workers who were provided information on the hazards of working with lead were significantly more likely to practice good hygiene, even after controlling for workplace characteristics. Hazard communication on lead also emerged as a predictor for consistent PPE use, although this effect was not retained after controlling for other workplace variables.

A previous study<sup>[15]</sup> identified barriers to PPE compliance in the workplace as unavailability, physical discomfort, and lack of awareness. In our study, despite the routine availability of respirators in the workplace, only approximately half of employees with elevated blood lead levels always wore one, and an even lower proportion wore one together with protective clothing. We found that availability predicted PPE use before, but not after, workplace characteristics such as employer enforcement, union membership, length of employment, and respirator fit testing were included in the model. This might be explained

in part by declining blood lead levels (data not shown), since PPE may be deemed unnecessary by an employee as their blood lead level declines. Another explanation could be a total lack of exposure assessment. A previous study<sup>[23]</sup> and common experience suggests it is likely that many employers have never conducted air lead monitoring. When employers fail to conduct legally mandated air monitoring, they are unable to determine if exposures are above the action level or PEL, which would warrant additional worker protection, or if exposures are below limits and no additional protection is necessary.

In addition to respirator availability and fit testing, care must be taken to ensure adequate training on the selection, use, and maintenance of respirators for those employees required to wear one. These findings highlight the role of employers in protecting workers by enforcing PPE use among lead-exposed workers, in addition to ensuring good worker hygiene. The employer that always requires the use of a respirator when working with lead was the strongest predictor of whether an employee donned PPE on the job. This is consistent with two similar surveys among construction workers, where a key barrier to PPE use was identified as lack of enforcement and positive reinforcement by employer.<sup>[15–17]</sup>

Other employer-dependent factors including the provision of clean break areas and laundered or

**Table 4.** Predictors of consistent PPE Use: Final adjusted model.

	Adjusted OR	95% CI
Length of employment	1.52	(1.03 – 2.26)*
Respirator fitted in past year	3.33	(1.52 – 7.29)*
Trained on respirator use in past year	2.51	(1.11 – 5.67)*
Employer always require respirator use when working with lead	22.17	(12.64 – 38.89)*

\*Significant at p value &lt;0.05

**Table 5.** Predictors of good employee hygiene: Bivariate model.

Independent Variable	Crude OR (95% CI)
Length of employment	
≤10 years	0.93 (0.71–1.23)
>10 years	ref
Availability of clean break area away from work site	
Always	6.35 (4.15–9.71)*
Sometimes or Never	ref
Current smoker	
No	0.97(0.74–1.25)
Yes	ref
Size of establishment	
≥50	1.32 (0.78–2.34)
<50	ref
Employer provided lead hazard communication	
Yes	7.32 (3.92–13.68)*
No	ref
Employer launder clothing or provide disposable	
Yes	10.15 (6.23–16.52)*
No	ref
Has child <7 years at home	
Yes	1.49 (1.12 - 1.96)*
No	ref
Anyone in the house pregnant or trying to conceive	
Yes	1.47 (0.79–2.74)
No	ref
Union Member	
Yes	1.84 (1.41–2.42)*
No	ref

\*Significant at p value &lt;0.05

**Table 6.** Predictors of good employee hygiene: Final adjusted model.

	Adjusted OR	95% CI
Employer launder clothing or provide disposable	7.16	(4.20–12.19)*
Employer provided lead hazard communication	3.56	(1.70–7.45)*
Availability of clean break area away from work site	3.94	(2.44–6.35)*
Has child <7 years at home	1.52	(1.06–2.18)*
Union Member	1.61	(1.16–2.23)*

\*Significant at p value &lt;0.05

disposable work clothing were the strongest predictors of good workplace hygiene among the workers. While these factors may be indicative of work sites where lead exposure potentially exceeds permissible limits, this finding is consistent with previous studies,<sup>[18–20]</sup> which found that workplace safety characteristics were more significant predictors of safe workplace behaviors than individual level factors including risk perception. Union membership has been known to be beneficial to workers and labor unions have a long history with the worker safety movement in the U.S. Through organizing and collective bargaining, unions gain stronger protections and rights for workers and give them a voice in the health and safety provisions in the workplace. Our study found that union

members were more likely to practice good worker hygiene after controlling for other variables. Union members were also more likely to use PPE consistently before adjusting for workplace characteristics, but not afterward.

A previous focus group conducted among workers exposed to lead in NYS revealed that the desire to protect their families was a strong motivating factor for practicing good workplace hygiene.<sup>[21]</sup> This was consistent with findings from our study where having a child below age 7 was significantly associated with taking showers and changing out of work clothing after a work shift even after adjusting for other covariates. Despite the decrease in PPE use and practice of good hygiene observed in this study, the prevalence

of elevated BLL among workers reported to the HMR has seen a decline in recent years.<sup>[22]</sup> Mean BLLs, although still elevated have decreased since the beginning of the study (data not shown). This suggests that other measures such as engineering controls may have been effective in reducing exposure, but not sufficiently enough that BLLs fall below NIOSH's health based reference level of 5 µg/dL. Collectively, these results add to evidence that point to the need for addressing discrepancies between health-based reference standards for lead exposure and current OSHA lead standards. Many protective requirements of the OSHA standards do not apply in work sites where air lead levels are below action level or PEL, although scientific and clinical research have documented adverse health effects associated with BLLs or exposures below the limits currently permissible under OSHA standards.<sup>[4]</sup>

This study has a few limitations. First, data was based on a sample of lead-exposed workers reported to our registry, which does not fully describe the magnitude and distribution of workers exposed to lead in NYS, since some employers may fail to provide BLL testing to their lead-exposed workers.<sup>[23]</sup> Inferences to a larger population of lead-exposed workers with elevated BLLs in NYS should therefore be made with caution. Also, the responses used in this study were self-reported and could not be independently validated; as such, they could be vulnerable to social desirability bias where workers might tend to over-report "good" behavior and under-report "bad" behavior.

## Conclusions

The results from this study demonstrate that consistency in adherence to recommendations for personal protection use and good worker hygiene largely requires employer efforts in facilities where lead exposures exceed action or permissible limits. The strongest predictors of consistent PPE use were employer enforcement, respirator fit testing, and training on proper use of respirator.

Hazard communication, provision of clean break area, provision of laundered or disposable clothing, belonging to a union, and presence of young child at home significantly predicted good worker hygiene.

## Funding

Funding for this study was provided by the Centers for Disease Control and Prevention, National Institute

for Occupational Safety and Health grant: 5U600H008474.

## Acknowledgment

The authors would like to thank the following people for their contributions to this study: Anne Marie Gibson, Kelly Hughes, and Jackie Figueroa.

## References

- [1] **Occupational Safety and Health Administration (OSHA):** "Safety and Health Topics – Lead." Available at <https://www.osha.gov/SLTC/lead/> (accessed September 9, 2017).
- [2] **National Toxicology Program (NTP):** "NTP Monograph: Health Effects of Low-Level Lead." Available at <https://ntp.niehs.nih.gov/pubhealth/hat/noms/lead/index.html> (accessed September 9, 2017).
- [3] **Lanphear, B.P., S. Rauch, P. Auinger, R.W. Allen and R.W. Hornung:** Low-level lead exposure and mortality in US adults: A population-based cohort study. *Lancet Publ. Health* 3(4):e177–e184 (2018)
- [4] **National Institute for Occupational Safety and Health (NIOSH):** "Adult Blood Lead Epidemiology and Surveillance (ABLES) Case Definition for an Elevated Blood Lead Level." Available at <http://www.cdc.gov/niosh/topics/ABLES/description.html> (accessed September 9, 2017).
- [5] **Occupational Safety and Health Administration (OSHA):** "Regulation Standards for General and Construction Industry – 29CFR: Standard Numbers 1910.1025 and 1926.62." Available at [https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10030](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10030) (accessed October 2, 2017).
- [6] **Decharat, S.:** Heavy metals exposure and hygienic behaviors of workers in sanitary landfill areas in Southern Thailand. *Scientifica* 2016: 1–9 (2016).
- [7] **Rodrigues, E. G., M. A. Virji, M. D. McClean, J. Weinberg, S. Woskie and L.D. Pepper:** Personal exposure, behavior, and work site conditions as determinants of blood lead among bridge painters. *J. Occup. Environ. Hyg.* 7(2): 80–87 (2010).
- [8] **Ulenbelt P., M.E. Lumens, H.M. Geron, R.F. Herber, S. Broersen, and R.L. Zielhuis:** Work hygienic behavior as modifier of the lead air-lead blood relation. *Int. Arch. Occup. Environ. Health.* 62(3):203–207 (1990).
- [9] **Silver, S.R., A.L. Steege, and J.M. Boiano:** Predictors of adherence to safe handling practices for antineoplastic drugs: A survey of hospital nurses. *J. Occup. Environ. Hyg.* 13(3):203–212 (2016).
- [10] **Tadesse, S., T. Kelaye and Y. Assefa:** Utilization of personal protective equipment and associated factors among textile factory workers at Hawassa Town, Southern Ethiopia. *J. Occup. Med. Toxicol.* 11:6–12 (2016).

- [11] **Lormphongs S., I. Morioka, N. Miyai, et al:** Occupational health education and collaboration for reducing the risk of lead poisoning of workers in a battery manufacturing plant in Thailand. *Ind. Health.* 42(4):440–445 (2004).
- [12] **Occupational Safety and Health Administration (OSHA):** “Permissible Exposure Limits – Annotated Tables.” Available at: <https://www.osha.gov/dsg/annotated-pels/> (accessed May 29, 2018).
- [13] **Porru, S., F. Donato, P. Apostoli, L. Coniglio, P. Duca, and L. Alessio:** The utility of health education among lead workers: The experience of one program. *Am. J. Ind. Med.* 23:473–481 (1993).
- [14] **Brewer N., G. Chapman, F. Gibbons, M. Gerrard, K. McCaul, and N. Weinstein:** Meta-analysis of the relationship between risk perception and health behavior: The example of vaccination. *Health Psych.* 26(2):136–145 (2007).
- [15] **Farooqui, R., S. Ahmed, K. Panthi, and S. Azhar:** “Addressing the Issues of Compliance with Personal Protective Equipment on Construction Worksites: A Workers’ Perspective.” Ph.D. diss., Florida International University, Miami, Florida, 2009. Available at <http://ascpro0.ascweb.org/archives/cd/2009/paper/CPRT176002009.pdf> (accessed September 9, 2017).
- [16] **International Safety Equipment Association. (ISEA):** Lack of employee enforcement is main barrier to road worker PPE use. Author, 2001. Available at [http://elcosh.org/document/1411/d000475/lack-of-employee-enforcement-is-main-barrier-to-road-worker-ppe-use-\(isea\).html](http://elcosh.org/document/1411/d000475/lack-of-employee-enforcement-is-main-barrier-to-road-worker-ppe-use-(isea).html) (accessed September 9, 2017).
- [17] **Lombardi, D. A., S. K. Verma, M.J. Brennan, and M.J. Perry.** Factors influencing worker use of personal protective eyewear. *Accid. Anal. Prev.* 41(4):755–762 (2009).
- [18] **Lee S.J., J. Faucett, M. Gillen, N. Krause, L. Landry:** Factors associated with safe patient handling behaviors among critical care nurses. *Am. J. Ind. Med.* 53(9):886–897 (2010).
- [19] **Kearney G.D., J.A. Balanay, and A.J. Mannarino:** Safety behavior and work safety climate among landscaping and grounds keeping workers in North Carolina: A pilot study. *Work.* 56(1):45–53 (2017).
- [20] **Schwatka, N.V., and J.C. Rosecrance:** Safety climate and safety behaviors in the construction industry: The importance of co-workers’ commitment to safety. *Work.* 54(2):401–413 (2016).
- [21] **Fletcher, A.M., and F.L. Schottenfeld:** “Using Worker Focus Groups to Evaluate a Worker Lead Brochure in New York State.” Poster presented at the Council of State and Territorial Epidemiologists annual conference, Nashville, Tennessee, June 22–26, 2014.
- [22] **Alarcon, WA:** Elevated blood lead levels among employed adults — United States, 1994–2013. *Morb. Mortal Wkly Rep.* 63:59–65 (2016).
- [23] **Rudolph, L., D.S. Sharp, S. Samuels, C. Perkins, and J. Rosenberg:** Environmental and biological monitoring for lead exposure in California workplaces. *Am. J. Publ. Health* 80:921–925 (1990).