Department of Industrial Relations
STATE OF CALIFORNIA

Standardized Regulatory Impact Assessment: Revisions to Occupational Lead Standards

Prepared for: California Department of Industrial Relations
Prepared by: David Roland-Holst, Samuel Evans, Samuel Neal
Berkeley Economic Advising and Research, LLC

February 2019, revised August 2020

Table of Contents

Abbreviations

AL – action level
BLL – blood lead level
CalEPA – California Environmental Protection Agency
CDPH - California Department of Public Health
DIR – California Department of Industrial Relations
DOF – California Department of Finance
DOSH – Division of Occupational Safety and Health
HEPA – high efficiency particulate air
MRP - medical removal protection
NTP - National Toxicology Program
ODPHP - Office of Disease Prevention and Health Promotion
OEHHA - Office of Environmental Health Hazard Assessment
OLPPP - Occupational Lead Poisoning Prevention Program
OSHA - Occupational Safety and Health Administration
PEL - permissible exposure limit
PHLW – presumed hazardous lead work
PPE – personal protective equipment
SECAL - separate engineering control air limit
SRIA – Standardized Regulatory Impact Assessment
µg/dL – micrograms per deciliter of whole blood
$\mu g/m^3$ – micrograms per cubic meter of air

1. Introduction

The California Department of Industrial Relations' (DIR) Division of Occupational Safety and Health (DOSH, also known as Cal/OSHA) is proposing a series of revisions to its Title 8 occupational lead standards for Construction (section 1532.1) and General Industry (section 5198). The proposed revisions are designed to mitigate adverse health effects for employees who have occupational exposure to lead. This Standardized Regulatory Impact Assessment (SRIA) analyzes the economic impacts of the proposed revisions to DOSH's occupational lead standards.

The existing Title 8 regulations are based on lead toxicity information and medical and epidemiological data that is now over 40 years old. More recent evidence suggests that even very low levels of lead exposure may have harmful health effects. Such adverse health effects include high blood pressure, heart disease, decreased kidney function, lower birth weight, reproductive, and neurological effects. The proposed regulations are designed to mitigate more recently recognized adverse health effects from lower levels of exposure to lead. In particular, the proposed revisions are designed to maintain employee blood lead levels (BLLs) below 10 µg/dL, whereas existing regulations were designed to maintain employee blood lead at levels below 40 µg/dL, a level four times higher.

Employees who work with lead can be exposed to it through both airborne and oral exposure routes. Employee BLLs reflect the employee's overall body burden of lead, which can be the combined result of exposure through both inhalation of airborne lead and oral ingestion of lead (e.g. from contaminated hands or other items put in the mouth). Therefore, the BLL is a better indicator of employee exposure to lead from both routes of exposure than are measurements of the ambient airborne concentration of lead. The proposed amendments are designed to (1) reduce airborne exposure to lead (2) reduce exposure to lead through the oral route of exposure; and (3) expand requirements for blood lead testing of employees who work with lead, independent of measured airborne levels of lead.

While Construction and General Industry activities are regulated in separate sections of the Title 8 codes, the proposed revisions are meant to update both sections. The following changes would apply to both section 1532.1 (Construction) and section 5198 (General Industry):

1. Lowering the **permissible exposure limit** (PEL) for airborne lead, calculated as an 8-hour time-weighted average (TWA) from 50 μg/m^3 to 10 μg/m^3.
2. Lowering the **action level** (AL) from 30 μg/m^3 as an 8-hour TWA to 2 μg/m^3.
3. Establishing general hygiene requirements when employees have occupational exposure to lead.
4. Removing the requirement to provide zinc protoporphyrin (ZPP) testing on a routine basis when blood lead testing is provided.
5. Increasing BLL testing for employees when their BLL is at or above 10 μg/dL, and requiring a response plan when a BLL is at or above 10 μg/dL.
6. Lowering the BLL at which employees must be offered medical examinations and consultations at least annually from 40 μg/dL to 20 μg/dL.
7. Lowering the criteria for temporary removal from work with lead due to elevated BLLs, known as medical removal protection (MRP), from a BLL of 50 μg/dL to a BLL at or above 30 μg/dL (or the last two BLLs at or above 20 μg/dL or an average BLL over 20 μg/dL when averaged over the most recent 6 months).
8. Requiring that employees on MRP be prohibited from exposure to lead at or above the proposed AL and from altering or disturbing lead-containing material, as defined in the standard.
9. Lowering the BLL at which an employee may return from MRP to work involving lead from 40 μg/dL to 15 μg/dL.
10. Expanding the contents of required training.

The Construction standard (1532.1) would also include the following additional revisions:

1. Defining level 1,2, and 3 trigger tasks, which trigger certain protective requirements, and revising the listing of specified tasks.

2. Requiring medical surveillance, regulated areas, eating areas, and a lead training program, as interim protection until an exposure assessment has been completed, based on performing trigger tasks, and additional protections when employees perform level 3 trigger tasks.
3. Requiring monthly BLL testing for employees whose airborne exposure is above 500 $\mu g/m^3$.
4. Requiring that employees on MRP be prohibited from performing trigger tasks.

In addition to the changes outlined above, the General Industry standard (5198) would also include the following revisions:

1. Establishing a separate engineering control air limit (SECAL) for particular processes in the manufacturing of lead acid batteries.
2. Requiring medical surveillance, a lead training program, personal protective clothing and equipment, along with warning signs for lead, as an interim protection until an exposure assessment has been completed, based on performing presumed hazardous lead work (PHLW), as defined in the standard.

These proposed regulatory changes, if adopted, are expected to have important and far-reaching impacts on the California economy. While they would give rise to compliance costs for industries where employees are currently exposed to lead, reforming decades-old exposure safety standards will confer health benefits on current and future California employees and their families that far exceed these costs. Compliance costs reflect the need to update 40+ year-old exposure and health intervention standards, providing employees with enhanced protective measures to reduce exposure (e.g. engineering controls, respiratory protection, hygiene, and personal protective equipment), while strengthening employee training, air testing, medical surveillance, and medical intervention requirements. These costs are expected to accrue to the sectors whose employees are exposed to lead, and ultimately would be passed along to consumers of products and services in these industries. The benefits of the proposed regulation include reductions in morbidity and mortality associated with lower levels of lifetime air and oral

exposure of employees to lead, a material whose toxicity occurs at much lower levels than had long been indicated. Employees in a large swath of California industries would experience health benefits from reduced exposure to lead. In addition, take-home lead exposures, to family and household members of employees would be reduced, resulting in additional health benefits.

1.1. Background of Proposed Regulation

DIR's proposed changes are based in part on recommendations from the California Department of Public Health (CDPH). The CDPH Occupational Lead Poisoning Prevention Program (OLPPP) reviewed the scientific information, including a review from the National Toxicology Program (NTP, 2012) and a report issued by the US Environmental Protection Agency (EPA, 2013), and concluded that there is convincing evidence that chronic, low-level exposure to lead can cause harmful health effects. CDPH-OLPPP concluded that the BLL of employees should not exceed 5-10 µg/dL over a working lifetime. This is consistent with goals set at the federal level by the Office of Disease Prevention and Health Promotion (ODPHP, 2010).

CDPH-OLPPP made health-based recommendations to DIR-DOSH for revising its Construction and General Industry lead standards for the protection of employees who are exposed to lead on the job. In its recommendations, CDPH stated that in order to prevent chronic BLLs at or above 5-10 µg/dL, air lead levels in the workplace must not exceed an 8-hour TWA concentration of 0.5-2.1 µg/m^3. At a PEL of 0.5 µg/m^3, 95% of employees would have a BLL less than 5 µg/dL over their working lifetime. At a PEL of 2.1 µg/m^3, 95% of employees would have a BLL less than 10 µg/dL over their working lifetime. DIR concluded that lowering the PEL to this low level was not a feasible regulatory option, but that a PEL of 10 µg/m^3, along with the suite of additional revisions outlined above, would have the same effect of reducing lifetime blood lead levels to 10 µg/dL for nearly all employees with occupational exposure to lead.

1.2. Major Regulation Determination

A regulation is determined to be a major regulation if the estimated economic impact of the regulation is expected to exceed $50 million per year once fully implemented. For the lead standards being considered, both the direct compliance costs and direct benefits of the proposed regulation are independently expected to exceed this threshold. Direct compliance costs are estimated to be approximately $248.4 million per year in year 1 and $195.4 million per year in subsequent years, and direct benefits are estimated to range from $27.9 million in year 1 increasing to $1.26 billion per year by year 45, when the full effect of the proposed revisions is realized. Therefore, revising the occupational lead regulations for Construction and General Industry in California qualifies as a major regulation, requiring a complete SRIA.

1.3. Public Outreach and Input

From February 23, 2011 through November 10, 2015, Cal/OSHA held six advisory committee meetings to determine what amendments should be proposed for sections 1532.1 and 5198. The meetings were open to the public. Representatives from industry, labor, occupational medicine, and government agencies participated. These meeting, held outside of the rulemaking process, provided opportunity for stakeholder comments and for solicitation of alternatives to the proposed regulation. In addition, a symposium, co-sponsored by CDPH-OLPPP and UC Berkeley, was held on November 13, 2013 to present the science behind CDPH-OLPPP's recommended revisions to the lead standards. Attendees included representatives from industry, labor, occupational medicine, and government agencies. In October 2018, meetings were held with several state government agencies to discuss the proposed revisions. After the revisions to the regulation are formally proposed, a public comment period will be held as provided for in the Administrative Procedure Act (APA).

1.4. Baseline

Both the direct costs and benefits, as well as the macroeconomic impacts of the proposed regulations, are evaluated in this SRIA relative to a baseline scenario. It is assumed that under

the baseline that occupational lead requirements remain as they currently are. For example, the baseline scenario assumes that all employers are in compliance with the current permissible exposure limit of 50 µg/m^3 and all other requirements of the standards. The costs and benefits associated with the proposed regulation should therefore be interpreted as the incremental costs and benefits associated with lowering the PEL, action level, and all the other proposed regulatory changes. For the macroeconomic assessment, the baseline is assumed to follow the California Department of Finance's conforming forecast for the California economy. All macroeconomic results are presented relative to the model baseline that was calibrated to this forecast.

2. Estimates of Employee Lead Exposure and Blood Lead Levels

Detailed estimates of current employee lead exposure and blood lead levels were developed to support this economic assessment of the proposed lead regulatory revisions. These current exposure estimates were developed by staff members of DOSH and OLPPP. A technical description of the methodology used to estimate employee exposure and blood lead levels is provided in Appendix A.

It is estimated that, in the course of their duties, approximately 228,000 California employees are exposed to potentially harmful lead exposure levels.[1] This represents approximately 1.2% of the 2018 California labor force. Approximately 85,000 of these employees are classified under the Construction regulation (section 1532.1) and about 143,000 are classified under the General Industry regulation (section 5198). Occupational exposure can occur at various levels of severity and, as shown in Figure 1, the majority of exposed employees are currently estimated to be exposed to lead at levels below the more stringent proposed PEL of 10 µg/m^3. While

[1] A more detailed explanation of this estimate was obtained from CDPH-OLPPP, "Estimating the Number of Lead-Exposed Workers and Affected Employers in CA," written communication to Cal/OSHA, March 23, 2017.

epidemiological literature strongly suggests that any lead exposure is harmful to an individual's health, current regulations require only limited actions below exposure levels of 50 µg/m^3.

Figure 1: Estimated Occupational Lead Exposure Profile for Construction and General Industry

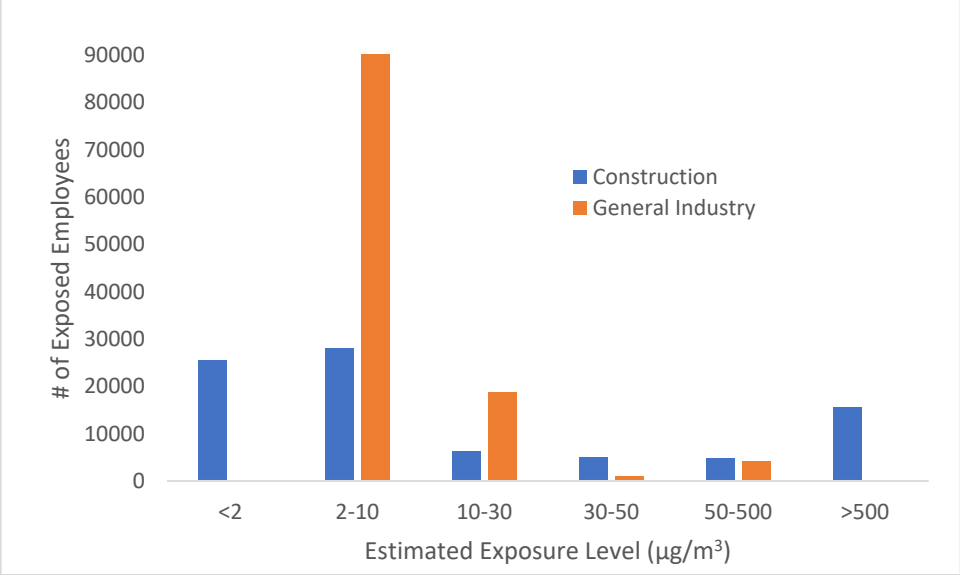


Table 1 and Table 2 show the estimated breakdown of employee lead exposure by 3-digit NAICS code for Construction and General Industry, respectively. A variety of activities in these sectors can result in employee lead exposure. For example, in Construction, approximately 61% of employee lead exposure arises during renovation and demolition activities that disturb lead-based paints and other lead-containing surface materials. Metal work and abrasive blasting on lead-coated surfaces are also significant sources of occupational lead exposure in Construction. In General Industry, the majority of employees with occupational lead exposure work in law enforcement and are exposed to lead as a result of using lead bullets for target practice and firearms qualification. However, the exposures to law enforcement personnel are generally low. Handling metals (either during manufacturing or recycling) accounts for most of the remaining lead exposure in General Industry.

Table 1: Estimated Number of Exposed Employees in Construction (§1532.1) by 3-digit NAICS

3-digit NAICS	Description	Estimated Number of Exposed Employees	% of Total
221	Utilities (e.g. electric power distribution)	2,165	3%
236	Construction of Buildings	8,190	10%
237	Heavy and Civil Engineering Construction	9,172	11%
238	Specialty Trade Contractors (e.g. painting contractors)	57,281	67%
531	Real Estate (e.g. building maintenance)	2,179	3%
562	Waste Management & Remediation Services (e.g. lead abatement)	4,762	6%
922	Justice, Public Order, and Safety Activities (e.g. fire protection)	1,119	1%
Total		**84,868**	

Table 2: Estimated Number of Exposed Employees in General Industry (§5198) by 3-digit NAICS

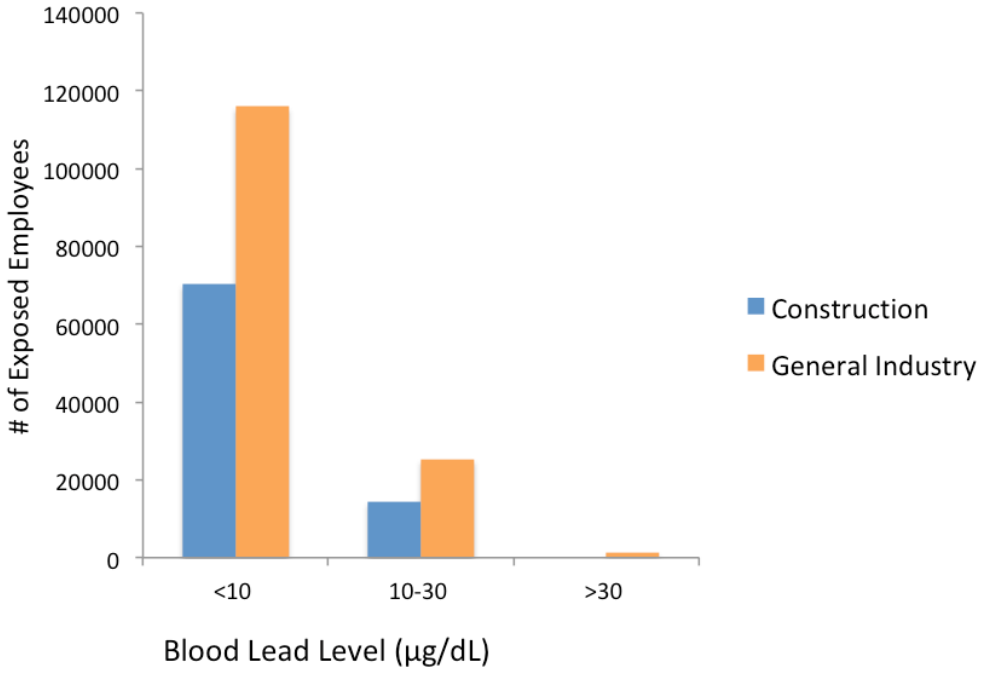
3-digit NAICS	Description	Estimated Number of Exposed Employees	% of Total
327	Nonmetallic Mineral Product Manufacturing	241	0%
331	Primary Metal Manufacturing (e.g. foundries and secondary smelting)	2,600	2%
332	Fabricated Metal Product Manufacturing (e.g. machine shops)	10,089	7%
334	Computer and Electronic Product Manufacturing	1,081	1%
335	Electrical Equipment, Appliance, & Component Manufacturing	943	1%
336	Transportation Equipment Manufacturing	660	0%
423	Merchant Wholesalers, Durable Goods (e.g. scrap metal recycling)	9,090	6%

512	Motion Picture and Sound Recording Industries (e.g. special effects)	644	0%
541	Professional, Scientific, and Technical Services (e.g. environmental consulting)	814	1%
561	Administrative and Support Services (e.g. security guards and armored cars)	5,590	4%
713	Amusement, Gambling, and Recreation Industries (e.g. firing ranges)	1,764	1%
811	Repair and Maintenance (e.g. automotive repair)	690	0%
922	Justice, Public Order, and Safety Activities (e.g. law enforcement)	108,351	76%
Total		**142,557**	

The employee exposure distribution is critical to accurately calculating direct costs attributable to the proposed regulatory revisions. Specific compliance actions, discussed in the following section, are often unique to particular levels of lead exposure. Therefore, not all industries with lead-exposed employees are required to undertake every compliance action.

In addition to occupational lead exposure estimates, DOSH and OLPPP staff also generated an estimate of blood lead levels for the California workforce. Whereas compliance costs are generally based on employee exposure (with some exceptions), the ultimate intent of the proposed regulations is to reduce the amount of lead that accumulates in employees' bodies. Therefore, in order to accurately estimate the benefits of the proposed regulations, an estimate of the BLL distribution before and after the implementation of the proposed revisions to the regulation is needed. Figure 2 shows the estimated BLL distribution in today's California workforce, distinguishing Construction from General Industry. Following the implementation of the proposed revisions to the regulations, nearly all California employees are expected to have BLLs below 10 µg/dL.

Figure 2: Estimated Blood Lead Level Profile for Construction and General Industry



3. Direct Costs

3.1. Overview of Compliance Actions

This section describes the various compliance actions that individual employers will likely need to take in order to conform to the revised occupational lead regulations. As noted above, these compliance actions are often specific to particular exposure levels and may not be required for all employers or industries. In general, proposed compliance actions fall into eight categories:

1. Air monitoring
2. Engineering controls
3. Respiratory protection
4. Personal protective equipment
5. Hygiene – Basic and Advanced
6. Medical surveillance
7. Medical removal protection
8. Training

While Medical Removal Protection is activated by a BLL threshold, the other seven compliance actions depend primarily on employee exposure levels, measured in $\mu g/m^3$. In Construction, some compliance actions are triggered when an employee conducts trigger tasks, as defined in the proposed standard. Similarly, in General Industry, some compliance actions are triggered when an employee performs presumed hazardous lead work (PHLW), as defined in the proposed standard. In both cases, these compliance actions are required as interim protection until the employer has conducted an exposure assessment. However, for both Construction and General Industry, we assume the employer has performed the required exposure assessment. Therefore, the required control measures are based on the requirements for the estimated exposures of employees performing trigger tasks or PHLW.

A summary of compliance actions required for Construction and General Industry, corresponding to particular exposure level ranges is shown in Table 3.

Table 3: Additional Compliance Requirements Proposed for Construction and General Industry

	Airborne Exposure Level (μg/m^3)					
Compliance Action	**<2**	**2-10**	**10-30**	**30-50**	**50-500**	**>500**
Air Monitoring		X	X			
Engineering Controls			X	X	X[1]	X[1]
Respiratory Protection			X	X	X[2]	X[2]
Personal Protective Equipment			X	X		
Hygiene – Basic	X	X	X	X		
Hygiene – Advanced			X	X		
Medical Surveillance		X	X	X[3]	X[3]	X[3]
Training		X	X			

1 Already required; upgraded engineering controls may be required
2 Already required; upgraded respiratory protection may be required
3 Already required; some additional BLL testing will be required

3.2. Methodology for Measuring Compliance Costs

Occupational lead exposure presents measurable health risk in nearly 60 different California industries. The nature of the exposure and the specific processes that expose employees to lead are often unique to individual industries. In recognition of this heterogeneity, we apply a simplified methodology for identifying direct costs borne by industries as they comply with DIR's proposed occupational lead regulatory revisions. Total costs for each affected industry would be calculated as follows:

$$TC_i = \sum_l EE_{i,l} * \sum_d c_{d,l}$$

where TC = total costs ($) in industry *i*

EE = # of employees exposed to lead at level *l* in industry *i*

c = is the cost per employee ($/employee) for implementing compliance action *d*, triggered at exposure level *l*

In Construction, we assume an intermittent exposure to lead (60 work days/year). Overall in General Industry, we assume a daily exposure to lead (250 work days/year). See Appendix A for additional assumptions and information.

The resulting costs estimate the additional cost of compliance with the proposed regulations by each industry subsector for employees who are exposed to lead at different levels of exposure. Estimates of exposed employees are taken from the DOSH and OLPPP results presented in section 2. Unit cost estimates for each compliance action and exposure level are discussed in detail in the following subsections.

It is worth noting that alternative approaches to measuring compliance costs are also available. Employers have essentially two choices if the proposed regulations take effect: they can continue to use lead, adapting operations to be compliant in terms of exposure risk management, or they can take actions to reduce or eliminate the use of lead in their operations. A rational employer would most likely choose the lowest cost compliance path, given the nature of their specific industry and whether alternative (lead-free) processes or materials are available.[2] However, because so many affected industries are being considered in this analysis, it is not feasible to evaluate which path a representative employer in each industry is likely to take. For this reason, we assume that no industries, with the exception of law enforcement, will opt to adopt entirely lead-free processes. This could have the effect of overestimating compliance costs since lower cost options may be available to certain employers in specific industries.

Air Monitoring

Currently, periodic air monitoring by employers is required to measure employee lead exposure levels at or above 30 µg/m^3. Under the proposed regulatory revisions, annual monitoring would also be required for lead exposures between the proposed action level (2 µg/m^3) and the existing

[2] In some industries, working in a lead-free environment may not be feasible. For example, removal of lead-containing paint will require exposure mitigation rather than avoiding lead altogether.

action level (30 μg/m^3). We assume that annual air monitoring would be conducted in a representative work environment. The costs associated with the additional air monitoring include the cost of the time for a person trained in air monitoring (such as an industrial hygienist), as well as the cost for laboratory analysis of each sample. Each monitoring session is estimated to cost approximately $472/sample in year 1 and $254/sample in years 2+. Costs in years 2+ are expected to be lower because the industrial hygienist would need only about half the time to conduct subsequent monitoring sessions (OSHA, 2016). We assume that each air monitoring sample would cover 4 employees, so the average cost per employee would be $118 (year 1) and $64 (years 2+).

Engineering Controls

Engineering controls are designed to remove lead from the air workers breathe. Under current regulations, engineering controls are required at exposure levels above the permissible exposure limit. Since the proposal would lower the PEL from 50 μg/m^3 to 10 μg/m^3, engineering controls would be required for employees exposed at airborne levels above 10 μg/m^3. Engineering controls are currently required for exposure levels exceeding 50 μg/m^3; however, upgraded engineering controls would be required for these employees to reduce exposures to the lower proposed PEL.

In Construction, the main sectors that would be required to adopt new or upgraded engineering controls are those involved in paint removal tasks. We assume that the primary engineering control would be a shrouded tool system where lead paint dust generated by the paint removal tool, such as a sander, is captured by a vacuum exhaust and deposited in a HEPA-filtered vacuum. A shrouded tool system is assumed to include a shroud, a hose, the vacuum, and the HEPA filter. Existing removal tools would not need to be replaced; however, there would be a cost for retrofitting existing removal tools with dust collection systems. The total annualized cost of this system is estimated to be $473/employee. For upgraded engineering controls, we assume a cost of 50% of this estimated annualized cost, or $237/employee.

Engineering controls in General Industry are somewhat more varied due to the different types of tasks and occupations that expose employees to lead. Various engineering controls are available, based on the nature of the work being performed. In this SRIA, we consider three engineering controls that would likely be suitable for most applications in California. Many industries are likely to use local exhaust ventilation (LEV) systems, which capture the lead particulate through a hood at the source of contamination and transfer the lead away from the employee to a filter or other air-cleaning system. Based on a review of the recent Federal OSHA Beryllium standard (OSHA, 2016), LEV systems are estimated to cost approximately $1,039 per exposed employee per year. A less expensive option that could be suitable in some situations is a simpler vacuum extraction system, similar to equipment in the shrouded tool system described above. The annualized cost of this vacuuming system is estimated to be $448/employee. The most expensive engineering control considered is a fully-enclosed exhaust system that, based on the federal OSHA Beryllium standard, has an annualized cost of approximately $2,590/employee.

For simplicity, we assume that the average unit cost per employee for engineering controls in General Industry is the average of these three systems with an annualized average adoption cost of $1,359/employee. We estimate that upgraded engineering controls would cost 50% of this, for an annualized cost of $680/employee. It is important to note that while we have annualized these costs, engineering controls often require high upfront capital expenditures. The economic feasibility of adopting these engineering controls would likely depend on the financing options and capital costs available to individual employers. This kind of financial heterogeneity would have important implications about compliance capacity and industry structure, particularly with respect to smaller incumbent employers.

At this point it is important to note that not all employees would need to use both engineering controls and respiratory protection (discussed in greater detail below). In some cases, these two compliance options would be redundant. For Construction, we assume that half of the employees exposed above the proposed PEL would use engineering controls and half would use respiratory protection. Across General Industry, it is assumed that all employees exposed above the

proposed PEL would require engineering controls and 10% of the employees would also require additional respiratory protection.

The proposed General Industry regulations include a separate engineering control air limit (SECAL) for particular processes in the manufacturing of lead acid batteries. Employers in this industry would have a longer phase-in period for adopting engineering controls and would have less stringent requirements for adopting engineering controls. To address this exception, we assume that employees in NAICS code 335911 (Storage Battery Manufacturing) would use respirators to achieve the PEL for the first 5 years after the proposed regulation is passed. It is assumed that employees exposed at levels of 30-50 $\mu g/m^3$ would use half-mask respirators and employees exposed at levels of 50-500 $\mu g/m^3$ would use full-face air-purifying respirators. From year 6 onward, engineering controls would be required for employees exposed above either 30 or 40 $\mu g/m^3$ (depending on the process) and it is assumed that 100% of these employees would also need to continue using respirators in addition to the engineering controls.

As an engineering control, law enforcement, security, and armored car services (NAICS 922000, 561612, 561613) are assumed to substitute the use of lead-safer bullets in place of standard lead-containing bullets for target practice and firearms qualification. Lead-safer bullets have lead-free primer and a fully-enclosed bullet. As a result, lead exposure to employees at the firing line would be largely eliminated. An analysis of the cost of lead-safer bullets relative to conventional ammunition found that switching to lead-safer ammunition would be a more cost-effective compliance route than adopting the engineering controls assumed for other industries.

Respiratory Protection

When the PEL cannot be achieved with engineering controls (or administrative controls, such as job rotation), respiratory protection is required. The proposed regulation would change the respiratory protection requirements for employees at various exposure levels. For example, no respiratory protection is required for employees exposed below the current PEL of 50 $\mu g/m^3$. However, since the proposed PEL would drop to 10 $\mu g/m^3$, employees between 10 $\mu g/m^3$ and 50

μg/m^3 would be required to use half-mask air-purifying respirators, unless engineering controls can reduce airborne exposure below 10 μg/m^3. Upgraded respiratory protection would be required for employees exposed at levels >50 μg/m^3. For employees in the 50-500 μg/m^3 exposure category, depending on exposure levels, half-mask or full-face air purifying respirators would be required. For employees exposed at levels >500 μg/m^3, supplied-air respirators would be required. For employees requiring upgraded respiratory protection, we assume that the only incremental cost would be the more expensive equipment since training, fit testing, and medical evaluation are already required. For employees below the current PEL of 50 μg/m^3, additional training and testing costs would be incurred. A summary of the estimated costs of the three types of respirators is shown in Table 4.

Table 4: Estimated Additional Annual Respirator Costs per Affected Employee

	Half-Mask Air Purifying Respirator	Full-Face Air Purifying Respirator	Supplied-Air Respirator
Construction			
Training	$67	-	-
Fit Testing	$34	-	-
Equipment	$59	$130	$361
Medical Evaluation	$40	-	-
Total	**$199**	**$130**	**$361**
General Industry			
Training	$67	-	-
Fit Testing	$34	-	-
Equipment[1]	$194	$265	$361
Medical Evaluation	$40	-	-
Total	**$335**	**$265**	**$361**

[1] Construction equipment costs differ from General Industry due to assumptions about the frequency of exposure to lead, and the number of respirator cartridges required.

Personal Protective Equipment

Personal protective equipment is required for employees exposed above the PEL. As the PEL falls from 50 μg/m^3 to 10 μg/m^3, additional employees would be required to use personal protective equipment. PPE for occupational lead exposure includes appropriate protective suits and gloves. PPE requirements differ based on exposure level. Under the proposed revisions, for employees exposed between 10 μg/m^3 and 30 μg/m^3, employers would be required to have the PPE laundered or replaced weekly. For employees exposed between 30 μg/m^3 and 50 μg/m^3, employers would be required to launder or replace the PPE each day an employee is exposed.

The cost of a suit/glove set is approximately $4.11, when provided weekly, and $3.11 per set when provided daily. Under the proposed revisions, the annual PPE costs for Construction employees exposed between 10 μg/m^3 and 30 μg/m^3 are estimated to be $49 per employee ($4.11 per set times 12 sets per year). For Construction, employees exposed at levels between 30 μg/m^3 and 50 μg/m^3, annual PPE costs are estimated to be $187 per employee ($3.11 per set times 60 sets per year). For General Industry, under the proposed revisions, the annual PPE costs for employees exposed between 10 μg/m^3 and 30 μg/m^3 are estimated to be $206 per employee ($4.11 per set times 50 sets per year), and $788 per employee ($3.11 per set times 250 sets per year) for employees exposed at levels between 30 μg/m^3 and 50 μg/m^3. These costs are summarized in Table 5.

Table 5: Estimated Additional Annual Personal Protective Equipment Costs per Affected Employee

Airborne Exposure Level	Construction	General Industry
10 – 30 μg/m^3	$49	$206
30 – 50 μg/m^3	$187	$778

Hygiene

There are two categories of hygiene requirements in the proposed occupational lead regulations: basic and advanced. Basic hygiene requirements involve periodic handwashing, while advanced hygiene requirements include the provision of lead-free eating areas, showers, and changing

facilities. These categories are estimated separately in this SRIA since they are required at different exposure levels.

Hygiene – Basic

The proposed basic handwashing requirements would require employees with lead exposure in the ≤ 50 µg/m^3 exposure groups to wash their hands 4 times per day. The cost of this requirement was estimated as the cost of lost time. We assume that handwashing requires 2 minutes per hand wash. Using industry-specific wage rates, the basic handwashing requirements would add an approximate cost of $188/employee/year for Construction and $783/employee/year for General Industry.

Hygiene – Advanced

Advanced hygiene requirements are required for employees exposed above the PEL. As the PEL drops from 50 µg/m^3 to a proposed PEL of 10 µg/m^3, additional accommodations would need to be made to provide changing facilities, showers, and lockers for these employees. We assume that designated eating areas are currently provided to employees; however, showering and changing accommodations would require either renting or purchasing additional equipment.

For Construction we assume that most employers would rent portable showers and changing facilities. This rental cost is estimated to be $210/employee/year. An additional cost of $30/employee/year is estimated for towels, cleansing agents, etc. It is assumed that employers would also need to provide lockers at an annual cost of $11/employee. There is also a time cost associated with the time spent showering and changing, and assuming approximately 15 minutes/employee/day, this time cost adds another $352/employee/year (assuming that the average Construction employee is exposed 60 days per year). The total estimated annualized cost for Construction employees is estimated to be $603/employee.

For General Industry, we follow the federal OSHA Beryllium standard and assume that suitable facilities would need to be purchased and installed at worksites (OSHA, 2016). The annualized cost per employee of changing rooms, showers, and lockers is calculated to be $353, $465, and $5, respectively. The time cost for General Industry employees, assuming 250 exposure days per year, is estimated to be $1,468/employee. The total annualized cost for General Industry employees is estimated to be $2,291/employee.

Medical Surveillance

Medical surveillance includes blood lead level testing and medical exams for certain employees exposed to lead. Currently, regular testing of employee blood lead levels is required at or above 30 μg/m^3 (the current action level). The proposed revisions would require regular testing for employees exposed to lead at or above 2 μg/m^3, the proposed action level. In addition, a medical exam will be required for employees exposed to lead at or above 2 μg/m^3. This implies that employers with employees exposed at levels between 2 μg/m^3 and <30 μg/m^3 would incur additional testing and exam costs.[3] There are two components of these costs. First, there is the actual cost of the BLL test or exam. A blood lead level test costs approximately $50/test, while an initial full exam costs approximately $279/exam. The testing requirements for Construction and General Industry are shown in Table 6**.** The revised standards would also eliminate the requirements for routine testing of an employee's zinc protoporphyrin level (ZPP). This would generate a savings of $35/test for each test required under the current regulations.

Table 6: Additional Proposed Blood Lead Level Tests and Medical Exam Requirements

	Airborne Exposure Level (μg/m^3)					
	<2	**2-10**	**10-30**	**30-50**	**50-500**	**>500**
Construction						
Additional BLL Tests						
Year 1	0	3	3	0	0	10

[3] There are also additional BLL testing requirements in Construction for employees exposed at levels greater than 500 μg/m^3.

Years 2+	0	2	2	0	0	10
Additional Medical Exams						
Year 1	0	1	1	0	0	0
Years 2+	0	0	0	0	0	0
General Industry						
Additional BLL Tests						
Year 1	0	3	3	2	2	2
Years 2+	0	2	2	0	0	0
Additional Medical Exams						
Year 1	0	1	1	0	0	0
Years 2+	0	0	0	0	0	0

The second cost is the cost employers would be required to pay for the employee's time associated with a BLL test or exam. To estimate this cost, we use the average wage in each industry where medical surveillance is required and assume that a BLL test requires 1.5 hours and a full medical exam requires 2.5 hours of the employees' time.[4]

Medical Removal Protection

The medical removal protection (MRP) program in the State's occupational lead standards requires that an employee be removed from work where significant lead exposure occurs if the employee's blood lead level is at or above 50 µg/dL. MRP benefits mean that an employer must maintain the earnings, seniority and other employment rights and benefits of the affected employee during the removal period. In year 1 of the proposed regulations, the MRP level would be lowered to one BLL test at or above 30 µg/dL. An employee can currently return to work once they have two consecutive BLL tests less than 40 µg/dL. Under the proposed regulatory revisions, an employee could return to this work only when two consecutive BLL tests are below 15 µg/dL. Additional criteria for medical removal of an employee would become effective in year 2 of the

[4] For 2017 industry wages, we use the Quarterly Census of Employment and Wages (QCEW) dataset for California. Wages are matched at the 6-digit NAICS code.

proposed regulation: when the employee's last two BLL results are at or above 20 μg/dL, or the average of all BLL tests in the prior 6 months is at or above 20 μg/dL.

The occupational lead standard revisions are designed to prevent employees from having blood lead levels that would necessitate medical removal. However, it is likely that in the first year of the proposed regulations, a number of employees will have a BLL at or above the 30 μg/dL cutoff, necessitating removal. We estimate the economic impacts of this provision by quantifying the time cost of work removal, assuming that all employees with predicted BLLs at or above 30 μg/dL would be removed from their work for 6 months. Because it is more likely that an employee would be reassigned to a different task (not involving lead exposure) than simply being sent home with pay, we assume that the net cost of lost time would be the employee's industry-specific wage rate minus the wage rate for an average administrative support employee.

Training

Comprehensive occupational lead training is currently required for employees exposed to lead at or above the current action level of 30 $\mu g/m^3$. Under the proposed regulatory revisions, comprehensive training would be required for employees exposed at or above the proposed action level of 2 $\mu g/m^3$. To estimate this cost, we considered two components: the cost of a training program and the cost of employees' and the instructors' time associated with the training. For the cost of the training program, we assume an instructor wage rate of $40/hr, based on the rates assumed in the economic analysis of the federal OSHA Silica Standard (OSHA, 2013). For attendees' wage rates, we use average industry wage rates from the QCEW. We assume, based on the 2007 OSHA Lead Lookback (OSHA, 2007), that comprehensive training takes approximately 4 hours. Under the proposed regulations, training would be required each year for employees exposed at or above the proposed action level of 2 $\mu g/m^3$.

3.3. Results

Compliance cost estimates for the proposed revisions are presented in the following section, reported by compliance cost category and 3-digit NAICS code. We also detail compliance cost

estimates into two time intervals, year 1 and years 2+. Some compliance actions would be more costly in year 1 than in year 2 and subsequent years, as discussed in previous sections.

Total direct compliance costs for the proposed regulatory revisions to the occupational lead standards are estimated to be approximately $248.35 million in year 1 of the proposed regulations and approximately $195.44 million per year in subsequent years. Table 7 (Construction) and Table 8 (General Industry) break down these costs by compliance category.

In Construction (Table 7), the compliance category with the highest cost is expected to be medical surveillance, accounting for 64% of the year 1 total compliance costs and 57% of the years 2+ compliance costs. Two particular groups of exposed employees are driving this result. Employers will be required to provide BLL testing and medical exams to approximately 28,000 employees estimated to be exposed to lead in the 2-10 $\mu g/m^3$ range, for whom they do not currently have to provide medical surveillance. Also, employers will have to provide additional BLL tests to over 15,000 employees estimated to be exposed at levels exceeding 500 $\mu g/m^3$; these workers will need 10 additional BLL tests each year. Together, these two exposure groups account for 92% of the estimated medical surveillance costs estimated for the Construction sector. While the BLL tests and medical exams themselves are relatively inexpensive and account for less than 10% of overall medical surveillance costs, the opportunity cost of the employees' time is the predominant expense in this category.

The time costs of basic hygiene requirements are another large source of Construction compliance costs, estimated to account for 12% of annual Construction compliance expenditure estimates in years 1 and 14% in years 2+. Each of the other categories of compliance costs account for less than 10% of the overall Construction compliance costs.

In General Industry (Table 8), costs are more evenly spread across compliance actions. As a fraction of the overall compliance costs, advanced hygiene (30% year 1; 39% year 2+), engineering controls (21% year 1; 28% year 2+), medical removal protection (14% year 1 only),

and basic hygiene (15% year 1; 20% year 2+), and medical surveillance (11% year 1; 4% year 2+) all account for large fractions of the overall estimated compliance costs. The total estimated compliance costs are significantly higher in year 1 ($144 million) than years 2+ ($111 million) primarily resulting from costs for MRP for workers with high lead body burdens due to years of exposure at higher levels. A year after the proposed revisions take effect, no employees are expected to need to be removed through the MRP program, as BLLs decrease due to the more stringent required compliance actions. In addition, the medical surveillance requirements would drop substantially for employees in year 2 of their employment tenure (reflected in year 2+ costs).

Table 7: Summary of Estimated Additional Direct Compliance Costs in Construction ($2017)

Cost Component	**Year 1**	**Year 2+**
Air Monitoring	$4,024,916	$2,170,303
Engineering Controls	$6,196,034	$6,648,190
Respiratory Protection	$3,122,623	$3,234,392
Personal Protective Equipment	$1,240,023	$1,240,023
Hygiene - Advanced	$6,754,845	$6,754,845
Hygiene - Basic	$12,151,886	$12,151,886
Medical Surveillance	$66,392,437	$47,657,446
Medical Removal Program	$0	$0
Training - Comprehensive	$4,422,197	$4,422,197
Total Compliance Cost - Construction (1532.1)	**$104,304,961**	**$84,279,284**

Table 8: Summary of Estimated Additional Direct Compliance Costs in General Industry ($2017)

Cost Component	Year 1	Year 2+
Air Monitoring	$3,073,914	$1,564,877
Engineering Controls	$30,422,099	$30,888,632
Respiratory Protection	$943,390	$854,977
Personal Protective Equipment	$4,456,861	$4,456,861
Hygiene - Advanced	$43,377,481	$43,377,481
Hygiene - Basic	$22,069,384	$22,069,384
Medical Surveillance	$16,173,535	$4,350,387
Medical Removal Program	$19,931,341	$0
Training - Comprehensive	$3,593,623	$3,593,623
Total Compliance Cost - General Industry (5198)	**$144,041,628**	**$111,156,223**

Estimated total costs by 3-digit NAICS for years 2+ are shown in Table 9. Construction NAICS code 238 (Specialty Trade Contractors), which includes structural steel and painting contractors, accounts for 43% of all estimated Construction compliance costs. This is a lower cost burden than the 67% share of exposed employees that this sector represents. Heavy and Civil Engineering Construction (NAICS code 237) and Building Construction (NAICS codes 236) account for 26% and 11% of total estimated Construction compliance costs, respectively. Industries outside of explicit Construction sectors, but that perform construction-related tasks, account for approximately 20% of the total estimated Construction compliance cost.

In General Industry, we estimate that 36% of the total estimated compliance costs would be incurred in Fabricated Metal Product Manufacturing (NAICS 332). This sector bears the highest additional cost burden in General Industry despite having only 7% of the total exposed General Industry employees, due to a large concentration of employees who are exposed at levels between 10 μg/m^3 and 30 μg/m^3 and for whom employers are currently required to do very little. This exposure level triggers nearly all compliance actions associated with lowering the PEL and action level. The subsector with the highest number of exposed employees, Law Enforcement (NAICS 922), will incur approximately 5% of the overall additional estimated General Industry compliance costs, despite having about 76% of the State's lead-exposed employees in General Industry, mainly because of our assumption that they will replace standard lead-containing ammunition with lead-safer ammunition for target practice and firearms qualification.

Table 9: Total Estimated Additional Compliance Cost by 3-digit NAICS in Years 1 and 2+ ($2017)

3-digit NAICS Code	**Description**	**Total Cost Estimate**	
		Year 1	**Year 2+**
	Construction		
221	Utilities (e.g. electrical power distribution)	$7,103,102	$7,103,102
236	Construction of Buildings	$10,773,966	$8,991,260
237	Heavy and Civil Engineering Construction	$22,599,018	$22,257,699
238	Specialty Trade Contractors (e.g., painting contractors)	$50,531,671	$36,128,873
531	Real Estate (e.g., building maintenance)	$2,313,072	$1,685,848
562	Waste Management Remediation Services (e.g., lead abatement)	$9,886,895	$7,434,347
922	Justice, Public Order, and Safety Activities (e.g., fire protection)	$1,097,238	$678,154
	Total	**$104,304,961**	**$84,279,284**
	General Industry		
327	Nonmetallic Mineral Product Manufacturing	$1,292,788	$1,172,465

331	Primary Metal Manufacturing (e.g. foundries and secondary smelting)	$9,254,547	$6,440,731
332	Fabricated Metal Product Manufacturing (e.g. machine shops)	$52,033,506	$47,087,104
334	Computer and Electronic Product Manufacturing	$2,437,745	$1,665,608
335	Electrical Equipment, Appliance, & Component Manufacturing	$2,549,846	$2,189,365
336	Transportation Equipment Manufacturing	$3,392,821	$3,005,315
423	Merchant Wholesalers, Durable Goods (e.g. scrap metal recycling)	$41,185,986	$36,762,646
512	Motion Picture and Sound Recording Industries (e.g. special effects)	$9,962,419	$2,820,740
541	Professional, Scientific, and Technical Services (e.g. environmental consulting)	$2,034,613	$1,394,118
561	Administrative and Support Services (e.g. security guards and armored cars)	$320,602	$307,634
713	Amusement, Gambling, and Recreation Industries (e.g. firing ranges)	$11,820,215	$1,108,613
811	Repair and Maintenance (e.g. automotive repair)	$1,231,507	$938,010
922	Justice, Public Order, and Safety Activities (e.g. law enforcement)	$6,525,032	$6,263,876
	Total	**$144,041,628**	**$111,156,223**

3.4. Costs to Small Businesses

The California legislature defines small businesses as businesses that have fewer than 100 employees, are not dominant in their field, and are independently owned and operated (A.B. 1033, Ch. 346, 2016). Data is only available to distinguish employer size based on the number of employees, so we only apply this criterion to define small businesses for the purposes of this SRIA. This likely overestimates the cost burden to small businesses.

Using data from the California Employment Development Department (EDD) Labor Market Information (LMI), Third Quarter 2018[5], we estimate that approximately 58% of the private sector compliance costs of the proposed regulation would fall upon small businesses. A breakdown by 2-digit NAICS industry code is shown in Table 10. We assume financing options are the same across each industry, meaning that we may be underestimating the compliance burden on small businesses.

Table 10: Estimated Year 1 and Year 2+ Additional Costs to Small businesses by Sector

2-digit NAICS Code	Sector	Total Private Cost Estimates		Total Small Business Cost Estimates	
		Year 1	Year 2+	Year 1	Year 2+
22	Utilities	$3,915,677	$3,915,677	$1,067,604	$1,067,604
23	Construction	$81,447,500	$65,708,377	$54,648,213	$44,087,853
31-33	Manufacturing	$70,961,253	$61,560,588	$28,837,944	$25,017,608
42	Wholesale Trade	$41,185,986	$36,762,646	$28,723,521	$25,638,639
51	Information	$9,962,419	$2,820,740	$3,305,010	$935,774
53	Real Estate and Rental and Leasing	$2,301,043	$1,677,081	$1,868,158	$1,361,579
54	Professional, Scientific, and Technical Services	$2,034,613	$1,394,118	$1,232,282	$844,360
56	Admin, Support and Waste Mgt & Remediation Services	$10,207,497	$7,741,981	$3,922,487	$2,975,051
71	Arts, Entertainment, and Recreation	$5,666,054	$531,417	$2,866,755	$268,872
81	Other Services (except Public Administration)	$1,231,507	$938,010	$1,006,305	$766,479
	Total	**$228,913,548**	**$183,050,635**	**$127,478,278**	**$102,963,818**

[5] EDD (California Employment Development Department) LMI (Labor Market Information), Table 2A, Third Quarter, 2018. https://www.labormarketinfo.edd.ca.gov/LMID/Size_of_Business_Data_for_CA.html

3.5. Other Impacts to California Businesses

This section considers several other potential business impacts of the proposed occupational lead standards, including, incentives for innovation, the creation or elimination of businesses, and competitive advantages or disadvantages to California businesses.

In nearly all sectors considered in this analysis, the simplifying assumption is made that businesses would comply with the proposed regulations by protecting workers from lead in the workplace. This assumption implies no major changes to the production processes in each sector. However, an alternative compliance option for some sectors would be to find alternative production processes that do not use lead-based materials. For example, law enforcement could plausibly switch over to lead-safer bullets rather than adopt the prescribed protective measures. In industries where this is feasible, this could provide some incentive to innovate as new lead-free methods of production would be sought out and developed. For many occupations, such as employees engaged in paint-removal, working in a lead-free space is likely unavoidable. In such sectors, we do not expect considerable incentives for innovation from the proposed regulation.

In the macroeconomic analysis discussed in Section 5, expected changes in sectoral output due to the proposed regulations are estimated. There are net short-term adjustment costs across many of the sectors affected by the proposed occupational lead standards, suggesting that output may decline (relative to the baseline, not in aggregate) in certain sectors. Data was not available to predict the relationship between these predicted changes in sectoral output and the profit margins and operational decisions of individual firms.

The new demand for labor and materials created by each compliance action could create an opportunity for new businesses to develop in the state. While some of the new demand will be for products that are imported from outside the state, other requirements present an opportunity for new businesses (or the expansion of existing business enterprises). For example, more stringent air monitoring requirements will increase demand for industrial hygienists. The

advanced hygiene requirements will increase demand for portable showers and washrooms. These services are likely to be met by an increase in business activity within the state.

The sectors that are most affected by the proposed regulations (for example, law enforcement, construction, fabricated metal product manufacturing, and scrap metal recycling) are not particularly susceptible to competition from outside of the state since the work must be performed in California. All firms engaging in these activities are therefore subject to the proposed regulations. Therefore, we do not expect California firms to be at a competitive disadvantage due to the new regulations.

4. Direct Benefits

Regulations that limit workplace exposure to environmental hazards generate benefits in the form of avoided costs associated with morbidity (induced illness) and mortality (shortened life expectancy) caused by occupational lead exposure. Prolonged workplace exposure to lead has been linked to, among other maladies, impaired kidney function, high blood pressure, cardiovascular disease, nervous system and neurobehavioral effects, cognitive dysfunction later in life, and cognitive effects associated with prenatal exposure (EPA 2013). Here we attempt to quantify the value of avoiding a portion of these health costs by limiting occupational lead exposure.

Evaluation of benefits associated with the proposed regulation is carried out according to the following steps:

1. Estimate the number of employees exposed and characterize their blood lead levels
2. Characterize the lead exposure – health outcome relationships
3. Estimate the number of cases of damage avoided by health outcome
4. Estimate the value of each avoided health damage
5. Discuss potential health benefits that are not included in our estimates

To summarize, we first calculate the number of exposed employees, by range of exposure level. Second, we model employee BLLs associated with these exposure levels. Next, we draw on cohort studies of health effects from lead to estimate the number of cases of select health damages that would be avoided under the proposed regulation. We then utilize cost estimates to quantify the value of these avoided health damages. Finally, because we only estimate avoided cases for a small subset of the potential health damages that have been linked to lead exposure, we discuss the health benefits that we are unable to quantify but that would potentially be accrued with the proposed regulation.

4.1. Estimating the number of exposed employees by BLL

DIR staff estimated the blood lead levels (BLL) of employees exposed to lead in California (see appendix for estimation methods). Bases on these estimates, most lead-exposed employees (>80%) have estimated BLLs < 10 µg/dL, however, nearly 40,000 employees have estimated BLLs >10 µg/dL and an additional 1,230 have estimated BLLs >30 µg/dL (Table 11). Employees with the highest estimated blood lead levels are employed in firing ranges, battery manufacturing, and motion picture production. Occupations with the most employees at risk (BLL > 10 µg/dL), because they have moderate to high exposures and a large workforce, include residential painting, residential remodeling, machine shops, and recycling material centers.

Table 11: Number of Employees by Estimated Blood Lead Level

3-digit NAICS Code	Description	Estimated # employees Total	Estimated # employees BLL >10 µg/dL	Estimated # employees* BLL > 30 µg/dL
Construction				
221	Utilities	2,165	578	0
236	Construction of Buildings	8,190	3,147	0
237	Heavy and Civil Engineering Construction	9,172	3,055	0
238	Specialty Trade Contractors	57,281	6,697	0
531	Real Estate	2,179	945	0

562	Waste Management Remediation Services	4,762	0	0
922	Justice, Public Order, and Safety Activities	1,119	0	0
	Construction Totals	84,868	14,422	0
	General Industry			
327	Nonmetallic Mineral Product Manufacturing	241	241	0
331	Primary Metal Manufacturing	2,600	1,903	265
332	Fabricated Metal Product Manufacturing	10,089	10,036	5
334	Computer and Electronic Product Manufacturing	1,081	168	0
335	Elec. Equip., Appliance, & Component Manuf.	943	547	363
336	Transportation Equipment Manufacturing	660	660	0
423	Merchant Wholesalers, Durable Goods	9,090	9,048	0
512	Motion Picture and Sound Recording Industries	644	635	195
541	Professional, Scientific, and Technical Services	814	0	0
561	Administrative and Support Services	5,590	0	0
713	Amusement, Gambling, and Recreation Industries (includes firing ranges)	1,764	1,764	402
811	Repair and Maintenance	690	379	0
922	Justice, Public Order, and Safety Activities	108,351	0	0
	General Industry Totals	142,5557	25,381	1,230
	Employee Totals	**227,425**	**39,803**	**1,230**

*Note the group with BLL > 30 µg/dL is a subset of the group with BLL > 10 µg/dL

4.2. Overview of lead exposure – health outcome relationships

Based on consultation with a leading expert on health impacts from lead (Michael Kosnett MD,MPH, personal communication, *8/30/18*), we draw on research that analyzes data from the Normative Aging Study (NAS) to characterize the relationship between cumulative lead exposure and select health endpoints. We then estimate the number of cases of these endpoints that

would be avoided if cumulative lead exposures were reduced according to the proposed regulation. The Normative Aging Study is a longitudinal study that began in 1963 by the United States Department of Veterans Affairs and has tracked health impacts from lead over the past several decades. Because of the time horizon, research on lead impacts that uses the NAS is uniquely able to quantify long-term health impacts from cumulative lead exposure. Many health damages from lead not quantified here are understood to occur but the long-run effects have not been precisely estimated. We therefore discuss these benefits in a later section but they are not included in our benefits estimates. This approach means that the quantified benefits estimates presented here are based on research derived from the highest standard study design but are not meant to be comprehensive. Instead they are lower-bound estimates of the total health benefits. The health damages that are quantified here include mortality (all-cause), hypertension, non-fatal heart attacks, and depression. Table 12 shows an overview of the studies used to quantify these health endpoints.

Table 12: Overview of Quantified Health Impacts

Health Endpoint	Source of estimate	Effect Estimate	Difference in bone lead level between comparison groups (µg/g)	Difference in cum. blood lead index between comparison groups (µg/dL years)
Mortality (all-cause)	Weisskopf et al 2015 (Table 2, Model 4)	HR = 1.86	20*	400
Hypertension	Hu et al 1996 (3rd paragraph page 1,174)	OR = 1.5	29+	580
Heart-attack (non-fatal)	Jain et al 2007 (Table 2)	HR = 1.71^	29.5+	590
Depression/ anxiety	Rhodes et al 2003 (Table 4)	OR = 3.62	45*	900

Bone lead type: *Patella lead, +Tibia lead;

^ The Hazard Ratio for non-fatal heart attacks was adjusted downward to account for Jain et al 2007 inclusion of fatal heart attacks (already included in our analysis with all-cause mortality endpoint), which accounted for approximately 16% of cases.

Effect estimates are reported as either Hazard Ratios (HR) or Odds Ratios (OR), which represent the ratio of health risks between study groups with high and low bone lead levels. The linear slope between bone lead (µg/g) and cumulative blood lead index (µg/dL years) is approximately 0.05 (Kosnett et al. 2007) so a difference in bone lead level between comparison groups of, for

example, 20 µg/g, is equivalent to a difference in cumulative blood lead index of 400 µg/dL years. These differences are then used in the next step to estimate the number of potential avoided health cases associated with reductions in long-term lead exposure.

4.3. Estimating the number of employees incurring avoidable health damages

In order to estimate the number of avoided health damages we first estimate the amount of avoided cumulative blood index (µg/dL years) associated with reducing blood lead levels to 10 µg/dL for different periods of time and then we relate these reductions to the differences in cumulative blood index between comparison groups shown for the studies shown in Table 12. This step requires several assumptions. We assume that:

1. Employees estimated to have BLL > 10 µg/dL will, on average, have BLL = 15 µg/dL.
2. Employees estimated to have BLL > 30 µg/dL will, on average, have BLL = 35 µg/dL.
3. The effect estimates described in Table 12 are linear in cumulative blood index years.
4. The number of employees entering and exiting each industry is constant.
5. Reduction in lead exposure has the same benefit for all employees of all tenures.

Assumptions 1 and 2 allow us to estimate the number of cumulative blood index years avoided, which are needed to relate avoided lead exposure to health outcomes. Assumption 3 allows us to relate different magnitudes of blood lead reductions to the estimated health effects and Assumption 4 allows us to estimate effects for different time periods. Assumption 5 allows us to treat the health benefits to employees from reduced lead exposure the same regardless of how many previous years of exposure they experienced.

In order to illustrate the process, we describe below how we estimate the number of avoided premature deaths associated with 10 years of reduced lead exposure for Construction employees with BLL = 15 µg/dL prior to enactment of the proposed regulation:

- Because the proposed regulation is estimated to reduce BLLs to 10 µg/dL, an employee estimated to have a BLL of 15 µg/dL would experience a reduction of 5 µg/dL each year.
- After 10 years each employee would experience a reduction of 5*10 = 50 µg/dL years.

- The difference between comparison groups in the all-cause mortality study (Weisskopf et al 2015) was 400 µg/dL years, which was found to be associated with a Hazard Ratio of 1.86. Therefore, relying on Assumption 3 above, we estimate a 50 µg/dL year reduction to be associated with a Hazard Ratio of 1 + 0.86*(50/400) = 1.125.
- We estimate 14,422 employees in Construction with BLL = 15 µg/dL and the baseline mortality rate in California is 617 deaths per 100,000 so on average we would expect 89 deaths per year among this population.
- With a hazard ratio of 1.125, 89 deaths in the low lead comparison group is estimated be associated with 100 deaths in the high lead comparison groups.
- Therefore 10 years of reducing 14,422 Constructions employees' BLLs from 15 µg/dL to 10 µg/dL would avoid an estimated 100 – 89 = 11 deaths.

We follow this process for both Construction and General Industry employees for each health endpoint with supporting evidence from studies using the Normative Aging Study dataset . In addition to the assumptions noted above, we convert Odds Ratios to Relative Risk using the conversions presented in Table 3 of Viera (2008) so that we can easily assess the number of avoided cases. For Hypertension, an Odds Ratio of 1.5 and an incidence of approximately 30% is associated with a Relative Risk = 1.3. Similarly, for depression, an Odds Ratio of 3.62 and a prevalence of 20.6% is associated with a Relative Risk = 2.35.

Table 13: Annual Baseline Rates for Health Endpoints Included in Benefits Estimates

Health Endpoint	Base Rate in CA (per 100,000)	Source
Mortality (all-cause)	617	CDC[6]
Hypertension	28,500	CDC[7]
Heart-attack (non-fatal)	387	Office of Statewide Planning and Development[8]
Depression/ anxiety[9]	20,600	National Institute of Mental Health[10]

[6] http://wonder.cdc.gov/ucd-icd10.html (CDC 2018)

[7] https://www.americashealthrankings.org/explore/annual/measure/Hypertension/state/CA

[8] http://www.cehtp.org/faq/heart_attack/heart_attack_who_is_at_risk#_faq_1

[9] We measure depression as persistent depressive disorder or anxiety disorder.

[10] https://www.nimh.nih.gov/health/statistics/persistent-depressive-disorder-dysthymic-disorder.shtml, https://www.nimh.nih.gov/health/statistics/any-anxiety-disorder.shtml

Table 13 shows the base rates for each quantified health benefit endpoint and Table 14 shows the estimated number of avoided cases following 10 years of lower exposures associated with the proposed regulation. We also estimate the number of avoided cases 1, 5, 20, 30, and 45 years after the proposed regulations were enacted (data not shown). The number of avoided cases depends on both the effect of lead exposure (Table 12) and the base rate (Table 13). Because depression has both a large effect and a high base rate, it has the highest estimated number of avoided cases with nearly 700.

Table 14: Estimated Number of Avoided Cases 10 Years after Proposed Regulation Implemented

Health Endpoint	Baseline # of Cases Expected for exposed employees	Estimated # of Avoided Cases: Construction	Estimated # of Avoided Cases: General Industry	Total Avoided Cases
Mortality (all-cause)	246	11	20	31
Hypertension	11,134	106	223	329
Heart-attack (non-fatal)	154	3	7	10
Depression	8,199	223	468	691

4.4. Monetizing avoided health damages

Broadly, there are two channels by which the proposed standard would generate benefits by lowering lead exposure levels faced by employees: (1) avoided morbidity and (2) avoided mortality. In order to monetize non-fatal health damages, we rely on Levin (2016), which includes estimates of costs associated with health damages from occupational lead exposure in the United States. Avoided morbidity costs can be divided into direct and indirect costs, where direct costs include spending associated with diagnosis, treatment, recovery and accommodation of a lead-

caused illness and indirect costs include productivity loss and personal time loss associated with a specific lead-caused illness. The Levin study develops a simple algorithm for monetizing both types of damages from health outcomes associated with high occupational lead exposure.

In order to value avoided premature deaths we rely on the EPA estimate of $9.0M (in $2017) for the Value of a Statistical Life (VSL). VSL is commonly used to measure the average person's willingness to pay to avoid risk of death and there are well-established ranges of estimates used in regulatory impact assessments in the United States. The concept of a VSL represents the value of an average American life and therefore values a life saved of any person equally. An overview of both types of monetized damages is shown in Table 15 broken down by health outcome.

Table 15: Overview of Direct and Indirect Monetized Health Damages (2017 $)

Damage	Direct per case cost	Indirect per case cost	Total per case cost
All-cause mortality	NA	NA	$9,000,000[+]
Hypertension	$1,700	$1,700	$3,500[*]
Heart-Attack (non-fatal)	$116,000	$116,000	$241,300[*]
Depression	$4,000	$8,000	$12,500[*]

Source: [*] Levin (2016) Table 3, [+]EPA.
+ With the exception of all-cause mortality, all costs are annual.

4.5. Results

We estimate that 41,000 employees have blood lead levels > 10 μg/dL and 1,200 of those employees have blood lead > 30 μg/dL. Given the baseline mortality rates for the general population, we would expect 253 deaths in a year for a population of that size. However, mortality rates for people exposed to high levels of lead are substantially higher (Weisskopf et al 2015). Moreover, the effects are cumulative so the longer the proposed regulation is in place, the more premature deaths are averted each year. Specifically, by reducing blood lead levels to

10 µg/dL we estimate that the regulation would help avoid 15 premature deaths in year 5, 31 premature deaths in year 10 and 59 premature deaths in year 20.[11]

Table 16: Annual Estimated Avoided Deaths Per Year

Years after proposed regulation enacted	Construction	General Industry	Total
1	1	2	3
5	5	10	15
10	11	20	31
20	19	40	59
30	29	60	89
45	43	90	133

Following the process outlined in the previous sections for each of the health endpoints, valuing avoided cases according to Table 15, we estimate annual health benefits from the proposed regulation to be $27.9M in year 1 increasing each year until they reach $1.3B per year by year 45. The selected estimated benefits are split between General Industry and Construction, roughly proportionately to the (exposure-adjusted) number of employees exposed to lead (65% General Industry, 35% Construction). By year 7 annual total benefits would have exceeded annual costs. The most valuable benefit is avoided premature deaths followed by depression, heart attacks, and hypertension, respectively.

Table 17: Annual Estimated Avoided Health Costs Per Year (Millions 2017 $)

Years after proposed regulation enacted	Construction	General Industry	Total*
1	9.0	18.9	27.9
5	45.0	94.6	139.6

[11] These calculations assume that employees with BLL = 10 µg/dL would have the same mortality rate as the general population. However, there is some evidence that even exposure to lower levels of lead causes excess mortality.

10	90.1	189.2	279.3
20	180.1	378.4	558.6
30	270.2	567.7	837.8
45	405.3	851.5	1256.7

*Includes value of avoided deaths, hypertension, depression/anxiety, and non-fatal heart attacks.

The value of the benefits estimated here is far greater than the estimated costs associated with the proposed regulation. Moreover, these benefits estimates represent only a fraction of the total potential benefits because we have not quantified many of the other health benefits likely to accrue from the proposed regulation.

4.6. Non-Quantified Benefits

Omitted Health Damages

The present estimates do not attempt to quantify all benefits from the proposed regulation because while lead exposure is understood to cause these health damages, there have not been careful studies using the Normative Aging Study dataset to precisely quantify the relationship between cumulative lead exposure and incidence. Non-quantified health endpoints linked to lead, but without sufficient data to reliably estimate the number of avoided cases, include muscular pain, ocular disorder, nervous system disorder, panic disorder, dementia, male fertility damages, and female fertility damages, among others.

Possible health damages with insufficient evidence to support causal linkages with lead

In addition to the health damages *known* to be associated with lead that we are unable to quantify, other health damages are *suspected* to be associated with lead exposure including cancer and chronic kidney disease. However, the causal links between lead and these outcomes are not well enough established to merit inclusion in this SRIA.

Benefits below regulation threshold

We assume the reduced exposure levels under the proposed regulation will be exactly equal to the maximum allowable amount. In other words, we assume lead concentrations are not reduced below their maximum allowable concentrations due to the regulation being enacted. If the revised regulations result in lead exposure levels lower than the maximum allowable limit, then additional benefits would come from larger reductions than we model here.

Benefits to non-employees

By lowering workplace exposure the proposed regulation will also lead to reduced "takehome" exposure for non-employees. When employees are exposed to lead over the course of the workday, small lead particles accumulate on exposed skin, hair, clothing and equipment. In many cases (unless the employee changes and showers prior to returning home) these lead particles are transported home and the employee's family is exposed to elevated levels of lead. Reducing levels of lead exposure in the workplace will therefore also reduce exposure of infants and children by reducing the amount of lead transported home from the workplace. However, while we acknowledge this additional benefit, limited information is available regarding the potential magnitude. It is expected to be relatively small compared to benefits accrued by exposed employees and is not quantified in this analysis.

5. Macroeconomic Impacts

5.1. Methodology

The economy-wide impacts of the revisions to the occupational lead safety regulations are evaluated using the BEAR forecasting model. The BEAR model is a dynamic computable general equilibrium (CGE) model of the California economy. The model explicitly represents demand, supply, and resource allocation across the California economy, estimating economic outcomes over the period 2016-2030. For this SRIA, the BEAR model is aggregated to 60 economic sectors.

The current version of the BEAR model is calibrated using 2015 IMPLAN data. Both the baseline and policy scenarios use the Department of Finance conforming forecast from June 2017. The conforming forecast includes official assumptions about future GDP growth for the State's economy and population.

5.2. Scenarios

The estimated macroeconomic impact of the regulation is based on expected changes in compliance costs and health expenditures for the various sectors identified in sections 3 and 4. The main scenario, *Proposed*, represents the expected macroeconomic impact of increasing compliance costs and health benefits from 2018-2030. While the compliance costs of the proposed regulations are expected to remain constant after the second year of implementation, the benefits of the proposed regulation will continue to increase as the workforce exposed to lead turns over. While this turnover process is assumed in section 4 to take approximately 45 years, the macroeconomic analysis only forecasts out to 2030. In this sense, the macroeconomic results presented here are likely to show only the medium-term effects of the proposed regulation, and to be conservative in terms of long term net benefits.

5.3. Inputs to the Assessment

The main inputs into the macroeconomic analysis are the sector-specific compliance costs of the proposed regulation over time and the reduction in health expenditures that can be expected as lead-induced health effects decline over time.

To model compliance costs, we match the 6-digit NAICS codes where lead-exposed employees have been identified to the relevant BEAR sector. There are two types of costs calculated in section 3: extra costs that employers must pay on intermediate goods and services (e.g. additional lab tests or engineering controls) and time costs that employers must pay for employees' lost time while undergoing testing, training MRP, etc. For each affected sector, we calculate the total compliance costs in each category of intermediate inputs and labor payments.

A summary of the direct costs and avoided health expenditures, which serve as the inputs to the BEAR model, is given in Table 18. The estimates shown are for a sample fully-implemented year (2025). Year 1 inputs into the model will be different as will health expenditure savings, which increase over time. All monetary inputs are in real $2015 and no discounting adjustments have been made.

Table 18: Macroeconomic Model Inputs by Sector for a Representative Year ($ million)

BEAR Sector	Labor Costs	Materials Costs	Health Expenditures
Hydroelectric Power Generation	0.01	0.58	-0.19
Fossil fuel Electric Power Generation	0.07	3.43	-1.10
Electric Power Transmission and Distribution	0.10	2.91	-1.61
Non-Electric Power Utilities	0.11	5.26	-5.37
Non-residential Construction	0.43	6.21	-5.26
Residential Construction	22.47	18.09	-45.14
Other Construction	1.34	13.66	-8.67

Non-Ferrous Metal Manufacturing	0.56	0.73	-1.20
Primary Metal Manufacturing	4.69	4.54	-14.81
Ferrous Metals Processing	22.61	29.29	-50.24
Electronics Manufacturing	1.28	1.16	-0.84
Electrical Equipment and Appliance Manufacturing	1.61	0.94	-9.99
Aircraft Manufacturing	1.50	1.89	-3.29
Wholesale Trade	18.38	22.71	-45.20
Information and Communications Services	8.08	1.88	-11.79
Professional Services	1.07	0.96	0.00
Hospitality Services	10.35	1.46	-16.84
Other Services	2.83	0.81	-1.89
Public Services	7.41	6.25	0.00

5.4. Results

This section presents the expected macroeconomic impacts of the proposed regulation. Table 19 shows the key macroeconomic indicators: real gross state product (GSP), employment, real output, investment, and household income. Several observations of the macroeconomic aggregates are worth of emphasis. First, despite the large estimated direct costs (section 3) and benefits (section 4), the macroeconomic impacts of the regulatory revisions are expected to be quite small. This is due to the fact that the compliance costs and reduction in health expenditures are have offsetting impacts over the assessment period. Generally speaking, costs dominate in the early years and benefits dwarf these in the long term.[12] There will also be macroeconomic adjustments in production and unemployment across sectors that will average out in the macroeconomic aggregates presented below. Some sectors (e.g. compliance services and products) may see increased employment and output, while other sectors may see lower unemployment and output as they internalize higher compliance cost impacts. In later years, the

[12] Given that we are only evaluating about half the long-term (full career) health improvement (to 2045), the dominance of benefits to California employees and their families is even more dramatic.

trends in macroeconomic indicators is largely reversed as the effects of higher health expenditure savings surpasses compliance costs. In 2030, the final year of our analysis period, real GSP is estimated to be $2.40 million higher than the baseline, small in percentage terms but important to the industries and employees involved. Similar impacts are also observed in other macro indicators, such as real output, investment, and household income.

The second observation is that in the early years of the proposed regulation, employment and the macroeconomic income and expenditure indicators move in opposite directions. Total employment actually increases for the early years of the proposed regulations. This is likely due to the nature of the employment composition in sectors that are affected by higher compliance costs. Compliance may adversely impact some jobs in covered industries, but at the same time stimulates employment in (generally smaller and more labor intensive) sectors providing compliance equipment and services. Finally, health related savings will be diverted from medical care to other consumption, about 70% of which is services in California. This expenditure shifting offers strong, job-intensive long-term stimulus from the regulation. Moreover, services are primarily in-state in their direct and indirect employment impact – these jobs cannot be outsourced.

Table 19: Economy-wide Impacts of Occupational Lead Standards

(billion $ difference from baseline, 2015$ unless otherwise noted)

	2018	2020	2025	2030
Real GSP	-0.26	-0.42	-0.02	2.40
Employment (1,000 FTE)	0.09	0.25	0.24	3.08
Real Output	-0.28	-0.51	0.23	4.36
Investment	-0.12	-0.1	0.42	1.84
Household Income	-0.04	-0.08	-0.02	0.75

Table 20 decomposes the total change in real business output into sector-specific changes in real enterprise output. The effects of the proposed regulation on sectoral output are varied

across both sectors and years. In the early years of the proposed regulations, when compliance costs are significantly larger then health benefits, all sectors of the economy see very small reductions in trend output.[13] This trend is reversed as health expenditures exceed compliance costs later in the analysis period.

Table 20: Decomposition of Industry Output

(billion $difference from baseline, million 2015$)

Sector	**2018**	**2020**	**2025**	**2030**
AgForestry	0.01	0	-0.02	-0.06
Mining	0	0	0	0.02
Utilities	-0.01	-0.03	-0.04	-0.01
Construction	-0.06	-0.07	0.14	0.83
Manufacturing	-0.14	-0.21	0.12	1.46
Wholesale Trade	-0.06	-0.08	0.08	0.69
Retail Trade	0	-0.01	0.01	0.16
Transportation	-0.01	-0.01	0.01	0.14
Services	-0.01	-0.08	-0.05	1.16
Government	0	-0.01	-0.02	-0.02

[13] It should be emphasized that reducing trend output by these amounts means, in every case, that these sectors will continue growing over time, but at negligibly slower rates in some years because of net compliance costs. Since baseline (trend) annual growth in California is assumed to exceed 2%, the largest effect above indicates that this growth would be slightly lower growth in the most impacted year. Thus, current employment would never decline (no jobs are lost) even in growth moderates.

6. Fiscal Impacts

This section details the expected fiscal impact of the proposed revisions to the occupational lead regulations. There are two dimensions to the fiscal impact considered here. First, a number of lead-exposed employees are employed in state and local governments. Table 21 shows that there are an estimated 72,439 local government employees and 41,038 state government employees exposed to lead. The vast majority of these employees are in law enforcement. There will be compliance costs, borne by local and state agencies, associated with reducing the lead exposure of those employees.

Table 21: Estimated Total Exposed Employees by Private/Public Sector

2-digit NAICS Code	Sector	Private Sector EEs	Local Gov't EEs	State Gov't EEs	Total Exposed Employees
	Section 1532.1 (Construction)				
22	Utilities	1,005	1,160	0	2,165
23	Construction	72,725	1,808	110	74,643
53	Real Estate and Rental and Leasing	2,168	11	0	2,179
56	Admin/Support/Waste Mgt and Remediation Services	4,762	0	0	4,762
92	Public Administration	0	1,119	0	1,119
	Total Exposed Employees (1532.1)	**80,660**	**4,098**	**110**	**84,868**
	Section 5198 (General Industry)				
31-33	Manufacturing	15,614	0	0	15,614
42	Wholesale Trade	9,090	0	0	9,090
51	Information	644	0	0	644
54	Professional, Scientific, and Technical Services	814	0	0	814
56	Admin/Support/Waste Mgt and Remediation Services	5,590	0	0	5,590
71	Arts, Entertainment, and Recreation	846	893	26	1,764

81	Other Services (except Public Administration)	690	0	0	690
92	Public Administration	0	67,448	40,903	108,351
Total Exposed Employees (5198)		**33,288**	**68,341**	**40,928**	**142,557**
Total Exposed Employees		**113,948**	**72,439**	**41,038**	**227,425**

The additional compliance costs to local and state governments are shown in Table 22. We estimate that the proposed regulations will cost local governments approximately $16.5 million and $9.7 million per year in years 1 and 2+, respectively. Just under half of this is expected to be associated with local police departments coming into compliance with more stringent occupational lead standards. Utilities and Construction employees employed by local governments account for most of the rest of the additional cost. The proposed regulations are expected to cost the California state government approximately $2.9 million and $2.7 million per year in years 1 and 2+, respectively. Eighty-six percent (86%) of this cost is associated with state law enforcement agencies.

Table 22: Estimated Additional Public Sector Compliance Costs

Digit NAICS Code	Sector	Total Public Sector Cost		Local Government Cost		State Government Cost	
		Section 1532.1 (Construction)					
		Year 1	Year 2+	Year 1	Year 2+	Year 1	Year 2+
22	Utilities	$3,187,425	$3,187,425	$3,187,425	$3,187,425	$0	$0
23	Construction	$2,457,155	$1,669,455	$2,103,268	$1,309,793	$353,887	$359,662
53	Real Estate and Rental and Leasing	$12,029	$8,767	$12,029	$8,767	$0	$0
56	Admin/Support/Waste Mgt Services	$0	$0	$0	$0	$0	$0
92	Public Administration	$1,097,238	$678,154	$1,097,238	$678,154	$0	$0
	Total Cost (1532.1)	$6,753,847	$5,543,801	$6,399,960	$5,184,139	$353,887	$359,662
		Section 5198 (General Industry)					
		Year 1	Year 2+	Year 1	Year 2+	Year 1	Year 2+
31-33	Manufacturing	$0	$0	$0	$0	$0	$0
42	Wholesale Trade	$0	$0	$0	$0	$0	$0
51	Information	$0	$0	$0	$0	$0	$0
54	Professional, Scientific, and Technical Services	$0	$0	$0	$0	$0	$0
56	Admin/Support/Waste Mgt Services	$0	$0	$0	$0	$0	$0
71	Arts, Entertainment, and Recreation	$6,154,161	$577,196	$5,982,656	$561,111	$171,506	$16,085
81	Other Services (except Public Administration)	$0	$0	$0	$0	$0	$0
92	Public Administration	$6,525,032	$6,263,876	$4,101,403	$3,937,540	$2,423,629	$2,326,336
	Total Cost (5198)	$12,679,193	$6,841,072	$10,084,059	$4,498,651	$2,595,135	$2,342,422
	Total Cost	$19,433,040	$12,384,874	$16,484,019	$9,682,790	$2,949,022	$2,702,084

DOSH, the government agency that would enforce the proposed revisions, does not anticipate any fiscal impact to the agency as a result of the proposed revisions.

7. Analysis of Regulatory Alternatives

In addition to the proposed regulatory revisions to the Title 8 occupational lead standards, we analyze the impacts of two regulatory alternatives. One of the regulatory alternatives is more stringent than the proposed regulation and other regulatory alterative is less stringent.

For the more stringent regulatory alternative, we assume that the permissible exposure limit is set at 2 µg/m^3, rather than the proposed level of 10 µg/m^3. This change would both increase the compliance costs for regulated entities and potentially increase employee benefits by reducing even low-level occupational exposure to lead. The additional compliance actions required under the lower PEL, compared to baseline requirements, are shown in Table 23.

Table 23: Compliance Requirements Under the More Stringent Regulatory Alternative

	Airborne Exposure Level (ug/m^3)					
Control Requirement	**<0.5**	**0.5 -2**	**2 - 30**	**30 - 50**	**50 - 500**	**>500**
Air Monitoring		X	X			
Engineering Controls			X	X	X[1]	X[1]
Respiratory Protection			X	X	X[2]	X[3]
Personal Protective Equipment		X	X	X		
Hygiene- Advanced			X	X		
Hygiene - basic	X	X	X	X		
Medical Surveillance		X	X	X	X	X
Medical Work Removal				X		
Training - Comprehensive		X	X	X		

[1] Upgraded engineering controls
[2] ½ full mask, ½ half mask respirator
[3] Supplied air respirators

For the less stringent regulatory alternative, we assume that the current occupational lead requirements remain as they are. There would be no additional compliance costs beyond what firms are already required to do under existing regulations. However, there would also be no additional benefits for California employees working in occupations with lead exposure.

7.1. Summary of Direct Costs and Direct Benefits

A summary of the direct costs and benefits for the more stringent and less stringent regulatory alternative are described below.

More Stringent Regulatory Alternative

Compliance costs for the more stringent regulatory alternative, with a lower PEL, are shown in Table 24 (for Construction) and Table 25 (for General Industry). The total compliance costs for Construction are nearly identical to the compliance costs under the proposed regulation. This is due to the fact that most exposure employees in Construction had exposure levels less than 10 ug/m^3 so a lower PEL would not capture many additional employees. However, in General Industry, the compliance costs nearly double from $144 million (year 1) and $111 million (year 2+) under the proposed regulation to $281 million (year 1) and $203 million (year 2+) with the lower PEL. This is driven almost entirely by the fact that thousands of law enforcement employees would be required to adopt more stringent control requirements than would be required under the proposed regulatory changes.

Table 24: Summary of Additional Compliance Costs for Lower PEL in Construction ($2017)

Cost Component	Year 1	Year 2+
Air Monitoring	$4,033,646	$2,175,011
Engineering Controls	$6,214,218	$6,666,374
Respiratory Protection	$3,130,275	$3,240,515
Personal Protective Equipment	$1,243,819	$1,243,819
Hygiene (lunchroom, showers, change rooms)	$6,801,272	$6,801,272
Hygiene - basic	$12,151,886	$12,151,886
Medical Surveillance	$66,452,139	$47,680,091
Medical Removal Program	$0	$0
Training - Comprehensive	$4,431,073	$4,431,073
Total Compliance Cost - Construction (1532.1)	**$104,458,328**	**$84,390,041**

Table 25: Summary of Additional Compliance Costs for Lower PEL in General Industry ($2017)

Cost Component	Year 1	Year 2+

Air Monitoring	$55,470,495	$14,666,867
Engineering Controls	$37,728,683	$38,195,216
Respiratory Protection	$1,124,288	$1,004,941
Personal Protective Equipment	$5,590,355	$5,590,355
Hygiene - Advanced	$55,785,858	$55,785,858
Hygiene - Basic	$22,009,542	$22,009,542
Medical Surveillance	$29,592,965	$12,215,519
Medical Removal Program	$19,931,341	$0
Training - Comprehensive	$53,604,343	$53,604,343
Total Compliance Cost - General Industry (5198)	**$280,837,869**	**$203,072,639**

Reducing the permissible exposure limit to 2 μg/m^3 would generate all of the same benefits as reducing the permissible exposure limit to 10 μg/m^3 as well as further benefits from the additional reduction below 10 μg/m^3. The benefits of reduction below 10 μg/m^3 depend on the health risks of low-level lead exposure and these remain unclear. While exposure to small amounts of lead was previously thought to present minimal health risk, recent work by Lanphear et al 2018 suggests that even low-level environmental lead exposure may increase the risk of cardiovascular disease mortality. While this new finding suggests substantial benefits would result from the additional reduction in exposure, most studies do not attempt to quantify the health benefits from reductions in exposure below these levels and so there is insufficient evidence to quantify the magnitude of these benefits.

Less Stringent Regulatory Alternative

The less stringent regulatory alternative, where the current regulatory requirements remain in effect, would produce no additional benefits to employees in California. There would also be no additional compliance cost for regulated entities. However, there is an opportunity cost of the less stringent regulatory alternative, which are the foregone employee benefits from reducing occupational lead exposure. Relative to the proposed regulation, these opportunity costs are quite large, as shown in Table 17, starting at approximately $28 million in year 1 and increasing to over $1.2 billion after 45 years.

7.2. Macroeconomic Impacts

In addition to the direct costs and benefits discussed above, we also analyzed the macroeconomic impacts of the more stringent regulatory alternative.[14] Table 26 summarizes the macroeconomic impacts of the more stringent regulatory alternative and provides a comparison to the expected macroeconomic impact of the proposed regulation. Across all key macroeconomic indicators, the lower PEL has larger adverse effects on the economy in the early years of implementation and more muted positive impacts on the economy in later years.

Table 26: Economy-Wide Impacts of Occupational Lead Standards – More Stringent Regulatory Alternative (billion $ difference from baseline, $2015 unless otherwise noted)

	2018		**2020**		**2025**		**2030**	
	Proposed	Lower PEL	Proposed	Lower PEL	Proposed	Lower PEL	Proposed	Lower PEL
Real GSP	-0.26	-0.4	-0.42	-0.6	-0.02	-0.86	2.40	0.34
Employment (1,000 FTE)	0.09	-0.09	0.25	-0.11	0.24	-2.46	3.08	-3.86
Real Output	-0.28	-0.37	-0.51	-0.75	0.23	-0.95	4.36	1.37
Investment	-0.12	-0.23	-0.1	-0.34	0.42	-0.29	1.84	0.57
Household Income	-0.04	-0.11	-0.08	-0.16	-0.02	-0.44	0.75	-0.35

7.3. Comparison to Proposed Regulatory Revisions

This analysis considered two regulatory alternatives: a more stringent alternative that delivers potential additional employee benefits from even less exposure to occupational lead, but at a significantly higher cost, and a less stringent alternative that considers keeping occupational lead standards as they currently are. The more stringent regulatory alternative can be rejected because the additional benefits, which are difficult to quantify, come at nearly double the cost of

[14] A macroeconomic analysis of the less stringent alternative is not necessary since so additional compliance costs would be imposed on regulated entities. Therefore, no macroeconomic impacts would be expected.

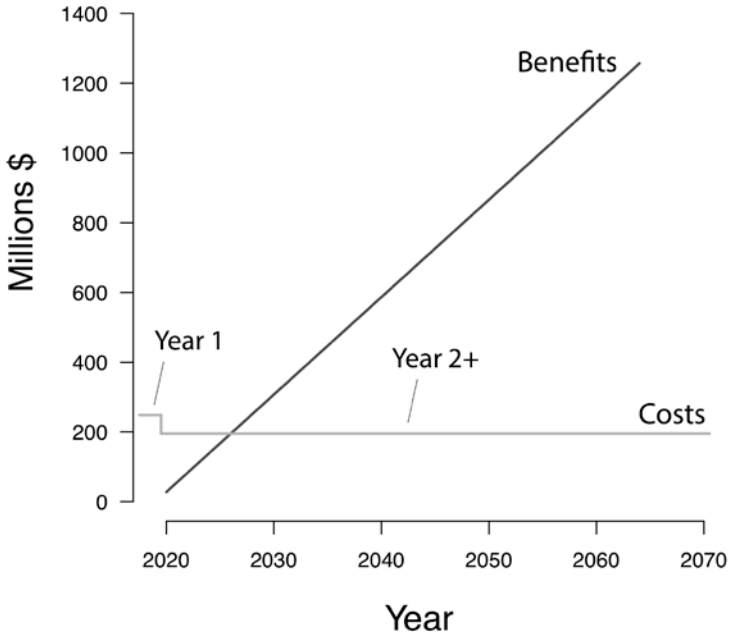
the proposed regulation. The less stringent regulatory alternative can be rejected for not delivering adequate benefits, given the known risks to lead exposure, to employees in California.

8. Interpretation of Economic Results

The Department of Industrial Relations' proposal to revise its occupational lead standards for Construction and General Industry is expected to give rise to compliance costs for industries where employees are currently exposed to lead, but reforming decades-old exposure safety standards will confer health benefits on current and future California employees and their families that far exceed these costs. Compliance costs reflect the need to update 40+ year-old exposure and health intervention standards, providing employees with enhanced protections to reduce exposure (e.g. engineering controls, respiratory protection, hygiene and personal protective equipment), while strengthening employee training, air monitoring, medical surveillance, and medical intervention requirements. These costs are expected to accrue to the sectors whose employees are exposed to lead, and ultimately would be passed along to consumers of products in these industries. The benefits of the proposed regulation include reductions in morbidity and mortality associated with lower levels of lifetime air and oral exposure to lead, a material whose toxicity occurs at much lower levels than had long been indicated. Employees in a large swath of California industries will experience and share health benefits from reduced exposure to lead. In addition, lead exposures to household members of employees from take-home lead would be reduced, resulting in additional health benefits.

As the full, long-term benefits of the proposed regulatory revisions are realized, the annual benefit-cost ratios for this regulation are quite high and sustained, with benefits expected be substantially larger than compliance costs. However, compliance costs begin to accrue immediately while the health benefits manifest themselves over time (Figure 3). The estimated aggregate breakeven point under the assumptions of this assessment would occur approximately within the first 7 years after the proposed revisions come into effect. It should also be recalled that the benefit estimates used in this study are not comprehensive and that total benefits are expected to be substantially higher.

Figure 3 Annual Costs vs. Benefits Over Time



Our macroeconomic results show the proposed revisions will likely have a negligible impact on the overall California economy, measured in terms of Gross State Product, employment, real business output, and household income. Because lead-exposed employees are spread across the diverse activities, the impacts of the regulation are not concentrated in any particular sector. The exception is in the early years of regulatory implementation when the construction and manufacturing sectors have high compliance costs, which reduces sectoral output. Even in sectors that show positive net compliance cost in some years, however, the impact is never high enough to reduce absolute output or jobs. All sectors remain growth and employment positive in every year, even if growth is moderated slightly by the need to improve employee health and safety.

9. References

Centers for Disease Control and Prevention (2016), National Center for Chronic Disease Prevention and Health Promotion, Division of Population Health. Disease Indicators Data [online]. 2016. https://nccd.cdc.gov/cdi.

Cheng, Y., Schwartz, J., Sparrow, D., Aro, A., Weiss, S.T., and H. Hu (2001). "Bone Lead and Blood Lead Levels in Relation to Baseline Blood Pressure and the Prospective Development of Hypertension The Normative Aging Study", *American Journal of Epidemiology*, Volume 153, Issue 2, 15 January 2001, Pages 164–171, https://doi.org/10.1093/aje/153.2.164

Environmental Protection Agency (2013). Integrated Science Assessment (ISA) for Lead. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-10/075F.

Kosnett, M.J., Wedeen, R.P., Rothenberg, S. J., Hipkins, K.L., Materna, B.L., Schwartz, B.S., Hu, H., and Woolf, A. (2007). "Recommendations for Medical Management of Adult Lead Exposure." Environmental Health Perspectives, Volume 115(3), Pages 463-471.

Lanphear, B. P. , S. Rauch, P. Auinger, R. W. Allen, and R. W. Hornung (2018). "Low-level lead exposure and mortality in us adults: a population-based cohort study". The Lancet Public Health, 2018.

Levin, R. (2016). "The attributable annual health costs of U.S. occupational lead poisoning", International Journal of Occupational and Environmental Health, 22:2, 107-120, DOI: 10.1080/10773525.2016.1173945

Hu H, Aro A, Payton M, et al (1996). "The Relationship of Bone and Blood Lead to Hypertension: The Normative Aging Study". *JAMA.* 1996; 275 (15):1171–1176. doi:10.1001/ jama.1996.03530390037031

HUD (2017). "Economic Analysis of the Proposed Rule on Lead-Based Paint: Requirements for notification, evaluation, and reduction of lead-based paint hazards in federally owned residential property and housing receiving federal assistance; Response to elevated blood lead levels". Office of Lead Hazard Control and Healthy Homes. U.S. Department of Housing and Urban Development. January 3, 2017.

Jain, N., Potula, V., Schwartz, J., Vokonas, P., Sparrow, D., Wright, R., Nie, H., and H. Hu. (2007). "Lead Levels and Ischemic Heart Disease in a Prospective Study of Middle-Aged and Elderly Men:

the VA Normative Aging Study". *Environmental Health Perspectives* Vol 115 (6), pages 871-875, June 2007.

OSHA (2007) "Regulatory Review of 29 CFR 1926.62: Lead in Construction." Occupational Safety and Health Administration. U.S. Department of Labor. Available at https://www.osha.gov/dea/lookback/lead-construction-review.html

OSHA (2013) "Preliminary Economic Analysis and Initial Regulatory Flexibility Analysis, Occupational Exposure to Crystalline Silica." Occupational Safety and Health Administration. U.S. Department of Labor.

OSHA (2016). "Final Economic Analysis and Final Regulatory Flexibility Analysis: Supporting Document for the Final Rule for Occupational Exposure to Beryllium. Chapter 6 – Benefits and Net Benefits". Occupational Safety and Health Administration. U.S. Department of Labor. 2016.

Rhodes, D., Sprio, A., Aro, A., and Hu, H. (2003). "Relationship of Bone and Blood Lead Levels to Psychiatric Symptoms: The Normative Aging Study". *Journal of Occupational and Environmental Medicine*. 45 (11) pgs 1144-1151.

Viera, Anthony (2008). "Odds ratios and risk ratios: what's the difference and why does it matter?". *Southern Medical Journal,* 101 (7) 730-734.

Weisskopf, M. G., Sparrow, D., Hu, H., & Power, M. C. (2015). "Biased Exposure–Health Effect Estimates from Selection in Cohort Studies: Are Environmental Studies at Particular Risk?" *Environmental Health Perspectives*, *123*(11), 1113–1122. http://doi.org/ 10.1289/ehp.1408888

Appendix A

A.1.1 Modeling employee exposures and blood lead levels

DIR Staff first identified a list of 6-digit NAICS codes representing the relevant industries in California in which CDPH-OLPPP reports evidence of significant lead exposure. Each code is associated with an estimated number of lead-exposed employees in CA and the NAICS codes were classified as either Construction or General Industry, based on the type of work the exposed employees do. For each of these NAICS codes, a lead exposure task that best described the exposure within the NAICS code was selected. A given lead exposure task was often used to describe the work conducted in a number of NAICS codes.

For each lead exposure task, DIR staff selected a task geometric mean (GMT) for airborne lead exposure from the published literature. These values were taken from data published in Koh et al 2015, Koh et al 2017, Locke et al 2017, and OSHA 1993. For NAICS codes in which employees use indoor shooting ranges for firearms qualifying, a GMT was constructed from four published studies representative of the diverse ranges where employees might shoot (National Research Council, 2013; Ramsey et al 2011; Ramsey et al 2013; Scott et al 2011).

A task geometric standard deviation (GSDT) was estimated following Table 5 in Kromhout et al (1993). A GSDT of 1.87 was used for inside work and 3.46 for outside work.

Where a GMT value was not available, but a task arithmetic mean (AMT) for airborne lead exposure was, the AMT was used to calculate the GMT from the equation: ln GMT = ln AMT – $1/2(\ln GSDT)^2$. The within-worker geometric standard deviation (GSDW) and the between-worker geometric standard deviation (GSDB) values were again taken from Table 5 in Kromhout et. al. (1993). The between-worker geometric mean value (GMB) was calculated from GMT and GSDW values for each task, using the following equation from Spear et al 1987: GMT = $\exp(GMB – ½(\ln GSDW)^2)$.

For each task, the parameters (ln GMB and ln GSDB) were calculated for the normal distribution of log-transformed between-worker arithmetic mean airborne exposure levels (Mark Nicas, PhD, personal communication, December 20, 2017).

At this stage the approaches to modeling employee airborne lead exposures and blood lead levels diverge.

A1.2 Modeling employee lead exposures

For each task, DIR staff then used the Excel normal probability distribution function to calculate the probability of employees' arithmetic mean exposure levels falling below exposure "cut-points" which trigger new expense-related actions in the proposed lead standards, when compared to the existing standards. The following "cut points" were used: <2 $\mu g/m^3$, <10$\mu g/m^3$, <30$\mu g/m^3$, <50$\mu g/m^3$, and <500$\mu g/m^3$.

DIR staff calculated the proportion of employees conducting the given task whose arithmetic mean exposure levels fall within exposure intervals, bounded by the "cut-points": <2 $\mu g/m^3$, 2-10 $\mu g/m^3$, 10-30 $\mu g/m^3$, 30-50 $\mu g/m^3$, 50-500 $\mu g/m^3$, and >500 $\mu g/m^3$.

For each NAICS code, the estimated number of exposed employees was then multiplied by the associated task exposure interval proportions. This resulted in the number of employees in each NAICS code estimated to be exposed (represented by their arithmetic mean exposure) in each of the relevant cost-related exposure intervals. These numbers could then be paired with unit costs to arrive at a full accounting of the costs associated with the proposed standards.

In addition to these modeled exposure levels, the following intermittency of exposure assumptions (days exposed per year) were made:

The NAICS codes in which employees use indoor shooting ranges for firearms qualifying (561612, 561613, 922110, 922120, 922140, 922150, 922190) were each split into two groups: 90% of the

employees in each NAICS code were assumed to be exposed on 2 consecutive days per quarter (8 days per year), and 10% of the employees were assumed to be exposed on 2 consecutive days per month (24 days per year).

All construction employees were assumed to be exposed to lead on 5 consecutive days per month (60 days per year). This assumption was informed by data from four sources: the benefits modeling which was part of the 1993 OSHA Lead in Construction standard; the California Painters Project produced by CDPH-OLPPP in 1998; Vork et al.(2001); and Vork (2004).

These intermittency assumptions functioned as a multiplier when calculating total costs based on exposure level-derived per day costs. They also played a role in calculating costs associated with medical removal protection (MRP) as these costs depend on blood lead levels, which are determined by the intermittency of exposure.

Finally, MRP costs for each NAICS code were calculated based on the number of exposed employees in the given NAICS code expected to have a BLL ≥ 30 µg/dL. This number was calculated part of the modeling of employee blood lead levels (see A.1.3). As an exception, the number of employees expected to have a BLL ≥ 30 µg/dL in battery manufacturing (NAICS 335911), and in secondary smelting (NAICS 331492), were calculated using the actual number of tested workers exceeding this level in the California Occupational Blood Lead Registry database (averaged over years 2014 – 2016). Reports by CDPH-OLPPP indicate that, in contrast to other industries, almost all employers in these industries are testing their lead-exposed employees. Therefore, the BLL distributions in the Registry are a good reflection of worker BLLs in these industries.

A.1.3 Modeling employee blood lead levels

Next, the breathing-zone 8-hour TWA exposure levels associated with blood lead levels (BLLs) of 10 µg/dL and 30 µg/dL were calculated. This was also done for the different exposure

intermittency assumptions that had been made (see A.1.2). These 8-hour TWA exposure levels were calculated using the model from CalEPA-OEHHA (2013).

From these exposure levels, the 'outside-respirator' breathing-zone 8-hour TWA exposure levels associated with BLLs of 10 μg/dL and 30 μg/dL were then calculated, assuming that employees were wearing the different levels of respiratory protection in compliance with the current lead standards. It was assumed that the levels of respiratory protection reduced employee exposure in accordance with their assigned protection factors.

For each task, the Excel normal probability distribution function was used to calculate the probability of employees' arithmetic mean exposure levels falling below: (i) exposure "cut-points" which trigger increased respiratory protection under the current standards; and (ii) exposure "cut-points" which result in 'inside-respirator' exposures associated with a BLL of 10 μg/dL and 30 μg/dL.

The proportions of employees conducting the given task whose arithmetic mean exposure levels fell within sequential, non-contiguous exposure intervals were then calculated. These exposure intervals were bounded, at the low end, by the "cut-points" at which 'inside-respirator' exposures would be associated with BLLs of 10 μg/dL and of 30 μg/dL and, at the high end, by the "cut-points" at which the employee is required to be upgraded to a more protective respirator under the current standards.

For each task, the discrete proportions were summed to attain total proportion of employees whose BLLs exceeded 10 μg/dL and 30 μg/dL. These total proportions take into account exposure intermittency patterns and respirator use.

Finally, for each NAICS code, the estimated number of exposed employees was multiplied by the associated task-specific total proportions of employees to arrive at the number of employees modeled to have BLLs exceeding 10 μg/dL and 30 μg/dL. The number exceeding 30 μg/dL was

used to calculate the NAICS-specific cost of employees being medically removed under the proposed standards. (See A.1.2.)

A2. Appendix References

CDPH-OLPPP "California Painters Project: Helping Small Business Work Safely With Lead", February 1998.

CalEPA-OEHHA "Estimating Workplace Air and Worker Blood Lead Concentration using an Updated Physiologically-based Pharmacokinetic (PBPK) Model", October 2013.

Koh et al., "Lead exposure in US worksites: A literature review and development of an occupational lead exposure database from the published literature," Am J Ind Med. 2015; 58(6): 605-616.

Koh et al., "Combining Lead Exposure Measurements and Experts' Judgement Through a Bayesian Framework", Annals of Work Exposures and Health, 2017, Vol. 61, No. 9, 1054-1075.

Kromhout et al., "A Comprehensive Evaluation of Within- And Between- Worker Components of Occupational Exposure to Chemical Agents", Ann. Occup. Hyg., 1993, Vol 37, No. 3, pp 253-270.

Locke et al., "Evaluating Predictors of Lead Exposure for Activities Disturbing Materials Painted With or Containing Lead Using Historic Published Data From U.S. Workplaces", Am J Ind Med. 2017; 60:189-197.

National Research Council, "Potential Health Risks to DOD Firing-Range Personnel from Recurrent Lead Exposure", Washington, DC: The National Academies Press, 2013. https://doi.org/10.17226/18249.

OSHA. 29 CFR part 1926, Lead Exposure in Construction, Interim final rule. Federal Register, 1993, Vol. 58, No. 84, Tuesday, May 4 1993.

Ramsey et al., NIOSH Health Hazard Evaluation Report: “Evaluation of Lead Exposure at an Indoor Firing Range – California”, NIOSH Report No. 2008-0275-3146, November 2011.

Ramsey et al., NIOSH Health Hazard Evaluation Report: “Followback Evaluation of Lead and Noise Exposures at an Indoor Firing Range”, NIOSH Report No. 2012-0065-3195, November 2013.

Scott et al., “Impact of Housekeeping on Lead Exposure in Indoor Law Enforcement Shooting Ranges”, J Occup. Env. Hyg. 2011.

Spear et al., “Benzene exposure in the petroleum refining industry,” Appl. Ind. Hyg., 1987, Vol. 2, No. 4, July 1987.

Vork K.L. et al., “Prevention of Lead Poisoning in Construction Workers: A New Public Health Approach”, AJIM, 2001, 39:243-253 .

Vork K.L., “Work and Blood Lead Relationships Among Bridge Workers: Final Report to NIOSH”, NIOSH, 2004.