Prevention of Lead Exposure in Adults
Recommendations for Public Health Action

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Report of the Prevention of Lead Exposure in Adults (PLEA) Workgroup

Prepared for: The Lead Exposure and Prevention Advisory Committee (LEPAC)
National Center for Environmental Health/Agency for Toxic Substances and Disease Registry

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Section I

Introduction to the Report of the Workgroup on Prevention of Lead Exposure in Adults of the Lead Exposure and Prevention Advisory Committee (LEPAC) National Center for Environmental Health/Agency for Toxic Substances and Disease Registry

In 2016, Public Law 114-322, "Water Infrastructure Improvements for the Nation Act", 42 U.S.C. §300j-27, "Registry for Lead Exposure and Advisory Committee" authorized the Secretary of the Department of Health and Human Services to establish a new federal advisory committee for better understanding and preventing exposures to lead. In accordance with this law, the Lead Exposure Prevention and Advisory Committee (LEPAC) was established under the aegis of the Centers for Disease Control and Prevention (CDC) National Center for Environmental Health/Agency for Toxics Substance and Disease Registry (NCEH/ATSDR). According to its charter, the purpose of LEPAC included the review of research and federal programs and services related to lead poisoning and the identification of effective services and best practices for addressing and preventing lead exposure in individuals and communities.

In May 2022, LEPAC members suggested convening a workgroup to draft to recommendations to CDC/ATSDR regarding adult environmental and occupational lead exposures. The Prevention of Lead Exposure in Adults (PLEA) Workgroup, hereafter "the Workgroup", was established to gather and review relevant literature and to consult with experts to define and update the status of adult lead exposures in the United States for CDC/ATDSR to consider when setting priorities and undertaking initiatives related to lead.

The Workgroup set out to examine adult lead exposure with a focus on actions by U.S. public health agencies' that might prevent exposure and mitigate lead-related adverse effects. To achieve this outcome, the group members developed the following objectives:

1. Generate a final report based on information gathered and discussed during meetings.
2. Provide specific recommendations to guide CDC/ATSDR's future activities related to lead poisoning prevention in adults.
3. Present the report at a LEPAC meeting for consideration and deliberation of acceptance.

This report by the Workgroup is structured in the form of recommendations, supported by narrative discussion, focused on five key topics:

a. Adverse effects of lead exposure in adults
b. Epidemiology of adult lead exposure
c. Best practices for prevention of lead exposure in adults
d. Health equity implications of lead exposure in adults
e. Communication strategies for reducing adult lead exposure

The findings and conclusions in this report are those of the PLEA workgroup and do not necessarily represent the official position of the Centers for Disease Control and Prevention (CDC).

Section II

Adverse Effects of Lead Exposure in Adults

Recommendation II-1: The Workgroup considers the substantial increased risk of death from cardiovascular disease caused by elevations in blood lead concentrations in the range of 10 to 25 µg/dL to be the most significant adult health risk posed by long-term overexposure to lead. Evidence also exists for increased cardiovascular mortality risk at lower blood lead concentrations. CDC, ATSDR, Environmental Protection Agency (EPA), Food and Drug Administration (FDA) and other public health agencies and institutions engaged in health care education, and organizations of health care professionals should recognize and emphasize this risk in their preventive health policies and communications. Similar attention should be devoted to other well-established adverse health effects of lead in adults, including but not limited to deficits in cognition and adverse reproductive outcomes.

More than a century of clinical and epidemiological research has established that acute and chronic lead exposure in adults is the cause of a myriad of major multi-systemic adverse health effects. It has long been known that lead exposure may result in the emergence of nonspecific symptoms such as headache, fatigue, sleep disturbance, anorexia, constipation, arthralgia, myalgia, and decreased libido. The level and duration of exposure required varies between individuals but generally consists of blood lead concentrations exceeding 60 µg/dL for acute exposures (days to weeks) and 40 µg/dL for chronic exposures (weeks to months) (ATSDR, 2020; EPA, 2024a; Kosnett et al., 2007; NTP, 2012).[1] It has also long been recognized that chronic blood lead concentrations of this magnitude may cause measurable neurocognitive deficits, peripheral nerve dysfunction, hypertension, kidney dysfunction and nephropathy, and anemia. These effects vary in penetrance and intensity with the extent and duration of blood lead elevation. The Occupational Safety and Health Administration (OSHA) workplace standards for inorganic lead established in the late 1970s were designed to maintain blood lead concentrations less than 40 µg/dL in most workers and to avoid blood lead concentrations greater than 60 µg/dL in almost all workers (OSHA, 1978). This was intended to minimize the risk of overt lead intoxication that could readily be assessed by signs or symptoms, physical examination, or available laboratory

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[1] In contrast to other toxic substances for which dose-response for adverse effects is often characterized in terms of external exposure (e.g. the concentration of a substance in air or water) or internalized dose (e.g. in micrograms per kilogram body weight per day), most epidemiological, clinical and experimental animal studies of lead hazards have relied on an internal biomarker of exposure, primarily lead in whole blood, to quantify dose-response. Whole blood lead, a measure of lead circulating throughout the body, offers a close approximation of the lead content of most soft tissues, (with the notable exception of the brain and skeleton). However, because blood lead reflects both recent exogenous exposure as well as endogenous redistribution of lead accumulated in the skeleton over years to decades, it is an imperfect biomarker of long-term cumulative lead exposure (Hu et al., 2007).

tests.[2] However, over the past two decades, high-quality epidemiological studies, in combination with clinical and experimental data, have established that lead exposure to individuals who experienced blood lead levels (BLLs) across the approximate range of 10 to 25 µg/dL for years to decades results in an increased risk of several adverse outcomes, particularly among middle-aged to elderly adults as well as pregnant women.

Cardiovascular Disease and Mortality

Epidemiological findings relevant to cardiovascular disease and mortality have emerged from a number of large prospective cohort studies of adults representative of the general population. In the U.S., studies have focused on individuals who lived a significant proportion of their lives in the time period of the 1940s to the early 1980s, an interval when average blood lead concentrations in the U.S. ranged from 10 to 25 µg/dL (Annest et al., 1984; EPA, 1973; Goldwater & Hoover, 1967; Hofreuter et al., 1961; Mahaffey et al., 1982; Robinson et al., 1958; Sawyer et al., 1939; Thomas et al., 1967; Working Group on Lead Contamination, 1965). During that period, the general U.S. population sustained near-ubiquitous lead exposure from environmental sources. Menke et al (2006) examined the mortality of participants in the CDC's Third National Health and Nutrition Survey (NHANES III) who were 17 years of age or older at the time of recruitment (1988 to 1994). Subjects (n = 13, 946) had a mean age at enrollment of 44.4 years and a geometric mean blood lead at enrollment of 2.58 µg/dL. After approximately 12 years of follow-up, comparing those with baseline blood lead in the lowest tercile (≤ 1.93 µg/dL) to those in the highest tercile (≥ 3.63 µg/dL), the covariate adjusted hazard ratios for cardiovascular, myocardial, and stroke mortality were 1.55 (95% CI, 1.08- 2.24), 1.89 (95% CI, 1.04-3.43) and 2.51 (95% CI, 1.20-5.26) respectively. Similar findings emerged in a more recent prospective mortality analysis of NHAHES III participants (n = 14,289) after a median of 19.3 years of follow-up (Lanphear et al., 2018). In examining the risks associated with an increase in baseline log-transformed BLLs from 1.0 to 6.7 µg/dL (10th–90th percentile), the covariate adjusted hazard ratio for cardiovascular disease mortality increased by 70% (HR, 1.70; 95% CI, 1.30–2.20), and that for ischemic heart disease mortality increased by 108% (HR, 2.08; 95% CI, 1.52–2.85).

The whole blood lead concentrations of NHANES III subjects measured at the time of enrollment reflected their recent exogenous exposure as well as endogenous redistribution of lead accumulated in the skeleton during prior years to decades of life when they sustained ubiquitous environmental lead exposure associated with the widespread presence of lead in gasoline, residential paint, and solder used in plumbing and canned food. Thus, many subjects in the NHANES III cohort likely experienced blood lead concentrations > 10 µg/dL for a variable but substantial proportion of their lives.

[2] At the time these workplace lead standards were established, OSHA recognized that adverse reproductive effects could occur at blood lead concentrations less than 30 µg/dL. OSHA therefore recommended a maximum permissible blood lead level of 30 µg/dL "in both males and females who wish to bear children", and authorized physicians at their discretion to order medical removal protection at lower blood lead concentrations.

Many additional recent U.S. and international studies have confirmed that in samples of the general population at relatively low BLLs (<10 µg/dL), lead is associated with increased blood pressure and/or risk of hypertension, such as Gambelunghe (2016; mean BLL: 2.8µg/dL); Lee (2017; geometric mean BLL 1.8 µg/dL); Lopes (2017; geometric mean BLL 1.97 µg/dL); Chen (2017; median BLL: 4.4 µg/dL); Teye (2020; mean BLL: 1.3-2.2 µg/dL); Tsoi (2021; mean BLL 0.92 to 1.75 µg/dL); and Yan (2022; geometric mean 4.7 µg/dL). Hypertension is a well-established risk factor for mortality from cardiovascular disease and stroke, and for chronic kidney disease. Hypertension has also been associated with an increased risk of cognitive deficits in middle to older age adults (Bakris et al., 2023). Lead exposure has remained a significant risk factor for cardiovascular mortality in studies where multivariable models adjusted for hypertension, (Lanphear et al., 2018; Menke et al., 2006) suggesting that several modes of action for lead's adverse effects exist (EPA, 2024a).

Epidemiological research has also taken advantage of a biomarker specific for chronic lead exposure. Because lead accumulates in the skeleton with a half-life of years to decades, noninvasive measurement of lead in bone by K x-ray fluorescence (KXRF) offers advantages over blood lead as a biomarker of cumulative lead exposure (Hu et al., 2007). In research using this instrument in the mid-1990s, KXRF measurements of lead in bone were conducted on a subset of healthy men aged 21 to 80 years who had enrolled in the early 1960s in the Normative Aging Study (NAS), a multidisciplinary prospective cohort study. KXRF measurements were also obtained in samples of women participating in the long-running Nurses Health Study (NHS) as part of a nested case-control study of clinical hypertension. After adjusting for numerous covariates, bone lead was found to be associated with a high risk of having developed hypertension in both the NAS (Hu et al., 1996) and NHS (Korrick et al., 1999) cohorts. Furthermore, in an analysis of prospective NAS data, terciles of lead in patella bone at baseline were used to calculate hazard ratios for cause-specific mortality through 2007 among men who were less than 45 years of age at the time of enrollment (n = 637). Compared to the reference group of individuals in the lowest tercile of patella bone lead (<20 µg lead per gram of bone mineral), subjects in the highest tercile of bone lead (>31 µg/g) exhibited a relative risk of 2.47 (95% CI, 1.23–4.96) for all cardiovascular mortality and a relative risk of 5.20 (95% CI, 1.61–16.8) for ischemic heart disease mortality (Weisskopf et al., 2009, 2015).

The precise temporal pattern and life stage of lead exposure that contributes to cardiovascular mortality is subject to uncertainty. However, the well-controlled prospective evaluations of the NHANES, NAS, and NHS cohorts offer strong evidence that community lead exposure was a substantial risk factor for cardiovascular mortality among adults who lived a significant proportion of their lives when blood lead concentrations in the range of 10 to 25 µg/dL were common.

Relatively modest elevations in BLLs (all under 10 µg/dL) have also been shown in U.S. general population data to be associated with uncontrolled hypertension defined as systolic blood pressure >130 Hg or diastolic blood pressure >80 mm Hg (Miao et al., 2020). In a study of the

NAS, bone lead levels were found to be associated with an increased risk of hypertension that is resistant to treatment, defined as (1) inadequate control of systolic blood pressure (>140 mm Hg) or diastolic blood pressure (>90 mm Hg) while taking 3 medications; or (2) requiring >4 medications for blood pressure control (Zheutlin et al., 2018).

In comparison to the neurocognitive and neurobehavioral risks of low-level lead exposure to children, the lead-related risk of cardiovascular mortality to adults has received relatively sparse attention in health professional education and outreach to the lay public. For example, the ATSDR monograph Case Studies in Environmental Medicine: Lead Toxicity (updated 2023) does not mention the risk of cardiovascular mortality. The CDC webpage on Heart Disease Risk Factors (CDC, 2024d) omits any mention of lead. The National Institute for Occupational Safety and Health (NIOSH) website contains a lay-oriented page entitled, "About Lead in the Workplace" that does contain a brief mention of cardiovascular mortality (CDC, 2024b), but other NIOSH webpages that mention this risk could not be located.[3] The Workgroup considers that omission of this consequential health risk in governmental health education materials is unwarranted, particularly in light of its documentation in the ATSDR Toxicological Profile for Lead (2022), the EPA Integrated Science Assessment for Lead (2024), and the recent position statement of the American Heart Association (AHA, 2023).

Cognition

Lead exposure associated with increased bone lead levels as well as relatively modest elevations in BLL (i.e., within 5 or 10 µg/dL) has been associated with worse neurological function in adults, in particular, cognitive abilities involving attention, memory and learning, altered neuromotor and neurosensory function, and altered mood and behavior (Bakulski et al., 2020; Farooqui et al., 2017; Przybyla et al., 2017; Rhodes et al., 2003) in men and women (Bandeen-Roche et al., 2009; Weuve et al., 2008). As reviewed in the 2024 EPA Integrated Science Assessment for Lead and the 2020 ASTDR Toxicological Profile for Lead, exposure that is higher (i.e., with BLLs>30 µg/dL) is associated with a variety of decrements in cognitive function, behavior and nerve function, including postural sway and stability; decreased walking speed; decreased visuospatial function and visual-motor performance; decrements in hearing; peripheral neuropathy; and psychiatric symptoms [depression, panic disorders, anxiety, hostility, confusion, anger, and schizophrenia].

Adverse Reproductive Outcomes

[3] Other federal public health agencies besides CDC have also failed to discuss lead as a risk factor for cardiovascular mortality in web-based educational materials targeted primarily for education of the public or health professionals. For example, the subsection on "What are the health effects of Lead?" on the EPA webpage entitled "Learn About Lead" fails to mention cardiovascular disease mortality, (EPA, 2013b, updated October 2024)), as does the subsection "Health effects of being exposed to lead in drinking water: Adults" of the EPA webpage "Basic Information about Lead in Drinking Water (EPA, 2016, updated 2024)). Cardiovascular mortality is not mentioned in the OSHA webpage, "Lead: Health Effects" (OSHA, n.d.)), nor in the FDA webpage: Lead in Food and Foodwares: Health Effects Information" ("Lead in Food and Foodwares," 2024)

A number of studies have demonstrated an association of moderate levels of lead exposure during pregnancy with an increased risk of pre-term birth and low birth weight. A recent meta-analysis was conducted of studies relating maternal BLLs to birth outcomes in which 19 of the 20 studies that contributed data for pooling involved women with BLLs under 10 µg/dL. Both the maternal blood and cord blood were found to be significantly associated with reductions in birth weight (Wang et al., 2020). Detailed studies of lead isotopic ratios among pregnant women (Gulson et al., 2016), as well as epidemiological studies using KXRF to measure maternal bone lead levels (Téllez-Rojo et al., 2004), have found that pregnancy is associated with a marked increase in bone resorption accompanied by the mobilization of bone lead stores into the maternal and fetal circulation. Maternal bone lead levels among women with a mean maternal BLL at birth <10 µg/dL, in turn, have been found to independently predict lower birth weight (González-Cossío et al., 1997), shorter head circumference and birth length (Hernandez-Avila et al., 2002), infant weight gain (Sanín et al., 2001), and measures of mental development in offspring at age 2 years (Gomaa et al., 2002). Higher maternal bone lead levels were also found to be associated with higher offspring blood pressure at age 7 to 14 years (Zhang et al., 2012), which, in turn, is well-known to be a predictor of adult hypertension. Research demonstrating an association between maternal lead exposure and maternal blood leukocyte DNA methylation (Goodrich et al., 2016) suggests that these downstream effects might be exerted through epigenetic programming phenomena. Overall, these studies demonstrate high sensitivity of the fetus to both moderate levels of acute maternal lead exposure as well as cumulative maternal lead burdens from chronic low-level lead exposure.

Recommendation II-2: The consequential health implications to adults of long-term lead exposure that result in blood lead concentrations ≥ 10 µg/dL merit decisive public health actions by public and private sector public health agencies and institutions, many of which are recommended throughout this report.

This conclusion is supported by multiple convincing factors. First, a prominent endpoint of concern is death, as opposed to subtle or subclinical effects on organ system function that are often sufficient for public health and regulatory action. Second, the epidemiological evidence that associates this outcome with lead exposure is derived from multiple large, high quality prospective cohort studies that extensively controlled for confounding and bias. Third, this epidemiological evidence is coherent with clinical and experimental findings that demonstrate plausible modes of action at consistent lead doses (EPA, 2024a). Fourth, because the background risk of cardiovascular mortality in populations with this ongoing extent of lead exposure (largely but not exclusively in the workplace) is high, the absolute increase in mortality may be substantial. Fifth, the magnitude of lead-related risk is on par with that of other prominent cardiovascular risk factors, such as elevated cholesterol, smoking, and hypertension, that have been the focus of extensive public health concern. Sixth, levels of chronic adult lead exposure linked to this risk remain prevalent in many workplace settings. Finally, it should be noted that the observed risk of cardiovascular mortality associated with blood lead concentrations ≥ 10 µg/dL does not establish the absence of risk at lower blood lead concentrations. The fraction of the general population whose lifetime blood lead concentrations were entirely less than 10 µg/dL (predominantly those born after 1980) has yet to reach the age at which death from cardiovascular disease emerges. Future epidemiological studies conducted in this population will be necessary to assess the potential risk at even lower lead dose.

Section III

Epidemiology of Adult Lead Exposure

Recommendation III-1: Adult Blood Lead Epidemiology and Surveillance (ABLES) programs operating at the state and national level (NIOSH) require improvements in the completeness and quality of data collection. Key improvements include:

a. **Healthcare providers, clinical laboratories, and employers should be encouraged to engage in expanded BLL collection and mandatory reporting of BLL results to state health departments for adults exposed in the workplace or to sources of elevated environmental or avocational exposure.**
b. **Enhanced compliance by private and public sector clinical laboratories with rules that require reports of blood lead data to contain complete and detailed demographic and employment information, including personalized contact information for the donor and their workplace.**
c. **Linkage of clinical laboratory certification to compliance with standardized state-mandated blood lead reporting requirements.**
d. **Linkage of Occupational Data for Health in electronic health records to job-exposure matrix data that may alert healthcare providers to the advisability of obtaining or reviewing blood lead measurements on their patients.**

A detailed understanding of the epidemiology of adult lead exposure – the magnitude, distribution and determinants of exposure – is essential to effective public health and clinical efforts targeted to primary, secondary, and tertiary prevention of the adverse health effects of lead. Lead exposure in adults is measured by the concentration of lead in whole blood, most commonly referred to as a blood lead level (BLL). In the U.S., lead in whole blood is expressed in units of micrograms of lead per deciliter of whole blood (µg/dL), although use of international units, expressed as micromoles of lead per liter of whole blood (µmol/L), may occasionally be encountered. Based upon public health concerns and the geometric mean BLL in adults from 2011 – 2012 NHANES survey (1.09 µg/dL), the Council of State and Territorial Epidemiologists (CSTE) released a position statement in 2015 to lower the definition of an elevated BLL in adults from 10 µg/dL to 5 µg/dL (CSTE, 2015). NIOSH has also adopted 5 µg/dL as a case definition for an elevated BLL in adults (CDC, 2024c). In a 2022 position statement, CSTE referred to 3.5 µg/dL as its blood lead reference value (BLRV) for adults (age 16 or greater), and considers BLLs at or above this value to merit case specific management (CSTE, 2022; CSTE Occupational Subcommittee, n.d.). CSTE encourages states to report all adult blood lead measurements to ABLES regardless of level. Data from the 2017 – 2018 NHANES cycle estimated the geometric mean adult BLL to be 0.855 µg/dL (National Center for Environmental Health Division of Laboratory Services, 2019).[4]

Lead exposure among adults can be attributed to both occupational and non-occupational sources, although the former is considered the predominant source in the U.S. The National Adult Blood Lead Epidemiology and Surveillance (ABLES) program, which has been maintained by NIOSH since 1991, houses the primary database for adult lead exposure within the U.S. (Tsai et al., 2023). ABLES is a state-based surveillance program, in that the lead exposure data are collected by the states and then shared with NIOSH. According to regulations established by participating states, the results of blood lead laboratory measurements performed by public and private sector clinical laboratories are reported to state and local health departments. State participation in the national ABLES program is not a requirement and only 28 states submitted 2021 data to the national ABLES program. This potentially skews national trends derived from the data as a large percentage of the population is not included.

It is likely that the proportion of lead-exposed workers that undergo biological monitoring is low relative to total workers exposed, further contributing to national under-estimation. This was highlighted in a California study that estimated only 2.6% of California lead-exposed workers received biological monitoring for lead (Rudolph et al., 1990). Because current OSHA standards (discussed further in Section IV) only require BLL measurements after a relatively high degree of airborne lead exposure is exceeded, some workers with significant exposure do not have BLLs measured. To our knowledge, no recent studies have been conducted deriving national estimates of industry participation in biological monitoring programs. Regardless, ABLES data highlights that lead exposure among adults remains a national concern with 27,550 unique individuals in 2021 having a BLL ≥ 5 µg/dL and 1,839 having a BLL ≥ 25 µg/dL (Figure 1).

[4] The NIOSH ABLES program continues to define a BLL ≥ 5 µg/dL to be an elevated BLL for surveillance purposes(CDC, 2024c) for the following reasons: a current BLL for adults may reflect past as well as recent exposures; children are more sensitive to lead exposure compared to adults; a BLL < 5 µg/dL in adults is less likely to pose a risk of immediate or long-term adverse health outcomes compared to a BLL ≥ 5 µg/dL. Ultimately, the BLLs relied upon for mandatory laboratory reporting requirements, case investigations, and follow-up are established by individual states.

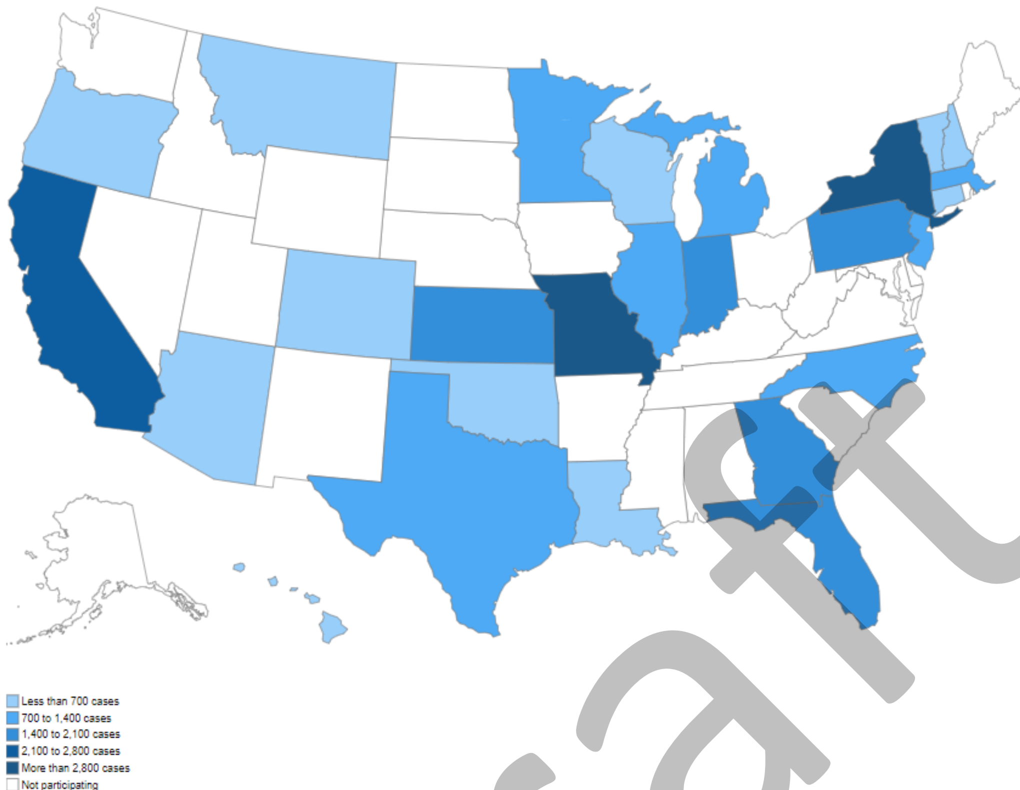

Figure 1: Number of adult cases with a BLL ≥ 5 µg/dL among all participating ABLES States, 2021
Source: Adult Blood Lead Epidemiology & Surveillance (ABLES) (CDC, 2024g)

Among states that submit blood lead data, important data elements that could reveal potential sources of exposure are frequently absent. Given that most adults are exposed to lead through their occupation, employer information should be provided in laboratory reports. Unfortunately, collection of employer information on laboratory reports is not a standard requirement in many states, resulting in this field to be marked as "unknown". Identifying employers is then left to state and local health departments to conduct interviews with patients and/or healthcare providers, which is a time and resource intensive process.

If employer information is available, the employer industry needs to be coded to the North American Industry Classification System (NAICS) prior to submission to ABLES (CDC, 2024a). This coding process can be complex and involve manual investigative work. Due to these factors, submission of employer NAICS to ABLES is not always possible. In 2021, only 20% of submitted reports were able to identify the source of lead exposure as either occupational or non-occupational. Among the 19% linked to occupational exposure, only 54% had a corresponding employer NAICS code. Given that an estimated 90% of adult cases with elevated BLLs from known exposures are occupational in origin a large amount of epidemiological information is missing (CDC, 2024g). This difficulty in obtaining employment information greatly hinders the identification and mitigation of occupational lead exposure. Analysis of this metric shows which industries are responsible for contributing to elevated BLLs among adults in the U.S. By monitoring trends in industry-specific exposure over time, industry exposure sources may be identified and mitigated through targeted educational material and other interventions (such as state or federal OSHA emphasis programs, e.g. OSHA Instruction National Emphasis Program Lead).

Occupational Data for Health, a NIOSH-developed framework for self-reported, structured and standardized patient work information (A Guide to the Collection of Occupational Data for Health, 2021) intended for inclusion in electronic health records (EHRs), could be leveraged to alert patients and health care providers to the potential for occupational lead exposure and lead-related adverse health effects. Job-exposure matrices created by NIOSH (Current Intelligence Bulletin 69, 2020) and other institutions could be electronically linked to occupational information present in a patient's health record. The EHR could then flag past or present employment associated with significant lead exposure. This in turn might prompt the patient or their health care providers to obtain or review blood lead measurements, and to consider further assessment of lead-related health risks.

Laboratory reports may also contain demographic information such as race, ethnicity, sex, and age. Race, ethnicity, and sex are often left blank on a BLL report, even if jurisdictions encourage healthcare providers and laboratories to submit this data. From 2015 – 2019, about 30% of reports submitted to ABLES included race and 24% included information for ethnicity. State ABLES programs have documented that up to 60% of annual reports are missing information on race and ethnicity (Kerrick & Rosenman, 2023; PA DOH, 2024). This data is critical to determine if certain demographic subpopulations are being disproportionately exposed to lead in the workplace or from other sources. Data submission is clearly lacking, resulting in an incomplete picture of the national burden of lead exposure among specific groups.

Mandating the collection of employer information, industry and occupation, age, race, ethnicity, pregnancy status, and contact details in laboratory reports and electronic health records would significantly enhance the completeness and usability of blood lead data. A potential approach to increasing reporting compliance would be for clinical laboratories to refuse to process requisitions for BLL testing that fail to contain all the required information. Automated refusal in the absence of complete information is readily possible via internet portals that are the source of many laboratory requisitions today. Exceptions for missing information could be granted where the health care provider formally attests that the patient is unable to provide the requested information. A complementary approach to increasing compliance with data collection may be for state health departments to withhold certification or partial reimbursement to clinical laboratories that fail to obtain the requested information on a substantial proportion of patients.

High-quality blood lead surveillance data will enable local, state, and federal agencies to more easily identify at-risk workers, allowing for early implementation of intervention measures. This may result in significant cost-savings across the board. One study estimated that the attributable annual health cost of U.S. occupational lead poisoning to be over 392 million (in 2014 dollars) per year for the 10,000 workers with high occupational lead exposures. (Levin, 2016). More recently, a report prepared for the California Department of Industrial Relations entitled, “Standardized Regulatory Impact Assessment: Revisions to Occupational Lead Standards” (BEAR, 2020) estimated costs and benefits associated with implementation of Cal/OSHA lead standards targeted to reducing BLLs throughout the California workforce to ≤ 10 µg/dL. Conservatively limiting the analysis to reductions in all-cause mortality, hypertension, non-fatal heart-attack, and depression/anxiety, the annual estimated avoided health costs per year (in 2017 dollars) was estimated at approximately $140 million within 5 years, and approximately $560 million within 20 years.

Decreased public spending on lead-related health care might enable state-based ABLES programs to gain back valuable resources to conduct mission-critical activities, such as conducting case investigations, educating the public, and monitoring for emerging lead concerns. Improved accessibility of industry, occupation, and other key demographic information may encourage states that are currently not submitting data to the ABLES program to participate in the future.

Recommendation III-2: State and national ABLES programs would benefit from programmatic improvements in their methods of operation, staffing levels, and data collection methods:

1. **Standardization of data elements across all state programs that collect and report adult blood lead data.**
2. **Development of standardized performance measures and resource requirements for effective state ABLES programs. These performance measures could be developed in part by a national workshop coordinated by NIOSH ABLES.**

The ability of the national ABLES program to aggregate and analyze blood lead surveillance information collected and reported by state programs will be enhanced if all states utilized standardized data collection instruments containing the same data elements. These may include date and location of blood collection; the subject’s full name; date of birth; sex; primary and secondary addresses; place of birth; primary and secondary spoken language; ethnicity; race; telephone numbers; email addresses; social security number (voluntary); parent or guardian data (if person tested is a minor); current or most recent employer name and address; employer NAICS code; person’s standard occupational classification (SOC) system code; ordering health care provider’s full name, degree or profession; healthcare office and/or facility address, telephone numbers, and email address. Collection of NAICS and SOC codes in a standardized manner might be facilitated by digital laboratory requisition forms that utilize drop down menus, or allow “other” entries to be mapped to suggested key terms. Drop down menus or key word mapping could also facilitate collection of standardized data elements regarding the known or suspected source, location, and date of person’s last lead exposure (e.g. from occupation, or from specific hobbies or activities, drinking water source, or suspected lead contaminated food, drug, or consumer product).

At present, state ABLES programs and affiliated lead poisoning prevention program activities may vary considerably with respect to staffing, resources, case management, and outreach activities. Interaction between state and national ABLES programs, in conjunction with a national workshop coordinated by NIOSH ABLES, could develop performance measures that may assist in optimization of state programs. Program performance measures might include, but not be limited to: a) sufficiency of personal, demographic and exposure information at the time of blood lead collection; b) use of electronic record keeping and reporting; c) follow-up and extent of case management of elevated BLLs and identification of index cases; d) outreach to workplaces with potential lead exposure to educate employers and workers on voluntary and mandatory requirements; e) outreach to clinical laboratories to facilitate the extent and quality of data reporting; f) linkage or cross-referencing of childhood and adult blood lead registry data such that an elevated childhood exposure will trigger an assessment of household adult exposures; and g) development and dissemination of effective, multilingual/multicultural worker and employer education and outreach programs.

Recommendation III-3: Unification of adult and child blood lead surveillance systems at the local, state, and federal level may offer efficiencies that enhance lead poisoning surveillance and prevention.

Variations in resources, experience, and state-level support have led to differences in how the ABLES program is implemented across states. One way to build a stronger ABLES program is to build a state-based community where more experienced states can easily share knowledge and materials (educational brochures, surveys, and investigative protocols) with less experienced states. Another approach to resource sharing is to create a standardized survey that all states can utilize for case investigations. Bringing together state partners to establish a framework for the ABLES program will help track performance measures and ensure the program's long-term success.

There is a need for the national ABLES program to evaluate state and jurisdictional adult and childhood blood lead surveillance programs for programmatic gaps and obstacles. For example, examining how blood lead data flows from laboratories to local, state, and federal agencies will identify areas in the system where relevant data may be lost or unused. Similarly, observing how adult and child programs interact with each other can provide insight into how data accessibility can be improved and how an ideal unified system could facilitate these types of activities. Conducting assessments across multiple states and jurisdictions will enable the ABLES program to pinpoint common areas where improvements are needed. Under the CDC's data modernization initiative, the ABLES program could leverage the cloud environment and its associated tools to propose innovative solutions that address states' immediate needs, while also seeking ways to unify the blood lead surveillance system as a long-term goal. Development of nationwide standards recommended for the operation of successful state ABLES programs could be facilitated by convening a national workshop of state and federal ABLES staff coordinated by

NIOSH and other CDC centers, such as the National Center for Environmental Health, and the National Center for Health Statistics.

The benefit of collecting industry and occupation data extends beyond understanding adult lead exposure and provides insight into take-home lead exposure affecting adult workers' family members. While workplace engineering and administrative controls (such as ventilation and showers) have reduced workers' exposure to lead, occupational exposure continues to be an issue in certain industries, such as battery manufacturing and construction (CDC, 2024e). Even more concerning, these workers are unintentionally bringing lead home, thereby exposing their young children and families to lead. A Michigan study found that there was widespread tracking of lead dust out of the workplace to the workers' vehicles (Oliveri et al., 2021). Another study in Boston found that the homes of construction workers had higher lead dust concentrations than the homes of auto body and janitorial workers (Ceballos et al., 2021). This tracking of lead dust into vehicles and homes is reflected in the BLL of children. A meta-analysis found that 52% of children of lead-exposed workers had a BLL ≥ 10 µg/dL, compared to only 8.9% of all children in the U.S. (Roscoe et al., 1999).

Currently, the U.S. blood lead surveillance systems for adults and children are separated or at best loosely linked at the local, state, and federal level. In some states, the adult and child blood lead surveillance programs may only communicate when warranted, such as when a child case investigation indicates that take-home lead exposure is likely. Other times, states may encounter difficulties trying to link adult and child data together (i.e., adult and child have different last names). This inefficient system poses obstacles to identifying additional adult and child cases. A unified adult and child blood lead surveillance system that collects data at the household level is needed to capture take-home lead exposure.

A unified blood lead surveillance system has implications far beyond capturing take-home lead exposure cases. Childhood lead exposure occurs at the household level, from where they live (lead paint, lead in water pipes, lead contaminated soil and dust, take-home lead), what they eat (lead contaminated spices and food, leaded cookware), what they play with (toys with lead paint), to how their families celebrate occasions (ceremonial powder). These routes of exposure may affect not only children but also the adults with whom they live. In a unified blood lead surveillance system, identifying a case (whether adult or child) could trigger testing for others in the household, helping to uncover cases that would otherwise be missed. In a 2015-2016 report, Michigan found that among adults with elevated BLLs, 35.1% of children under 6 years old living in the same household had BLLs ≥ 10 µg/dL (Rosenman et al., 2018).

Unfortunately, unifying the adult and child blood lead systems at local, state, and federal levels will be a challenging endeavor. Many states are under-resourced, with insufficient funds for their adult programs. In some states, blood lead surveillance and case follow-up activities are conducted manually using Excel, while their childhood lead counterparts utilize more advanced systems. It is estimated that at least one full-time employee (FTE) is necessary to support state-based ABLES activities, with ideally two FTEs, especially in more populous states. A unified surveillance system could also address this issue, as the general processes for handling blood lead data—such as data import, cleaning, and management—are nearly identical. This approach could reduce overhead costs and allow more resources to be directed toward case findings and public health interventions.

Section IV

Best Practices for Prevention of Lead Exposure in Adults

In addition to recommendations presented in other sections of this report, the Workgroup has identified the following recommendations that constitute best practices in the prevention of adult lead exposure.

Recommendation IV-1: Current federal and state OSHA workplace standards for lead in general industry and construction merit prompt revision because they fail to adequately protect workers against adverse effects of chronic lead exposure and acute effects on reproductive outcomes. Revised California OSHA (Cal/OSHA) lead workplace standards that take effect on January 1, 2025, may serve as a model for feasible health protective revisions.

Recommendation IV-2: Pending revision of federal OSHA lead standards, physicians supervising lead workers should be encouraged to exercise their discretionary authority under the existing OSHA standards to recommend medical removal protection or special protective measures at lower BLLs than those specified in the standard. NIOSH and OSHA, as well as state lead programs, should undertake initiatives to educate workers, healthcare providers, and employers regarding this discretionary authority.

As summarized in section II of this report, state and federal workplace lead standards enacted 45 years ago were designed to minimize overt effects of lead that could readily be assessed by signs or symptoms, physical examination, or common laboratory tests. However, these outdated standards have failed to offer protection against major effects of chronic lead exposure that include a substantial increased risk of cardiovascular disease and mortality and adverse cognitive effects. Existing standards also fail to provide adequate protection against the risk of adverse reproductive and birth outcomes.

On February 15, 2024, after a thirteen-year process that considered input from multiple stakeholders the California Occupational Safety and Health Standards Board adopted revised standards for lead in construction and general industry based on a critical mass of the most rigorous recent research. Intended to maintain the BLLs of workers below 10 µg/dL over the long-term, the revised standards (California Occupational Safety and Health Standards Board, 2024) feature several new approaches to reducing occupational lead exposure:

a. Lowering the statutory threshold for medical removal protection from a single BLL > 50 or 60 µg/dL to a single BLL > 30 µg/dL or two consecutive BLLs > 20 µg/dL.

b. Lowering the Permissible Exposure Level and the corresponding Action Level for lead in workplace air from 50 µg/m^3 and 30 µg/m^3 to 10 µg/m^3 and 2 µg/m^3 respectively, (as 8-hour time-weighted averages).
c. Instead of relying exclusively on air lead monitoring to assess whether the lead standard for general industry may be applicable to a workplace and necessitate medical surveillance, the revised general industry standard introduced the concept of "presumed significant lead work." This includes any work that alters or disturbs material containing lead ≥ 0.5% by weight.
d. Increasing the frequency of blood lead testing for workers when any BLL exceeds 10 µg/dL.
e. Adding requirements for direct communication between physicians or other licensed health care professionals and workers regarding BLL test results and follow-up recommendations.
f. Expanding training, hygiene, and housekeeping requirements for those who work with lead.

In a recent Position Statement, the American College of Occupational and Environmental Medicine (ACOEM) stated, "ACOEM considers the weight of the evidence supporting the need for revised standards to reduce occupational lead exposure and the BLLs of workers to be among the most conclusive and compelling that has ever existed for a workplace chemical regulated by OSHA" (Kosnett et al., 2023). The Workgroup considers the revised Cal/OSHA lead standards to represent a vast improvement over existing OSHA lead standards in protecting workers against the adverse effects of lead. The revised standards reflect extensive stakeholder input regarding safety and feasibility, and a required cost-benefit analysis assessed that the revised standards would be highly cost-effective (BEAR, 2020). The new Cal/OSHA standards may therefore serve as a model for revision of federal OSHA lead standards and standards in other states. Notwithstanding the health protective nature of the new Cal/OSHA standards, the Workgroup considers that their goal of maintaining workers BLLs less than 10 µg/dL provides a narrow margin of safety. Accordingly, it may be reasonable to enact revised federal standards intended to maintain BLLs in all workers less than 5 µg/dL, or less than the CDC reference value (currently 3.5 µg/dL) in the case of workers who are or may become pregnant.

In June 2022, OSHA issued an "advance notice of proposed rulemaking" seeking stakeholder input on health protective revisions of the BLL triggers for medical surveillance and medical removal protection in its general industry and construction standards for lead (OSHA, 2022). Pending enactment of revised OSHA standards, it should be noted that the existing OSHA standards provide physicians who supervise the medical surveillance of lead workers with the authority to recommend medical removal protection or other special protective measures at lower BLLs than specified in the standards if the physician considers this necessary to protect a worker against material health impairment from exposure to lead. The existence of this authority was highlighted by CDC in its 2010 report, "Guidelines for the Identification and Management of Lead Exposure in Pregnant and Lactating Women"(CDC, 2010), wherein it quoted sections of

Appendix C (*1910.1025 App C - Medical Surveillance Guidelines | Occupational Safety and Health Administration*, 1978) to the 1979 OSHA general industry lead standard that stated,

> "Recommendations [regarding medical removal protection] may be more stringent than the specific provisions of the standard. The examining physician, therefore, is given broad flexibility to tailor special protective procedures to the needs of individual employees. This flexibility extends to the evaluation and management of pregnant workers and male and female workers who are planning to raise children. Based on the history, physical examination, and laboratory studies, the physician might recommend special protective measures or medical removal for an employee who is pregnant or who is planning to conceive a child when, in the physician's judgment, continued exposure to lead at the current job would pose a significant risk…
>
> …The adverse effects of lead on reproduction are being actively researched and OSHA encourages the physician to remain abreast of recent developments in the area to best advise pregnant workers or workers planning to conceive children."

The aforementioned 2010 CDC report on lead in pregnancy went on to advise:

> "Since substantial research developments have occurred since the 1970s when the OSHA standards were developed, occupationally exposed women who are or may become pregnant should be removed from lead exposure if their blood lead level is ≥10 µg/dL. If the blood lead level is in the range of 5 to 9 µg/dL, the health care provider should ask about potential sources of lead exposure on the job and review appropriate use of personal protective equipment in an effort to reduce exposure…"

The Workgroup agrees with this CDC recommendation regarding lead exposure to occupationally exposed women who are or may become pregnant. The Workgroup considers that the risk of cardiovascular disease and mortality at chronic BLLs > 10 µg/dL that has been recognized in recent decades *renders it prudent and advisable for physicians and other health care providers to utilize their discretionary authority under current OSHA standards to recommend similar protective measures for all workers*. NIOSH, OSHA, state lead programs, and professional associations of healthcare providers should undertake initiatives to educate workers, healthcare providers, and employers regarding this discretionary authority, and to feature this information on public websites and in outreach activities.

Recommendation IV-3: Public and private sector efforts should be undertaken to eliminate all unnecessary workplace and commercial uses of lead where substitution of safer alternative materials is possible and feasible. Research into substitutes for the major remaining uses of lead should be encouraged and prioritized for federal funding.

Elimination of the use of a hazardous substance or product represents the most effective means to reduce occupational or environmental exposure. Elimination stands at the top of the hierarchy of controls for hazards long recognized by the occupational health and safety community (OSHA, 2023). Over many decades, safer substitutes for lead have replaced or greatly reduced its presence in occupational settings and commercial products where such use might result in human exposure. The phase out of lead in automobile gasoline, residential paint, pigments or glazes in consumer products, and solder for canned food and potable water plumbing represent notable historical advances. However, in other settings elimination of the use of lead where feasible alternatives exist has been incomplete. These include, but are not limited to, the use of lead pigment (e.g. lead chromate) in industrial paints (WHO, 2024), automobile wheel weights (EPA, 2024b), ammunition and fishing tackle (Bellinger et al., 2013; Department of the Interior Fish and Wildlife Service, 2023), cosmetics intended for application to the lips and face (FDA, 2024a), aviation gasoline for piston aircraft (Sundeen, 2024); radiation shielding in medical and industrial settings (Safari et al., 2024); cable sheathing, solder in electronics, and oxides in glass and ceramics. Legislation restricting the use of lead in some of these applications, such as the 2019 California ban on the use of lead in ammunition for hunting, and the ban on lead in wheel weights in eight states, should be promoted in other states by public health agencies and enacted on a federal level. A practical substitute for the widespread use of lead in lead-acid storage batteries (88 percent of apparent US consumption;) may require ongoing research and development (National Minerals Information Center, USGS, 2024).

Recommendation IV-4: The lead exposure prevention activities of NCEH/ATSDR, NIOSH, and other federal and state departments and programs should be leveraged to increase awareness of and compliance with the EPA Renovation Repair and Painting (RRP) program, which since 2010 has required that projects that disturb lead-based paint in homes, childcare facilities and preschools built before 1978 be performed by lead-safe certified contractors.

Recommendation IV-5: The lead exposure prevention activities of NCEH/ATSDR, NIOSH, and other federal and state departments and programs should advocate for inclusion of mandatory lead hazard mitigation activities for permits and inspections conducted in accordance with model codes of the International Code Council, which do not currently recognize such lead paint hazards.

Lead present in paint and plumbing in older residential and commercial buildings poses a significant source of potential lead exposure to building occupants and workers involved in maintenance or remodeling work that alters or disturbs lead-containing material. The American Healthy Homes Survey II (AHHS II) sponsored by the U.S. Department of Housing and Urban Development and the EPA recently estimated that 34.6 million homes (29.4%) have lead-based paint somewhere in the building, of which 22.3 million (18.9% of all homes) have one or more significant lead-based paint hazards (using the definition of lead dust hazards applicable to AHHS). Of homes with lead-based paint, 30.9 million (89%) were built before 1978 (National Minerals Information Center, USGS, 2024). Since 2010, the EPA's RRP rule has required that renovation, repair and painting projects that disturb lead-based paint in homes, child care facilities and preschools built before 1978 be performed by lead-safe certified contractors (EPA, 2013a). However, compliance with the RRP appears to be suboptimal, in part because of inadequate resources for enforcement and lack of awareness (Kreher, 2020). The lead exposure prevention activities of NCEH/ATSDR, NIOSH, and other federal and state programs should be leveraged to increase awareness of and compliance with the EPA RRP program. As recently recommended in a report by the EPA Children's Health Protection Advisory Committee, (EPA Children's Health Protection Advisory Committee, 2024) expanded collaboration between federal lead hazard reduction programs may contribute to optimized results.

Federal programs within CDC and EPA can advocate for revisions of local building codes that will require compliance with the lead safe practices and related provisions of the EPA RRP rule. Most local building codes throughout the U.S. incorporate the format and language of model codes developed by the International Code Council (ICC). In 2008, the CDC Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) submitted a CDC-cleared letter to the ICC requesting that the International Property Maintenance Code and Existing Building Code explicitly and effectively prohibit lead-based paint hazards and prevent their creation and dispersion during activities that disturb lead-based paint in existing buildings beyond a *de minimus* area of two square feet or less. However, the ICC has declined to institute these provisions in the model code or to reference EPA requirements under the RRP rule. Consequently, in most localities in the U.S., the permitting and inspection process conducted by building code personnel does not require the prevention or remediation of lead paint hazards associated with the same work that is regulated or inspected to control other hazards recognized in the code (Health Impact Project, 2017).

Recommendation IV-6: CDC should reallocate resources to create a unified blood lead surveillance system and Lead Poisoning Prevention Program designed to monitor and reduce lead exposure across all ages.

Effective action on many of the recommendations of this report will require a federal program that dedicates adequate personnel and resources to the task. Many sources of lead exposure to adults and children overlap or interact. Accordingly, efficiencies in the execution of the public and health professional education, policy development, surveillance, and research and outreach may be achievable by creating a unified blood lead surveillance system and Lead Poisoning Prevention Program that addresses lead exposure across all ages. This unified surveillance system and program would have a single funding stream to provide support for state-based surveillance systems that focus on monitoring and reducing environmental and occupational lead exposure in homes, workplaces, and consumer products. Moreover, a unified surveillance system would not only allow for more efficient use of limited resources, but would also enhance the surveillance systems' capacity to detect previously unidentified lead exposed cases (Egan et al., 2019).

Section V

Health Equity Implications of Lead Exposure in Adults

Recommendation V-1: All institutions, agencies, and programs engaged in research, education, prevention programs and interventions designed to address health inequities should recognize and incorporate occupational and environmental lead exposure as a factor.

Recommendation V-2: Local health clinics should offer no-cost blood lead screening to uninsured or low-income adults without regard to their immigration or documentation status. This may be supported by federal and state funding in a manner analogous or comparable to no-cost screening offered to adults for tuberculosis and sexually transmitted diseases, or to persons receiving laboratory tests for prenatal care.

Recommendation V-3: In accordance with recommendations by the CDC and the American College of Obstetricians and Gynecologists (ACOG), assessment of lead exposure, including indicated blood lead screening, should occur preconceptionally or at the earliest contact with the pregnant patient. CDC and ACOG should take action to assess and enhance compliance with these recommendations, which should also be considered for inclusion as a Healthcare Effectiveness Data and Information Set (HEDIS) measure for healthcare organizations and health care plans.

Residents of low-income and urban areas and communities of color are most at risk for lead exposure. It is essential to identify and mitigate lead exposures from multiple sources and to address the ongoing disparities in lead exposure (LeBrón et al., 2019). NHANES data has shown that most black adults experienced much higher blood lead levels in early life than did white adults. This racial inequity is consistent with prior research and longstanding patterns of environmental hazards in communities of color (Yeter et al., 2020). Underserved neighborhoods with a high concentration of people of color are ecologically distinct and suffer disproportionately from "toxic inequality." This means that residents of these neighborhoods have a higher body burden of lead than residents of other neighborhoods (Sampson & Winter, 2016). Intergenerational transfer of lead toxicity may also result. Parental exposure to lead in childhood may contribute to decreased educational attainment, employment opportunities and socioeconomic status. To the extent that lower household socioeconomic status may be a risk factor for childhood lead exposure through unremediated residential lead paint hazards, neighborhood environmental pollution, poorer nutrition, low access to health care, and take-home lead exposure from unsafe parental lead work, children’s likelihood of exposure to lead may be increased. This indirect transfer may perpetuate basic inequities in lead exposure across entire populations and generations (Leech et al., 2016). Estimates show that more than half of adults in the U.S. live with the legacy of childhood lead exposure (McFarland et al., 2022).

In general, more low-wage and racial/ethnic minority workers are employed in hazardous industries than white workers. This disparity contributes to social inequalities and the burden of occupational exposure. These health problems may result in lost work time, lower productivity, and higher medical costs (Steege et al., 2014). The overrepresentation of minority workers in hazardous jobs is preventable, and advocacy efforts through community-engaged research and community coalitions, supported by federal and state associations that can provide technical expertise, is one method that can help to improve the work and home environments (Ingram et al., 2021). The same individuals working in high-risk jobs may be more likely to live in older housing or communities where other environmental exposures to lead may be present (lead paint, old water lines, soil), increasing total exposure to lead (Bonney et al., 2022).

Industries with historical and ongoing uses of lead in products, such as lead radiator repair, lead processing, electronic waste recycling, and construction, disproportionately employ groups who have been historically disenfranchised (Lipscomb et al., 2006). In consequence, take-home lead exposures from working in these industries may compound lead exposure pathways already present in their community. A study from the American Journal of Industrial Medicine examining occupational determinants of bone and BLLs in middle-aged and elderly men from the general community (Elmarsafawy et al., 2002) found that in multivariate regression models an interaction between race and occupational status was suggested; non-white status was found to be associated with a 4.8 µg/dL increase in blood lead in blue-collar subjects but only a 0.3 µg/dL increase in blood lead in white-collar subjects. Results from NAS also suggest that low educational attainment (high school or less) was an important risk factor significantly associated with bone lead concentration.

Regulatory workplace lead standards are intended to keep workers safe, but significant questions exist regarding compliance and enforcement in informal work arrangements (e.g.- day laborers, LeBrón et al., 2019). These work arrangements can vary on a day-to-day basis. Often these workers do not receive proper training and personal protective equipment. Frequently such workers are immigrants, including some without legal status and little perceived or actual recourse to remedial legal action. Immigrants not aware of workplace lead standards and associated protections are less likely to ask for appropriate medical surveillance or workers compensation evaluations because they are not aware of their rights.

The lack of access to employer-provided blood lead testing by workers potentially exposed to hazardous lead in the informal job sector or in workplaces non-compliant with OSHA standards may often result in their foregoing such testing entirely. This is particularly a concern for low-income individuals who lack health insurance, and for undocumented immigrants who may not have access to Medicaid or other state or local insurance programs. As noted previously, elevations in lead exposure pose a direct health risk to these workers as well as to their children and other household members through take-home exposure on work clothes and other belongings. While local health agencies may offer free blood lead screening as a preventive measure to children regardless of their documentation status, the same benefit may often be unavailable to adults. The Workgroup recommends that local health departments provide free access to blood lead screening for uninsured low-income adults regardless of their immigration or documentation status. This screening could be offered in a manner analogous or comparable to the no-cost screening frequently provided to such individuals for tuberculosis and sexually transmitted disease in many localities, often with funding support from federal and state programs.

Access to health insurance can not only impact a person's ability to get tested for lead but also their ability to undergo treatment for elevated BLLs. Access to health insurance can help eliminate health inequities for populations, improve health outcomes, and provide better access to care ("Access to Healthcare and Disparities in Access," 2021). Historically, Americans have experienced varying access to care based on race, ethnicity, socioeconomic status, age, sex, and residential location. Information about places to seek no or low-cost, sliding-scale fee care should be easily available and provided to all, especially to immigrants, undocumented workers, those living in marginalized communities, and pregnant people. The CDC has recommended a risk evaluation of every person immigrating to the U.S., with screening recommended when one or more risk factors are identified (CDC, 2024f).

Obstetric healthcare providers should consider the possibility of lead exposure in pregnant people and perform blood lead testing when indicated as part of pre-conceptional or prenatal care. The CDC (CDC, 2010), and ACOG (Committee on Obstetric Practice, 2023) have recommended that assessment of lead exposure should occur preconceptionally or at the earliest contact with the pregnant patient. Common risk factors for lead exposure in these populations include recent emigration from or residency in a country with high lead contamination, working with lead or living with someone who does, use of traditional remedies or supplements, spices, or cosmetics manufactured overseas, traditional lead-glazed pottery, renovating or remodeling older houses, and pica behavior during pregnancy. The Workgroup recommends that the CDC and ACOG take steps to assess and enhance compliance with their recommendations for prenatal assessment of lead exposure. Just as childhood blood lead screening is a HEDIS measure for healthcare organizations and health plans by the National Committee for Quality Assurance, documented prenatal assessment of lead exposure and indicated prenatal blood lead screening should be considered for inclusion as a HEDIS measure (Healthy People 2030, n.d.).

Section VI

Communication Strategies for Reducing Adult Lead Exposure

Recommendation VI-1: CDC centers, especially NIOSH and NCEH/ATSDR, should collaborate with federal partners such as the Consumer Product Safety Commission (CPSC), FDA, and EPA to increase awareness of sources of elevated lead exposure to adults. This outreach should incorporate educational materials that are appropriately tailored to audiences with a diversity of health literacy and cultural and linguistic backgrounds.

Recommendation VI-2: To enhance communication about preventive strategies, federal agencies should develop or expand partnerships with associations of health care professionals, and with business sectors that utilize lead or sell or distribute products with potential lead hazards.

In general, creating culturally competent health materials and messages requires a multifaceted approach that considers cultural sensitivity, language accessibility, and appropriate health literacy levels for the target audience. To ensure that health-related materials and messages are relevant and culturally sensitive, it is important to engage with community members and cultural experts (Feinberg et al., 2021). Improving health literacy, or the ability of individuals to obtain, understand, and practice health information and services, can also improve healthcare usage (Zhou et al., 2022). People with average or good reading skills appreciate messages that are conveyed simply and clearly (NIH, 2021).

Effective communication on lead exposure prevention should use numerous media strategies to convey messaging, including radio, television, newspaper, brochures, fact sheets, websites, and social media (e.g.- Instagram, Facebook, YouTube, and TikTok) (Feinberg et al., 2021). This ensures that potential at-risk groups receive the information they need to make informed decisions. When developing educational materials around the subject of lead, it is important to consider the literacy and education level of the target audience. As previously discussed, racial and ethnic minority workers are frequently employed in lead-related industries and occupations. Therefore, lead materials should be translated into multiple languages. If employer blood lead testing isn't mandated or otherwise offered, workers receiving comprehensible educational materials may not understand the importance of asking their primary care physicians for a blood lead test.

Local businesses should be engaged to offer lead hazard reduction information to the at-risk community. This could be done by making educational materials available at physician offices, home improvement and construction supply stores such as Lowes and Home Depot, paint retailers and wholesalers, and community centers. Partnering with local businesses to provide information about lead testing and lead abatement is also important. Such collaboration with partners can be an important part of effectively helping vulnerable communities (Di Giovanna, 2021). For example, local or regional health departments can collaborate with resettlement agencies to educate refugee families and those living in older housing on lead poisoning prevention. This collaboration can help overcome language barriers and other challenges of coordinating care for refugee cases and will ensure that the educational materials go directly to those most at risk from their environment. It is important to use imagery and symbols that resonate with the target culture and avoid visuals that could be offensive or confusing. Additionally, collaboration with community partners can help build trust and rapport with the vulnerable community, which can be essential for effective service delivery (Ahmed & Palermo, 2010).

Collaboration among federal partners including the CDC (particularly NCEH and NIOSH), CPSC, EPA, and FDA can be useful for the development and dissemination of educational materials regarding the recognition, reduction, and elimination of lead hazards. Lead exposure subject matter experts can present at health care conferences and collaborate with associations of healthcare professionals in disseminating information on lead testing and high-risk populations. These federal partners can assist with the creation of a national, internet-based clearinghouse of multilingual, multi-audience documents and materials created by state and federal lead prevention programs. A clearinghouse can be an effective mechanism to ensure the materials are available to all who need them in an easily accessible location. Social media campaigns can extend the reach of these materials and encourage at-risk people to visit the clearinghouse or other web pages for additional information on lead hazard reduction. In recent years, social media has been effectively utilized to rapidly disseminate crucial messages on immunization, healthy lifestyles, and disease prevention (Jain et al., 2024).

Employee success stories are an excellent means of motivating others to make healthy lifestyle changes (*Seeing Others' Big Triumphs, We May Feel More Motivated than Usual to Succeed*, 2021). They highlight the benefits of healthy living and celebrate the employees' accomplishments. Success stories can also help employees identify with others who have made similar changes and overcome similar challenges. This can help motivate employees to stay on track and achieve their goals. In terms of the reduction of lead exposure among workers, reminders for good hygiene at the workplace, such as washing hands, eating, and drinking in a clean break room, showering at work, and washing work clothes separately, may be easy to implement and effective in protecting workers and their families. Emphasizing methods of protecting a lead worker's family, such as changing out of work clothes prior to leaving work, or washing work clothes separately from their family's clothes, may strongly motivate awareness and preventive behaviors.

Healthcare providers should be encouraged and reminded to identify high-risk patients and have them tested for lead. Since lead exposure often occurs at the household level (shared exposure), inquiries about potential lead exposure to all members of a patient's household should be considered. By taking a thorough exposure history, a primary healthcare provider can play an important role in detecting, treating, and preventing disease due to environmental exposures (CDC, 2024h). Healthcare providers should be aware of relevant OSHA regulations and CDC guidelines that govern screening and clinical management of lead-exposed or potentially exposed patients. It is critical for obstetricians to understand the importance of incorporating exposure assessment for lead exposure into prenatal screening, regardless of their patient's occupation or risk factors, since there is evidence that prenatal lead screening has been underutilized (Johnson et al., 2022). Education should also be provided to pregnant people so they know the importance of getting tested for lead and ask for a blood lead test or speak to their obstetrician/gynecologist (OBGYN) or primary care physician about it (NY DOH. New York Department of Health, n.d.). If a pregnant person has an elevated blood lead test, it's important to ensure the pediatrician is aware so the baby can be tested promptly at birth for best maternal and child outcomes. The CDC should consider partnering with the American Academy of Family Physicians (AAFP) or the American College of Physicians (ACP) to increase the awareness of the adult healthcare provider community of the risks of adverse health effects of low-level lead exposure (e.g. cardiovascular morbidity and mortality). It is also important to expand the education of prenatal and maternal care providers regarding the role of calcium in the diet and/or calcium supplementation in mitigating lead mobilization to mother and offspring during pregnancy and lactation (Ettinger et al., 2008).

It is also essential to communicate about non-occupational lead exposure in a way that will encourage behavior change. Hobbies such as target shooting, stained glass and other craftwork; home renovation; and the use of certain spices and traditional folk medicines from countries outside the U.S. are potential sources of lead exposure that should not be overlooked (FDA, 2024b). When communicating about these issues, it is important to consider cultural and religious practices and family rituals, especially among immigrant populations. Despite existing regulations on lead content for domestic and imported foods and consumer products, certain imported spices and cookware remain at risk of occult contamination with elevated amounts of lead. It is important to be culturally sensitive in these situations and provide culturally relevant and appropriate recommendations to reduce or stop the use of these products (Hore, n.d.). Targeted messaging, education, and outreach to consumers, retailers, and distributors of high-risk products and foods may facilitate primary and secondary prevention of lead exposure from these sources. Educational outreach by public and private sector public health agencies and organizations should encourage large retailers and distributors of consumer products to assess, reduce or eliminate lead content or hazards throughout the supply chain (*Retailers*, n.d.).

Section VII

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