United States Government Accountability Office

Report to Congressional Requesters

December 2020

DRINKING WATER

EPA Could Use Available Data to Better Identify Neighborhoods at Risk of Lead Exposure

Accessible Version

GAO-21-78

GAO Highlights

Highlights of GAO-21-78, a report to congressional requesters

Why GAO Did This Study

Lead in drinking water comes primarily from corrosion of service lines connecting the water main to a house or building, pipes inside a building, or plumbing fixtures. As GAO reported in September 2018, the total number of lead service lines in drinking water systems is unknown, and less than 20 of the 100 largest water systems have such data publicly available.

GAO was asked to examine the actions EPA and water systems are taking to educate the public on the risks of lead in drinking water. This report examines, among other things: (1) the extent to which neighborhood data on cities served by lead service lines can be used to focus lead reduction efforts; and (2) actions EPA has taken to address WIIN Act requirements, and EPA's risk communication documents.

GAO conducted a statistical analysis combining geospatial lead service line and ACS data to identify characteristics of selected communities; reviewed legal requirements and EPA documents; and interviewed EPA officials.

What GAO Recommends

GAO is making four recommendations, including that EPA develop (1) guidance for water systems on lead reduction efforts,

View GAO-21-78. For more information, contact J. Alfredo Gómez at (202) 512-3841 or gomezj@gao.gov.

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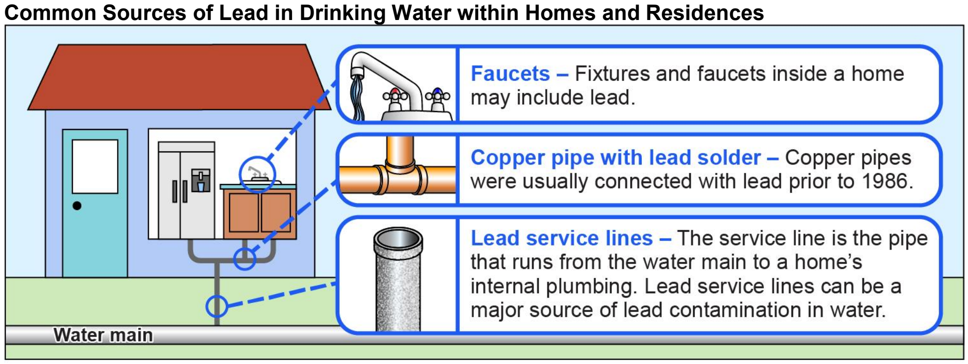
What GAO Found

GAO's statistical analysis indicates that areas with older housing and vulnerable populations (e.g., families in poverty) have higher concentrations of lead service lines in the selected cities GAO examined. By using geospatial lead service line data from the selected water systems and geospatial data from the U.S. Census Bureau's American Community Survey (ACS), GAO identified characteristics of neighborhoods with higher concentrations of lead service lines. The Environmental Protection Agency's (EPA) guidance for water systems on how to identify the location of sites at high-risk of having lead service lines has not been updated since 1991 and many water systems face challenges identifying areas at risk of having lead service lines. By developing guidance for water systems that outlines methods for identifying high-risk locations using publicly available data, EPA could better ensure that public water systems test water samples from locations at greater risk of having lead service lines and identify areas with vulnerable populations to focus lead service line replacement efforts. (See figure for common sources of lead in home drinking water.)

Common Sources of Lead in Drinking Water within Homes and Residences



Source: GAO adaptation of Environmental Protection Agency information. | GAO-21-78

EPA has taken some actions to address the Water Infrastructure Improvements for the Nation (WIIN) Act requirement, which include developing a strategic plan regarding lead in public water systems. However, EPA's published plan did not satisfy the statutory requirement that the agency's strategic plan address targeted outreach, education, technical assistance, and risk communication undertaken by EPA, states, and public water systems. For example, the plan does not discuss public education, technical assistance or risk communication. Instead, EPA's plan focused solely on how to notify households when EPA learns of certain exceedances of lead in their drinking water. Moreover, EPA's plan is not consistent with leading practices for strategic planning. For example, EPA's plan does not set a mission statement or define long-term goals. Developing a strategic plan that meets the statutory requirement and fully reflects leading practices for strategic planning would give EPA greater assurance that it has effectively planned for how it will communicate the risks of lead in drinking water to the public.

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Abbreviations

CCR	Consumer Confidence Report
EPA	Environmental Protection Agency
GPRAMA	GPRA Modernization Act of 2010
LCR	Lead and Copper Rule
ACS	U.S. Census Bureau's American Community Survey
WIIN	Water Infrastructure Improvements for the Nation Act

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December 18, 2020

The Honorable Frank Pallone
Chairman
Energy and Commerce Committee
House of Representatives

The Honorable Paul D. Tonko
Chairman
Subcommittee on Environment and Climate Change
Energy and Commerce Committee
House of Representatives

The Honorable Rosa L. DeLauro
House of Representatives

The Honorable Mike Quigley
House of Representatives

Lead contamination poses a threat to the safety of drinking water in many communities across the United States. Lead is a toxic metal that when ingested through water or other sources can have significant effects on human health, including slowed growth, and learning and behavioral problems in children; and detrimental effects on adults' cardiovascular, renal, and reproductive systems.[1] According to the Environmental Protection Agency (EPA), there is no established level of lead that is safe for consumption. Lead exposure through the drinking water supply occurs primarily through the corrosion of pipes (such as service lines made of lead)[2] that water systems use to deliver water to customers, plumbing fixtures made with lead or brass, or the lead solder used to connect pipes. EPA's strategic plan for fiscal years 2018-2022 states that one of the agency's highest priorities is to reduce exposure to lead in our nation's drinking water systems.

[1]For more information on the health effects of lead in drinking water, see GAO, *K-12 Education: Lead Testing of School Drinking Water Would Benefit from Improved Federal Guidance*, GAO-18-382 (Washington, D.C: July 5, 2018), 5.

[2]The service line is the pipe that runs from the water main to a home's internal plumbing.

As we reported in September 2018, the total number of existing lead service lines used in drinking water systems is unknown, although estimates range between 6.1 million and 10 million nationwide.[3] EPA's Lead and Copper Rule (LCR), first promulgated in 1991, seeks to reduce the amount of lead consumed in drinking water by requiring water systems to (1) monitor lead levels at customers' taps, and (2) take additional actions if levels are higher than allowed under the LCR, such as controlling corrosion, providing information to the public, and in some circumstances, replacing lead service lines under water systems' control. According to EPA officials and documents, the LCR is one of the most complex drinking water regulations under the Safe Drinking Water Act.[4] As of April 2020, the drinking water systems required to follow the LCR served about 318 million people—most of the U.S. population.[5]

Generally, the responsibility for ensuring safe drinking water is shared by EPA, states, and local water systems. EPA is charged with national implementation of the LCR, which includes overseeing states' implementation of the rule and providing training and technical assistance to states and water systems, among other efforts. States generally have primary responsibility for enforcing the LCR,[6] and water systems self-report information about their compliance with the LCR to state regulatory agencies. In addition, community water systems develop an annual report—a Consumer Confidence Report (CCR)—that provides consumers with information on the level of contaminants in the system's drinking water, among other things.

[3]GAO, *Drinking Water: Approaches for Identifying Lead Service Lines Should Be Shared With All States*, GAO-18-620 (Washington D.C.: Sept. 21, 2018).

[4]EPA issued the Lead and Copper Rule, a treatment technique rule, in 1991 (40 C.F.R. pt. 141, subpt I). The Lead and Copper Rule also includes requirements to minimize copper in drinking water. This report examines only the requirements applicable to lead.

[5]The Lead and Copper Rule applies to community and non-transient, non-community water systems. A community water system supplies water to the same population year-round. A non-transient, non-community water system regularly supplies water to at least 25 of the same people at least 6 months per year. The Lead and Copper Rule does not apply to water systems that provide water in places where people do not remain for long periods of time, such as a gas station or campground.

[6]EPA can also issue orders necessary to protect human health if a contaminant in a public water system presents an imminent and substantial endangerment and state and local authorities have not acted to protect human health. 42 U.S.C. § 300i(a).

EPA is also responsible for making information available to the public regarding lead in drinking water, as required by the Water Infrastructure Improvements for the Nation (WIIN) Act, which was enacted in December 2016.[7] In contrast to the LCR, the WIIN Act requires EPA—rather than water systems—to provide this information, and the requirement is not dependent on a triggering event, such as water samples exceeding the action level for lead. The WIIN Act further requires EPA to develop a strategic plan in collaboration with states and public water systems for providing targeted outreach, education, technical assistance, and risk communication to populations affected by the concentration of lead in a public water system.[8]

You asked us to examine the actions that EPA and water systems are taking to inform the public about the risks of lead in drinking water, including information about lead service lines. This report examines:

- the extent to which available data identify the characteristics of neighborhoods served by lead service lines in selected cities, and the extent to which such information could be used to focus lead reduction efforts;
- the actions EPA has taken to ensure that the risks of lead in drinking water are communicated to the public through EPA's actions to address the WIIN Act requirements and the extent to which EPA has risk communication guidance documents; and
- the extent to which selected water systems have public education materials that communicate the risks of lead in drinking water.

To determine the extent to which available data identify the characteristics of neighborhoods served by lead service lines in selected cities and the extent to which such information can be used to focus lead reduction efforts, we relied on geospatial lead service line data (geospatial lead data) from four selected water systems: Greater Cincinnati Water Works in Ohio, Pittsburgh Water and Sewer Authority in

[7]Pub. L. No. 114-322, § 2106(b), 130 Stat. 1628, 1726 (2016) (*codified at* 42 U.S.C. § 300g-6(f)).

[8]Pub. L. No. 114-322, § 2106(a)(6), 130 Stat. 1628, 1724 (2016) (*codified at* 42 U.S.C. § 300g-3(c)(5)(A)). The WIIN Act requires the strategic plan to include, among other things, "dissemination of information described in subparagraph C," which is information required to be disseminated when EPA develops data, or receives information from a source other than a state or public water system, about a lead action level exceedance.

Pennsylvania, Providence Water in Rhode Island, and Rochester Water Bureau in New York. Based on our research, we identified six potential water systems for inclusion—four from the 100 largest water systems and two from other large water systems.[9] Five of those water systems agreed to share their geospatial lead data with GAO. Due to when we received the data and time constraints, we were only able to incorporate four water systems into our analysis. We also selected these water systems because they were recommended to us during interviews with EPA officials and representatives from national drinking water system associations that we asked to identify water systems that had up-to-date lead service line data. We also relied on data from the U.S. Census Bureau's (Census) American Community Survey (ACS), specifically 5-year estimates of population and housing data for 2013 through 2017.[10] We used the geospatial lead data and the ACS data to develop statistical models and maps to identify the housing and demographic characteristics of neighborhoods with high concentrations of lead service lines.[11]

We took several steps to assess the reliability of the data used in our statistical analyses. For the lead service line data, steps included interviewing officials from the four selected water systems to understand their lead service line data, how they collect and update lead service line data, and their lead reduction efforts. In addition, we reviewed the selected water systems' websites for additional information pertaining to lead service lines and lead service line replacement programs, and evaluated the completeness of the data. For the ACS data, steps included examining the sampling error of estimates and assessing the completeness of data. Based on such steps, we deemed these data to be sufficiently reliable for the purposes of assessing the extent to which the

[9]The top 100 public water systems serve populations greater than 300,000. The four selected water systems serve a total population of 1.8 million people.

[10]The 5-year estimates are based on data collected from a sample of households during 60 months of the 5 most recent calendar years to provide annually updated information. Because the American Community Survey 5-year data followed a probability procedure based on random selections, the sample selected is only one of a large number of samples that might have been drawn. All 5-year ACS percentage estimates presented have margins of error at the 95 percent confidence level of plus or minus 10 percentage points or less, unless otherwise noted. All non-percentage estimates presented using the 5-year ACS had data within 20 percent of the estimate itself, unless otherwise noted.

[11]We use "neighborhoods" to refer to census tracts in this report. Census tracts are statistical subdivisions of counties whose boundaries follow geographic features, such as streams, highways, railroads, and legal boundaries, and that generally contain between 1,200 and 8,000 people.

lead service line data from the four public water systems were associated with neighborhood population and housing characteristics.

To examine the actions EPA has taken to address WIIN Act requirements and the extent to which EPA has risk communication guidance documents, we reviewed statutory requirements, EPA documentation related to the implementation of those requirements, and the agency's risk communications guidance. We also interviewed EPA officials and obtained related documentation. We compared the steps EPA has taken to address a statutory requirement with leading practices for strategic planning based on the GPRA Modernization Act of 2010 (GPRAMA) and compared EPA risk communication guidance with the principles for internal and external communication from Standards for Internal Control in the Federal Government. We assessed the content of EPA's guidance and documents against these principles and leading practices.

To assess water systems' public education materials, we identified and assessed public education materials about the risks of lead in drinking water from 54 water systems, including the 50 largest public water systems.[12] We assessed the extent to which each water system had developed the annually required CCR and reviewed the language about lead used in each CCR. We did not verify whether the water systems developed the language for lead in drinking water in their CCRs in consultation with their state. We also identified additional public education materials on lead in drinking water from these water systems' websites that are not the public education materials required by 40 C.F.R. § 141.85(a) by searching for "lead" and "lead in drinking water." We assessed the extent to which these materials included key content on the risk of lead in drinking water, derived from EPA, including sources of lead in drinking water, health effects from exposure to lead in drinking water, and actions for addressing lead in drinking water. We also assessed the materials for clarity, such as use of active voice throughout the materials, simple sentences, and clear and concise headers, and sections, based on best practices for developing clear documents that EPA included in its 2007 Risk Communication Workbook.[13] We also conducted a readability

[12]We identified the largest 50 public water systems using EPA's Drinking Water Information System Federal Reporting Services website in November 2019. Public water systems in Puerto Rico were beyond the scope of this report and were excluded from the analysis. We additionally included four water systems, within the largest 100 public water systems, that were willing to share geospatial lead service line data with us for the first objective.

[13]EPA: *Risk Communication in Action: The Risk Communication Workbook* (2007).

assessment designed to indicate how difficult written communication is to understand; this assessment included a readability score for the materials produced by each water system in terms of word usage and frequency, word length, and sentence length to determine the reading grade and age levels of the materials.

We conducted this performance audit from May 2019 to December 2020, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform our audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Sources of Lead in Drinking Water

Lead was widely used in plumbing materials, including drinking water service lines, until 1986, when the Safe Drinking Water Act was first amended to generally prohibit the new installation of lead pipes and use of solder. According to EPA, homes built before 1986 are more likely to have lead pipes, solder, and fixtures. When the Lead and Copper Rule (LCR) was promulgated in 1991, it required all drinking water systems covered under the rule to conduct a materials evaluation to collect information about the infrastructure that delivers drinking water to customers, including any known lead pipes and lead service lines. The purpose of the materials evaluation was to identify locations that may be at risk of having high lead concentrations so that systems could take tap water samples at high-risk locations. Specifically, the LCR prioritizes samples to be taken from single-family homes with lead pipes, with copper pipes with lead solder installed after 1982, or that are served by lead service lines and then from buildings, including multi-family residences, with those same characteristics.[14] The required frequency and number of samples to be collected are based primarily on the number of people served and previous sample results, with monitoring typically conducted at 6-month intervals. However, water systems can, after meeting certain criteria, take samples less frequently.[15]

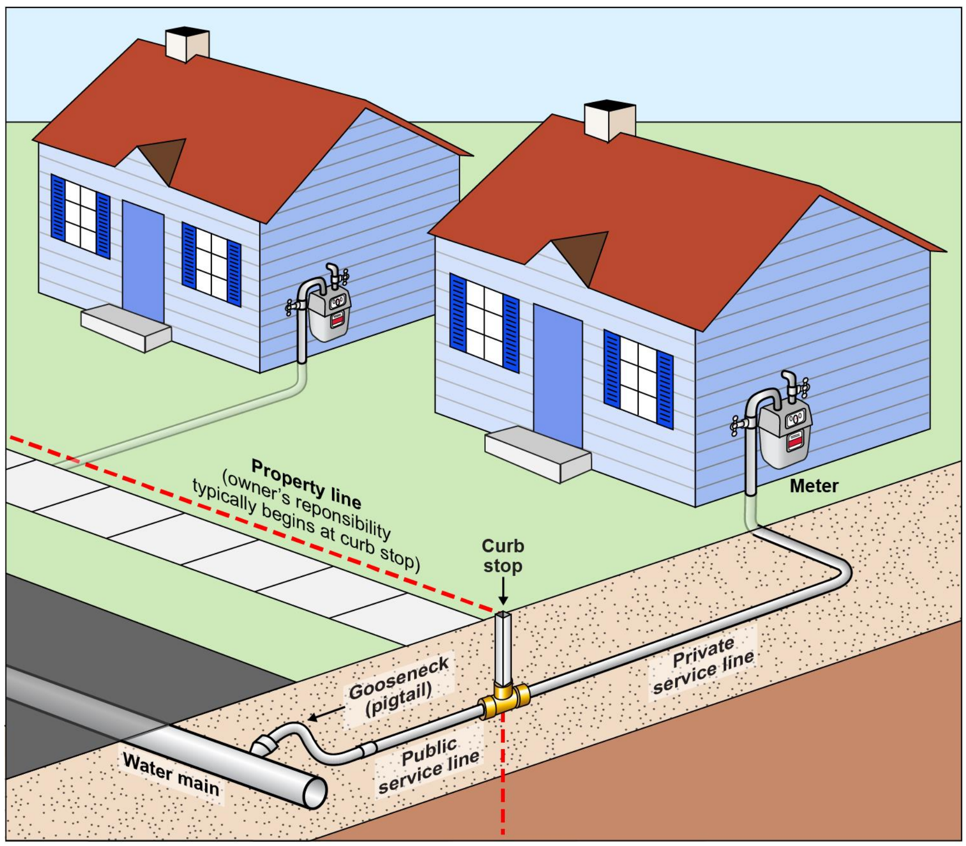
Service lines used by water systems to deliver water to customers are generally made of lead, steel, copper, or plastic. Service lines can be fully owned by the water system (publicly owned) or by the homeowner (privately owned), or ownership can be shared. In most communities, lead service lines are partially owned by the water system and partially owned by the homeowner. With shared ownership, the water system typically owns the service line from the water main to the curb stop, and the homeowner owns the service line from the curb stop into the home. In

[14]40 C.F.R. § 141.86(a)(3)-(5).

[15]*See* 40 C.F.R. § 141.86(d)(4); Environmental Protection Agency guidance 816-R-10-004 for details.

such cases, each party is responsible for maintaining the part of the service line that it owns (see fig. 1). To support homeowners and others, EPA has established a grant program for projects and activities that reduce lead in drinking water.[16]

Figure 1: Typical Location of Water Main, Service Line, and Other Pipes That Deliver Drinking Water to Homes



Source: GAO. | GAO-21-78

Public Education Requirements

For purposes of this report, we define EPA's public education requirements for lead in drinking water as the requirements in the LCR,

[16]This grant program is required by section 2105 of the WIIN Act. Pub. L. No. 114-322, § 2105, 130 Stat. 1628, 1720-1722 (2016) (*codified at* 42 U.S.C. § 300j-19b).

the CCR, and the WIIN Act public education requirement, as described below:

- **LCR:** Water systems that have an “action level lead exceedance,” as defined by the LCR, are required to provide public education materials regarding the health effects of lead in drinking water, the sources of lead, and steps consumers can take to reduce their exposure to lead in drinking water, among other things.[17] Specifically, the LCR requires water systems to provide public education materials to specified individuals and entities when more than 10 percent of the required tap water samples collected have lead concentration levels that exceed 0.015 mg/L—which is known as an exceedance of the lead action level. LCR public education materials regulations were first promulgated in 1991 and were amended in 2000 and 2007.
- **CCR:** All community water systems are required to include educational statements about lead in drinking water in their annual CCR.[18] Water systems publish CCRs to inform their customers about the level of contaminants in their drinking water, as required by a 1998 regulation issued by EPA in response to the Safe Drinking Water Act Amendments of 1996.[19] This regulation requires CCRs to include a specified short information statement about lead in drinking water and its effects on children, but also allows water systems to write their own educational statement in consultation with the state.
- **WIIN Act:** This law requires EPA to make information available to the public regarding lead in drinking water, including information about (1) the risks associated with lead in drinking water and (2) the conditions that contribute to drinking water containing lead in a residence.[20] We

[17]The LCR requirements for these public education materials are found in 40 C.F.R. § 141.185(a), (b).

[18]The requirements for lead-specific information in annual CCRs by community water systems are found in 40 C.F.R. § 141.154(d).

[19]The Safe Drinking Water Act Amendments of 1996 required EPA to issue regulations requiring each community water system to mail, or provide by electronic means, a report on the level of contaminants in the system’s drinking water to each consumer at least annually. The CCR regulation establishes the minimum requirements for the content of these consumer confidence reports, including information on the quality of water and characterization of the risks, if any, from exposure to contaminants detected in the drinking water in an accurate and understandable manner.

[20]Pub. L. No. 114-322, § 2106(b), 130 Stat. 1628, 1726 (2016) (*codified at* 42 U.S.C. § 300g-6(f)).

refer to this as the WIIN Act public education requirement.

In November 2019, EPA issued a proposed rule to revise LCR procedures and requirements related to protecting public health and implementing the existing LCR in areas such as public education, and to amend the CCR regulation, among other things. EPA received 79,636 public comments—from public water utilities, associations representing utilities, and environmental groups, among others—on the proposed revisions to the LCR and CCR. After reviewing the comments and determining whether to make changes to the proposed rule, EPA officials told us they will issue a final rule amending the LCR and CCR. EPA officials told us they expect to issue the final rule by the end of 2020, but the final rule had not been issued as of December 13, 2020.

Water Systems' Efforts to Locate Lead Service Lines and Reduce Exposure

The total number of existing lead service lines is unknown and while there are national, state, and local estimates, the approaches used to count lead service lines vary.[21] A 2016 study by the American Water Works Association estimated that nationally there were 6.1 million lead service lines, but we previously found that the study has significant sampling limitations and, as a result, may not accurately reflect the total number of lead service lines nationwide.[22] As we reported in September 2018, water systems were in the beginning stages of conducting complete inventories to identify the locations of lead service lines, with a limited number of water systems publishing information on their inventories.

In reviewing websites for the nation's 100 largest water systems for this report, we found 16 water systems with publicly available information.[23] For example, water systems including Greater Cincinnati Water Works, Pittsburgh Water and Sewer Authority, Providence Water, and Rochester Water Bureau identified the locations of lead service lines, and they used this information to publish online maps that identify and inform their customers about the location of these lines. Some water systems have also established programs to replace publicly owned lead service lines,

[21]GAO-18-620, 8.

[22]GAO-18-620.

[23]In January 2018, we found that 12 of the 100 largest water systems had publicized their inventories, while the rest had not. See GAO-18-620.

and provide homeowners with options for replacing privately owned lead service lines. However, various challenges hinder many water systems' ability to conduct and publish information about their inventories and create maps of lead service line locations for their websites. Such challenges include lack of records about the locations of lead service lines; difficulty locating lead service lines that are underground; limited resources (e.g., time, staff, funding) to conduct complete inventories of lead service lines or to post information on a website; and potential adverse effects on homeowner property values from publicly posting information about lead service lines on private property.[24]

Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directed federal agencies to make achieving environmental justice part of their mission.[25] To do so, agencies are to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations. Agencies are also directed to establish environmental justice strategies. Since the issuance of the order, EPA has focused on integrating environmental justice into its programs and policies. In its *EJ 2020 Action Agenda*, EPA's strategic plan for environmental justice for years 2016-2020, EPA set a goal to demonstrate progress on significant national environmental justice challenges, including lead in drinking water.[26]

In Selected Cities, Data Can Identify Common Characteristics of Neighborhoods with Lead

[24]GAO-18-620, 16.

[25]59 Fed. Reg. 7629 (Feb. 16, 1994).

[26]EPA, *EJ 2020 Action Agenda: The U.S. EPA's Environmental Justice Strategic Plan for 2016-2020*. EPA defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Service Lines and Be Used to Focus Lead Reduction Efforts

Our statistical analysis of geospatial lead data from water systems in four selected cities—Cincinnati, Pittsburgh, Providence, and Rochester—and data from the ACS indicates that older homes and poverty,[27] as well as other indicators of social vulnerability,[28] are common characteristics of neighborhoods that have higher concentrations of lead service lines.[29] Water systems and EPA could use available geospatial data on the location of lead service lines, as well as ACS data about neighborhood demographic characteristics, to focus lead reduction efforts, such as lead service line replacement.

Neighborhoods with Older Homes, Higher Rates of Poverty, and Other Characteristics Have Higher Concentrations of Lead Service Lines

Our analysis of four selected water systems' geospatial lead data and data from the ACS indicates that areas with older homes are more likely

[27]The ACS neighborhood characteristic of poverty we examined is percentage of families in a neighborhood that have an income below the poverty level. We refer to this as percentage of families in poverty or rates of families in poverty. In this context, "higher" means "higher rates" or "higher percentages" of families in poverty within the neighborhood, rather than experiencing an even more intense poverty (e.g., an even lower household income).

[28]For the purposes of this report, we use the term "vulnerable" to describe populations or communities generally characterized by the demographic indicators of higher percentages of families in poverty, such as racial and ethnic minorities based on EPA documents on environmental justice.

[29]In this context, "higher" means that an increase in the neighborhood characteristic is associated with a statistically significant increase in the likelihood of having lead service lines. See appendix II for further information.

to have lead service lines.[30] According to some water system officials we interviewed, building practices and municipal ordinances in the early 20th century allowed for the use of lead, whereas later in the century they did not. For example, Cincinnati and Providence prohibited the use of lead service lines after 1927 and 1940, according to the respective water system officials. Using our statistical model, we found that in Cincinnati there was a 24 percent chance of a household having a lead service line in Census tracts for which the median home construction year was 1946, whereas the chances were less than 1 percent when the median home construction year was 1976.[31] In Providence, the chances of a household having a lead service line were 56 percent where the median home construction year was about 1939 or earlier, whereas the chances were 9 percent where the median home construction year was 1967. We found similar results in Pittsburgh and Rochester, the two other cities we examined.[32]

[30]We developed statistical models for each of the four cities to estimate the likelihood of a home having a lead service line based on its neighborhood characteristics, while controlling for the other characteristics in the model. Our statistical models are multivariate regression models that generally controlled for home age and at least one other housing or demographic characteristic. This allowed us to quantitatively describe the association between home age and lead service lines, while controlling for other housing and demographic characteristics. Similarly, we are able to quantitatively describe the association between other housing and demographic characteristics and lead service lines, while controlling for home age. See the technical appendix II for additional details.

[31]The years presented for each city correspond to one standard deviation below the sample average and one standard deviation above the sample average median home construction year for that city, averaged across all observations in our sample. For example, in Cincinnati, we compare 1946 and 1976 because 1961 was the sample average for that city, and the standard deviation was around 15 years. The sample means and standard deviations for each city are given in table 4 of Appendix II.

[32]Please see appendix II for details of our statistical analysis.

History of Lead Pipes

Installation of lead pipes in the United States for water distribution on a major scale began in the late 1800s, particularly in larger cities. Pipes made out of lead were more expensive than those commonly made out of iron, but had two significant advantages: durability (they lasted about 35 years compared with 16); and they were more malleable and could bend around existing structures.

Concerns about the potential toxicity of lead from water that passes through lead pipes were documented into the early 1900s. By the 1920s, many cities had concluded that the engineering advantages of lead were outweighed by the public health risks, and local and state plumbing codes were revised to prohibit or limit the use of lead in pipes for water distribution. To combat this trend, the lead industry carried out a prolonged and effective campaign to promote the use of lead pipes. The Lead Industries Association (LIA) conducted decades-long advocacy for use of lead pipes by water works, much of which contributed to the present-day public health and economic cost of lead water pipes.

Source: The American Journal of Public Health, "The Lead Industry and Lead Water Pipes "A Modest Campaign." See https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2509614 (Sept. 2008). | GAO-21-78

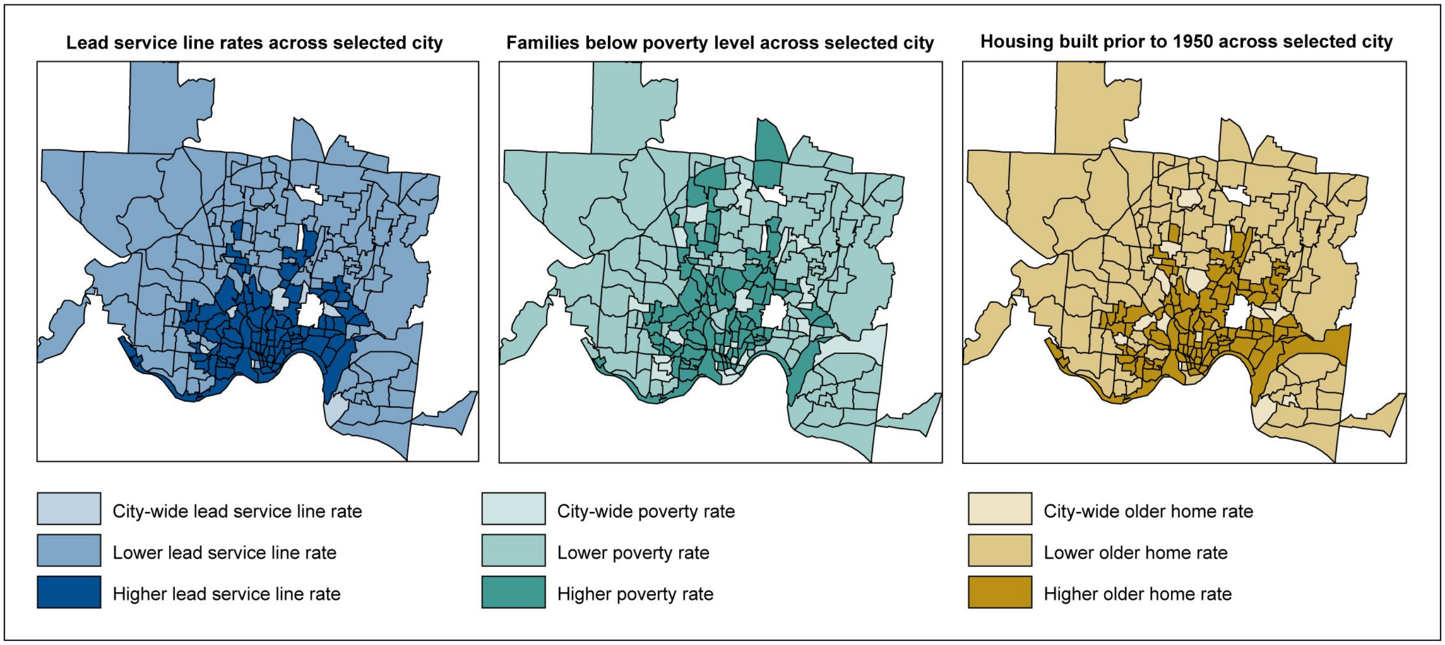
Our analysis also indicates that households in Census tracts with higher rates of families living in poverty have a greater probability of having lead service lines, even after accounting for the median age of the area's housing stock—which we refer to as home age.[33] In addition to the statistical models, figure 2 individually displays the spatial distribution of (1) lead service lines, (2) households living in poverty, and (3) and housing stock built prior to 1950 for Cincinnati.[34] A comparison of the three maps in figure 2 reveals that the south central parts of Cincinnati generally have neighborhoods with higher rates of lead service lines, families in poverty, and housing stock built prior to 1950 than the other parts of the city.[35]

[33]We note that there may be a distinction between the age of a home and the age of a home's plumbing. However, we did not include that distinction in conducting our analysis. We examine home age using the ACS estimate of Median Year Structure Built, the estimated year by which half of the homes within a Census tract were built (constructed). Within a Census tract, there is no variation of this estimate, but the estimated Median Year Structure built varies across Census tracts.

[34]To explore the spatial distribution of lead service lines and key neighborhood characteristics, we developed probability maps. These maps allowed for the analysis of spatial patterns, without considering non-significant random variations, and accounted for potentially small population sizes in certain Census tracts. These maps do not allow for a quantitative assessment of whether these housing and demographic neighborhood characteristics are associated with higher rates of lead service lines. To do that, we developed statistical models. See appendix II for additional details.

[35]In figure 2, we used 1950 as the cutoff year for the year that homes were built—or home age—to simplify the illustration. However, our statistical analysis treats home age as a continuous measure rather than a dichotomous before and after measurement. See appendix II for further details.

Figure 2: Rates of Lead Service Lines, Families in Poverty, and Homes Built before 1950 for Cincinnati, Ohio



Source: GAO analysis of a Water System's geospatial lead data and American Community Survey 5-year (2013-2017) estimates. | GAO-21-78

Notes:All of the Census tracts in the three maps have at least 30 service lines served by the water system depicted in the figure. Some of the Census tracts might not be fully served by the water system.

In the map on the left, the southern area has Census tracts with significantly higher rates of lead service lines than the city-wide rate. In the center map, the central and southern areas have Census tracts with significantly higher estimated percentages of families in poverty than the city-wide rate. In the map on the right, the southern area has Census tracts with significantly higher estimated percentages of homes built before 1950 than the city-wide rate. The level of statistical significance is 5 percent. Comparing the maps illustrates that the southern area has Census tracts with significantly higher rates of lead service lines and percentages of homes built before 1950, as well as families in poverty, than other areas of the city. Because the rates of families in poverty and homes built before 1950 are based on the U.S. Census Bureau's American Community Survey (ACS), which involves a probability sample, these are estimated rates with sampling error. All ACS estimates have 95 percent confidence intervals that are within +/- 30 percentage points.

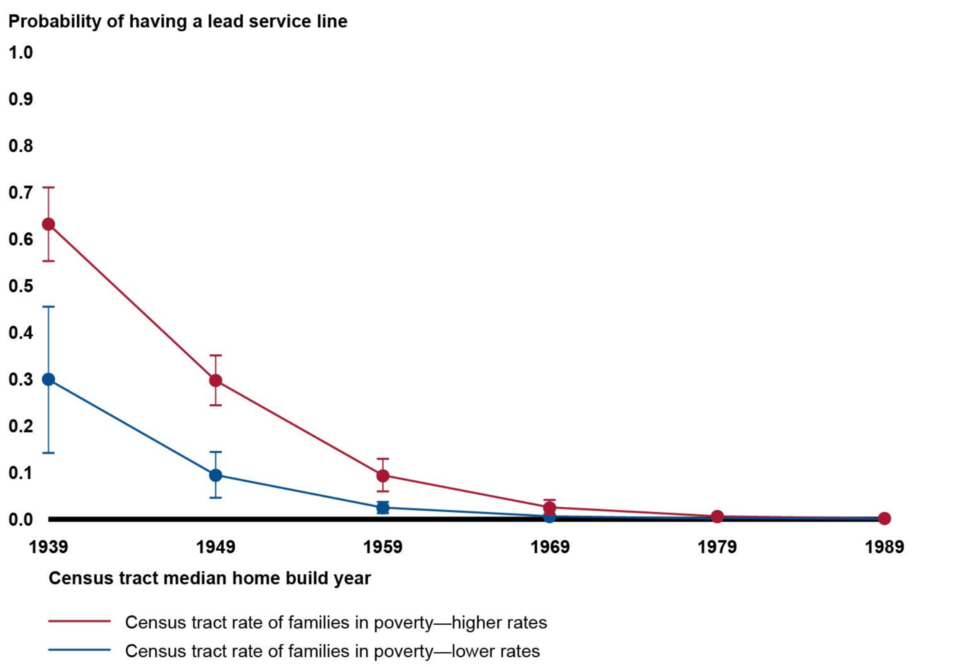
Figure 3 shows the results of one of our statistical models for Cincinnati. We found similar results in the other three cities we examined: Pittsburgh, Providence, and Rochester.[36] Cincinnati households in Census tracts with higher rates of families living in poverty have a greater probability of having lead service lines even after accounting for the median age of the neighborhood's housing stock. Specifically, we estimated the following:

[36]Please see appendix II for details of our statistical analysis of those cities.

- In Census tracts where the median construction year of homes was 1939 or earlier and the poverty rate was above the city average, there was a 63 percent chance of a home having a lead service line. This dropped to a 30 percent chance in tracts with the same median home age, but where the poverty rate was below the city average.
- In Census tracts where the median construction year of homes was 1949 and the poverty rate was above the city average, there was a 30 percent chance of a home having a lead service line. This dropped to a 9 percent chance in tracts with the same median home age, but where the poverty rate was below the city average.
- In Census tracts where the median construction year of homes was 1959 and the poverty rate was above the city average, there was a 9 percent chance of a home having a lead service line. This dropped to a 3 percent chance in tracts with the same median home age, but where the poverty rate was below the city average.

Figure 3: Probability of a Home Having a Lead Service Line, by Median Home Age and Poverty Rates in Cincinnati, Ohio

The probability of having a lead service line is higher in neighborhoods (Census tracts) with higher poverty rates, even after accounting for housing age.



Source: GAO analysis of water system geospatial lead data and American Community Survey 5-year (2013-2017) estimates. | GAO-21-78

Note: The information presented in this figure is based on estimated probabilities of our multivariate regression model that evaluated an otherwise typical Census tract in Cincinnati, but where the Census tract median home build year ranged from 1939 to 1989, by decade, and by varying poverty rates. We defined Census tracts as having above-average poverty rates (i.e., “higher rates”) as those where the percentage of families in poverty was one standard deviation above the sample average for that city. Conversely, we defined Census tracts as having below-average poverty rates (i.e. “lower rates”) as those where the percentage of families in poverty was one standard deviation below the sample average for that city. Since in this particular city one standard deviation was around 12 percent and the average poverty rate was 12 percent, we defined an above-average poverty rate as 24 percent and a below-average poverty rate as 1 percent to illustrate the results of our model. We define a Census tract as otherwise typical in that is has the sample average percentage of families with children under 5. The 95 percent confidence intervals for our probabilities are indicated by the T-shaped whiskers.

Furthermore, we found that the rates of lead service lines in neighborhoods with newer homes and higher poverty rates are comparable with neighborhoods with older homes and lower poverty rates, a finding that may not be apparent when examining home age alone.

In addition to poverty, we found other housing characteristics (e.g., multi-unit households) and demographic characteristics associated with higher concentrations of lead service lines in each of the four cities we selected for review (see table 1). For example, in Cincinnati, Providence, and Rochester, neighborhoods with characteristics indicative of vulnerable populations—such as higher levels of vacant homes, unemployment, minority populations, single female-headed households, renters, and residents with only a high school level education—were more likely to have lead service lines, even when controlling for home age. In Pittsburgh, certain characteristics—such as multi-unit households, households without vehicles, and unemployment—were associated with an increased likelihood of having a lead service line, even when controlling for home age.

Table 1: Census Tract Characteristics Associated with Increased Likelihood of Having a Lead Service Line, by City

	Cincinnati	Pittsburgh	Providence	Rochester
Housing				
Higher percentage of households that are multi-unit	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.

Older median home age	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.
Demographic				
Higher percentage of households with children under 5 years old	Characteristic was significantly associated with having a lead service lines in some but not all of our statistical models.	Characteristic was not significantly associated with having a lead service line in any of our statistical models.	Characteristic was significantly associated with having a lead service lines in some but not all of our statistical models.	Characteristic was significantly associated with having a lead service lines in some but not all of our statistical models.
Higher percentage of vacant households	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was not significantly associated with having a lead service line in any of our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.
Higher percentage of families in poverty	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.
Higher percentage of population that is unemployed	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.

Higher percentage of population with highest education level of high school degree	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was not significantly associated with having a lead service line in any of our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.
Higher percentage of single, female headed households	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was not significantly associated with having a lead service line in any of our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.
Higher percentage of population that is a minority	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was not significantly associated with having a lead service line in any of our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.
Higher percentage of population that is a renter	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was not significantly associated with having a lead service line in any of our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.
Higher percentage of households without a vehicle	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.	Characteristic was significantly associated with having a lead service line in our statistical models.

Source: GAO analysis of water utility and 5-year American Community Survey data (2013-2017). | GAO-21-78.

Notes: We refer to Census tracts as neighborhoods for the purposes of this analysis.

We used multiple imputation to adjust for the higher rate of missing lead material in Pittsburgh and accounted for the within and between imputation variability in our statistical analyses. It is possible that imputation variability contributes to the different pattern of significance observed in Pittsburgh, when compared to other cities. For example, the variability between imputations might make statistically significant differences more difficult to detect due to less precise estimates within this city.

The level of statistical significance is 0.05, unless otherwise noted.

[a]The level of statistical significance is 0.10.

Data Could Help Water Systems Identify Vulnerable Populations and Focus Lead Reduction Efforts

ACS data and, where available, lead service line data (geospatial lead data) could be used to better inform water systems' lead reduction efforts, such as tap sampling and lead service line replacement. If geospatial lead data for a given water system are not available, it is possible to use ACS data to identify vulnerable populations in locations within a city that may have higher concentrations of lead service lines.[37]

The four selected water systems we reviewed have used geospatial lead data to develop maps to inform the public about where lead service lines are located and to focus the systems' lead reduction efforts. For example, Pittsburgh Water and Sewer Authority provides customers with an online map that includes information about the location of lead service lines (where known) as well as the status of lead service line replacement efforts in its communities.

Two of the selected water systems we reviewed have used geospatial lead data alongside demographic data and other available data (e.g., data on blood lead levels) to identify and prioritize lead reduction efforts in vulnerable populations.[38] For example, Greater Cincinnati Water Works has developed preliminary neighborhood maps that overlay its geospatial lead data with demographic data taken from Cincinnati's Department of City Planning Statistical Database;[39] these maps are available on the water system's website.[40] Officials from Greater Cincinnati Water Works told us they were conducting the analysis to allow them to identify and prioritize vulnerable populations served by lead service lines, such as by

[37]Water systems from which we obtained data illustrate one way of creating a geospatial dataset by using: (1) reliable historical paper records on pipe materials and the locations of lead service lines and (2) the resources (i.e., funding, time, and staff) to convert paper records to an electronic database and import that data into a geographic information system (GIS), linking the records with the locations of lead service lines.

[38]Vulnerable populations are more likely to be exposed to other sources of lead contamination, such as lead paint, which can exacerbate the risks posed by lead in drinking water. See https://www.lslr-collaborative.org/equity.html.

[39]The Department of City Planning Statistical Database website contains U.S. Census Bureau 2010 Data and 2006-2010 American Community Survey 5-year estimates.

[40]See for example: https://la.mygcww.org/neighborhoods/east-walnut-hills/.

identifying neighborhood characteristics that may serve as indicators for the presence of lead service lines. These officials also told us that areas of their water system that were potentially associated with a concentration of lead service lines have a wide variation of populations, such as those with low incomes, including those who may rely on social assistance programs, as well as populations with higher incomes. Officials from Pittsburgh Water and Sewer Authority said they developed a prioritization model that uses other demographic data—such as numbers of children under 6 years old, number of women of child-bearing age, income level, and blood lead level data from the county health department—in addition to information about lead levels in particular neighborhoods to select areas for lead service line replacement.

In our interviews with officials from the selected water systems, officials recognized the benefits of our analysis and offered insights about how their water system could use such an analysis. For example, officials from one water system said our analysis gave them further insight into their system and the demographic characteristics of the communities they serve. These officials also said they would like to use the results of our analysis to further inform their decision-making in choosing future areas for lead service line replacements. Officials from another water system said they may use our analysis and ACS data to help them apply for grants for their lead service line replacement efforts, as they have limited funding for such projects. Last, officials from another water system said some water systems that do not have comprehensive lead service line data could use the analysis to better identify the location of lead service lines and where to focus their lead reduction efforts.

As we previously reported, many water systems face challenges identifying areas at high risk of having lead service lines.[41] The LCR requires water systems to collect drinking water samples from locations that may be particularly susceptible to high concentrations of lead, but many water systems have struggled to identify those locations without additional guidance. According to the 1991 preamble to the LCR, EPA acknowledged the potential inadequacy of records needed to identify high-risk locations. The agency suggested water systems use other methods for gathering information, such as looking at the material

[41]As we reported in September 2018, many water systems face challenges that include insufficient records and resources, among others. See GAO-18-620, 16.

composition of service lines during the course of their normal maintenance and repair work, and other activities.

EPA developed guidance in 1991 with information for identifying high-risk sites that would describe where systems can obtain the needed information such as methods for locating these sites, and procedures for establishing a reliable and accurate recordkeeping system to catalogue these sites.[42] In 2018, EPA developed training, incorporating the 1991 guidance, with information for identifying high-risk sites that was provided directly to water systems and states via webinar, according to EPA officials.[43] The 1991 guidance has not been updated and the 2018 webinar did not address how to incorporate social and demographic factors when identifying high-risk sites.

Water system officials we interviewed said that guidance on how to use ACS data to prioritize lead service line replacements would be useful to water systems' lead reduction efforts.[44] By developing guidance for water systems that outlines methods for identifying high-risk locations using available geospatial lead data and publicly available ACS or other data, EPA could better ensure that public water systems (1) collect drinking water samples from locations that may be at greater risk of having lead service lines, and (2) identify areas with vulnerable populations to focus

[42]*LCR Guidance Manual, Vol. 1: Monitoring* (1991).

[43]EPA provided additional information on a two-part webinar training delivered to water systems in two sessions in September 2020. The two-part webinar expanded on the 2018 one, including information on identifying high-risk sites through methods that use geospatial patterns and proximity to known lead service lines and plumbing materials to predict lead service lines and plumbing materials.

[44]In our 2017 report, we identified general challenges with sampling for lead in drinking water. For example, state regulators told us such challenges include water systems failing to collect drinking water samples, collecting samples improperly, or having other problems with collecting samples. Water systems also struggle to find enough homeowners willing to collect water samples for testing. If the water system is able to find homeowners willing to collect samples, homeowners may collect samples improperly. See GAO, *Drinking Water: Additional Data and Statistical Analysis May Enhance EPA's Oversight of the Lead and Copper Rule* GAO-17-424, (Washington, D.C.: Sep. 1, 2017), 68.

lead service line replacement efforts.[45] This guidance would also help EPA further its Environmental Justice goal to ensure that vulnerable communities have drinking water that meets applicable health-based standards.[46]

EPA Is Working to Reduce Lead Exposure through Its Federal Action Plan, but EPA Has Not Incorporated Use of ACS and Lead Service Line Data

ACS data and, where available, geospatial lead data could also be used to help EPA focus its lead reduction efforts. EPA officials told us that they are working to reduce exposure to lead, including lead in drinking water and lead service lines, through the *Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts*.[47] Among various actions, the plan includes (1) generating data, maps, and mapping tools to identify high exposure communities or locations and disparities for prioritization efforts to reduce children's blood lead levels and (2) generating data to address critical gaps for reducing uncertainty in lead modeling and mapping for exposure and risk analyses and for

[45]The LCR requires water systems that continue to exceed the lead action level after implementing applicable corrosion control and source water treatment requirements to conduct lead service line replacement. These systems must annually replace at least 7 percent of the number of lead service lines in its distribution system at the time the replacement program begins. In November 2019, EPA proposed revising the LCR to require water systems to replace the portion of the lead service line owned by the water system when the consumer owned portion is replaced; to annually replace a minimum of 3 percent of the number of known or potential lead service lines the system's required inventory when samples of tap water exceed the lead action level; and to set an annual goal for conducting lead service line replacement when lead in samples of tap water exceed 10 µg/L but not the lead action level.

[46]EPA: EJ 2020 Action Agenda: The U.S. EPA's Environmental Justice Strategic Plan for 2016-2020, iv.

[47]EPA officials told us that goal 1.2 of the *Federal Action Plan* is also relevant. Goal 1.2 includes actions, among others, such as (1) revising the LCR; (2) enhancing the implementation of the LCR; (3) assisting schools and child care centers with the 3Ts approach (Training, Testing, and Taking Action); and, (4) finalizing regulatory changes to the definition of lead-free plumbing products. See President's Task Force on Environmental Health Risks and Safety Risks to Children: *Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts* (December 2018), 9.

estimating the population-wide health benefits from actions to reduce lead exposures.[48]

According to EPA officials' written responses to our questions, the agency is working closely with federal partners on the President's Task Force on Environmental Health Risks and Safety Risks to Children to address these actions and to develop an interagency approach for identifying communities with the highest risk of childhood lead exposure.[49] EPA officials also told us they have encouraged water systems to collect lead service line data and post geospatial information for the public, and a small number have done so.

To date, EPA has not completed and publicly disseminated an agency-specific action plan for generating data, maps and mapping tools to identify communities at high risk of lead exposure as part of EPA's implementation of the federal action plan. It is not clear whether EPA's plan will include the use of ACS and geospatial lead data. By incorporating into its action plan the use of ACS data—specifically, data on neighborhood characteristics potentially associated with the presence of lead service lines—and where available, lead service line information, EPA could better identify neighborhoods at high risk of exposure to lead in drinking water.

EPA Has Taken Some Actions to Address WIIN Act Requirements but Has Not Updated Key Risk Communication Documents

EPA has taken some actions to ensure that the risks of lead in drinking water are communicated to the public, including by developing public education materials and a plan for targeted outreach to populations affected by lead in public water systems. However, this plan did not fully satisfy the WIIN Act requirement and was not consistent with leading practices for strategic planning. In addition, EPA has not updated key risk

[48]President's Task Force on Environmental Health Risks and Safety Risks to Children: *Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts* (December 2018), 16.

[49]See "*Implementation Status of EPA Actions Under the 2018 Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts*" posted on EPA's website: accessed October 6, 2020, https://www.epa.gov/leadactionplanimplementation.

communication documents or published new risk communication guidance.

EPA Has Taken Some Actions to Address WIIN Act Requirements to Provide Public Education about Lead in Drinking Water and to Develop a Strategic Plan

EPA has taken several actions to communicate the risks of lead in drinking water to the public and respond to WIIN Act requirements. For example:

- **Developed a public education infographic.** EPA officials we interviewed provided us with an infographic that they said the agency had developed to address the WIIN Act public education requirement. The infographic—which is on EPA's website—describes the sources of lead in drinking water; ways to reduce exposure to lead; other sources of lead in homes, such as lead paint; and information about replacing a home's lead service line. The infographic also points the reader to more information at EPA's main webpage for drinking water. EPA posted the English version of this infographic online in 2017. According to EPA officials, this infographic had been downloaded 9,885 times as of February 25, 2020, while a Spanish-language version of the infographic, which was posted in 2019, had been downloaded 92 times.
- **Published a plan.** The WIIN Act requires EPA to develop a strategic plan for targeted outreach, education, technical assistance, and risk communication by EPA, states, and public water systems to populations affected by the concentration of lead in drinking water.[50] The act specifically requires the plan to include dissemination of

[50]Pub. L. No. 114-322, § 2106(b)(a)(6), 130 Stat. 1628, 1724 (2016) (*codified* at 42 U.S.C. § 300g-3(c)(5)(A)). The WIIN Act requires the EPA Administrator, in collaboration with others, to establish a strategic plan for how the Administrator, a State with primary enforcement responsibility, and owners and operators of public water systems shall provide targeted outreach, education, technical assistance, and risk communication to populations affected by the concentration of lead in a public water system, including dissemination of information required when EPA develops, or receives from a source other than a state or public water system, data that indicates a lead action level exceedance.

information to households when EPA learns of certain lead action level exceedances.[51] To address this requirement, in June 2017, EPA published its Strategic Plan for Targeted Outreach to Populations Affected by Lead. This plan focused on how to notify households when EPA learns of certain lead action level exceedances in their drinking water. EPA officials told us that this plan was challenging to complete because the agency had a short timeline of 6 months to get stakeholder input and to coordinate with state agencies and local health organizations before the statutory publication deadline for the plan. As part of its coordination efforts, EPA hosted two public webinars to solicit stakeholder input—in March and May 2017. These webinars had a combined attendance of over 700 individuals representing public water systems, states, national associations, and EPA, according to EPA documentation. EPA also held two public comment periods for stakeholders to provide feedback on the draft strategic plan, and received 23 written comments on the plan, according to EPA documentation.

However, EPA's published plan did not satisfy the statutory requirement for the strategic plan. For example, the plan does not discuss education, technical assistance, or risk communication. Instead, the plan only discusses the steps to disseminate information to households when EPA learns of certain lead action level exceedances.

According to EPA officials we interviewed, the plan's focus was limited because it would have been impossible to meet the statutory deadline for issuing the plan if it included anything beyond dissemination of information when EPA learns of certain lead action level exceedances. In addition, officials from EPA's Office of the General Counsel interpreted the WIIN Act strategic plan requirement differently from GAO. Specifically, these officials interpreted this requirement as addressing the targeted outreach required when EPA learns of certain lead action level exceedances. EPA officials provided several reasons for this interpretation, including that there was no statutory definition of strategic plan and the strategic plan requirement is located in a section of the WIIN Act about dissemination of information required when EPA learns of certain exceedances.

[51]This dissemination of information is required by section 1414(c)(5)(C) of the Safe Drinking Water Act, which is codified at 42 U.S.C. § 300g-3(c)(5)(C).

However, EPA's interpretation ignores the plain language of the WIIN Act. There would be no need for the act to use the term "including" if the requirement was for the strategic plan to address only dissemination of information when EPA learns of certain lead action level exceedances. Moreover, there is nothing in the statutory language or legislative history that indicates the plan is to be limited to the dissemination of information when EPA learns of certain lead action level exceedances.

Strategic Plan Requirement in the WIIN Act Section 2106(a)(6)

Section 2106(a)(6) of the Water Infrastructure Improvements for the Nation (WIIN) Act amends section 1414(c) of the Safe Drinking Water Act by adding a paragraph 5 with several subparagraphs:

(5)(A) Strategic Plan. Not later than 180 days after the date of enactment of this paragraph, the Administrator shall, in collaboration with owners and operators of public water systems and States, establish a strategic plan for how the Administrator, a State with primary enforcement responsibility, and owners and operators of public water systems shall provide targeted outreach, education, technical assistance, and risk communication to populations affected by the concentration of lead in a public water system, **including** [emphasis added] dissemination of information described in subparagraph (C). …..

(5)(C) Information required. The information described in this subparagraph includes--

(i) a clear explanation of the potential adverse effects on human health of drinking water that contains a concentration of lead that exceeds the lead action level under section 141.80(c) of title 40, Code of Federal Regulations (or a prescribed level of lead that the Administrator establishes for public education or notification in a successor regulation promulgated pursuant to section 1412);

(ii) the steps that the owner or operator of the public water system is taking to mitigate the concentration of lead; and

(iii) the necessity of seeking alternative water supplies until the date on which the concentration of lead is mitigated.

Source: Pub. L. No. 114-322, § 2106(a)(6), 130 Stat. 1628, 1724-1726 (2016) (codified at 42 U.S.C. § 300g-3(c)(5). | GAO-21-78

EPA's plan is also inconsistent with leading practices for strategic planning. The GPRA Modernization Act of 2010 (GPRAMA) establishes requirements for agency-level strategic plans.[52] We have previously reported that GPRAMA's requirements, including those for strategic plans, can serve as leading practices at lower organizational levels within federal agencies, including EPA, such as individual divisions, programs, or initiatives—in this case, EPA's Office of Water.[53]

Strategic Plan Contents

Strategic plans are to describe

[52]5 U.S.C. § 306. The GPRA Modernization Act of 2010, Pub. L. No. 111-352, 124 Stat. 3866 (2011), amended the Government Performance and Results Act of 1993 (GPRA), Pub. L. No. 103-62, 107 Stat. 285.

[53] For example, see GAO*, Coast Guard: Actions Needed to Enhance Performance Information Transparency and Monitoring,* GAO-18-13 (Washington, D.C.: Oct 27, 2017); GAO, *Motor Carriers: Better Information Needed to Assess Effectiveness and Efficiency of Safety Interventions*, GAO-17-49, (Washington, D.C.: October 27, 2016); and GAO, *Environmental Justice: EPA Needs to Take Additional Actions to Help Ensure Effective Implementation*, GAO-12-77 (Washington, D.C.: Oct. 6, , 2011).

- a mission statement;
- long-term goals and objectives;
- strategies and resources to achieve the goals and objectives;
- interagency collaboration to achieve the agency's goals and objectives;
- how the agency's performance goals relate to the general goals and objectives;
- how congressional input from consultations influenced goals;
- how external factors could affect achieving goals and objectives; and
- how program evaluations helped shape the plan.

When developing their plans, agencies should solicit and consider the views of their various stakeholders.

Source: GAO analysis of requirements in the GPRA Modernization Act of 2010, which amended the Government Performance and Results Act of 1993 (GPRA). | GAO-21-78

EPA's plan does include the following three items: (1) a description of the requirements in section 2106(a)(6) of the WIIN Act; (2) a workflow illustration of the roles and responsibilities of EPA, the primacy agencies, and public water systems in implementing the notice required when EPA learns of certain lead action exceedances; and (3) standard forms and templates to assist in data evaluation, targeted outreach to households, and notification confirmation when EPA learns of certain lead action level exceedances. EPA's workflow illustration is a step towards the leading practice of describing interagency collaboration in federal strategic plans, and as noted earlier, EPA's efforts to seek and consider stakeholder views when developing the plan, is another attribute of federal strategic plans. However, the plan does not include any of the other content generally consistent with leading practices for federal strategic plans. For example, EPA's plan does not set a mission statement or define long-term goals. Effective strategic plans define what the agency seeks to accomplish, identify the strategies it will use to achieve desired results, and determine how well it succeeds in achieving results-oriented goals and objectives.[54] Developing a strategic plan that meets the statutory requirement and fully reflects leading practices for strategic plans would give EPA greater assurance that it has effectively planned for how it will communicate the risk of lead in drinking water to the public.

EPA Has Not Updated Key Risk Communication Documents or Published New Risk Communication Guidance

EPA officials we interviewed in the Drinking Water office told us that in their risk communication efforts, they rely on the two key risk communications manuals that EPA published in 2007: *Risk Communication in Action: The Tools of Message Mapping and Risk Communication in Action: The Risk Communication Workbook.*[55] These manuals are the most recent documents devoted to risk communication strategies identified on EPA's website of risk communications documents

[54]GAO, *Agencies' Strategic Plans under GPRA: Key Questions to Facilitate Congressional Review,* GGD-10.1.16 (Washington, D.C.: May 1, 1997).

[55]Risk communications are intended to supply lay people with the information they need to make informed, independent judgments about risks to health, safety, and the environment. See Baruch Fischoff PhD, Noel T. Brewer, PhD, and Julie S. Downs, PhD, eds., *Communicating Risks and Benefits: An Evidence-Based User's Guide,* FDA, U.S Department of Health and Human Services (Silver Spring, MD: August 2011), 129.

and by EPA officials we interviewed.[56] Water systems and the public also have access to these documents, which are available online. However, as of July 2020, EPA had not updated its two key risk communications manuals to reflect new modes of communication, such as social media, and lessons the agency has learned about risk communications over the last decade, nor had it published new risk communication resource materials.

EPA officials we interviewed told us that the agency reduced its focus on risk communication following a reorganization of EPA's Office of Research and Development in 2008, which led to a reduction of risk communications work within the agency for about a decade. However, in July 2018, the Acting Administrator identified risk communications as the agency's most important priority in comments to agency staff.[57] In November 2019, EPA hired a senior risk communications advisor to work on risk communication strategy across the agency. According to a May 2020 letter from the EPA Administrator, the senior risk communications advisor will lead the coordination of EPA-wide risk communication efforts including, developing risk communication toolkits on emerging and cross-cutting contaminants and standing up an overall risk communication training program for EPA staff.[58] EPA officials also told us that the senior risk communication advisor is working to change the culture and foundational understanding of risk communication within EPA. The advisor will coordinate across the EPA's regions, programs, and offices through a cross-agency EPA Risk Communication Working Group composed of EPA scientists and senior EPA officials in communications and public affairs, among others, according to EPA documentation. EPA officials we interviewed told us that the working group held its first meeting in January 2020 and will generally meet on a monthly basis, with its most recent meetings held from August through October 2020.

[56]For further information, see https://www.epa.gov/risk/risk-communication. Of the 32 EPA documents on the risk communication website, 28 documents focus on specific topic areas within EPA, such as lead in schools or vehicle inspection and maintenance programs. Of the four documents that are devoted to risk communications, the most recent are the two manuals from 2007; the other two documents are from 2002 and 1994.

[57]In testimony to Congress on February 27, 2020, the EPA Administrator stated that improving risk communication at EPA was one of his top priorities.

[58]The EPA Administrator sent this May 2020 letter to the Chair of the Children's Health Protection Advisory Committee.

EPA's senior risk communications advisor told us in February 2020 that EPA plans to develop new documents for risk communication but that the agency did not have a time frame for doing so. In addition, the informal agendas for the Risk Communication Working Group that EPA provided to us in June 2020 indicate that the Working Group plans to develop three toolkits for risk communication, including one on lead, but EPA did not provide us with a time frame for completing the toolkits.[59]

Standards for Internal Control in the Federal Government state that agency management should internally and externally communicate the necessary current, quality information to achieve the entity's objectives.[60] In this case, EPA's objectives are to create internal guidelines and documents for EPA risk communications, as well as external risk communication documents for the public, according to EPA's senior risk communications advisor. By establishing a time frame for updating EPA's risk communications manuals, or creating new documents with more current information, EPA could ensure that its staff would have access to current guidance about how to effectively communicate risk, including the risks of lead in drinking water.

Selected Water Systems Have Annual Reports That Include Lead Information and Most Have Public Education Materials That Vary by Content and Clarity

We found that all 54 water systems we selected for review—which serve a combined population of more than 66.7 million customers—included information on lead as part of the annually required Consumer Confidence Reports (CCR), and that 39 of these systems provided additional public education materials for communicating about the risks of

[59]According to EPA's website, risk communication tools are written, verbal, or visual statements that include information about risk and put a particular risk in context, possibly in comparisons with other risks; includes advice about risk reduction behavior, and encourages a dialogue between the sender and receiver of the message.

[60]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

lead in drinking water.[61] Almost all of the selected water systems that provided additional public education materials on lead in drinking water communicated some key information, such as the sources of lead. However, we found that these additional materials varied in the extent to which they included other risk information, such as the health effects from lead exposure and actions consumers could take to reduce potential exposure, as well as the readability and clarity.

All Selected Water Systems Had Annually Required Reports to Inform the Public about the Risks of Lead in Drinking Water

Of the 54 water systems we selected for review, all had developed and made publicly available in their annual CCR information about the risk of lead in their water. EPA regulations require that community water systems provide customers with information on lead in drinking water in their CCRs, irrespective of whether the systems detect lead in any of their water samples. EPA stated in its state implementation guidance that lead exposure can occur locally even if there has not been a lead action level exceedance.[62] Further, the guidance stated that providing information on the risks of lead in drinking water in CCRs would help ensure that consumers receive information on how to reduce the risks of lead in drinking water.

EPA regulations require water systems to include specific language regarding lead in drinking water in their CCRs, including steps on how to reduce exposure to lead in drinking water and where to obtain additional information. The specified language is as follows:

> "If present, elevated levels of lead can cause serious health problems, especially for pregnant women and young children. Lead in drinking water is primarily from materials and components associated with service lines and home plumbing. [NAME OF

[61]We selected 54 public water systems—50 were selected based on largest population served, and we also included the four additional water systems that provided data on lead service lines for this report. The additional public education materials we reviewed are not the public education materials required by 40 C.F.R. § 141.85(a) when there is a lead action level exceedance.

[62]EPA, *Lead and Copper Rule, 2007 Short-Term Regulatory Revisions and Clarifications State Implementation Guidance* (2007). An action level exceedance occurs when more than 10 percent of the tap water samples that public water systems are required to collect have lead concentration levels greater than 15 µg/L.

> UTILITY] is responsible for providing high-quality drinking water, but cannot control the variety of materials used in plumbing components. When your water has been sitting for several hours, you can minimize the potential for lead exposure by flushing your tap for 30 seconds to 2 minutes before using water for drinking or cooking. If you are concerned about lead in your water, you may wish to have your water tested. Information on lead in drinking water, testing methods, and steps you can take to minimize exposure is available from the Safe Drinking Water Hotline or at http://www.epa.gov/safewater/lead."

EPA regulations also allow water systems to write their own statement if it is written in consultation with their state. Additionally, EPA requires that each system report the results of the most recent round of lead sampling. The results include (1) the 90-percentile value of the most recent samples, and (2) the number of sampling sites exceeding the lead action level.

All 54 of the selected water systems we reviewed included information on the risks of lead in drinking water and all provided tables on the results of lead sampling at residential taps. For the 54 selected water systems we reviewed, we found that 43 water systems' CCRs included the specified regulatory language.[63] The remaining 11 water systems provided information on the risks of lead in drinking water in their CCRs but did not use the specified regulatory language; as noted earlier, water systems can write their own statements in consultation with their state.[64]

Most Selected Water Systems Developed Additional Public Education Materials, Which Varied in Key Risk Content and Clarity

We found that 39 of the 54 water systems we selected for review had developed and made available on their websites additional public

[63]More specifically, 25 of the 43 used only the specified regulatory language in the CCRs released by July 2019, the most recent annual reports available. The remaining 18 water systems used the specified regulatory language and included additional information on lead in drinking water in their CCRs, such as providing additional information on the risks of lead in drinking water that are not included in the specified regulatory language.

[64]We did not verify whether the information was developed with the state as that was beyond the scope of our review.

education materials on the risks of lead in drinking water.[65] These public education materials included specific web pages about lead in drinking water, as well as flyers and brochures that consumers could download and print. Of the 39 water systems that developed additional public education materials, we found that most water systems included key content, such as information about the sources of lead in drinking water, the most significant and probable health effects associated with exposure to lead in drinking water, and actions consumers can take to reduce potential exposure to lead in drinking water. However, the details and extent of this content varied among the systems' materials. Table 2 summarizes key content about lead in drinking water that the selected water systems provided in their public education materials.

Table 2: Key Content for Lead in Drinking Water Included in Public Education Materials of Selected Water Systems

Key content for lead in drinking water	Number of systems whose materials include key content
Any content about sources of lead in drinking water	**38**
Lead pipes, faucets and fixtures,	38
Lead service lines	33
Home built before 1986	23
Galvanized pipes or lead solder	31
Any content about health effects for at-risk population	**24**
Young children and infants	17
Pregnant women or fetuses	21
Adults with certain health conditions	10
Any content about actions to reduce exposure to lead in drinking water	**34**
Learn if home has lead service lines	16
Test drinking water lead levels	28
Flush pipes or run water from pipes	30
Use water filters	19
Use cold water for food or drink	27
Clean aerators	23
Replace lead service lines	18

Source: GAO Analysis. | GAO-21-78

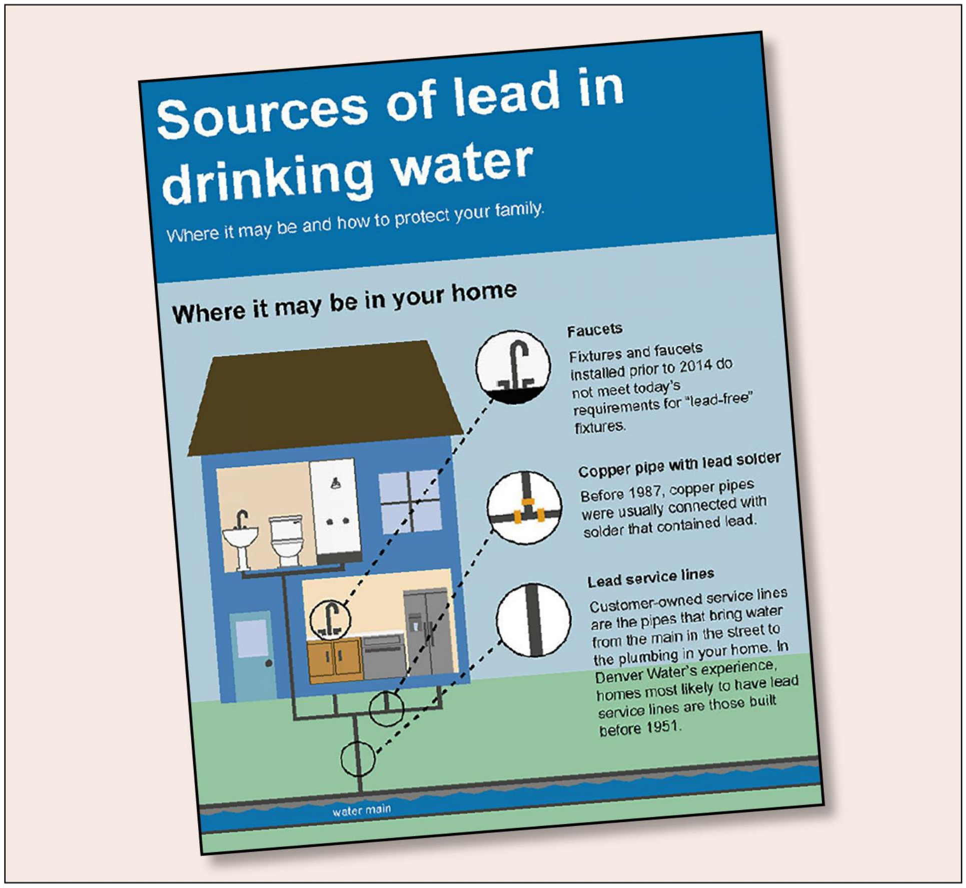
[65]The additional public education materials we reviewed are not the public education materials required by 40 C.F.R. § 141.85(a) when there is a lead action level exceedance. We did not determine whether the additional public education materials we reviewed were developed to comply with 40 C.F.R. § 141.85(b)(2)(vi).

Note: Water systems selected for this analysis included the 50 water systems with the largest service populations, and four additional water systems that provided data on lead service lines for this report. Of the 54 water systems, 39 had public education materials on lead in drinking water, which were assessed for key content. The public education materials summarized in this table are not the public education materials required by 40 C.F.R. § 141.85(a) when there is a lead action level exceedance.

Most of the water systems—38 of the 39 that provided additional public education materials—included information about the sources of lead in drinking water, and all of these 38 water systems listed lead faucets and fixtures within the home as a potential source of lead in drinking water. In addition, many of the water systems public education materials listed copper pipe with lead solder or galvanized pipes, homes built before 1986, and lead service lines as sources of lead in drinking water.[66] Figure 4 is a graphic from Denver Water that highlights several sources of lead in drinking water.

[66]Information on sources of lead may be tailored to the specific characteristics of the drinking water system. According to EPA, solder made or installed in homes prior to 1986 generally contained high levels of lead.

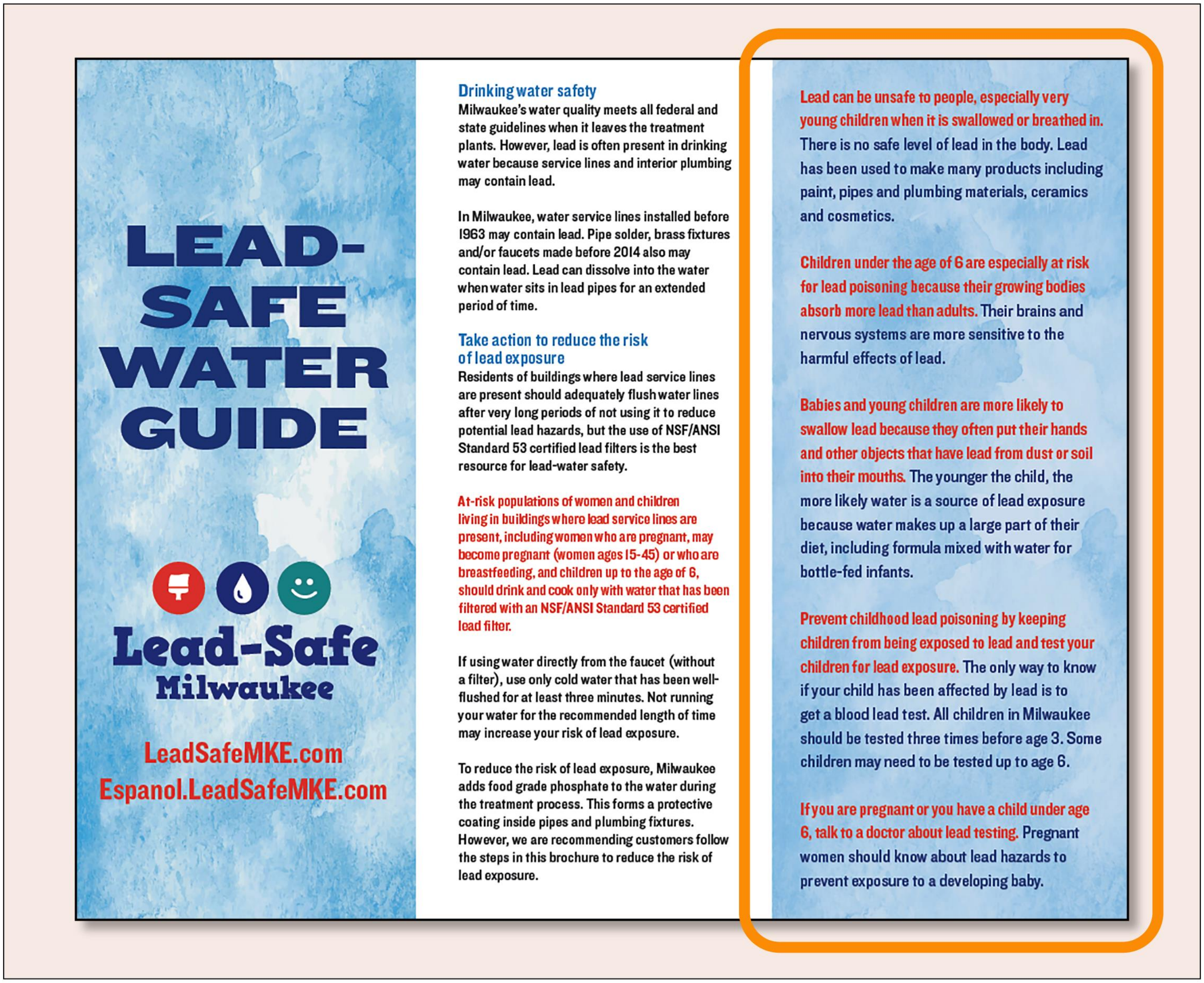
Figure 4: Example of Public Education Materials Providing Information on Sources of Lead in Drinking Water



Source: Denver Water. | GAO-21-78

Twenty-four of the 39 water systems that provided additional public education materials included information in their materials on the potential health effects of lead in drinking water to populations at risk, such as children, infants, and pregnant women and fetuses. However, the extent to which the materials provided details of the health effects associated with exposure to lead in drinking water also varied. For example, the materials of 17 of the water systems discussed the health effects of lead exposure on children, such as slowed growth and development or learning and behavioral problems. Figure 5 shows a portion of a brochure on the Milwaukee Water Works that highlights the health effects of exposure to lead in drinking water.

Figure 5: Example of Public Education Materials Providing Information on Health Effects of Exposure to Lead in Drinking Water

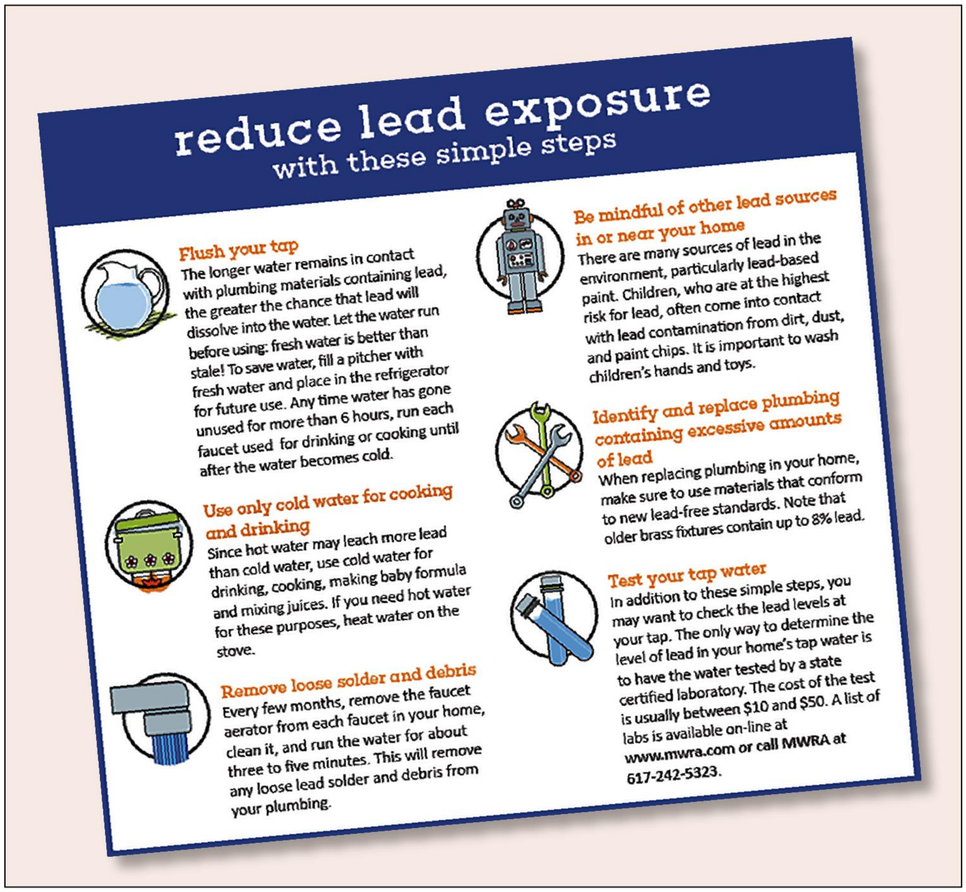


Source: Milwaukee Water Works. | GAO-21-78

Thirty-four of the 39 water systems that provided additional public education materials included various actions that consumers could take to reduce potential exposure to lead. For example, of the 34 water systems, 30 of them included flushing pipes (i.e., running water through pipes before use), and 18 of them included replacing lead service lines. Figure

6 shows a portion of a brochure from the Massachusetts Water Resources Authority that highlights several ways to reduce potential exposure to lead in drinking water.

Figure 6: Example of Public Education Materials Providing Information on Actions to Reduce Potential Exposure to Lead in Drinking Water



Source: Massachusetts Water Resources Authority (MWRA). | GAO-21-78

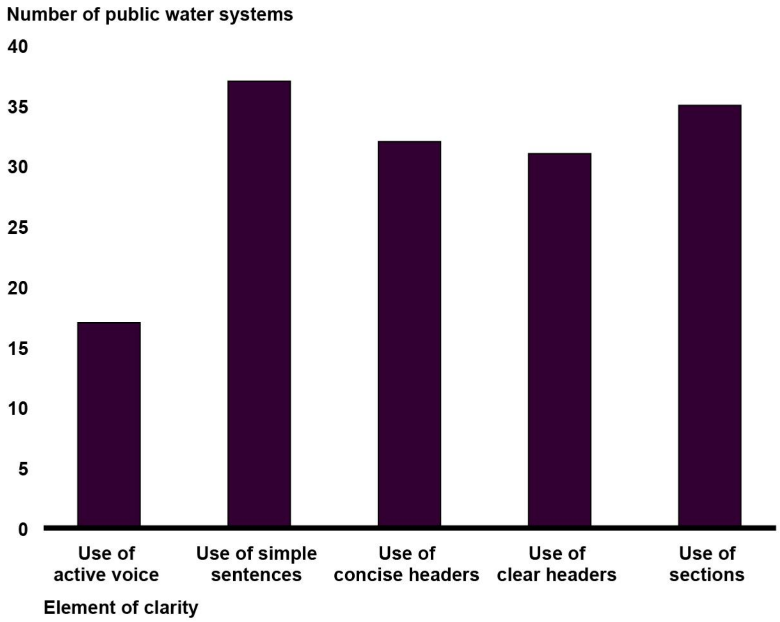
The readability and clarity of the public education materials also varied across the water systems.[67] In terms of readability—defined as the quality of writing that includes the use of everyday language the public can easily understand—we found that the materials ranged from easily understood

[67]We used the Flesch Reading Ease Test and the Flesch-Kincaid Grade Level Formula to calculate readability. Factors for clarity were based on EPA guidance in EPA, *Risk Communication in Action: The Risk Communication Workbook* (Washington, D.C.: August 2007).

by an average student in seventh grade to easily understood by students in twelfth grade. We found that the average age that the public education materials could be understood was age 14, and that the readability range for public education materials showed that most were easily read between the ages of 12 and 17. We also found the majority of the water systems materials' utilized the indicators of clarity, such as use of simple sentences, and formatting to provide a clear and organized structure, such as clear and concise headers and the use of sections to communicate the key risk information.[68] The clarity level of the materials varied across the water systems. Almost all of the water systems—37 of 39 that provided additional public education materials—used simple sentences throughout the materials. Almost all water systems—36 water systems—used sections to present the key information, such as information on sources of lead in drinking water and actions to reduce lead in drinking water. Most of the water systems used clear and concise headers throughout the materials. However, only 17 of the water systems used the active voice throughout their materials. Figure 7 shows our assessment of the elements of clarity for the water systems' additional public education materials.

[68]Described in EPA's 2007 guidance as clear and concise headers and the use of sections to communicate the key risk information, EPA: *Risk Communication in Action: The Risk Communication Workbook* (2007).

Figure 7: Assessment of Selected Water Systems' Additional Lead Public Education Materials for Elements of Clarity



Source: GAO analysis of water system public education materials. | GAO-21-78

Note: Water systems selected for this analysis included the 50 water systems with the largest service populations, and four additional water systems that provided data on lead service lines for this report. Of the 54 water systems, 39 had public education materials on lead in drinking water, which were assessed for clarity.

Conclusions

EPA's strategic plan for fiscal years 2018-2022 states that one of the agency's highest priorities is to reduce exposure to lead in the nation's drinking water systems. EPA also has an environmental justice goal of ensuring that vulnerable communities have drinking water that meets applicable health-based standards, including limits on concentrations of lead. EPA officials told us they are addressing lead exposure, including lead in drinking water and lead service lines, through the *Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts*. According to EPA, the agency is working closely with federal partners through the President's Task Force on Environmental Health Risks and Safety Risks to Children to focus on communities with the highest risk of childhood lead exposure.[69] However, it is not clear whether an EPA-specific action for generating data, maps, and mapping tools to identify neighborhoods at high risk of lead exposure will include use of (1) ACS data that we found could be used to identify neighborhoods likely to have higher concentrations of lead service lines or (2) geospatial lead data, when available. By incorporating the use of such data into its action plan, EPA could better identify neighborhoods at high risk of exposure to lead in drinking water.

The LCR requires water systems to collect drinking water samples from locations that may be particularly susceptible to high concentrations of lead. However, many water systems face challenges identifying areas at high risk of having lead service lines.[70] By developing guidance for water systems that outlines methods to identify high-risk locations using ACS data, and where available, geospatial lead or other available data, EPA could better ensure that public water systems (1) collect drinking water samples from locations that may be at greater risk of having lead service lines, and (2) identify areas with vulnerable populations to focus lead service line replacement efforts. Developing such guidance for states and water systems would also help EPA set a goal to demonstrate progress on significant national environmental justice challenges, including lead in drinking water.[71]

The WIIN Act requires EPA to develop a strategic plan to provide targeted outreach, education, technical assistance, and risk communication undertaken by EPA, states, and public water systems to populations affected by the concentration of lead in public water systems—including dissemination of information to households when certain exceedances of the lead action level occur. The plan EPA developed does not satisfy the WIIN Act requirement because it only discusses the dissemination of information when there are certain lead action level exceedances. The plan does not discuss education, technical assistance, and risk communication as required. The plan also does not meet GPRAMA leading practices for strategic plans. Developing a strategic plan that meets the statutory requirement and fully reflects leading practices for

[69]See "*Implementation Status of EPA Actions Under the 2018 Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts*" posted on EPA's website: https://www.epa.gov/leadactionplanimplementation.

[70]See GAO-18-620,16.

[71]EPA, *EJ 2020 Action Agenda: The U.S. EPA's Environmental Justice Strategic Plan for 2016-2020,* iv.

strategic plans would give EPA greater assurance that it has effectively planned for how it will communicate the risk of lead in drinking water to the public.

Finally, EPA does not have a time frame for publishing new risk communications material, even though its two key risk communications manuals date from 2007 and do not account for new modes of communication, such as social media. By establishing a time frame for updating EPA's risk communications manuals or creating new documents with more current information, EPA could ensure that its staff would be better informed and have access to current guidance about how to effectively communicate risk, including the risks of lead in drinking water.

Recommendations for Executive Action

We are making the following four recommendations to EPA:

EPA's Assistant Administrator for Water should develop guidance for water systems that outlines methods to use ACS data and, where available, geospatial lead or other data to identify high-risk locations in which to focus lead reduction efforts, including tap sampling and lead service line replacement efforts. (Recommendation 1)

EPA's Assistant Administrator for Water should incorporate use of (1) ACS data on neighborhood characteristics potentially associated with the presence of lead service lines and (2) geospatial lead data, when available, into EPA's efforts to address *the Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts*. (Recommendation 2)

EPA's Assistant Administrator for Water should develop a strategic plan that meets the WIIN Act requirement for providing targeted outreach, education, technical assistance, and risk communication to populations affected by the concentration of lead in public water systems, and that is fully consistent with leading practices for strategic plans. (Recommendation 3)

The Administrator of EPA should establish a time frame for publishing new risk communication guidance or updating existing risk communication manuals. (Recommendation 4)

Agency Comments and Our Evaluation

We provided a draft of this report to EPA for its review and comment. In its comments, reproduced in appendix III, EPA agreed with one recommendation and disagreed with three recommendations. More specifically, EPA agreed with the recommendation to establish a time frame for publishing new risk communication guidance or updating existing risk communication manuals. In EPA's letter, the agency stated that it expects to update its risk communication website with new guidance by March 2021. This is an encouraging step, and we will continue to monitor EPA's actions as the agency publicly articulates a time frame for its efforts to issue guidance documents, such as risk communication tools on lead and other emerging and crosscutting contaminants.

EPA stated its disagreement with the remaining recommendations but said that the agency will be unable to provide additional feedback on them until the revisions to the Lead and Copper Rule are completed. As noted in the report, EPA officials told us they expect to issue the final Lead and Copper Rule in December 2020, but as of December 13, the agency had not issued the rule. We believe these three recommendations are warranted and that EPA should implement them.

EPA also stated that the agency disagreed with many of our findings and conclusions. EPA did not explain the basis for its disagreement other than to say that the draft report did not include several significant actions EPA and water systems are taking to educate the public on the risks of lead in drinking water. However, EPA provided no mention of or documentation about any such actions.

Our report discusses numerous actions EPA and water systems are taking to educate the public about the risks of lead in drinking water. We worked with EPA officials during the course of our review to identify and discuss public education actions the agency had taken. With regard to water systems, we identified and reviewed certain public education materials from public water systems serving approximately 67 million people within the U.S. We believe the content of our report is consistent with the scope of our review, and supports our findings, conclusions, and recommendations.

We are sending copies of this report to the appropriate congressional committees, the EPA Administrator, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or gomezj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix IV.

J. Alfredo Gómez
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

We examined (1) to what extent available data identify the characteristics of neighborhoods served by lead service lines in selected cities and to what extent such information could be used to focus lead reduction efforts; (2) what actions EPA has taken to ensure that the risk of lead in drinking water is communicated to the public through EPA's actions to address the Water Infrastructure Improvements for the Nation (WIIN) Act requirements and the extent to which EPA has risk communication guidance documents; and (3) the extent to which selected water systems have public education materials that communicate the risks of lead in drinking water.

For the first objective, we assessed the extent that lead service line data from four public water systems were associated with neighborhood population and housing characteristics. We used data from the U.S. Census Bureau's American Community Survey to determine housing and population demographic variables associated with concentrations of lead service lines. We also reviewed available EPA documentation to determine the extent that EPA has conducted an analysis using geospatial lead data from water systems and U.S. Census Bureau's American Community Survey data to identify areas at high-risk for having lead service lines and developed guidance with actionable steps for water systems to focus lead reduction efforts in those areas.

To assess lead service line data, we selected four large public water systems—Greater Cincinnati Water Works, Pittsburgh Water and Sewer Authority, Providence Water, and Rochester Water Bureau—from which to collect and analyze geospatial lead service lead data.[1] To select these water systems, we compiled a list of the 100 largest water systems using EPA's Safe Drinking Water Information System. We also sought recommendations to identify water systems that had updated lead service line data during interviews with EPA officials and representatives from national drinking water system associations. We reviewed the water systems' websites to determine if they had publicly available lead service

[1]Under the LCR, a large water system serves more than 50,000 people. EPA classifies water systems according to the number of people they serve and whether they serve the same customers year-round or on an occasional basis.

line data and identified 16 systems that had such data. For our analysis, we needed water systems with geospatial lead service line data that could be used to create geographic information system (GIS) maps. Therefore, for 16 water systems with publicly available data, we attempted to access the data to conduct a preliminary analysis to identify how the data were organized, coded, and whether a large number of data points were missing. We excluded water systems that would not work for our analysis from our selection process.

Based on our research and input from EPA and drinking water association officials, we identified six potential water systems for inclusion—four from the 100 largest water systems, and two from other large water systems. Five of those water systems agreed to share their geospatial lead data with GAO. Due to when we received the data and time constraints, we were only able to incorporate four water systems into our analysis. We received the geospatial lead data from the four water systems in September and November 2019; as a result, our analysis reflects the geospatial lead data as of that time. We also interviewed officials from the four selected water systems to understand their lead service line data, how they collect and update lead service line data, how they prioritize their lead reduction efforts, and gathered contextual information about their city's history that could help explain patterns in the location of their lead service lines.

In addition, we reviewed the selected water systems' websites for additional information pertaining to lead service lines, and lead service line replacement programs. These water systems' GIS databases include the location and material information for all of the water systems' distribution systems. For example, Greater Cincinnati Water Works' GIS database includes the location and material information for all of its distribution system. According to the Greater Cincinnati Water Works website, the water system continues to update its map as it obtains more information from its customers. We deemed the data provided by the water system to be sufficiently reliable for the purposes of assessing the extent to which the lead service line data from the four public water systems were associated with neighborhood population and housing characteristics. Please see appendix II for details on our assessment.

To determine the extent that the selected water systems served by lead service lines were associated with neighborhood population and housing characteristics, we assessed the four selected water systems' geographic lead service line data to determine whether each water system had certain geographic regions with higher rates of lead service lines. We conducted a literature review to identify housing and demographic characteristics associated with lead exposure to understand how previous studies have used the US. Census Bureau's American Community Survey data to examine the characteristics of communities exposed to lead. We also reviewed EPA's environmental justice materials to identify demographic indicators, such as percentages of low-income and minority populations, among others, that are used by EPA to identify the social vulnerability characteristics of disadvantaged populations.[2] We then analyzed American Community Survey data 5-year estimates for 2013 through 2017 to develop statistical models and maps to identify the housing and demographic characteristics of areas with concentrations of lead service lines within these water systems' geographic regions.[3] We assessed the geographic variation in community variables of housing and demographic characteristics. We used multivariate regression models to assess which characteristics were associated with having lead service lines. Results from these public water systems are not generalizable to all public water systems. Appendix II provides further technical details.

To determine the extent that EPA has used available data to identify high-risk locations for lead service lines and the extent that EPA has developed guidance on how to identify locations that are high-risk for lead service lines, we reviewed available guidance, policies and documents from EPA on identifying and addressing lead service lines. The available materials we reviewed included the Lead and Copper Rule, the preamble to the 1991 Lead and Copper rule, and EPA's *Strategies to Achieve Full Lead Service Line Replacement*. We also met with EPA officials to better understand the efforts taken by public water systems to identify lead service lines. We compared the steps EPA had taken with steps found in the Federal Data Strategy 2020 Action Plan, the Federal Data Strategy's

[2]The academic literature defines vulnerable populations to include racial and ethnic minorities due to historic discrimination in housing and unemployment.

[3]We used data from the Census Bureau's American Community Survey, specifically 5-year estimates of housing and population data for 2013 through 2017. The 5-year estimates are based on data collected from a sample of households during 60 months of the 5 most recent calendar years to provide annually updated information. Because the American Community Survey 5-year data followed a probability procedure based on random selections, the sample selected is only one of a large number of samples that we might have drawn. All 5-year American Community Survey percentage estimates presented have margins of error at the 95 percent confidence level of plus or minus 10 percentage points or less, unless otherwise noted. All non-percentage estimates presented using the 5-year American Community Survey had data within 20 percent of the estimate itself, unless otherwise noted.

Practices. We also compared steps EPA had taken with steps found in the *Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts* regarding the use of data to prioritize efforts to reduce exposure to lead.[4]

For the second objective, to examine the actions EPA has taken to ensure that the risk of lead in drinking water is communicated to the public through its actions to address the Water Infrastructure Improvements for the Nation (WIIN) Act requirements, we reviewed requirements in the WIIN Act for EPA to make information available to the public regarding lead in drinking water and for EPA to develop a strategic plan for targeted outreach, education, technical assistance, and risk communication to populations affected by the concentration of lead in public water systems. We identified the documentation by doing a search on EPA's website, and by asking cognizant EPA officials to provide the documentation the agency developed in response to the requirements. We then compared those requirements to documentation that EPA developed to implement those requirements, namely the two infographics on lead in drinking water, and the plan that EPA developed in response to the requirements in the WIIN Act. We also compared EPA's plan for targeted outreach with leading practices based on the GPRA Modernization Act of 2010. We focused our analysis on leading practices for federal strategic plans, such as setting a mission statement; defining long-term goals; and describing strategies and resources to achieve the goals. In addition, we interviewed EPA agency officials who developed the EPA documentation in response to the WIIN Act requirements.

To examine the extent to which EPA has guidance on risk communication, we reviewed EPA risk communication guidance and documents. Specifically, we examined EPA's risk communication website, which includes links to 32 EPA risk communications documents. We analyzed the 32 documents and categorized them based on their content as either focusing on risk communication strategies, or focusing on more specific topic areas within EPA, such as vehicle inspection and maintenance programs. We then compared the information in EPA's two most recent documents focused on risk communication with guidance on internal and external communication in *Standards for Internal Control in*

[4]President's Task Force on Environmental Health Risks and Safety Risks to Children: *Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts* (December 2018).

the Federal Government.[5] In addition, we interviewed EPA officials who have worked, or are currently working, on risk communication for the agency. We also asked four risk communication experts a set of standard interview questions to learn more about the field of risk communications; we interviewed three of the experts by phone, and one expert provided written responses to our questions. In addition, we spoke with two national drinking water associations—the Association of State Drinking Water Administrators and the American Water Works Association—to get their views on risk communication, among other topics.

For the third objective on public education materials, we identified and reviewed public education materials that communicated about the health risk of lead in drinking water from selected public water systems. We selected water systems by generating a list of the top 50 public water systems by population served in November 2019, using the EPA's Safe Drinking Water Information System Federal Reporting Services website.[6] Additionally, we included the four public water systems that agreed to share data for our analysis on lead service lines. These 54 public water systems serve approximately 67 million people within the U.S. population.

To determine the extent that the selected water systems have Consumer Confidence Reports that communicate the risk of lead in drinking water, we reviewed the regulatory requirements for information about lead in Consumer Confidence Reports (CCR). We reviewed EPA guidance and best practices to better understand the development of CCRs. For identifying CCRs, we visited each selected water systems' main websites during January and February 2020 to identify links to "consumer confidence reports" or "water quality reports" issued by July 2019.

Water systems are required to include specific language regarding lead in drinking water in their CCRs but are allowed to write their own statement in consultation with their state. We reviewed each CCR to identify the information on lead in drinking water contained within each report. We analyzed the extent that (1) each report included results of sampling for lead for the public water system, and (2) the water system used the specified regulatory language. For CCRs that did not use the specified

[5]GAO, *Standards for Internal Control in the Federal Government*, GAO-14-704G (Washington, D.C.: Sept. 10, 2014).

[6]We define the top 50 public water systems as those serving populations greater than 300,000. Public water systems in Puerto Rico were beyond the scope of this report, and were excluded from the analysis.

regulatory language, we did not assess or verify the extent that the public water system wrote the language in consultation with the state as required by the CCR regulation.

To assess the selected water systems' additional education materials, we (1) identified online public education materials about lead in drinking water from the water systems using search criteria; (2) developed a standardized data collection instrument to assess the materials based on their content and clarity; and (3) assessed the identified public education materials for content, clarity, and readability.

First, to identify the online public education materials, we visited the 54 selected water systems' websites to identify those materials that met the criteria: specific webpages and documents, including text and graphics that focused on lead in drinking water. We searched the water systems' websites for "lead" and "lead in drinking water" between January and February 2020. We excluded webpages and documents that were not primarily focused on lead in drinking water, such as those that mentioned lead briefly but focused on other aspects of drinking water safety. We excluded webpages and documents about lead that were created by entities other than the public water systems, such as federal or state agencies. The additional public education materials we reviewed are not the public education materials required by 40 C.F.R. § 141.85(a) when there is a lead action level exceedance. We identified 39 public water systems that had additional public education materials about lead in drinking water, with a total of 57 public education materials.

Next, we developed a standardized data collection instrument composed of multiple-choice fields, check-box fields, and text fields to assess each of the water systems' public education materials based on their content and clarity. To identify key content for communicating the risk of lead in drinking water, we reviewed EPA's website to identify key information about the risk of lead in drinking water. Based on EPA's information, we developed three key content areas about lead in drinking water: (a) sources of lead in drinking water, (b) health effects from lead in drinking water, and (c) actions to reduce exposure to lead in drinking water. For each of these content areas, we reviewed the EPA information and developed a list of specific details that were key to communicating the risk of exposure to lead in drinking water. Specifically, the instrument included an assessment of the sources of lead in drinking water including lead pipes, faucets, and fixtures; lead service lines; homes built before 1986; galvanized pipes or lead solders; or any additional sources. It also included an assessment of the materials' inclusion of information about the health effects from various levels of exposure, specific health effects for the at-risk populations of children under the age of 6, pregnant women or fetuses, adults with kidney disease or other health issues, or other population groups. Specifically:

- For children under the age of 6, we assessed the extent the public education materials included health effects of damage to the brain and nervous system; slowed growth; slowed development; learning and behavioral problems; impaired hearing; speech problems; impaired formation and function of blood cells; and other health effects.
- For pregnant women or fetuses, we assessed the extent the public education materials included exposure of the fetus to lead; reduced growth of the fetus; premature birth; or other health effects.
- For adults with kidney disease or other health problems, we assessed the extent the public education materials included cardiovascular effects, increased blood pressure and incidence of hypertension; decreased kidney function; reproductive problems; and other health effects.

The instrument also included an assessment of whether the materials included actions to reduce exposure to lead in drinking water. These actions included: learn if you have lead service lines; test for lead service lines; test drinking water for lead levels; flush pipes or run water from pipes; use water filters; use cold water for food and drink; clean aerator; replace lead service lines; or other actions. The instrument also included an assessment of clarity, based on best practices on how to present technical information to the public from EPA's *2007 Risk Communication in Action: The Risk Communication Workbook*. This assessment included the use of active voice throughout the materials, simple sentences, clear and concise headings, and use of headings in sections for each of the key content areas.

To conduct the analysis for the public education materials, two individuals separately assessed the extent the identified public education materials discussed the key content about lead in drinking water and for clarity through the data collection instrument. Differences in these assessments were reconciled between the dual-coded assessment results. The data were exported from each assessment instrument, via a series of Adobe-created comma-separated values files into Excel, and the data were then verified against the source files. For those water systems with more than one public education material, the results were combined for the water system—the water system was assessed across the materials only once for either including the content or not including the content. The data were analyzed using Excel functions to identify summary measures about the extent that the selected water systems included key content about lead in drinking water and that those public education materials were clear.

We also conducted text analysis on the public education materials using statistical software to analyze the readability of the materials for each water system. We used the Flesch Reading Ease test and the Flesch-Kincaid Grade Level Formula—readability tests designed to measure the comprehension difficulty of text using standard formulas—to calculate the reading age, reading grade level, and reading ease score for the selected water systems. We then analyzed the readability scores across all water systems to calculate simple descriptive statistics such as the mean, median, minimum, and maximum readability scores across all of the water systems in our sample to describe the distribution of readability scores.

We conducted this performance audit from May 2019 to December 2020, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform our audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Geospatial and Statistical Analysis of Lead Service Lines and Neighborhood Characteristics

To describe the neighborhood characteristics associated with having a lead service line in selected communities, we conducted a geospatial and statistical analysis using data from four large drinking water systems. To conduct our analysis, we merged data for service lines, which we obtained from these drinking water systems, with Census tract characteristics from the American Community Survey (ACS). We examined the spatial patterns of lead service lines and of Census tract characteristics within each of these cities. We then developed statistical models to assess whether these characteristics were associated with the likelihood of having a lead service line. In each of these four cities, our results indicated that lead service lines were concentrated in areas with older homes and more vulnerable populations, such as families living in poverty. Our results generally did not indicate that areas with greater concentrations of lead service lines had higher percentages of children under 5 years of age. The details of our analysis are described below.

Methods

Selected Drinking Water Systems

We conducted our analysis using data from drinking water systems in four cities: Cincinnati, Ohio; Pittsburgh, Pennsylvania; Providence, Rhode Island; and Rochester, New York.[1] For purposes of this report, we refer to

[1]The four large water systems are Greater Cincinnati Water Works in Cincinnati, Ohio; Pittsburgh Water and Sewer Authority in Pittsburgh, Pennsylvania; Providence Water Authority in Providence, Rhode Island; and Rochester Water Bureau in Rochester, New York.

these water systems by their city name.[2] In our earlier report, we found that 12 of the 100 largest drinking water systems in the country publicized information on their inventory of lead service lines in 2018.[3] Based on a more recent review of websites for the 100 largest water systems, we found 16 water systems with publicly available information. To develop a list of potential systems for our analysis, we examined the websites of these 16 systems and determined whether they posted data on the geographic locations of their service lines. To supplement our list, we asked EPA regional officials to recommend other large drinking water systems that might have available data. We then selected the four systems named above based on the comprehensiveness and availability of their data. We contacted each city to describe our proposed analysis and to invite it to share their data with us. Each of them agreed to participate. These four cities are not a statistically representative sample of cities nationwide; however, they do comprise a range of the small number of large drinking water systems that publicize data on the locations of lead service lines. A fifth large drinking water utility also agreed to share its data, but we were unable to include it in our analysis because the data were not ready within GAO's analysis timeframe.

Lead Service Line Data

Each of the four drinking water systems transmitted to us a geospatial dataset of the service lines within their boundaries. We restricted the data to active, residential service lines and identified a service line as lead if either the public or private side is lead, except in Rochester. In that city, most of the private side information was unavailable.[4]

In Cincinnati, Providence, and Rochester, the material type was unknown for approximately 3 percent of the service lines so we excluded those service lines from our analysis. In Pittsburgh, however, the material type was unknown for approximately 20 percent of the service lines, and

[2]While these drinking water systems are located in the cities mentioned, their boundaries are not necessarily coterminous with municipal boundaries. For example, not all parts of the city are within their service area.

[3]GAO, *Drinking Water: Approaches For Identifying Lead Service Lines Should Be Shared With All States*, GAO-18-620 (Washington D.C.: Sept. 21, 2018).

[4]Service lines are generally composed of both a publicly owned portion and a privately owned portion. The publicly owned portion extends from the water main to the edge of an individual property and the privately owned portion connects from the edge of the property to the home.

excluding those service lines could have biased our estimates. Therefore, for Pittsburgh, we used a technique known as multiple imputation to account for these unknown values as described in a subsequent section.

A summary of the lead service line data for these cities is given in table 3. These data reflected the most current data available to the drinking water systems as of the data delivery, between September and November, 2019, depending on the city. Because each of these drinking water systems is in the process of replacing its lead service lines, our analysis reflects the location of lead service lines at a single point in time.

Table 3: Service Line Data for Four Drinking Water Systems

Drinking water system	Number of service lines[a]	Lead[b]	Non-lead	Unknown
Cincinnati, Ohio	229,588	42,696	178,937	7,955
Pittsburgh, Pennsylvania[c]	70,100	25,580	30,182	14,338
Providence, Rhode Island	76,223	26,762	47,354	2,107
Rochester, New York	59,193	20,784	37,032	1,377

Source: GAO analysis of water system data. | GAO-21-78

[a]Total number includes active, residential service lines from data obtained from the respective drinking water systems.

[b]We classified the service line material as lead if either the public or the private side of the service line was classified as lead. The exception is Rochester, where we only used public side information because private side lead was generally unavailable.

[c]We classified the material type as unknown if the data were missing for either the public portion or the private portion unless data for the non-missing side were classified as lead.

Neighborhood Characteristics

To measure neighborhood characteristics, we used data from the American Community Survey 5-year estimates for 2013-17. We used 5-year estimates because they are the most reliable estimates at the Census tract level. We focused on housing and population characteristics that were conceptually related to lead service lines or that measured residents' vulnerability to lead exposure. To identify these characteristics, we first reviewed EPA's guidance on Environmental Justice, which defines six characteristics of communities that historically have been exposed to disproportionate levels of environmental contaminants.[5] Based on this guidance, we selected four characteristic measures to include in our analysis: the percentage of households with children under 5 years old; the percentage of families in poverty; the percentage of population with highest education level of high school; and the percentage of population that is a minority.[6] According to EPA guidance, an important part of environmental justice is ensuring that all people, regardless of race, color, national origin, or income, have the same degree of protection from environmental and health hazards.

[5]See https://www.epa.gov/ejscreen/overview-demographic-indicators-ejscreen.

[6]We excluded two measures—the percentage of individuals living in linguistically isolated households and the percentage of individuals over the age of 64—because of imprecision in the associated ACS estimates and as a GAO decision.

Second, we reviewed published literature on lead exposure, neighborhood effects, and environmental inequality and identified additional neighborhood characteristics. To conduct the review of literature, we searched over 35 scholarly and peer reviewed databases, such as AGRICOLA, BIOSIS, Ei Compendex, ProQuest's Environmental Science Professional, and SCOPUS. Multiple abstract, title, and keyword searches were conducted in iterations. Searches were limited to articles published between 2014 and 2019 that contained synonyms of terms such as "community," "characteristics," "demographics," "population," "underserved," "vulnerable," or "environmental racism," in close proximity to "lead," and "drinking water." We conducted the search in September 2019. This search returned 98 articles. We supplemented our initial literature search results with an additional 16 articles that were recommended to us by colleagues with knowledge of lead exposure or that were highly cited by the articles returned from our literature search. We reviewed the abstracts of these articles and selected 13 that empirically assessed the relationship between lead exposure and neighborhood characteristics using ACS or Census data.

We examined these articles to identify the neighborhood characteristics that were found to be associated with lead exposure. These included the four EPA environmental justice characteristics mentioned above, in addition to seven additional population and housing characteristics. Of these additional characteristics, three were population characteristics: the percentage of population that is unemployed; the percentage of single, female-headed households; and the percentage of households without a vehicle. The remaining four were housing characteristics: the percentage of households that are vacant; the percentage of the population that is a renter; median home age; and the percentage of multi-unit housing units.[7] These articles indicate that major sources of lead are often found in impoverished urban communities, and as a result, residents of those communities face greater exposure to lead and are more likely to suffer from childhood lead poisoning.

[7]The median home year build within a Census tract is an important indicator of housing stock age. However, we note that it is possible that the home build year does not necessarily reflect the age of the pipes. For example, a home may be built at a time that is different (earlier or later) than the time when service lines were placed in that same location.

Geospatial Analysis

We conducted a geospatial analysis to assess whether there is spatial variation in lead service lines and other neighborhood characteristics, using Census tracts as the geographic unit of analysis. Census tracts are statistical subdivisions of counties whose boundaries follow geographic features, such as streams, highways, railroads, and legal boundaries, and that generally contain between 1,200 and 8,000 people. We refer to Census tracts as neighborhoods for the purposes of this analysis. For each drinking water system, we produced a hierarchical dataset by combining each service line with the Census tract in which it was located. At the lower level, these datasets contained a variable indicating whether each service line was made of lead; at the higher level, these datasets contained the housing and population characteristics for the corresponding Census tract.[8]

To produce stable estimates, we took certain steps such as excluding Census tracts with fewer than 30 service lines or where material type was missing for more than 20 percent of the service lines.[9] In Pittsburgh, we retained all Census tracts since dropping those with more than 20 percent of the material type missing would result in dropping most Census tracts. Instead, we imputed missing material type in Pittsburgh as described in a subsequent section.

To access the ACS data, which are publically available data from the U.S. Census Bureau, we used the Census Bureau Application Programming Interface (API) that allows for custom queries, such as by year, state, and statistical subdivision, such as Census tract.[10] The geographical information necessary to produce maps, including the Census tract identifier, are available through the API. By specifying a county, all

[8]Census tract boundaries are not necessarily coterminous with water system boundaries. While some of the Census tracts might not be fully served by the water system, we only used service line data that belongs to the water system.

[9]Based on these criteria, we removed less than 2 percent of service lines.

[10]The API allows for automatic download of ACS estimates and their 95 percent margins of error. We conducted our analysis using R Studio statistical software and the “tidycensus” package. Kyle Walker (2020). tidycensus: Load US Census Boundary and Attribute Data as ‘tidyverse’ and ‘sf’-Ready Data Frames. R package version 3.6.0.

Census tracts within the county can be downloaded, along with the ACS estimates and margins of errors for those counties.

To explore the spatial distribution of lead service lines and key neighborhood characteristics, we developed probability maps. In each of the four cities, for each Census tract, we examined the rates of lead service lines, families in poverty, and homes built before 1950, relative to the city-wide rates. The statistical significance of rates, rather than the rates themselves, are used to classify each Census tract as statistically higher than, statistically lower than, or statistically equal to the city-wide rate, for each of these three measures. Statistical significance is determined by one-tailed tests based on a Poisson distribution.[11] These maps allowed for the study of spatial patterns without considering non-significant random variations and accounted for potentially small population sizes in certain Census tracts. These maps do not allow for a quantitative assessment of whether these housing and demographic neighborhood characteristics are associated with geographic areas that have higher rates of lead service lines. To do that, we developed a series of regression models.

Regression Analysis

We developed statistical models for each of the four cities to estimate the likelihood of a home having a lead service line based on its neighborhood characteristics, while controlling for the other characteristics in the model. For example, we assessed whether homes in neighborhoods with high poverty rates were more likely to have lead service lines even after accounting for the median home age and the percentage of the population under 5 years old. Each model included two neighborhood characteristics—median home age and the percentage of the population under 5 years old—along with one of the remaining nine neighborhood characteristics. The model for Pittsburgh also included the percentage of multi-unit housing. Generally, we could not include more than one of these nine characteristics in a single model because they were highly

[11]The Poisson distribution is appropriate to examine the number of occurrences – the number (or rate) of lead service lines - within a particular exposure, accounting for the number of service lines.

correlated with each other.[12] For computational efficiency, we selected a random sample of 20,000 service lines for each city to develop our regression models. Our objective was to test whether each neighborhood characteristic was associated with the likelihood of having a lead service line rather than to develop a single model that best predicted whether a home would have a lead service line.[13]

We used a statistical model, a hierarchical generalized linear model with a logit link function that is suited for data with a hierarchical structure and a dichotomous outcome.[14] The data had a hierarchical structure in that each service line was nested within a particular Census tract. The data had a dichotomous outcome in that each service line was classified as having one of two possible values, either lead or not lead. Due to the logit link function, the model results express the likelihood of having a lead service line on a log odds scale. Because of the spatial clustering described in the previous section, service lines located in the same Census tract may be more similar than service lines located in different tracts. This similarity can persist even after accounting for neighborhood characteristics. To account for this clustering, our models included a statistical parameter, referred to as a random effect, for each census tract.

To simplify the interpretation of the model results, we standardized each of the covariates. A standardized covariate has mean of zero and

[12]A statistical model that simultaneously includes related characteristics can describe the association between each individual characteristic in the model and the outcome, while accounting for all characteristics included in the model. Not including characteristics simultaneously may result in misleading conclusions. On the other hand, if two characteristics are highly related to each other, then including both characteristics in a model is unnecessary and causes problems with statistical estimation. For example, neighborhoods with high percentages of families living in poverty also tended to be neighborhoods with high percentages of racial and ethnic minorities, high percentages of unemployed individuals, high percentages of individuals without a high school diploma, and high percentages of vacant, renter-occupied, and multi-unit housing.

[13]We included these characteristics in our models regardless of whether they were associated with having a lead service line in bivariate tests and did not use model fit statistics, such as Akaike Information Criteria (AIC), to compare these models against each other.

[14]Considering a continuous measure of lead, such as the proportion of lead service lines in a geographic area, is problematic as an outcome measure due to a violation of assumptions of normality. For example, fitting a normal model to these data could result in estimated lead rates that are less than zero, which it is not meaningful since we would expect lead rates to be between zero and one. See for example, Raudenbush and Bryk, Hierarchical Linear Models, 2nd Edition (2002).

standard deviation of one. Accordingly, each of the fixed effect coefficients in our models can be interpreted as providing the change in the log odds of having a lead service line that is associated with a one standard-deviation increase above the average value for a particular independent variable for a Census tract with the average random effect. Standardization changed the scale of the covariates but did not change the statistical significance of the relationships between these variables and the likelihood of having a lead service line. We also transformed median home age into its natural logarithm to assist with model stability. See table 4 for the summary statistics for some of the characteristics within our sample. In addition to the steps described above, we took steps to help ensure the validity of our models by calculating robust standard errors and removing highly collinear variables. We discussed the results of our analysis with officials from each of the four drinking water systems to confirm that we analyzed the data properly and that the results aligned with their understanding of lead service line data within their service areas.

Table 4: Sample Summary Statistics for American Community Survey (ACS) Estimates of Neighborhood Characteristics for Four Drinking Water Systems, 2013-2017

Drinking water system	Cincinnati		Pittsburgh		Providence		Rochester	
Neighborhood characteristic	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Median home age	1961.18	14.99	1942.73	9.09	1952.71	14.3	1942.39	6.03
Percentage of households with children under 5 years old	6.53	2.75	4.88	2.77	5.98	2.59	6.94	3.01
Percentage of families in poverty	11.92	11.73	15.06[a]	12.62	12.49	10.72	27.83	15.78
Percentage of households that are multi-unit	30.65	21.15	35.98	18.89	51.39	23.27	43.02	17.25

Source: GAO analysis of ACS data. | GAO-21-78

Notes: We refer to Census tracts as neighborhoods for the purposes of this analysis.

All 95 percent margins of errors for the ACS Census Tract level estimates are within +/-30 percentage points unless otherwise noted.

[a]All 95 percent margins for this estimate are within +/-43 percentage points.

Data Reliability

We took several steps to assess the reliability of the data we used in our analysis. To evaluate the accuracy of the lead service line data, we held three interviews with drinking water officials from each of the four large water systems about their process for developing these datasets and about the underlying source of information; we also discussed our preliminary data analysis results with them. The underlying source of information for these maps is primarily historical records, often referred to as “tie-cards,” which indicate the type of material used in the service line when the home was built. Drinking water officials converted these paper records into electronic maps by linking the service line information to the location of the home. They update the data as new information becomes available from service line replacements or service visits to homes.

To evaluate the completeness of the data, we assessed the extent of missing data and whether missing data could bias our statistical estimates. In three of the four cities, the material type was indicated for more than 97 percent of the service lines in the data. And, in those cities, the small amount missing data were concentrated in a small number of Census tracts. In those cities, we removed Census tracts in which more than 20 percent of the service lines were missing their material type. In the fourth city, approximately 20 percent of the service lines were missing data for material type, and the missing data were in most Census tracts. In this city, we conducted a separate imputation analysis, as described in the Imputation section, to assess and address the missing data.

To assess the reliability of ACS data, we took several steps. Because ACS estimates are based on a probability procedure, we examined and disclose the 95 percent margins of errors. We excluded from our analyses certain ACS variables that had higher rates of missing information, but that were highly correlated with other ACS variables in our analysis. For example, we excluded the estimated median home value and median rent because they were missing for several Census tracts, yet were correlated with other measures of financial well-being that had little/no missing information, such as the percentage of families in poverty and unemployment. Based on the steps described above, we determined the lead service line data and the ACS data were sufficiently reliable for the purpose of assessing the relationship between neighborhood characteristics and lead service lines.

Imputation

Because there was a high rate of missing data for material type in one of the cities, Pittsburgh, we conducted a statistical process—multiple imputation—that replaces missing data items with values observed from other sampled cases or with estimated values obtained from a model. This procedure prevented potential bias that would result from restricting our analysis to service lines with complete data and ignoring those with missing data, since those with missing data could differ from the others.

To conduct this imputation, we assessed the relationship between missing material type and the ACS neighborhood characteristics in our analyses. There is no evidence that whether the data were missing depended upon whether the material type was lead.[15] We did find evidence, however, that neighborhood characteristics were associated with whether the service line material type is missing.[16] For example, based on bivariate logistic regressions of missing material type status, we found that:

- As the Census tract median home age increases (i.e. is newer), the odds of having missing service line material type increases. Therefore, areas with more new homes are more likely to have missing information.
- As the Census tract percentage of housing units that are multi-unit increases, the odds of having missing service line material type increases. Therefore, areas with more multi-unit homes are more likely to have missing information.

Such a situation, where the missing data may depend on the observed data (e.g., the median home age in the region), but the probability that data are missing does not depend on the unobserved data (i.e., whether a housing unit has a lead service line), are said to be missing at random (MAR), conditional on the value of these observed characteristics. We used a probabilistic approach to impute missing values of the lead variable using the same ACS neighborhood characteristic we examine in our regression models, repeating this process 5 times. We accounted for the fact that the missing data are being imputed by using the within and between imputation variation, across the five imputed datasets, in statistical analyses based on imputed data. In doing so, we accounted for the potential bias of a complete case analysis and are able to reliably

[15]If the missing status of the lead variable depends on whether or not a service line is lead, the data would be considered not missing at random (non-ignorable missingness). See for example, Little, R. J. A., and D. B. Rubin *Statistical Analysis with Missing Data*. 2nd ed. (Hoboken, NJ: Wiley 2002); or Rubin, D. B. *Multiple Imputation for Nonresponse in Surveys*. (New York: Wiley 1987).

[16]When the binary outcome of missing status (missing/non-missing lead information) was tested against each of the ACS characteristics that we used in our regression models of lead service lines, there was a significant association between most of the ACS characteristics and missingness. These regressions on missing status accounted for the clustered nature of our data and the binary outcome, just as in our other regressions analyses. We also examined differences on these ACS characteristics between the two groups, those with complete versus incomplete lead information, using simple t-tests, and a similar picture results.

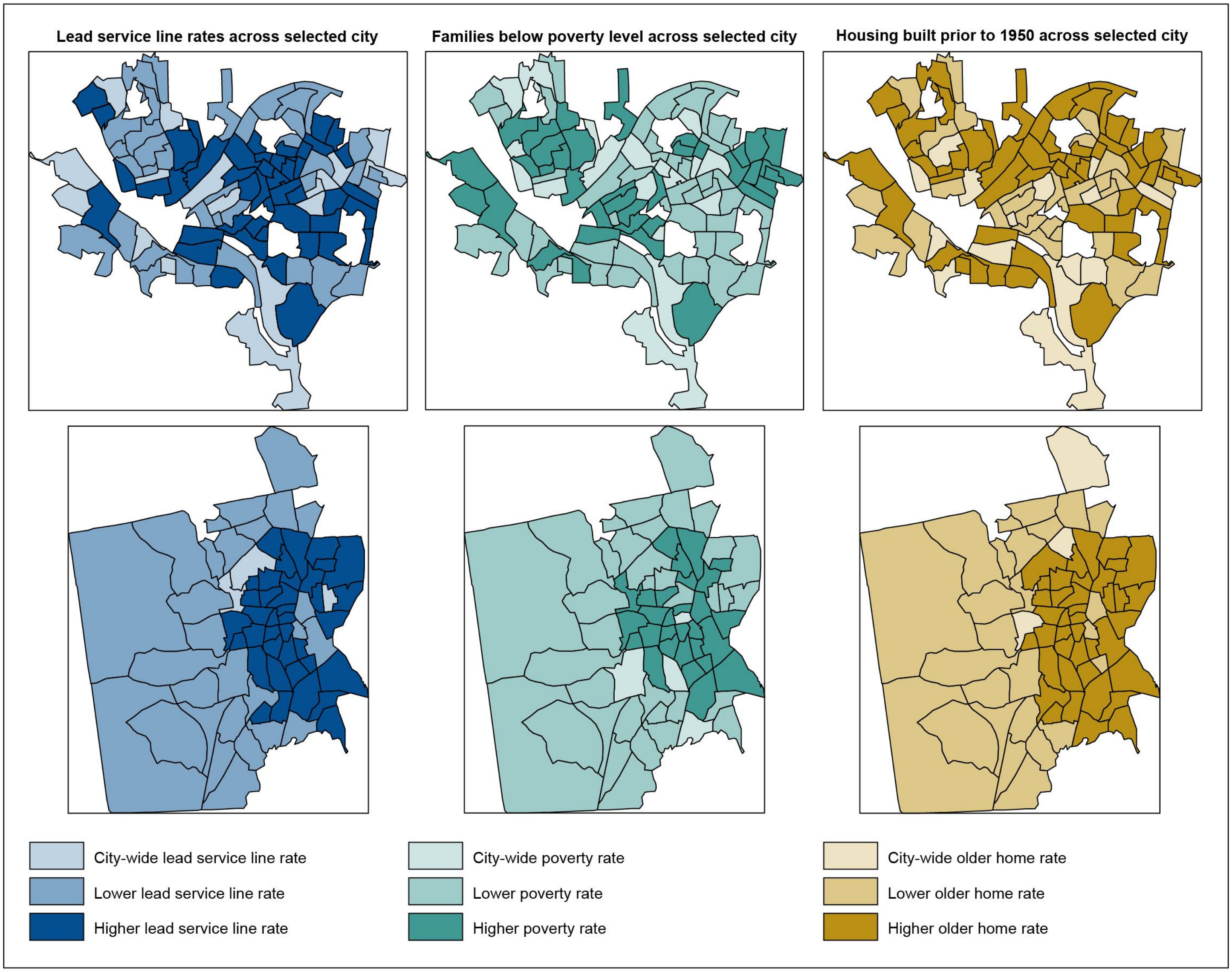
estimate the statistical association between various ACS neighborhood characteristics and the likelihood of having lead service lines, incorporating the imputation variability. Regression results are based on this imputation procedure.

Results

Geospatial Analysis

Based on our probability maps, we found that certain portions of each of the four cities have higher concentrations of lead service lines, higher concentrations of homes built before 1950, and higher concentrations of families in poverty. See figures 8 and 9 (see figure 2 in the main report for maps of Cincinnati, OH). For example, in Providence, lead service lines, families in poverty, and homes built before 1950 are more concentrated in the eastern portion of the city, whereas in Rochester, they are more concentrated in the areas surrounding the city center. In Pittsburgh, they are concentrated in certain Census tracts that are spread throughout the city.

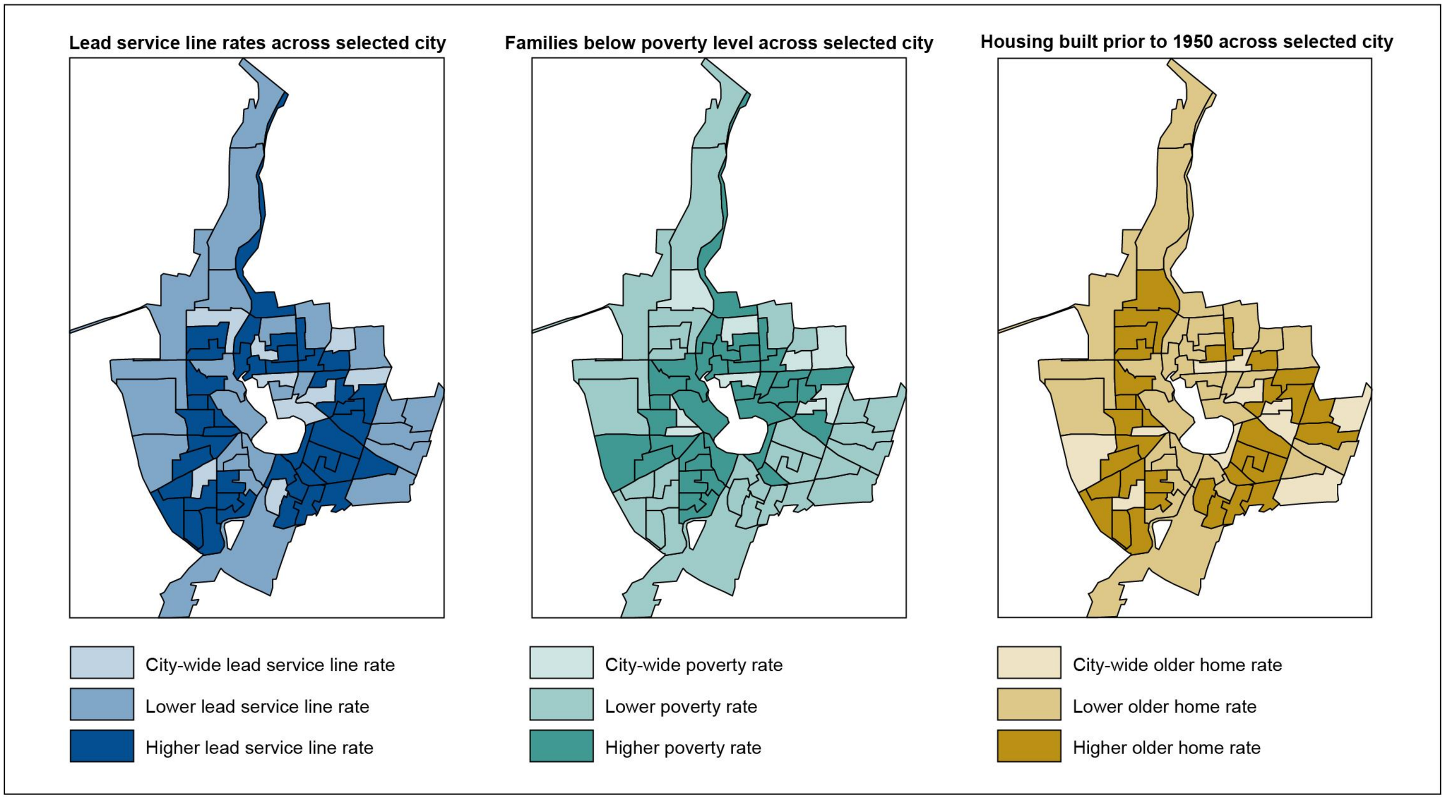
Figure 8: Rates of Lead Service Lines, Families in Poverty, and Homes Built before 1950 for Pittsburgh, Pennsylvania, and Providence, Rhode Island



Source: GAO analysis of a Water System's geospatial lead data and American Community Survey 5-year (2013-2017) estimates. | GAO-21-78

Notes: The level of statistical significance is 5 percent. All American Community Survey estimates have 95 percent confidence intervals that are within +/- 43 percentage points. All Census tracts in our figures have at least 30 service lines served by the water system depicted in the figure. While some of the Census tracts might not be fully served by the water system, we only use service line data that belong to the water system.

Figure 9: Rates of Lead Service Lines, Families in Poverty, and Homes Built before 1950 for Rochester, New York



Source: GAO analysis of a Water System's geospatial lead data and American Community Survey 5-year (2013-2017) estimates. | GAO-21-78

Notes: The level of statistical significance is 5 percent. All American Community Survey estimates have 95 percent confidence intervals that are within +/- 30 percentage points. All Census tracts in our figures have at least 30 service lines served by the water system depicted in the figure. While some of the Census tracts might not be fully served by the water system, we only use service line data that belong to the water system.

Regression Results

The results of our models show that lead service lines were more concentrated in neighborhoods with certain population and housing characteristics. Specifically, in each of the 4 cities we examined, homes were more likely to have a lead service line in neighborhoods with older homes, higher percentages of multi-unit housing, higher percentages of people in poverty, higher percentages of unemployed people, and higher percentages of people without a vehicle. In 3 of the 4 cities, homes were also more likely to have a lead service line in neighborhoods with higher percentages of people with less than a high school education, of people without a bachelor's or doctorate degree, of single, female-headed households, of minorities, of renters, and of vacant housing units. Tables 1 - 4 on the landing page shows the results of our regression models for each of the four cities (see www.gao.gov/products/GAO-21-78).

Within these tables, the direction (positive or negative) and magnitude of statistical association is determined by the coefficient estimates for the log-odds of fixed effects, which estimate the log-odds of having a lead service line, while controlling for other neighborhood characteristics in the model (see tables 1 - 4 on the landing page). Log-odds can be transformed into estimated odds and probabilities through appropriate transformations.[17] In tables 1 to 4 on the landing page, a significant positive coefficient denotes an increase in the neighborhood characteristic is associated with a statistically significant increase in the likelihood of having a lead service line. For example, as the Census tract percentage of families in poverty increases, the likelihood of having a lead service line increases, while controlling for other neighborhood characteristics in the model. A significant negative coefficient denotes an increase in the neighborhood characteristic is associated with a statistically significant decrease in the likelihood of having a lead service lines. For example, as the Census tract median year of home build increases (i.e., the median value of homes is a newer/more recent value), the likelihood of having a lead service line decreases, while controlling for other neighborhood characteristics in the model.

Below we present selected estimates from the models to illustrate the quantitative results based on transformations of the log-odds to the predicted probability scale. For example, for a typical Census tract with the average percentage of families living in poverty and the average percentage of children under 5 years old with a zero random effect, our models estimate the following:

- In Cincinnati, the chances of having a lead service line were 24 percent in Census tracts where the median home was built in 1946 whereas the chances were less than 1 percent when the median home was built in 1976.
- In Pittsburgh, the chances of having a lead service line were 50 percent where the median home was built in about 1933 whereas the

[17]Log-odds x can be transformed to the odds scale using an exponent and to the probability scale by using the transformation $f(x) = 1/(1+\exp(-x))$.

chances were 42 percent when the median home was built in about 1952.[18]

- In Providence, the chances of having a lead service line were 56 percent where the median home was built in about 1939 whereas the chances were 9 percent when the median home was built in 1967.
- In Rochester, the chances of having a lead service line were 43 percent where the median home was built in about 1936 whereas the chances were 26 percent when the median home was built in 1948.

The years reported above roughly correspond to one standard deviation below the sample average and one standard deviation above the sample average median year of home build for each of the four cities. For example, in Cincinnati, we compare 1946 and 1976 because 1961 was the sample average and the standard deviation was around 15 years. The sample means and standard deviations for each of the four cities are given in table 4.

Similarly, our models show that neighborhoods with more vulnerable populations were more likely to have lead service lines than neighborhoods with less vulnerable populations even after accounting for other neighborhood characteristics, such as home age. For example, for a typical Census tract with the average median home age and the average percentage of children under 5 years old with a zero random effect, our models estimate the following, when comparing the percent of

[18]These values are not statistically different at the alpha = 0.05 level of significance. We used multiple imputation to adjust for the higher rate of missing lead material in Pittsburgh and accounted for the within and between imputation variability in our statistical analyses. It is possible that imputation variability contributes to the different pattern of significance observed in Pittsburgh, when compared to other cities. For example, the variability between imputations might make statistically significant differences more difficult to detect due to less precise estimates within this city.

families in poverty that are one standard deviation below and above the average poverty[19]:

- In Cincinnati, the chances of having a lead service line were 2 percent in Census tracts where the percent of families in poverty was around 1 percent whereas the chances were 7 percent when the percent of families in poverty was around 24 percent.
- In Pittsburgh, the chances of having a lead service line were 43 percent where the percent of families in poverty was around 2 percent whereas the chances were 48 percent when the percent of families in poverty was around 28 percent.[20]
- In Providence, the chances of having a lead service line were 18 percent where the percent of families in poverty was around 2 percent whereas the chances were 35 percent when the percent of families in poverty was around 23 percent.
- In Rochester, the chances of having a lead service line were 26 percent where the percent of families in poverty was around 12 percent whereas the chances were 44 percent when the percent of families in poverty was around 44 percent.

[19]For the purposes of this analysis, we define Census tracts as having an above-average poverty rate as those where the percentage of families in poverty was one standard deviation above the sample average for that city. Conversely, we defined Census tracts as having below average poverty rates as those where the percentage of families in poverty was one standard deviation below the sample average for that city. See table 4 for the means and standard deviations. For example, in Cincinnati, one standard deviation was around 12 percent and the average was 12 percent, we defined an above-average poverty rate as 24 percent and a below-average poverty rate as 1 percent to illustrate the results of our model. If a Census tract poverty rate is higher than 24 percent, predicated probabilities of having a lead service line may be higher. Similarly, predicated probabilities of having a lead service line may be lower for a Census tract with a poverty rate that is lower than 24 percent.

[20]These values are not statistically different at the alpha = 0.05 level of significance when comparing confidence intervals as there is a slight overlap. We used multiple imputation to adjust for the higher rate of missing lead material in Pittsburgh and accounted for the within and between imputation variability in our statistical analyses. It is possible that imputation variability contributes to the different pattern of significance observed in Pittsburgh, when compared to other cities. For example, the variability between imputations might make statistically significant differences more difficult to detect due to less precise estimates within this city.

Discussion

Like any quantitative model, our estimates are subject to certain limitations. Because we analyzed housing and population characteristics at the neighborhood level, our results cannot be used to draw inferences about the characteristics of particular individuals, families or households. For example, our results demonstrate that residential service lines within Census tracts with higher rates of families in poverty have a higher likelihood of having a lead service line; however, they do not demonstrate that families living in poverty are more likely to have lead service lines. While these two phenomena may be correlated, we did not have housing or demographic data for individuals, families, or households that would allow us to draw such inferences.

Because many of the neighborhood characteristics we analyzed were highly correlated with each other, we were unable to disentangle their independent relationships with the likelihood of having a lead service line. For example, our models found that the likelihood of a residential line being lead is higher in Census tracts with higher percentages of families living in poverty and higher percentages of racial and ethnic minorities. However, those two characteristics were so highly correlated with each other that our models were unable to distinguish their independent relationships with the likelihood of having a lead service line.

Although we systematically reviewed documentation and literature to identify neighborhood characteristics for our analysis, characteristics other than those we obtained from the ACS may further account for the likelihood of having a lead service line. For example, a drinking water system may replace lead service lines in locations where a water main is being replaced. As a result, homes in those neighborhoods may be less likely to have lead service lines for reasons that are not accounted for by the neighborhood characteristics we examined.

Our results are not generalizable beyond the four cities we examined: Cincinnati, Ohio; Pittsburgh, Pennsylvania; Providence, Rhode Island; and Rochester, New York. Instead, these cities were selected from among the small number of large drinking water systems that publicize data on the locations of lead service lines. Furthermore, we generally found consistent results across the cities we examined.

Appendix III: Comments from the Environmental Protection Agency

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF WATER

Mr. Alfredo Gomez
Director
Natural Resources and Environment
U.S. Government Accountability Office
Washington, D.C. 20548

Dear Mr. Gomez:

Thank you for the opportunity to review and comment on the Government Accountability Office's (GAO) draft report, *Drinking Water: EPA Could Use Available Data to Better Identify Neighborhoods at Risk of Lead Exposure* (GAO-21-78). As you are aware, the U.S. Environmental Protection Agency (EPA or Agency) is in the process of finalizing revisions to the Lead and Copper Rule and therefore, the timing of this evaluation makes it difficult for EPA to provide detailed feedback on the contents of the draft report.

I want to share with you that EPA's proposed new rule strengthens every aspect of the Lead and Copper Rule to better protect Americans, especially children, from the risks of lead exposure by getting the lead out of our nation's drinking water, better protecting children at schools and child care facilities, and empowering communities through information. EPA's proposed rule uses science-based testing protocols, would trigger earlier actions in more communities, and would reduce lead in drinking water by more effectively managing corrosion control treatment and removing more lead service lines – a root source of lead in drinking water.

Overall, EPA disagrees with many of the findings, conclusions, and recommendations in the draft report. For example, the draft report does not include several significant actions EPA and water systems are taking to educate the public on the risks of lead in drinking water, which is the stated purpose of the report. EPA expects to finalize the Lead and Copper Rule revisions by the end of this year. After revisions to the rule are completed, EPA would like to follow up with GAO in more detail on the public health benefits of the Lead and Copper Rule revisions and more specifically address the GAO report and recommendations.

GAO Recommendation 1: EPA's Assistant Administrator for Water should develop guidance for water systems that outlines methods to use U.S. Census Bureau's American Community Survey (ACS) data and, where available, geospatial lead or other data to identify high-risk locations in which to focus lead reduction efforts, including tap sampling and lead service line replacement efforts.

EPA Response: EPA disagrees with the recommendation and will be unable to provide additional feedback until the revisions to the Lead and Copper Rule are completed.

GAO Recommendation 2: EPA's Assistant Administrator for Water should incorporate use of (1) ACS data on neighborhood characteristics potentially associated with the presence of lead service lines and (2) geospatial lead data, when available, into EPA's efforts to address *the Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts*.

EPA Response: EPA disagrees with the recommendation and will be unable to provide additional feedback until the revisions to the Lead and Copper Rule are completed.

GAO Recommendation 3: EPA's Assistant Administrator for Water should develop a strategic plan that meets the WIIN Act requirement for providing targeted outreach, education, technical assistance, and risk communication to populations affected by the concentration of lead in public water systems, and is fully consistent with leading practices for strategic plans.

EPA Response: EPA disagrees with the recommendation and will be unable to provide additional feedback until the Lead and Copper Rule is completed.

GAO Recommendation 4: The Administrator of EPA should establish a time frame for publishing new risk communication guidance or updating existing risk communication manuals.

EPA Response: EPA agrees with this recommendation. The Agency will be updating its risk communication website with several new Agency-wide guidances, including: (1) an updated research-based definition of risk communication; (2) a new risk communication framework for all EPA staff to use in carrying out risk communication, which is grounded in the latest research from the decision, risk, and management sciences; and (3) specific risk communication tools on several emerging and cross-cutting contaminants, including lead. While we expect to complete the website update by March 2021, EPA is not waiting for the website update to start using the new risk communication framework guidance document. Over the past several months, the Agency has begun a series of risk communication training sessions for managers and staff, prioritizing across roles and our programs, and including how to use the new framework guidance when communicating about risk. EPA recognizes that risk communication is critical to meeting our mission of protecting human health and the environment and is committed to improving the way it is carried out across our offices and programs.

Thank you again for the opportunity to review the draft report. EPA looks forward to sharing information with GAO once the final Lead and Copper Rule revisions are completed. If you have any questions, please contact Jennifer McLain, Director of the Office of Ground Water and Drinking Water, at McLain.Jennifer@epa.gov or (202) 564-4029.

Sincerely,

DAVID ROSS

Digitally signed by DAVID ROSS
Date: 2020.12.09 12:27:02 -05'00'

David P. Ross
Assistant Administrator

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Enclosure

cc: Susan Perkins, Office of the Chief Financial Officer
Travis Voyles, Office of Congressional Intergovernmental Relations
Meredith Cody, Office of General Counsel
Stuart Miles-McLean, Office of Policy
Amanda Kasper, Office of the Administrator
Michael Benton, Office of the Administrator
Wesley Carpenter, Office of the Administrator
Tiffany Crawford, OW EPA GAO Liaison
Jennifer McLain, OW Office of Ground Water and Drinking Water

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Test of xAppendix III: Comments from the Environmental Protection Agency

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460
OFFICE OF WATER

Mr. Alfredo Gomez Director
Natural Resources and Environment
U.S. Government Accountability Office
Washington, D.C. 20548

Dear Mr. Gomez:

Thank you for the opportunity to review and comment on the Government Accountability Office's (GAO) draft report, Drinking Water: EPA Could Use Available Data to Better Identify Neighborhoods at Risk of Lead Exposure (GAO-21-78). As you are aware, the U.S. Environmental Protection Agency (EPA or Agency) is in the process of finalizing revisions to the Lead and Copper Rule and therefore, the timing of this evaluation makes it difficult for EPA to provide detailed feedback on the contents of the draft report.

I want to share with you that EPA's proposed new rule strengthens every aspect of the Lead and Copper Rule to better protect Americans, especially children, from the risks of lead exposure by getting the lead out of our nation's drinking water, better protecting children at schools and child care facilities, and empowering communities through information. EPA's proposed rule uses science-based testing protocols, would trigger earlier actions in more communities, and would reduce lead in drinking water by more effectively managing corrosion control treatment and removing more lead service lines – a root source of lead in drinking water.

Overall, EPA disagrees with many of the findings, conclusions, and recommendations in the draft report. For example, the draft report does not include several significant actions EPA and water systems are taking to educate the public on the risks of lead in drinking water, which is the stated purpose of the report. EPA expects to finalize the Lead and Copper Rule revisions by the end of this year. After revisions to the rule are completed, EPA would like to follow up with GAO in more detail on the public health benefits of the Lead and Copper Rule revisions and more specifically address the GAO report and recommendations.

GAO Recommendation 1:

EPA's Assistant Administrator for Water should develop guidance for water systems that outlines methods to use U.S. Census Bureau's American Community Survey (ACS) data and, where available, geospatial lead or other data to identify high-risk locations in which to focus lead reduction efforts, including tap sampling and lead service line replacement efforts.

EPA Response:

EPA disagrees with the recommendation and will be unable to provide additional feedback until the revisions to the Lead and Copper Rule are completed.

GAO Recommendation 2:

EPA's Assistant Administrator for Water should incorporate use of (1) ACS data on neighborhood characteristics potentially associated with the presence of lead service lines and (2) geospatial lead data, when available, into EPA's efforts to address the Federal Action Plan to Reduce Childhood Lead Exposures and Associated Health Impacts.

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EPA Response:

EPA disagrees with the recommendation and will be unable to provide additional feedback until the Lead and Copper Rule is completed.

GAO Recommendation 4:

The Administrator of EPA should establish a time frame for publishing new risk communication guidance or updating existing risk communication manuals.

EPA Response:

EPA agrees with this recommendation. The Agency will be updating its risk communication website with several new Agency-wide guidances, including: (1) an updated research- based definition of risk communication; (2) a new risk communication framework for all EPA staff to use in carrying out risk communication, which is grounded in the latest research from the decision, risk, and management sciences; and (3) specific risk communication tools on several emerging and cross- cutting contaminants, including lead. While we expect to complete the website update by March 2021, EPA is not waiting for the website update to start using the new risk communication framework guidance document. Over the past several months, the Agency has begun a series of risk communication training sessions for managers and staff, prioritizing across roles and our programs, and including how to use the new framework guidance when communicating about risk. EPA recognizes that risk communication is critical to meeting our mission of protecting human health and the environment and is committed to improving the way it is carried out across our offices and programs.

Thank you again for the opportunity to review the draft report. EPA looks forward to sharing information with GAO once the final Lead and Copper Rule revisions are completed. If you have any questions, please contact Jennifer McLain, Director of the Office of Ground Water and Drinking Water, at McLain.Jennifer@epa.gov or (202) 564-4029.

Sincerely,

David P. Ross
Assistant Administrator

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Wesley Carpenter, Office of the Administrator
Tiffany Crawford, OW EPA GAO Liaison
Jennifer McLain, OW Office of Ground Water and Drinking Water

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact:

J. Alfredo Gómez, (202) 512-3841 or gomezj@gao.gov

Staff Acknowledgments:

In addition to the contact named above, Diane Raynes (Assistant Director); Rebecca Makar (Analyst-in-Charge); Natalie Block; Mark Braza; Lawrence Crockett; Caitlin Cusati; John Delicath; Daniel Emirkhanian; Jennifer Gould; Rich Johnson; Benjamin Licht; Cynthia Norris; Dan Royer; Jeanette Soares; and Sonya Vartivarian made key contributions to this report.

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