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A collaborative approach to assess legacy pollution in communities near a lead-acid battery smelter: The "Truth Fairy" project

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Unequal Exposures, Science, and the Search for Truth

Disproportionate exposure to toxic chemicals is a burden faced by poor communities of color across the United States (Morello-Frosch & Jesdale, 2006). The past four decades have brought to light the role of policies, land-use decisions and regulations contributing to environmental injustice and resultant health disparities (Morello-Frosch, Pastor, Sadd, Porras, & Prichard, 2005; Shepard, 2002; Wing, 1998). Even as toxic exposures and associated health risks have been on the decline nationally, such reductions have been less evident in low-income communities and communities of color (Cushing et al., 2015; Mikati, Benson, Luben, Sacks & Richmond-Bryant, 2018; Shapiro, 2005).

Lead Exposure Remains an Important Public Health Justice Issue.

Lead (Pb) is a toxic metal that can cause damage to almost all organs and organ systems (Tong, Schirnding, & Prapamontol, 2000). Cognitive deficits and neurodevelopmental delays are associated with even very low levels of Pb exposure (Levin et al., 2008; Jusko et al., 2008). Regulations regarding the manufacturing, use, and disposal of lead have been implemented over the past five decades and lead has been largely phased out from gasoline and paint, decreasing lead levels in ambient air, water and soil (Needleman, 2004). As a result, the country has seen marked declines in blood lead levels (McClure, Niles, & Kaufman, 2016). However, lead poisoning persists nationwide, with over 500,000 children still burdened by elevated blood lead levels (>5 ug/dL) as of 2016 (McClure et al., 2016) as outdated regulations for lead have failed to protect children's health (Lanphear, 2017). Particularly vulnerable are children of color where housing stock is older, increasing the risk of lead in paint or plumbing, and in communities near industrial lead sources (Lanphear et al., 1996; Levin et al., 2008; Wheeler & Brown, 2013).

Despite marked reductions in the use of lead in gasoline additives, ambient air emissions from lead-smelting operations remain high in neighboring communities (Wilburn, 2014). Second only to China, the United States (US) is the leading producer of refined lead, producing about 11 percent of the world's refined lead through recycling lead-acid batteries at smelters (Cooperation, 2013). The tonnage of lead-acid batteries recycled in US smelter facilities has more than doubled over the last 40 years, as the industry has rapidly consolidated production into a handful of facilities (Cooperation, 2013). Because lead-acid batteries are heavy, and therefore expensive to transport, battery smelters are often located near the largest users (i.e., cities) (Eckel, Rabinowitz, & Foster, 2001). Atmospheric lead released from smelters deposits in nearby soils, creating a pathway of exposure for nearby communities. Lead concentrations in shallow soil near battery smelters may exceed 50,000 parts per million and persist indefinitely (Boggess & Wixson, 1977). Research demonstrated extremely high rates of childhood lead poisoning among those living near US lead smelters (Morse, 1979) (Sullivan, 2015) as well as adverse health effects to smelter workers since the 1970s (Winegar et al., 1977). Currently, a few urban communities in the US bear the majority of pollution from recycling lead-acid batteries (Levin et al., 2008).

The legacy of lead-acid battery smelting in Southeast Los Angeles.

A lead-acid battery recycling plant in Vernon, California, approximately 6 miles southeast of downtown Los Angeles, opened in 1922. The surrounding areas are densely populated neighborhoods of predominantly working-class Latinx residents. For decades, this operation crushed, washed, and processed up to 40,000 lead-acid vehicle batteries per day. Community organizing by Mothers of East Los Angeles-Santa Isabel identified the battery smelter facility (currently owned by Exide Technologies) in the 1990s as a hazard to the health and well-being of nearby communities. By 2000, the facility had been cited numerous times for environmental violations, but the State of CA continued to allow the facility to operate on a less stringent temporary permit despite repeated air, water and hazardous waste violations (Jill E Johnston & Hricko, 2017). Those violations continued after the plant was acquired by Exide Technologies and expanded production in 2000. There were documented lead and acid leaks at the 15-acre facility, as well as an overflowing toxic sludge pond, holes in the roof and cracks in the floor (Barboza, 2015a). Public concern and organizing that started in the 1990s was reinvigorated in 2007 following an increase in the production of recycled lead and complaints over dust and ash fallout in local neighborhoods (Exide Technologies, 2008; SCAQMD, 2008). In 2013, a Health Risk Assessment (released March 2013) concluded that as many as 250,000 residents face a chronic health hazard from exposure to lead and arsenic emitted from the stacks of the smelter and settling onto residential soil (ENVIRON, 2013).

Collaboration for Environmental Justice.

Community-based organizations in the Southeast Los Angeles (LA) area (Figure 1) including East Yard Communities for Environmental Justice (EYCEJ, Commerce/East LA), Resurrection Church (Boyle Heights), Comité Pro Uno (Maywood), and Communities for a Better Environment (Huntington Park), requested the participation of the University of

Southern California Community Engagement Program on Health and the Environment (USC CEPHE) in community-led meetings about concerns regarding the battery smelter in 2014. Community meetings and workshops largely hosted by EYCEJ or Resurrection Church led to protests and marches over the inaction of the governmental agencies to curb exposure to smelter-related pollution (Barboza, 2015b). The USC CEPHE activities were supported through the NIEHS-funded USC Southern California Environmental Health Sciences Center Community Engagement Core and subsequently through a pilot grant from the same Center. This work built upon existing partnerships with USC CEPHE to address pollution related to goods movement via the Trade, Health and the Environment Impact Project (Hricko, 2008). This crisis fostered closer relationships between the university and community organizations, with the goal to ensure that regulatory agencies and the Exide company take decisive and timely actions to protect public health. The collaboration then expanded to engage elected officials and public agencies to discuss the scope of the contamination, the government response, and need to reduce lead, arsenic (As) and other toxic chemical exposures. In 2015, the collaborative between community organizations, academics and public health agencies eventually formalized into an official State advisory board on the closure and cleanup of the smelter. EYCEJ served as the co-chair with two regulatory agencies with USC CEPHE, community leaders and elected officials as board members. Secondly, the partnership fostered the launch of a community-engaged research project in the Spring of 2016 to assess legacy lead exposure in children, along with other smelter-related toxic metals such as arsenic.

Community Organizing, Environmental Justice and Biomonitoring Chemical Exposures

Facing environmental hazards, community organizations and the environmental justice movement have turned to gathering their own data in the face of government inaction or industrial denial about chemical exposure (O'Rourke & Macey, 2003). In many cases, it is insufficient to show that pollutants exist in the environment: it may also be necessary to demonstrate people's exposure to such pollutants and that exposure causes adverse health effects. As a result, the burden of scientific proof of environmental harm falls on affected communities, not polluters. Biomonitoring, or body burden research, involves the assessment for the presence and concentration of chemicals in humans by measuring the chemical (or its derivative) in the human body (Paustenbach & Galbraith, 2006) and has been leveraged as a tool of social justice organizations to document the presence and extent of chemicals not normally present in human bodies (Shamasunder & Morello-Frosch, 2016).

Understanding Past Exposures to Toxicants.

Measuring exposure at legacy pollution sites is challenging, and misclassification of historical exposures is often a key obstacle in assessing the resulting health damages. Blood-lead levels commonly are used as an indicator of lead exposure; however, this measurement only reflects exposure from the recent past few months due to the short half-life of lead in blood which is approximately 4 weeks (Arora et al., 2006). Blood-lead levels decline when exposure declines, but past exposures may be important indicators of harm (Nie et al., 2011). Residents of the communities near the battery smelter were concerned that measuring current blood-lead levels would not reflect historical exposure which may be potentially higher during active operations. Thus, the call from the community was not only to fully characterize the extent of lead (and other toxicants) in the residential areas, parks, and schools in the surrounding neighborhoods, but also to understand the role that the smelter may have played in past exposures and current health disparities.

Tooth biomarkers as a tool to understand exposure burden in communities.

Deciduous teeth ("baby teeth") have been central in the history of biomonitoring efforts to assess population-level changes in early-life exposures to toxics. In the human fetus, baby teeth start incorporating minerals (including toxic metals) around second trimester and continue through early childhood. The formation of teeth occurs incrementally, like tree rings. Measurements in teeth have an advantage for use as biomarkers to characterize and time-stamp historical environmental exposures (Arora & Austin, 2013). As early as 1958, baby teeth were proposed as biomarkers to understand population exposure to radiation (Kalckar, 1958). A study describing the concentrations of strontium-90, a radioactive compound, in 61,000 baby teeth (Reiss, 1961) together with expert testimony about exposure risks to children ("Local Fallout: Hazard from Nevada Tests," 1963; United, 1963) was instrumental in cultivating support for a treaty to end nuclear arms testing. After this ban, teeth were again used to demonstrate a dramatic drop in strontium levels (Kolehmainen & Rytomaa, 1975; Mangano, Gould, Sternglass, Sherman, & McDonnell, 2003). Shifting from the population to community level, baby teeth established disproportionate exposure among low-income and children of color to lead (Needleman, Davidson, Sewell, & Shapiro, 1974; Needleman, Tuncay, & Shapiro, 1972). This research provided an evidence base for longitudinal studies showing lead exposure at subclinical levels was associated with a decline in intellectual functioning, ultimately shifting policy toward addressing chronic low-level lead exposure (Bellinger & Bellinger, 2006; Needleman, Schell, Bellinger, Leviton, & Allred, 1990).

The Truth Fairy Project

Selection of the Research Question.

Since its founding in 2001, East Yard Communities for Environmental Justice (EYCEJ) has brought together residents of Commerce, East LA and surrounding communities concerned about the health impacts of industrial pollution. The organization is grounded in community base-building, self-advocacy, and community power to achieve self-determination for those disproportionately burdened by environmental hazards. EYCEJ coalesced as a community-based organization around a massive railyard, which operates around the clock to transfer 1.2 million containers annually using diesel trains and trucks. Since that time, EYCEJ has grown to: develop of a local network of community gardens, stop the expansion of a freeway, and cultivate new leaders to promote full and authentic community and youth participation in advocating for policies that protect the local health and environment. The residential communities closest to Exide are more than 90% Latinx and rank among the top 10% of the most environmentally burdened areas in California (Assessment, 2015). Approximately 50% of residents near the battery smelter were born outside the US, and their median income is less than $35,000 annually (Bureau, 2014).

As concerns regarding the exposure to lead and other toxic metals over many decades continued to rise, community organizations and residents started to demand assessment of soil contamination for homes near the smelter, a clean-up plan, and information on how to protect families, especially children, from lead exposure. Historically, the penalties for the facility were few, and regulatory agencies had repeatedly declared that neither the emissions nor the hazardous waste at the facility were of significant impact to the environment or health (DTSC, 2006; SCAQMD, 2008). The millions of pounds of toxic chemicals released by the battery smelter on to surrounding working-poor communities of color, the illegal storage and dumping of hazardous waste, coupled with the acceptance of such practices by government agencies was characterized as environmental racism by community organizations and leaders. In March of 2015, after extensive community organizing, the battery smelter permanently ceased all operations as part of an agreement to avoid criminal prosecution (DOJ). In a press release issued by the Department of Justice, the EPA Regional Administrator Jared Blumenfeld acknowledged:

> “The closure of this facility is a victory for the residents of Vernon who have suffered from decades of toxic pollution. This historic action was made possible because of the tireless efforts of local community members, including parents, environmental groups and religious leaders” (DOJ).

Nonetheless, as of late 2016 only 216 homes had been assessed for potential soil remediation, limited to two neighborhoods within 1/2 mile of the facility. Initially, the state made only one measurement per home by mixing soil, skipped renter-occupied homes, and used federal rather than a more stringent state threshold of assessing risk. After the smelter closure, EYCEJ requested support to assess: (1) the extent of the contamination in residential neighborhoods; (2) the levels of exposure in the population, particularly among children; and (3) the impact on the health and well-being of the residents and the scope of a health-protective remediation plan.

Methods

Study Approach.

Our community-academic collaboration considered the use of historical records on blood-lead levels to understand the chronology of exposures in this community. However, we identified several hurdles to using blood lead screening. First, individual-level information is not released; the California Department of Public Health only shares blood-lead data at the ZIP code level (rather than neighborhood scale). The laboratories measuring blood lead levels routinely do not report low-level lead concentrations (e.g. <5 μg/dL) (Jill E Johnston & Hricko, 2017). While, the local public health department offered free blood lead screening to community residents, there was concern that current measurements may underrepresent the historical exposure due to the smelter activities.

Seeking alternatives, the USC CEPHE and EYCEJ worked with Icahn School of Medicine at Mount Sinai, whose laboratory has developed a method to assess in utero and early life exposure to multiple toxic metals in the community using baby teeth. Parents often save their child’s teeth, which offer archives of samples to generate evidence regarding exposures in this community. Coined the "Truth Fairy Project", this community-academic collaboration aimed to understand prenatal and early life exposure to toxic metals possibly released by the smelter. All human subjects research activities were approved by the USC Institutional Review Board.

Recruitment, Education and Engagement.

We developed a two-pronged strategy to engage study volunteers and build the capacity of the community to understand routes of exposure to lead, the health impacts, and behaviors and policies that may reduce exposure. First, we developed a bilingual interactive workshop for parents of elementary school students on understanding lead, discussing both the smelter as well as other common routes of lead exposure using infographics (Figure 2). The content was co-created by USC CEPHE and EYCEJ through an iterative process with review by the analytical team at Mt. Sinai. CEPHE and EYCEJ outlined the concept for the infographic, developed the appropriate language to use on the graphic (both English and Spanish), and determined action steps to recommend. After initial content was outlined, the CEPHE drafted the graphic that was then went through a feedback loop through which organizers asked for and received feedback from their membership, including those living in communities near the smelter

At the conclusion of the workshops, the facilitator described the Truth Fairy project. Eligibility for study was based on the family's residential address since pregnancy, ability to understand Spanish or English, and willingness to provide a baby tooth of one or more of their children that would not be returned. The protocol was later amended to specify that the tooth need to be whole (e.g. not broken) and cavity- and filling- free. While study recruitment was conducted through local parent groups, EYCEJ organizers were going door-to-door in the neighborhoods surrounding the battery smelter to discuss health and justice concerns and encourage residents to register for soil testing. The collaborative used the campaign as an opportunity to share information about the Truth Fairy project and provide study recruitment materials. Once the details of the study were provided and participants felt their questions were adequately addressed, we obtained written consent for the Truth Fairy project.

Participants were visited at home, at school or at an agreed-upon community location (e.g. library) to collect the tooth and complete the study questionnaire. In partnership with EYCEJ we designed a short survey to be completed by the parent (either self-administered or read by an interviewer depending on the participant's preference). The survey included a complete residential history since pregnancy. The cross street was recorded if the participant could not remember the exact address. In addition, the survey included questions asked about pregnancy, infancy, parents' sociodemographic information, home characteristics and child's behavior. We enumerated a variety of jobs associated with lead exposure and asked whether any household member held that type of employment as well as whether a list of herbal medicines known to contain lead were used in the house. Further, we asked whether the participant or child had been tested for lead, and whether the paint or soil had ever been tested for lead. Finally, the participant indicated if they would be interested in future health-related studies. After the visit we provided information about Pb exposure and health risks, the blood-lead screening and soil-lead testing program, offered by the county and state, respectively.

Results

The majority of the workshop participants were mothers living in the local community. Awareness at the start of the workshops about the smelter ranged from none to residents that had actively participated in public meetings. Most people had heard of the smelter issue and were aware that lead was harmful but knew few specifics. Workshop participant questions included measures to prevent lead exposure, how to get soil testing, how to interpret soil or blood lead results and presence of lead in the schools and parks. We provided suggestions for personal actions to limit exposure, such as removing shoes when inside, avoiding playing in bare soil (or covering bare soil) and frequent dusting or mopping inside. The majority of workshop participants said they felt the workshops shared new and valuable information, however some expressed frustrations with the public agencies involved in oversight of the smelter and/or lead poisoning prevention. We reached approximately 400 residents during the Spring and Summer of 2016.

A key component of information sharing both in workshops and in the communities through door-to-door information sharing was through the use of infographics. The CEPHE has used infographics as a tool to introduce communities to the scientific information, expand the awareness around environmental exposure, and enhance the environmental health literacy of environmental justice communities.. Our popular education-based techniques built upon local concerns and leveraged knowledge based on personal experience, to provide a foundation to understand the contaminants of concern associated with the smelters, and links to health effects – a key component of building environmental health literacy (Finn & O'Fallon, 2017). Applying Bloom's conceptual model of educational objectives (Bloom, 1956), addressed the foundational levels of environmental health literacy framework of *recognize* and *understand* (Finn & O'Fallon, 2017). Community capacity to understand environmental health risks can lead to the ability to apply and analyze such information, which is critical to the empowerment of communities to advocate for themselves and stimulate action (Finn & O'Fallon, 2017). Through this collaborative process, we created new infographics to capture the factors related to lead, health impacts, exposure, and vulnerability. Infographics are a tool to communicate scientific information, expand awareness around exposures, and enhance environmental health literacy among vulnerable populations.

Additionally, in response to the repeated questions from the community about why in particular we wanted to collect teeth, we developed a bilingual infographic to illustrate why the study was collecting baby teeth, what information the teeth could provide, and how the research project was connected to the broader public health concerns (Figure 3). Collectively, through community workshops and door-to-door blockwalking, 79 community residents were recruited and provided 1–2 teeth over 3 months from May to July 2016 in each of the neighborhoods surrounding the facility for the initial study.

As soil lead data from the CA Department of Toxic Substance Control (DTSC) became available for this community, the information was summarized, mapped and shared. Only 3.3% of the 7,766 residential homes tested had lead levels that meet the “safe” health-based screening threshold for residential soil established by the State of CA (<80 ppm) (OEHHA, 2009). Further, nearly 40% of all homes exceeded the soil lead health screening limits for industrial property (>320 ppm). Homes with soil above 400 ppm were prioritized to receive remediation (Figure 1). All samples exceeded the CA residential soil screening levels for arsenic (0.07 ppm). Nearly one-fifth of samples were more than 100 times the arsenic residential soil screening level.

50 teeth from 43 Latinx children that spend their whole lives in this community were analyzed at Mt. Sinai for pre- and postnatal lead levels. The findings from the Truth Fairy study suggests that legacy soil contamination in this urban environmental justice community near a smelter is associated with that prenatal and early life exposure to lead (Jill E. Johnston, Franklin, Roh, Austin, & Arora, 2019). Both pre- and post-natal tooth lead levels were significantly and positively associated with soil lead levels even after adjusting for maternal education (Jill E. Johnston et al., 2019). We observe lead concentration in the teeth of our cohort to those a similar study Mexico City, where lead levels in the environment and consumer products are, on average, higher than in the U.S. (Horton et al., 2018) and higher than children in Sweden (Arora et al., 2017).

Discussion

Developing Solutions, Actions and Policy Change.

Understanding the relationship between industrial activities, chemical pollution and human health is key to determining environmental health and justice. Rooted in principles of equity and justice, the collaboration between community organizations and academia facilitated the implementation of transformational community-based research. Research conducted as a collaborative process with community participants whose demand for individual research results is not driven solely by learning clinically actionable information, but also to learn information about themselves that they would not otherwise obtain. The researchers and community leaders assessed and interpreted the study results. As part of the research design, we developed materials to communicate back the results for teeth to the participants prior to sharing overall findings more broadly with the community. There is limited population-level data on lead concentration in baby teeth and even fewer studies using an approach to differentiate prenatal and early life exposure. Therefore, we developed a rank-order approach to compare any individual’s result to the entire cohort (Brody et al., 2014), integrating recommendations from returning chemical exposure results without risk information. These graphical representations facilitated a conversation between the environmental health researchers and the community regarding personal exposure data, exposure pathways, and measures to protect health (Ramirez-Andreotta et al., 2016). The materials for communicating individual results were coupled with community and individual meetings to contextualize and explain the information, answer question, and direct concerned participants to additional screening (e.g. blood lead tests). The researchers used data visualization and maps to share teeth lead and arsenic levels, and compared levels preand post-natal, by neighborhood, by birth year, by gender and by parent's preferred language. Over the course of multiple meetings with the research team and EYCEJ staff and community leaders, key messages were generated to share back to the broader community. The process distilled the research into a key point: that lead exposure began in utero and levels were positively associated with soil lead contamination.

The collaboration between USC CEPHE and EYCEJ, facilitated connecting personal information to collective action, and addressed larger systemic issues of environmental racism and health disparities, the first principle of collaborating for equity and justice (Wolff et al, 2017). By joint presentations to the community, and later, local policymakers and representatives of public health and regulatory agencies, we shared research findings together with community-driven demands regarding decreasing exposure levels and remediating contaminated soil.

Implications for policy, and/or practice.

Over the course of the Truth Fairy Project and the on-going collaboration between social justice organizations and academics, we built a foundation for learning and engagement in order to increase awareness and support local community power to transform the debate on battery smelter facilities and legacy lead contamination across the state of CA. Community leaders, including key members of the Truth Fairy project, in partnership with public officials and academics who met as part of a formal appointed advisory committee with governing bodies, resulted in:

- Extending the investigation zone to over 10,000 properties up to 1.7 miles from the facility.
- Securing $176.6 million dollars to support remediation in the community.
- Making all data regarding soil contamination publicly available and easily interpretable (DTSC, 2018).
- Establishing new regulations to reduce emissions from large battery smelters and other lead processing facilities to protect health of children living near such facilities (SCAQMD, 2017).

Community organizing at the grassroots level was integrated into the Truth Fairy project as an intentional strategy to support both public health action and the related research agenda (Wing, 2005; Wolff et al, 2017). The collaboration and focus on social justice and protecting public health shifted the debate in CA on lead exposure and legacy lead contamination, as well as implementing systemic change. The CA state legislature passed the Lead-Acid Battery Recycling Act of 2016, sponsored by a representative of the community impacted by the battery smelter, whereby battery manufacturers and consumers would each pay a $1 fee on each new battery to fund removal of lead-contaminated soil for communities where lead smelters have operated (Lead-Acid Battery Recycling Act of 2016). The fund generated nearly $14 million dollars in the first year (DTSC, 2018b).

Conclusion

Low-income communities of color often have limited influence on land-use practices or the decisions to locate polluting facilities near homes, schools, or parks. These communities often have less access to resources for conducting research into the relationships between industry, environmental quality, and health conditions, which can help increase environmental health literacy, raise awareness, inform policymakers and contribute to decisions that improve public health (Wing et al., 2008). The Truth Fairy project integrated community organizing and education with use of biomarkers typically collected and stored by local families to address systemic forms of environmental racism and provide critical insights into retrospective exposure to toxic metals. Specifically, we leveraged innovative infographics to communicate risk in a working poor multilingual community and explain how teeth can provide a window into past exposures. The use of biomarkers together with the process of conducting collaborative research, facilitated engagement in the political process supported regulatory and legal action to create policy change. Additionally, the intentional effort to integrate concepts of environmental health literacy into the collection and analysis of baby teeth demonstrates how community-based science can move people from awareness to action on issues of environmental justice. Uplifting the principles for collaborating for equity and justice (Wolff et al, 2017), we designed a collaborative process addressed questions important to community health, provided relevant research and scientific experience, supported efforts for exposed community members to protect themselves, motivated participation in democratic processes, and influenced structural change to address the underlying injustices.

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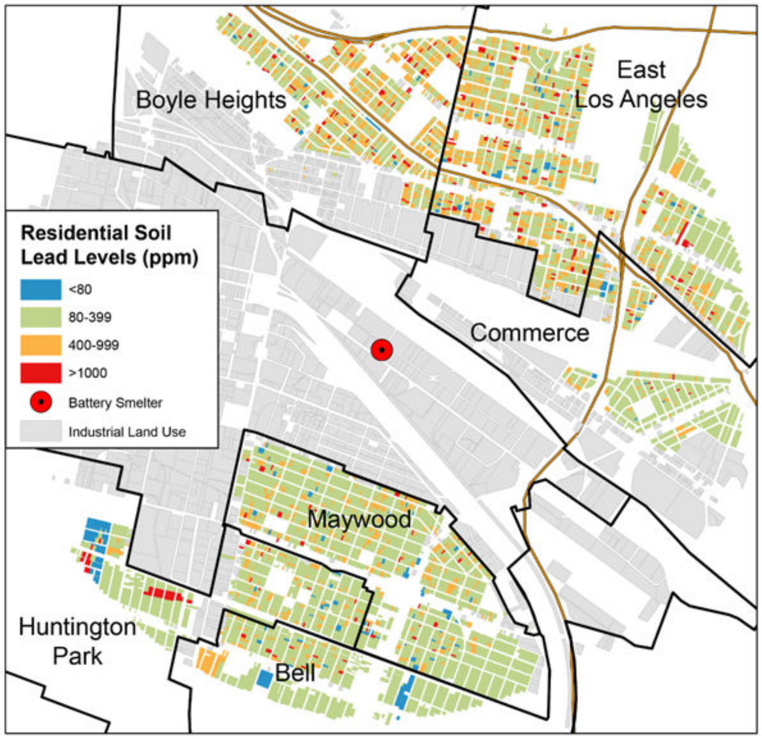

Figure 1.

Residential neighborhoods near the battery smelters and measured soil lead levels based on sampling by the California Department of Toxic Substances Control (2018).

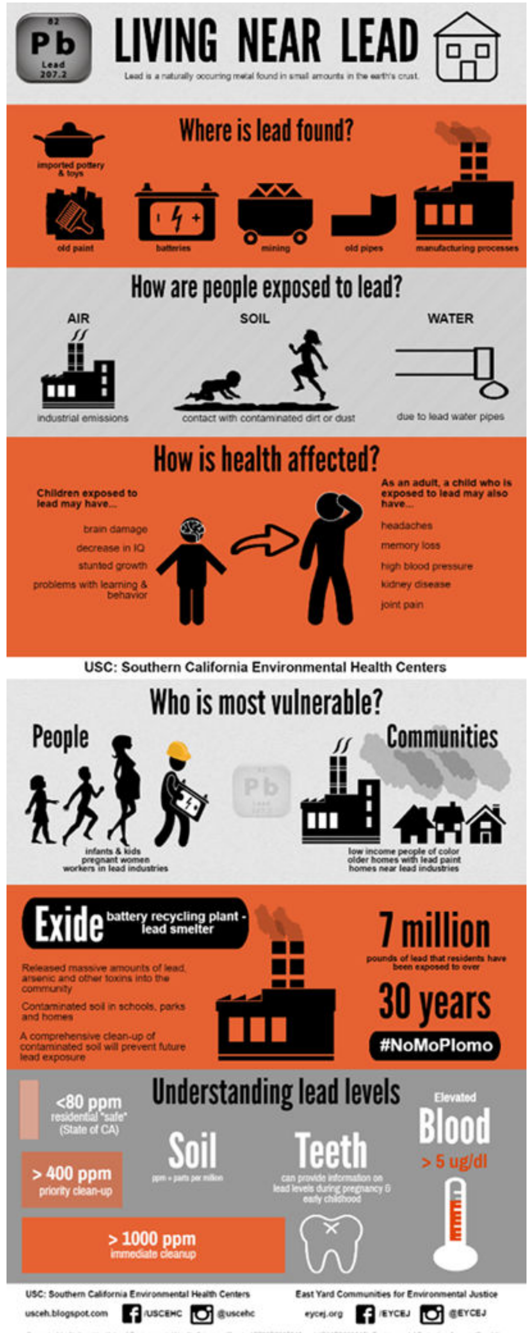

Figure 2.

Community infographic on lead, exposure, and health to build community environmental health literacy.

Figure 3.

Infographic to describe the role of tooth biomarkers for measuring early-life exposure to toxic metals.