CITIZEN SCIENCE:
THEORY AND PRACTICE

Practical Guidance for Small-Scale Initiatives: Including Simple, Adaptable Impact Assessment or Evaluation Tools for Specific Purposes

COLLECTION:
IMPACT ASSESSMENT AND EVALUATION

RESEARCH ARTICLES

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ABSTRACT

A youth-led movement in Santa Ana, California (US) has transformed how the city addresses legacy soil lead (Pb) contamination from roadways. Here we have leveraged the community science organizing model (CoSOM) developed by Orange County Environmental Justice (OCEJ), which was developed without academic input, to determine how insights from a community-developed CoSOM can add to the academic literature on community science frameworks, and in turn, how best practices and theory from the community science literature can enhance and inform community-driven organizing frameworks. Through interviews with youth leaders, community organizers, and OCEJ, we analyze how the CoSOM framework sustained political attention, expanded data collection, and advanced environmental justice goals. Youth participation proved essential to maintaining momentum and reframing lead contamination as an issue requiring immediate and sustained action. Academic partnerships enhanced research credibility and funding opportunities, prompting the establishment of a city-level environmental justice office. However, challenges remain around sustaining volunteer engagement and securing resources for mitigation. In line with the polycentric governance and adaptive management models, we propose updating the linear CoSOM to a circular design to guide participatory impact assessment in other communities confronting environmental contamination. This adaptive model underscores the importance of diverse coalitions, institutional partnerships, and flexibility to navigate funding cuts and political shifts. By embedding evaluation within community action, CoSOM demonstrates how citizen science can achieve durable policy and equity impacts.

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INTRODUCTION

Participatory research with community members can lead to structural changes that address issues related to environmental justice (EJ) (Averett 2021; Davis and Ramírez-Andreotta 2021). Here, we refer to EJ as both a field of research and a social movement that seeks to address the unequal distribution of environmental harms, benefits, and impacts of decision-making (Bryant and Callewaert 2003). We also refer to community science as a subset of participatory research that engages community members in determining and researching an issue (Davis and Ramírez-Andreotta 2021). Community science models are useful tools for addressing EJ issues because they identify the best practices and key players necessary to achieve long-term structural change. A review of community-based environmental monitoring studies found that case studies examining the use of, and barriers to use of, community science by decision-makers were limited (Conrad and Hilchey 2011). We aim to address this research gap by presenting a case study of the soil lead crisis in Santa Ana, California (US), and how a coalition of community and academic partners co-designed and implemented a community science organizing model (hereafter referred to as "CoSOM") that resulted in significant policy change.

Existing community science classification frameworks emphasize differences in the level of community engagement, relationship with researchers, and authority over the community science effort. Conrad and Hilchey (2011) defined three categories for community-based monitoring: *Consultative/functional*, in which community members provide observations and have little power over how they are used; *collaborative*, in which the monitoring effort is governed by a group representative of the various stakeholders; and *transformative*, in which community members lead the monitoring effort. Charles et al. (2020) defined a complementary typology based on the type of scientists that the community chooses to engage with: (1) external science organizations, (2) resident scientists, and (3) employed and/or contracted scientists. These three partnership types differ with respect to the rate of development of credible trust between the community and researchers; trust developed more gradually with external organizations, whereas trust was built rapidly with resident volunteer scientists and in-house contracted scientists due to pre-existing relationships (Charles et al. 2020).

The key principles of community science that all three partnership types had in common were that the research was community-driven and -controlled, supported by credible trust between communities and scientists, and had strong links to decision-making. Fernández-Viña, Chen, and Schwarz (2022) reviewed 16 urban soil community science studies and analyzed them using a framework called the Spectrum of Community Engagement to Ownership (SCEO). This framework is similar to that of Conrad and Hilchey's (2011) in that it is based on the level of community engagement and authority; however, the SCEO delineates six classes of increasing engagement: Level 1 (Inform), Level 2 (Consult), Level 3 (Involve), Level 4 (Collaborate), and Level 5 (Defer to/Community Ownership). A key finding of the systematic review was that deeper community engagement (Levels 3–5) directly correlated with structural change such as soil remediation funding (Fernández-Viña et al. 2022). The CoSOM presented here is best classified as *transformative* according to Conrad and Hilchey's (2011) typology, an example of engagement with an *external science organizatio*n according to the Charles et al. (2020) typology, and Level 5 according to the SCEO because the community affected by the EJ issue recruited a local university to join the coalition it formed to address the issue through a community-led monitoring effort.

Moreover, the frameworks of polycentric governance and adaptive management are both relevant to impact assessment of the CoSOM. Polycentric systems are defined by multiple independent governing bodies operating at different scales rather than a "monocentric unit" (Ostrom 2010). Ostrom (2010) applies this framework to the issue of climate change, highlighting empirical evidence of individuals and governments at diverse scales taking positive action without waiting for international agreement. So, too, is this a study of individuals affected by an EJ issue taking it to their city council rather than waiting for state or county legislation. Further, adaptive management refers to an approach to managing natural resources that emphasizes iterative learning through management and has long been deployed in decision-making around soil management and contamination (Allen et al. 2011; Birgé et al. 2016; Farag et al. 2017; Monib et al. 2024).

THE CASE OF SOIL LEAD CONTAMINATION IN SANTA ANA

In the US alone, one in four households experiences soil lead levels that exceed the Environmental Protection Agency (EPA) safe threshold of 200 ppm (Filippelli et al. 2024). To address soil lead, participatory research is used extensively (London et al. 2018; Peters et al. 2023; Price et al. 2024; Sharp and Brabander 2017). Led by community organizations, adult and youth activists joined forces with academics to demonstrate that soils within several zip codes surpassed the California Environmental Protection Agency safe threshold of 80 ppm of lead (Masri et al. 2020). Activists used the data to successfully advocate for changes to the city's General Plan. This General Plan (also referred to as a "comprehensive" or "master plan" in other US cities)

is a long-term planning document that provides policy guidance (City of Santa Ana 2023). The update directed the city to increase blood lead testing and treatment for residents, collaborate with the appropriate institutions and affected residents to remediate contaminated soils, and partner with community organizations to improve education and outreach (City of Santa Ana 2023). Additionally, the City established the Office of Neighborhood Initiatives and Environmental Services (NIES) to address more than 70 "implementation actions" that included addressing soil lead contamination (City of Santa Ana 2022).

Santa Ana is a 70-km^2 city in Orange County, California with a total population of approximately 308,000 (U.S. Census Bureau 2020). According to the 2022 U.S. Census, the most represented racial/ethnic groups in Santa Ana are Hispanic or Latino (77.3%), White (19.5%), and Asian (12%; U.S. Census Bureau 2020). The city is also known for being predominantly of Mexican descent with a large immigrant population (Sarmiento 2022). Santa Ana has a relatively young population, with nearly 25% of residents aged 18 and younger. Santa Ana community members, especially children and other vulnerable populations (e.g., pregnant persons, older adults, and residents with immunocompromising conditions), are at risk for long-term health issues due to the ongoing soil-lead crisis (LeBrón et al. 2019).

The ¡Plo-NO! Santa Ana Coalition (a Spanish play on words meaning "no lead," hereafter, ¡Plo-NO!) formed in 2017 to combine grassroots mobilization with scientific research to document lead contamination and advocate for policy changes. The initial coalition was formed by OCEJ, the youth-led Jóvenes Cultivando Cambios (JCC), and researchers at the University of California, Irvine (UCI). OCEJ is the community-based organization that developed the CoSOM in 2020 and continues to spearhead ¡Plo-NO!. The authors include one current OCEJ team member, a former executive director of OCEJ, and former Ph.D. students at UCI (hereafter, the UCI student team) who have coordinated a public awareness campaign since 2022 to bring attention to the work done by ¡Plo-NO!. The UCI student team consists of scholars in Civil and Environmental Engineering, Anthropology, and Ecology and Evolutionary Biology, disciplinary and academic frames that we acknowledge color our interpretation of the results. A senior author from the UCI Research Justice Shop (RJS), and member of OCEJ's Advisory Board, supports students' engaged work with OCEJ through a training program in participatory research. None of the authors are currently Santa Ana residents, though the former OCEJ director is from Santa Ana, yet all are part of ¡Plo-NO! through their continued support of its efforts.

The goal of this study is to produce practical guidance on developing an effective CoSOM with the potential to apply it to a variety of EJ issues and achieve policy change. We leveraged OCEJ's CoSOM, which was developed initially without academic input, to answer the following research questions: How can the insights from a community-developed CoSOM add to the academic literature on community science frameworks? In turn, how can best practices and theory from the community science literature enhance and inform community-driven organizing frameworks? Our approach was to use direct interviews since they have been traditionally used to determine the success of community-based environmental monitoring efforts (Fernández-Viña et al. 2022; Walls et al. 2022). Moreover, we assess the CoSOM's impact on the EJ issue of soil lead contamination using the Citizen Science Impact Assessment Framework (CSIAF) based on its influence on five domains: society, economy, environment, science and technology, and governance (Wehn et al. 2021). With soil lead being a global issue (Hou et al. 2025), our goal in sharing the CoSOM here is to inspire other communities to develop a CoSOM in a way that suits their local needs.

METHODOLOGY

DATA COLLECTION: INTERVIEWS WITH ¡PLO-NO! PARTNERS

To understand the development of the CoSOM in Santa Ana, five semi-structured interviews were conducted between 2020 and 2021. The purpose of the interviews was to attain respondents' reflections on the CoSOM, centering on "depth over breadth" as suggested by Creswell and Poth (2016). For the recruitment process, OCEJ identified respondents who were directly involved in the development and implementation of the CoSOM. The interviews included 16 core questions, four canvasser- and community organizer–specific questions (Supplementary File 2: Appendix A), and tailored follow-up questions for each respondent. The core interview questions centered on respondents' roles in the CoSOM, the barriers they faced, and how the CoSOM could be improved.

The interviews were carried out by two PhD students participating in the RJS Fellowship. Initially the Fellowship aimed to "support the development of a community science organizing model" with OCEJ. Interviewees included two canvassers who conducted door-to-door surveys during the 2018 UC-led soil lead study, two staff members from OCEJ, and one community organizer. One participant was considered a youth (hereafter as youth canvasser) based on the California Department of Public Health definition of youth as under the age of 25. Since the recruitment efforts focused on participant roles in the CoSOM, demographic data such as ethnicity were not collected. However, during interviews it was determined participants were bilingual. This was especially important

when participants communicated with community members whose primary language was Spanish. Interview durations ranged from 30 to 90 minutes. All interviews were conducted via Zoom, recorded, and transcribed using Otter.ai. Each participant received a $50 Visa gift card for their time. This research was approved by the University of California, Irvine Institutional Review Board on January 1, 2017 (IRB #3690). To protect participants' identities, direct quotes are attributed by role: "adult canvasser," "youth canvasser," "staff," or "organizer."

Codes were developed through an interpretive coding approach by repeated review of interview transcripts, consistent with past work on community inquiries via semi-structured interviews (Gibbs 2007; Lopez et al. 2025). We coded the interviews using a shared codebook (Supplementary File 2: Appendix B). Initially, the interviewers developed the preliminary codes and thematic categories. The codebook then underwent three rounds of review with the four additional coauthors. After deliberation, the research team reached consensus on the final code book and themes. This consensus approach supported collaborative interpretation of themes and codes (Cascio et al. 2019). Since we centered our approach on consensus-based thematic analysis with academic and OCEJ authors, a "negotiated agreement" on themes was used instead of a formal intercoder reliability test (Campbell et al. 2013; O'Connor and Joffe 2020). One purpose of OCEJ co-authorship was to ensure the thematic analysis and coding worked to add to the utility of the CoSOM. A complete list of codes and subcodes is available in Supplementary File 2 (Appendix B). The final analysis resulted in three overarching themes: (1) building a community science model, (2) resistance and structural barriers, and (3) empowerment, action, and sustainability.

In addition to our interviews, OCEJ staff led a series of focus groups between fall 2022 and summer 2023 to obtain community input. Participants were recruited via social media posts, flyers, the OCEJ mailing list, and word of mouth. During the focus groups, ethnicity of the attendees was not recorded. These sessions engaged 33 community members who provided feedback that was synthesized into the Environmental Health Equity Action Plan (EHEAP). The summary of the interviews and participants is published on the OCEJ ¡Plo-NO! webpage, where respondents remain anonymous. Participant A was a youth campaign manager for the Latine community in Santa Ana (hereafter, youth participant A), whereas participant B was anonymously identified as an adult resident of Santa Ana for 15 years.

Following the completion of the community focus groups, UCI researchers (not associated with the authors), OCEJ, and members from the Santanero Project compiled and summarized quotes and authored the EHEAP. The Santanero Project (@santaneroproject) is a youth empowerment initiative in Santa Ana that regularly posts on social media in support of EJ and social justice issues. Published two years after the interviews were conducted, the EHEAP findings offer additional insight into later stages of organizing compared with the interviews. The EHEAP action plan was used to guide future solutions to address soil lead in Santa Ana.

RESULTS

BUILDING A COMMUNITY SCIENCE MODEL

Figure 1a maps a timeline of key achievements in the development of the soil lead crisis to their corresponding CoSOM step. The "key players," or most heavily involved groups, are also indicated for each event in the timeline to show how involvement from different groups changed over time. The CoSOM (depicted graphically in Figure 1b) was initially developed at OCEJ as a set of linear but has been updated here to reflect the need to complete multiple cycles to achieve lasting change. The updated, circular version of the CoSOM was developed with OCEJ leadership as a result of internal discussions regarding the need for multiple iterations of the linear steps. OCEJ plans to publish the circular model on its website and use it in future focus groups with community members, where additional suggestions are welcome. For a full description of each event, see Supplementary File 2: Appendix B. Figure 1a additionally plots these events along an axis of "Kindling for Success," and groups the key players for each event.

Prior to the establishment of OCEJ in 2016, coalition building with existing organizations (*CoSOM step 1: establish relationships with local communities*) spurred the recruitment of youth to participate in EJ issues. As the organizer stated, the 2009 Santa Ana Building Healthy Communities Initiative (Funded by the California Endowment) established JCC, which became a "platform to educate ourselves and facilitate youth participation in city decisions." Starting in 2013, the community organizer stated that JCC was focused on EJ issues related to "waste diversion and composting," but shifted their focus on organizing around the 2017 lead study. Eventually, OCEJ would be the central group organizing around lead. With the CoSOM born out of the early organizing by JCC, OCEJ staff reflected during our interviews:

> The ultimate goal of any work is to improve society, and the particular work we're doing at OCEJ is to do that by improving the environment for communities burdened by toxins. The model is just a vehicle towards advancing that bigger vision. (staff)

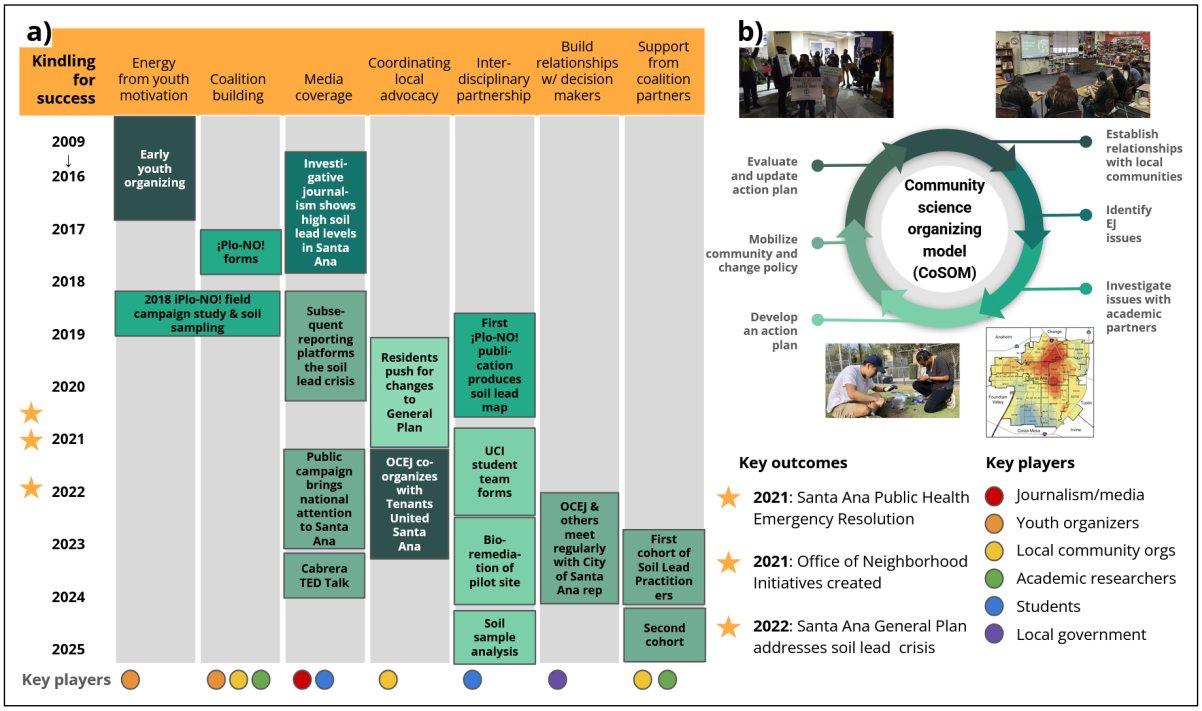


Figure 1 (*a*) Graphical representation of the timeline of events color-coded by CoSOM step and the key players involved in each event. **(*b*)** CoSOM, including the soil lead map and pictures of advocacy, outreach, and soil sampling activities in Santa Ana. (Soil lead map sourced from Masri et al. (2020), reproduced under a Creative Commons Attribution (CC BY 4.0) license).

The model was published on the OCEJ website in 2020 and served as a guiding framework for community activism. Prior to the establishment of the CoSOM, OCEJ lacked a unified framework to establish community ties around EJ issues.

RESISTANCE AND STRUCTURAL BARRIERS

All stages of the project encountered challenges, although the most notable was proving that soil lead contamination was an EJ issue that required urgent action (*CoSOM step 2: identify EJ issues*). Key challenges included skepticism from agencies, funding limitations, volunteer turnover (especially youth), and determining which mitigation efforts could be initiated. One community organizer recalled their experience of the early steps of the CoSOM:

> We weren't able to secure money at that time to hire organizers who could build relationships with people…to really support them to run their own campaigns is ultimately what we wanted, for people to develop their own solutions. (organizer)

Persistence, adaptability, and a focus on interdisciplinary collaboration were key to overcoming these obstacles. Yvette Cabrera's 2017 study of soil lead contamination in Santa Ana was initially met with skepticism (Cabrera 2017). First, the field XRF (X-ray fluorescence) scanner used in Cabrera's analysis was considered an unreliable source of data:

> The initial study that was published by ThinkProgress, which really brought to light the issue of toxic soil lead, that study was done using a method that was not as respected by decision-makers, or by the scientific community because it involved the portable measurement instrument. (staff)

Since Santa Ana is a predominantly Latine community with strong ties to Mexico, skeptics suggested that Mexican candy and pottery was the source of lead contamination. A community organizer characterized the key issue as, "They basically blamed it on the community, totally ignoring a history of development in the city." An OCEJ staff member attributed this disconnect to the perception that lead was not an issue due to existing "bans on gasoline and leaded paint." Moreover, they articulated that "people feel like lead is an old school thing… but our findings show that it actually is very relevant." The initial lack of action after Cabrera's baseline study led to the formation of ¡Plo-NO!, which set out to reaffirm the Cabrera study.

KNOWLEDGE EXCHANGE

Initially, staff mentioned that the "original researchers, community researchers, and journalists were regarded as

non-experts and the issue was dismissed." Scientists from Thermo-Fisher Scientific trained the authors of the 2017 Cabrera Study, however, and a portion of the soil samples were sent to Tulane University for verification (Cabrera 2022). Despite this backing from the initial study, bringing in UCI researchers (the local research university; *CoSOM step 3: investigate issues with academic partners*) helped add an additional layer of legitimacy. During the door-to-door canvassing of the follow-up study, it was found that making the UCI researchers a point of contact to back up the reported lead levels from the initial study helped to improve receptiveness to repeated sampling. An OCEJ youth canvasser reflected, "because we were able to put the university in as a point of contact in that letter… people felt empowered to say, 'Okay, this is legitimate… I need to go get [blood] tested."

The 2018 ¡Plo-NO! field campaign with UCI verified that the Cabrera study results were valid (Masri et al. 2020). A youth canvasser also described the research exchange with UCI and OCEJ members, mentioning "it was really great to be a thought partner in that [publication]." UCI researchers and students also learned from the community members, as the youth canvasser describes:

> It was nice to work with UCI in the field because it really showed the [UCI] students [what Santa Ana was like]. I had a few students who thanked me for sharing saying 'that actually gives me more context about what we're doing.' (Youth Canvasser)

EMPOWERMENT, ACTION, AND SUSTAINABILITY

The most critical step of the CoSOM is the final "action plan" step (*CoSOM step 4: develop an action plan)*. Following the two major studies, OCEJ began to assess the perception of the results from residents. Specifically, the EHEAP became an opportunity for community members to voice their concerns. Central to the EHEAP was getting the word about the results and increasing blood level testing. Participants in the EHEAP also voiced their opinion regarding two mitigation efforts. The conventional approach, known as "dig and dump," involves digging up the soil and disposing of it. As an OCEJ staffer describes, this method is "a costly and inequitable solution by which contaminated soil is moved to other communities." This method was also met with some reservations in the EHEAP, where participants recognized that:

> A solution is not throwing….your problems in some[one] else's backyard. (participant C)

Youth participant A in the EHEAP noted that workers conducting these efforts would need to "be really protected." The second option pitched to community members centered around bioremediation, in which native plants that could hyper-accumulate lead and heavy metals into the biomass could be deployed to limit exposure from soil particles.

The EHEAP describes that most participants felt that bioremediation would better protect workers from soil particles. The idea to use bioremediation to address the Santa Ana soil lead crisis came from University of California, Riverside researchers, who demonstrated that native plants effectively remove heavy metals from the soil (Stevenson 2023). In addition to the bioremediation efforts, EHEAP participants wanted to support a soil practitioner program that trained community members. As one participant described:

> This is the perfect opportunity for apprentice programs (soil practitioners) out there to get local people involved with these paying jobs. It could provide a strong benefit and invest in folks' livelihood. (participant B)

The youth canvasser we interviewed also mentioned "San Diego did a very similar lead research project and what they actually were able to do is get the city to create funding to have the soil tested…. We were trying to figure out a way that we can do that." At this step of the CoSOM, it became apparent that results of the studies had bolstered the community desire to implement mitigation efforts.

Following these revelations from the community, UCI PhD researchers were able to obtain funding to support the Soil Lead Practitioner Program from the EPA Environmental Justice Video Challenge for Students and the Health and Human Services Environmental Justice Community Innovator Challenge. Participants numbered 12 individuals in the first cohort of the training (fall 2024), 14 in the second (fall 2025), and 13 in the third (fall 2026). While OCEJ has also secured its own funding to support the soil lead work, these examples illustrate how additional funding streams can become accessible when diverse stakeholders get involved.

The importance of the time frame in which the CoSOM unfolds was addressed in our interviews as well as the EHEAP focus groups. Since the scale of the problem is at the city level, most feasible remediation solutions must be implemented on a site-by-site basis at a pace contingent on funding and the long-term outlook of the bioremediation efforts. While remediation efforts were adopted in Santa Ana's General Plan, implementing bioremediation takes time. The EHEAP describes that most residents expressed a sense of urgency to act. To ensure the mitigation efforts are successful, the CoSOM requires a long-term outlook that includes outreach and youth involvement. As one OCEJ Staffer describes, "Youth didn't just volunteer, they led

organizing and testing." Each respondent in our interview was passionate about supporting youth:

> When you go at the speed of young people, which oftentimes it's not the speed of most organizations who are adult-led... I think great magic can happen. (community organizer)

> I wish that in the future any efforts to support youth organizing can be sensitive towards those realities... [being] an ally in supporting them to develop their project and their personal development and healing. (community organizer)

Youth leadership and creativity are exemplified by the comic book "Lead Me to the Garden," which was authored by youth (Estrada et al. 2023). The youth authors developed the comic with awareness of the potential of mycorrhizal fungi (bioremediation) to clean up lead hotspots in Santa Ana (Figure 2). Despite the challenges of addressing soil lead contamination, the CoSOM created a platform for training young leaders, enabling them to remain engaged for years to come (critical for *CoSOM step 5: mobilize community and change policy*). Moreover, youth had the opportunity to participate and recognize the difficulty in addressing soil lead in the EHEAP:

> The problem of soil lead is difficult to get people to pay attention to because the problems associated with soil lead are subtle and hard to attribute to any particular cause. It takes time and energy for people in the community to go out and investigate. (youth participant A)

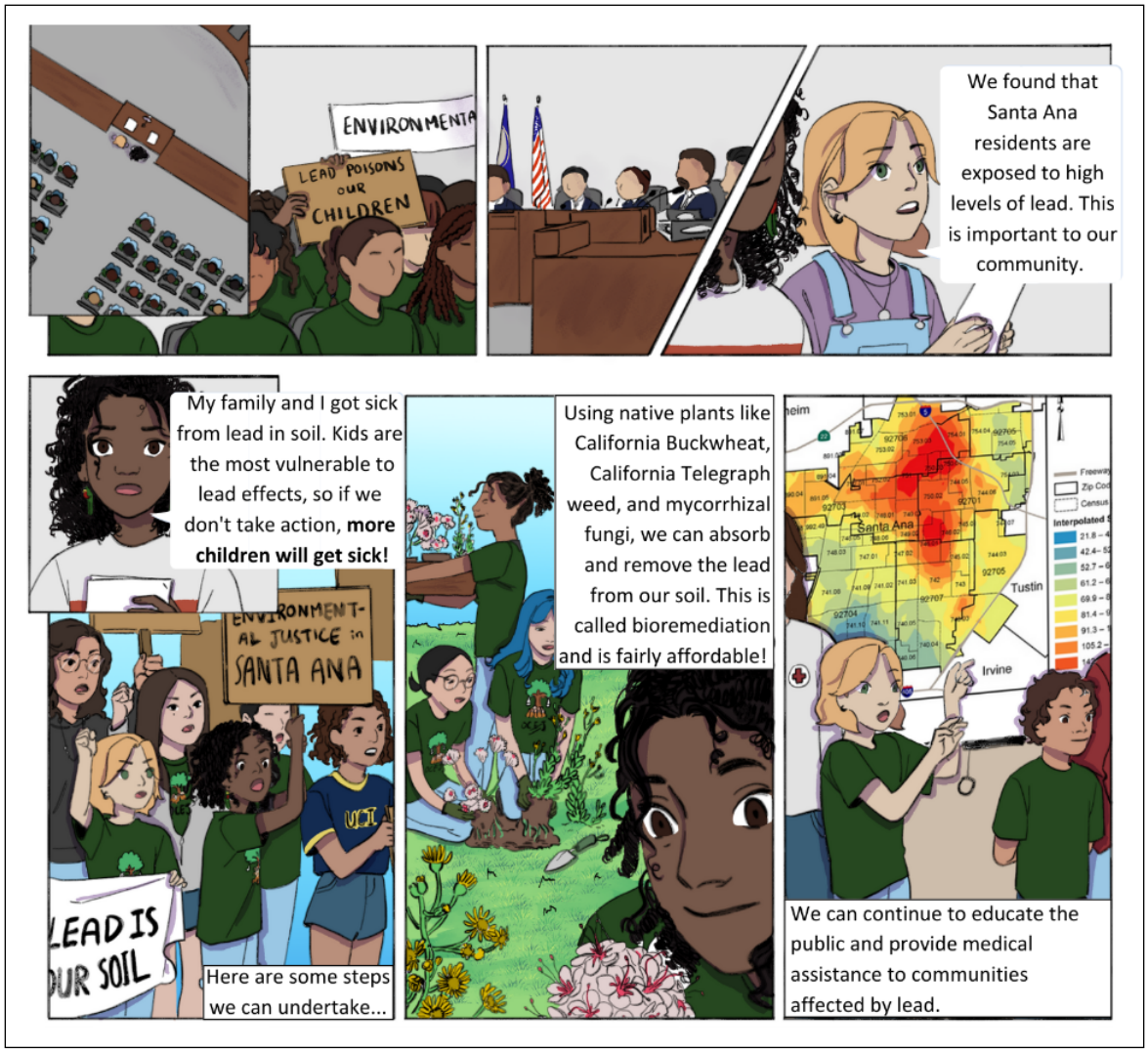


Figure 2 The "Lead Me to the Garden" article chronicles the journey of Santa Ana youth as they communicate the lead soil findings. The comic book also describes the potential of using native plants in unison with mycorrhizal fungi to clean up lead hotspots.

MODEL EFFECTIVENESS

A lesson learned from reflecting on the CoSOM with OCEJ leadership is that the initial CoSOM developed by OCEJ in 2020 needed to be updated from a linear to a circular model, to account for the many iterations of community organizing required to achieve progress. As an OCEJ staff member recounts, "We started organizing how to even begin handing out a study or community-based action to the way the city received the Cabrera study." In many cases when a goal of the linear CoSOM was achieved, a period of reassessment was needed. It was also evident that the community needed to be part of the periodic reassessment that included the dissemination of results:

> We didn't want to prescribe certain remediation efforts, we wanted to have a conversation, to develop our own priorities, and then to make demands to the City. (organizer)

> Also, the promise of accountability on our end, telling people that we would go back once we had the results to give them the information. (staff)

These perspectives suggest that certain aspects of the model will need to be revisited. As youth come in and out of the movement, the circular design can reorient new members of the CoSOM.

Despite major policy changes, such as the establishment of NIES or the changes to the General Plan, progress remains to be made to address soil lead contamination throughout the city. The "Evaluate and update action plan" step of the updated CoSOM (Figure 1b) represents the process of reflecting on the knowledge produced from community science, the policy wins from advocacy, and how they affect the next iteration of the CoSOM.

DISCUSSION

Circular models such as the CoSOM presented here are used widely in creating and disseminating community-led research in climate, ecology, and EJ spaces (Feurt 2008; Lemos 2015; Wilson et al. 2025). According to the CSIAF framework (Wehn et al. 2021), the Santa Ana CoSOM made significant impacts in the domains of society (via widespread awareness and community bioremediation training), governance (via changes to the Santa Ana General Plan and establishment of NIES), and science and technology (via overcoming initial skepticism to the issue with peer-reviewed studies on soil lead contamination in the area) (Supplemental File 2: Appendix D). The remaining domains, environmental and economic, are denoted here as emerging. Impacts to the environmental domain will include large-scale cleanup efforts to the soil surface. One purpose of developing and evaluating the CoSOM is to strengthen the dialogue between Santa Ana community members and NIES to accomplish remediation efforts. This type of *polycentric governance* sheds light on the interaction between stakeholders and governing bodies.

Complementarily, *adaptive management* focuses on the iterative evaluation of environmental management. Adaptive management has previously been used in circular models (e.g., the "adjust" phase in Allen et al. [2011]) and is recommended as a key part of iterative assessment steps of environmental remediation projects (Farag et al. 2017). The "Evaluate and update action plan" step of the Santa Ana CoSOM added to OCEJ's initial linear model is consistent with these prior examples of adaptive management, and was evident in the interviews where the organizer cited the need for an evaluation period. As the Santa Ana CoSOM moves toward remediation, determining the most suitable solutions is critical (i.e., dig-and-dump versus bioremediation) and requires pilot testing. This assessment step should be developed under the guise of adaptive management and may require OCEJ to develop a specific version of the CoSOM related to soils (see, e.g., Birgé et al. 2016).

STANDARDIZING THE MAPPING OF URBAN SOILS

Cabrera's methodology initially received some skepticism, but subsequent work by academic partners in collaboration with community members (¡Plo-NO!) confirmed the initial findings. Cabrera and others demonstrated that the field XRF can be a reliable tool when proper training and supervision is in place (Cabrera 2022; Ringwald et al. 2021), enabling a standard practice for mapping and eliminating lead hotspots and making the CoSOM more effective. Recently, the EPA updated the regional screening level (RSL), recommending further investigation and monitoring for soils at 100 ppm (Breen 2024). Contributing to the contradiction between federal and state guidance, CalEPA designates a threshold of 80 ppm (Hung et al. 2018). As Cabrera describes, a "Clean Soil Act" would address these concerns where use of a field XRF can be defended (Cabrera 2024).

DEVELOPING BROAD COALITIONS

Academic partnerships

The relationship between community members and academics early on in the CoSOM leads to *transformative* change (Conrad and Hilchey 2011). Known as a "Communiversity" model, the academic-community partnership builds trust between partners, increases

community capacity, and facilitates policy change (Wright et al. 2024). It is apparent from the interviews that the CoSOM was effective in accomplishing these goals. First, the UCI study became an important follow-up to the Cabrera Study. Second, the partnership led to numerous funding opportunities. Third, the UCI, JCC, and OCEJ partnership led to the adoption of measures to address soil lead contamination in Santa Ana's General Plan.

501(c) (3) non-profit partnerships

In parallel to the Santa Ana CoSOM, the Soil Lead and Urban Gardens (SLUG) coalition in Sacramento, California relied heavily on community input to address soil lead contamination (London et al. 2018). SLUG mirrored OCEJ's CoSOM in that relationships between community members and researchers (at the University of California, Davis) were facilitated by a non-profit organization (Ubuntu Green). The success of SLUG was highly dependent on Ubuntu's trust with community members, as was the case with ¡Plo-NO! in Santa Ana. Unfortunately, Ubuntu is listed as inactive as of the writing of this manuscript, highlighting the need for a contingency plan in case agencies or groups shutter. If there is no community-academic partnership in place, government agencies and private consulting firms can fulfill this role. Although consulting firms are typically concerned with large-scale mitigation, community-based peer-reviewed research can occur (Davis et al. 2022). Additionally, the EPA plays a pivotal role in developing community-led research at Superfund and Brownfield Sites (Klemick et al. 2020; Ye et al. 2022).

IMPORTANCE OF YOUTH

Santa Ana youth were involved early on and became a critical part of the ¡Plo-NO! UC-led study by conducting the actual soil testing. There were several levels of youth involvement, from youth organizers, volunteers, and students from UCI. Such advances are defined under the transformative co-learning model in which universities create knowledge of "local value (with global implications)," while supporting economic development (Loh 2016). This was evidenced by the reflections of the youth canvasser who recognized the interaction of community and UCI youth working together. In addition to co-learning, the academic partnership has led to direct and indirect economic support for Santa Ana to study lead exposure (CalEPA 2020; US EPA 2023; Wu et al. 2026). OCEJ and UCI coming together for these grants ensure that youth continue to participate in co-learning. Outreach opportunities that engage youth via various media and artistic forms are also imperative to a CoSOM. This is exemplified by publication of the youth-authored 2020 OCEJ comic book (Estrada et al. 2023) in Santa Ana. Such strategies work to include historically marginalized communities (Kapoor and Rishbeth 2026). An essential trait of a CoSOM is to create opportunities for youth to exert agency.

FUTURE SOLUTIONS

A key mechanism for addressing the soil lead crises in Santa Ana was California Senate Bill 1000 (SB 1000), which mandated that EJ issues must be addressed by local governments (California State Legislature 2016). The passing of this legislation spurred the development of the NIES Office in Santa Ana. Nationally, the abandonment of EJ at the federal level along with inadequate funding, the absence of state mandates, and limited community organizing is inhibitory (Park et al. 2020). Despite this, EJ policies in California remain intact. A review of 628 EJ policies adopted by California cities identified disparate goals and innovations, but those rooted in civic engagement tended to be the most successful (Brinkley and Wagner 2024). Since the review prioritized the identification of lead-based paint and soil contamination broadly, it remains unclear how widespread lead-soil contamination policy is in California. Studies like ours help highlight community groups that may be left out of EJ reviews and analysis.

In addition to tracking the success of community led movements locally and globally, differentiating what step a particular movement reaches are critical. Two steps of the Santa Ana CoSOM that are emerging according to the CIAFS framework are the environmental and economic domains. For the Santa Ana CoSOM to achieve success on the environmental front, cleanup efforts are needed. Paid soil practitioner cohorts provide economic value to the community by training community members to eventually contribute to scaled up clean-up efforts. This is consistent with the SCEO framework, in which community-led coalitions to address urban soil pollution typically reach the highest step of the model when clean-up efforts occur (Fernández-Viña et al. 2022; González 2020; Johnston et al. 2019). Like many communities, the CoSOM will require sustained financial investment to achieve long-term remediation.

LIMITATIONS

One drawback of our study was the lack of youth voices during interviews. At the outset of the interviews, our goal was to understand the development of the CoSOM. From the interviews, it became apparent how essential youth are to the CoSOM. Future studies should ensure youth voices are incorporated along with senior organizers and academics. Additionally, our goal was to center on interviews with

more content compared with more respondents. In hindsight, having a larger sample size would have helped to broaden our perspective on the CoSOM and potentially better characterize codes and themes. The interviews could have benefited from collecting demographic data. Since OCEJ does not collect demographic data (EHAEP), we opted not to collect such data during our interviews. However, we contend this would help to understand trends in the participation of the CoSOM. Future studies should consider adding demographic data during the interview process.

CONCLUSION

The impact assessment framework described by Wehn et al (2021) acknowledges that impact trajectories are rarely siloed. The CoSOM presented here focuses on the intersecting domains of society and governance, in addition to knowledge generation byproducts in the science and technology domain. We have demonstrated here that OCEJ's CoSOM informed community science organizing frameworks that can be applied in other locations (through key strategies of standardizing soil lead mapping practices, engaging youth, and developing broad coalitions across academic and governmental spaces), while also benefitting from an update to a circular structure based on both the academic literature and organizers' experiences. What started out as a grassroots effort targeted at youth became a city-wide effort to demand changes to soil lead policy. First, the journalistic effort to study soil lead in Santa Ana was the initial spark that led to the formation of ¡Plo-NO! (Step 1: Establish Relationships with Local Communities; Step 2: Identify EJ Issues). Then, OCEJ developed the CoSOM based on their experience working with coalition partners to conduct participatory research that further characterized the scope and severity of the soil lead crisis (Step 3: Investigate Issues with Partners). Third, the OCEJ and Santa Ana residents leveraged California SB 1000 to compel the city government to act on the soil results (Step 4: Develop an Action Plan; Step 5: Mobilize Community and Change Policy). This, in turn, led to the city of Santa Ana incorporating provisions to protect residents from soil lead in the General Plan and establishing NIES.

More broadly, NIES is part of a new wave of EJ frameworks created by California cities. In an early review of these frameworks in 33 California cities, many positive outcomes have already taken shape but continue to need support from elected officials and resources for implementation (Zuñiga and Méndez 2024). This is where the Santa Ana CoSOM is today, where one iteration of its initial linear steps has taken place. Our findings show that a sixth step (Step 6: Evaluate and Update Action Plan) is needed to continue to address systemic barriers to implementing solutions and ensuring long-term effectiveness. When applying the CoSOM in other areas of heavy metal contamination, the movement should be centered on a youth-inclusive community-based organization, with variable funding. The local city will also need to have accountability to address the contamination (i.e., SB 100). When academic partners are not present, consulting firms and government agencies need to fill this role.

Effectively addressing legacy pollutants that cause chronic health impacts such as soil lead require multiple iterations of the CoSOM. One of the most important aspects of the CoSOM is the incorporation of youth ("When you move at the speed of young people, great magic can happen"). With the ever-changing funding landscape for EJ in the US (Kozlov 2025), developing a CoSOM is more important than ever. To achieve *transformative* community-based monitoring, we implore future efforts involving the mitigation of soil contamination to work diligently to acquire baseline studies and incorporate the community into the decision-making framework.

SUPPLEMENTARY FILES

The Supplementary files for this article can be found as follows:

- **Supplemental File 1.** Table of acronyms. DOI: https://doi.org/10.5334/cstp.978.s1
- **Supplemental File 2.** Appendix A. Interview questions used for semi-structured interviews. DOI: https://doi.org/10.5334/cstp.978.s2
- **Supplemental File 3.** Appendix B. Codebook for categorizing data. DOI: https://doi.org/10.5334/cstp.978.s3
- **Supplemental File 4.** Appendix C. Timeline of events. DOI: https://doi.org/10.5334/cstp.978.s4
- **Supplemental File 5.** Appendix D. CoSOM domains of impact. DOI: https://doi.org/10.5334/cstp.978.s5

ETHICS AND CONSENT

The above-mentioned research was conducted under the University of California, Irvine Institutional Review Board, issued on January 1, 2017 (IRB #3690). For all interviews, verbal consent was received prior to the interviews.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

DCB, TS, and CM contributed to the conceptualization and design of the interview guide. DCB and TS conducted the interviews. AH developed the figures and contributed to manuscript revisions. DCB led the data analysis and drafted the original manuscript. MC and PF assisted with manuscript editing and revisions. AH, AG, AJ-L, and TS contributed to the interpretation of findings and manuscript revisions.

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