Analysis and Evaluation of Environmental Justice Programs and Screening Tools

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Abbreviations

ACS	American Community Survey
AIM	American Innovation and Manufacturing
BRFSS	Behavioral Risk Factor Surveillance System
CAFO	Concentrated Animal Feeding Operation
CalEPA	California Environmental Protection Agency
CalOEHHA	California Office of Environmental Health Hazard Assessment
CARB	California Air Resources Board
CCI	California Climate Investment
CDPHE	Colorado Department of Public Health and Environment
CEJST	Climate and Economic Justice Screening Tool
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C-FERST	Community-Focused Exposure and Risk Screening Tool
DALY	Disability-Adjusted Life Year
EJ 2020	EJ 2020 Action Agenda
EJ	Environmental Justice
EO	Executive Order
GIS	Geographic Information System
HFC	Hydrofluorocarbons
HI	Hazard Index
HPA	Hypothalamic-Pituitary-Adrenal
HPSA	Health Professional Shortage Area
HUD	United States Department of Housing and Urban Development
IUR	Inhalation Unit Risk
LUST	Leaking Underground Storage Tank
MassDOER	Massachusetts Department of Energy Resources
NATA	National Air Toxics Assessment
NCDEQ	North Carolina Department of Environmental Quality
NEJAC	National Environmental Justice Advisory Council
NJDEP	New Jersey Department of Environmental Protection
NJDOT	New Jersey Department of Transportation
NPL	National Priorities List
NRC	National Research Council
NYSDEC	New York State Department of Environmental Conservation
OCSPP	Office of Chemical Safety and Pollution Prevention
OECA	Office of Enforcement and Compliance Assurance
OSF	Oral Slope Factor
PFAS	Per- and Polyfluoroalkyl Substances
$PM_{2.5}$	Fine Particulate Matter
PRP	Potentially Responsible Party
QALY	Quality-Adjusted Life Year
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose

RIA	Regulatory Impact Analysis
RMP	Response Management Plan
RPS	Renewable Energy Portfolio Standard
RSEI	Risk Screening Environmental Indicators
SEP	Supplemental Environmental Project
STAR	Science to Achieve Results
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage and Disposal Facility
UCC	United Church of Christ
US EPA	United States Environmental Protection Agency
US GAO	United States General Accounting Office
UST	Underground Storage Tank
VISION	Visual Information System for Identifying Opportunities and Needs
WHEJAC	White House Environmental Justice Advisory Council
WHEJIC	White House Environmental Justice Interagency Council

1 Overview of Environmental Justice and Related Legislation/Policies

The United States Environmental Protection Agency (US EPA), which provides much of the leadership in the US on environmental justice (EJ) issues, defines EJ 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" (US EPA, 2017). While this definition broadly marries the concepts of fair treatment and environmental laws, in practice, EJ is focused on the observation that low-income, non-white communities may bear a disproportionate burden of environmental contamination, which leads to poorer health outcomes. The issues vary by community, but disproportionate environmental burden is often characterized by proximity to industrial activities, disposal sites, and high traffic areas, as well as living conditions that may make these communities uniquely vulnerable to chemical exposures (*e.g.*, substandard housing, poor nutrition, substance abuse, stress from violence). Other, more community-related factors such as inadequate enforcement of existing environmental laws and insufficient access to health care can also contribute to disproportionate health outcomes.

The recognition of EJ issues dates back many decades, but in the current backdrop of more general concerns with racial inequities and wealth disparities, EJ initiatives have become a focal point of the Biden Administration (see Section 1.1). In support of these efforts, significant resources at both the federal and state levels have been dedicated to developing tools to identify communities with profiles that may indicate EJ concerns. At present, the practical application of these tools is largely related to prioritizing resources related to compliance and enforcement, as well as directing outreach efforts. However, a role for these tools in informing regulatory decision-making, including facility permitting and health-based regulations, is likely to increase.

This report serves as resource to understand key underpinnings the scientific connection between EJ concepts and human health risk, and technical approaches that are being used (and are expected to be used) to translate EJ concepts into actionable regulatory activities. Based on the current state of EJ initiatives, this report is focused on the tools that are being developed at the federal and state levels to screen communities for possible EJ concerns. To a lesser extent, this report also examines the state of science of cumulative risk assessment, which will be at the forefront of making the connection between EJ issues and quantitative human health risk assessment. The report is organized as follows:

- **Environmental justice overview**: Includes a brief history of EJ movements and an outlook on current initiatives and tools, general issues related to assessing population vulnerabilities, key terminology, and a bibliography of key research (related to key EJ policy documents, EJ tool development, and the science of combining chemical and non-chemical stressors). The introductory section also includes possible intersections between EJ analysis and the chemical industry.
- **Detailed information on EJSCREEN**: Overviews the tool functionality, provides detailed information on the environmental indicators and how they are used to quantify/qualify exposures, and discusses how EJSCREEN results are being applied (or plan to be applied) in the current regulatory environment.

- **Detailed information on other tools developed by the federal and state governments.** Includes detailed information on CalEnviroScreen (the EJ tool developed by California), as well as other federal and state resources that are being built to complement and/or refine the identification of communities with possible EJ concerns.
- **Considerations for the general framework and application of existing tools:** Addresses strengths and weaknesses of tools and the general refinements that have been made over time, as well as further planned improvements.
- **Application of EJ tools:** Includes example case studies that highlight strengths and limitations, example application of EJ tools by the federal and state governments, and implications for the chemical industry.

1.1 History and Outlook

Although recognition of EJ issues began as early during the civil rights movement in the 1960s, a series of protests and lawsuits aimed at preventing landfills from being built in low-income, predominately African American communities in the 1980s put EJ issues in the federal spotlight (US EPA, 2021a). One particular case (Bean *vs*. Southwestern Waste Management, Inc.; cited in US EPA, 2021a) was the first time in the United States in which a waste management company was charged with environmental discrimination under existing civil rights laws. In the wake of these incidents and court cases, the United States General Accounting Office (US GAO) issued a study that ultimately concluded that hazardous landfills were disproportionately located in low-income areas with a high proportion of African Americans. According to US EPA, this study "galvanized the environmental justice movement and provided empirical support for the claims for environmental racism" (US EPA, 2021a; US GAO, 1983). This study was underscored by results from another nationwide study by the United Church of Christ (UCC) Commission for Racial Justice published in 1987. This sentinel report concluded that hazardous waste facilities were disproportionately located in areas with a high percentage of minority populations. One specific finding was that "[c]ommunities with the greatest number of commercial hazardous waste facilities had the highest composition of racial and ethnic residents. In communities with two or more facilities or one of the nation's five largest landfills, the average minority percentage of the population was more than three times that of communities without facilities (38 percent *vs*. 12 percent)" (UCC, 1987). The report also found that disproportionate citing of hazardous waste facilities was more closely tied to race than low socioeconomic factors.

It was not until the 1990s, however, that the federal government's recognition of EJ as a national concern was formalized through the creation of the Environmental Equity Workgroup. In 1992, the workgroup produced a landmark report ("Environmental Equity: Reducing Risk for All Communities") that supported the position that "racial minority and low-income populations bear a higher environmental risk burden than the general population" and made several recommendations for action (US EPA, 1992). Following that report, the US EPA Office of Environmental Equity – later called the Office of Environmental Justice – was formed.

In one of the most significant actions to address EJ issues, President Bill Clinton signed Executive Order (EO) 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," in 1994 (Clinton, 1994). This brought further national attention to EJ as an issue and formalized resource allocation within the federal government to identify communities with possible EJ concerns and "address the disproportionately adverse human health and environmental effects of programs, policies, and activities on minority and low-income populations" (US EPA, 2021a).

Since the passage of EO 12898, the consideration of EJ issues in federal policy has made steady advancements throughout the years. Progress has mainly included periodic affirmations of the importance of the principles of EJ (in statements or memoranda), establishing the statutory authority of US EPA's role in enacting and enforcing EJ-related polices, developing strategies and training for community engagement, and funding research and developing tools and methods to evaluate (and reduce) risk in communities with EJ concerns. The development of EJSCREEN, a federal tool designed to use sociodemographic and environmental indicators to characterize community level EJ concerns, is an example of such progress and was the direct result of the EJ 2014 Action plan (US EPA, 2011). Some of the key reports and activities that highlight progress in EJ-related issues at the federal level can be found at the Environmental Justice Timeline published by US EPA.[1] It is also noteworthy that US EPA's annual reports on the progress on EJ issues from 2015 to 2020 are published on a US EPA website.[2]

While the steady release of reports, policy, and research over the last 30 years has collectively shaped the federal government's involvement in EJ issues, the EJ 2020 Action Agenda (EJ 2020; released in 2016 [US EPA, 2016a]) is a useful document for understanding US EPA's current thinking on the future outlook for EJ-related research and implementation. The EJ 2020 plan put forth three key goals (US EPA, 2016a):

- Goal 1: "Deepen EJ practice within EPA programs to improve the health and environment of overburdened communities"
- Goal 2: "Work with partners to expand positive impact within overburdened communities"
- Goal 3: "Demonstrate progress on EJ issues"

US EPA's plan for goal 1 is to "[i]nstitutionalize environmental justice in rulemaking through implementation of guidance, training, monitoring, evaluation and community involvement, including rigorous assessments of environmental justice analyses in rules" (US EPA, 2016a). The expected activities under these areas are described in more detail in Table 1.1.

Table 1.1 Facets of US EPA's Stated Goal 1

Stated Goals	Description
Rulemaking	"Ensure environmental justice is appropriately analyzed, considered and addressed in EPA rules with potential environmental justice concerns, to the extent practicable and supported by law."
Permitting	"Consider environmental justice concerns in all appropriate EPA permitting activities, and collaborate with state, tribal and local co-regulatory partners, communities and permit applicants to identify and share tools, promising practices, and approaches."
Compliance and Enforcement	"Address pollution and public health burdens caused by violations of environmental laws in the nation's most overburdened communities, strengthen the role of environmental justice in EPA's compliance and enforcement work, and enhance work with our regulatory partners in overburdened communities."
Science	"Strengthen the scientific foundation for considering environmental justice in decision-making through research on decision support tools, adverse and cumulative impacts and risks, innovative monitoring and solution technologies."

Notes:
EPA/US EPA = United States Environmental Protection Agency.
(a) Goal 1 aims to "Deepen EJ practice within EPA programs to improve the health and environment of overburdened communities."
Table adapted from US EPA (2016a).

[1] https://www.epa.gov/environmentaljustice/environmental-justice-timeline.
[2] https://www.epa.gov/environmentaljustice/annual-environmental-justice-progress-reports.

The report also formulated a strategic plan for four issues that US EPA considered to be the nation's most significant EJ-related concerns. Specifics on these issues are presented in the EJ 2020 plan Appendix and include the following:

- Reduce disparities in childhood lead exposure, particularly from drinking water sources.
- Ensure that EJ communities have access to drinking water that meets federal drinking water health standards, with a focus on small and tribal water systems.
- Achieve fine particulate matter ($PM_{2.5}$) standards across the nation, with a specific emphasis on EJ communities.
- Reduce exposure from hazardous waste sites by evaluating the number of facilities and sites that have complete exposure pathways in EJ communities.

The Biden Administration picks up where the EJ 2020 plan left off. On one of his first days in office, President Biden issued EO 14008, "Tackling the climate crisis at home and abroad" (Biden, 2021). This EO, while focused on climate issues, explicitly ties in EJ issues with the overall environmental agenda by promoting a broad policy whereby the Administration will "secure environmental justice and spur economic opportunity for disadvantaged communities that have been historically marginalized and overburdened by pollution and underinvestment in housing, transportation, water and wastewater infrastructure, and health care" (Biden, 2021). Under this policy, the Biden Administration sets out specific goals:

- Establish the White House Environmental Justice Interagency Council (WHEJIC), which includes key cabinets and agency leadership positions within the federal government.
- Establish the White House Environmental Justice Advisory Council (WHEJAC) to advise WHEJIC. The committee includes individuals with expertise in EJ issues from outside the federal government (*e.g.*, community organizers, academics, local government officials).
- Create a geospatial "Climate and Environmental Justice Screening Tool."
- Publish maps highlighting disadvantaged areas (annually).
- Prioritize enforcement of environmental violations in disadvantaged communities.
- Monitor and communicate real-time data to the public "on current environmental pollution, including emissions, criteria pollutants, and toxins, in frontline and fenceline communities—places with the most significant exposure to such pollution."
- Provide recommendations on how to implement the Justice40 Initiative, which directs 40% of benefits from new regulations to go towards disadvantaged communities. The EO's suggested priorities are investments in "clean energy and energy efficiency; clean transit; affordable and sustainable housing; training and workforce development; the remediation and reduction of legacy pollution; and the development of critical clean water infrastructure."

In addition to the objectives articulated in EO 14008, there are other planned activities that will support the implementation of EJ considerations in regulatory activity at the federal level. Most recently, US EPA has indicated that it will release guidelines for cumulative risk assessment for comment by the end of 2021 (with an intent to finalize by 2023 [Hegstad, 2021]). This document was planned for release in 2013 but it was never issued. Although the specific content of this new guidance document has not yet been made public, and in fact no official announcement by US EPA has been made, it is likely to address the quantitative consideration of non-chemical stressors, such as those typically encountered in communities with EJ concerns. This expectation is based on the cumulative risk framework published in 2003 (US EPA, 2003), which highlighted the need to account for non-chemical stressors in combination with chemical stressors when evaluating community health risks (see Section 1.3 for more information on cumulative risk assessment).

Some of the key policy documents that have been issues to date under the Biden Administration are highlighted below in Table 1.2. These documents help provide insight into the nature and direction that federal activities related to EJ issues might undertake over the next several years.

Table 1.2 Recent Strategic Documents Issued by the Biden Administration

Title	Authors	WebLink	Abstract
White House Environmental Justice Advisory Council Justice40, Climate and Economic Justice Screening Tool & Executive Order 12898 Revisions (Interim Final Recommendations)	White House Environmental Justice Advisory Council	Link	This report, written by the White House Environmental Justice Advisory Council (WHEJAC) provides recommendations on Justice40, Climate and Economic Justice Screening Tool, and Executive Order 12898 Revisions as per a request from The Council on Environmental Quality. In this report, WHEJAC outlines its belief that the Justice40 Initiative is vital for the effectiveness of the Biden Administration's Environmental Justice Initiative, and that it must start as soon as possible. WHEJAC also outlines the transformation that is required for the just distribution of resources to the environmental justice (EJ) communities.
Executive Order 14008 of January 27, 2021: Tackling the Climate Crisis at Home and Abroad	The White House	Link	This is an executive order from the Biden Administration on the need to tackle the climate crisis domestically and abroad. It is divided into two parts. Part I is titled, "Putting the Climate Crisis at the Center of United States Foreign Policy and National Security." Part II is titled, "Taking a Government-Wide Approach to the Climate Crisis." In Part II, there is a specific section on securing EJ and spurring economic opportunity.
Our Commitment to Environmental Justice (April 7, 2021)	Michal Regan, EPA Administrator	Link	Directs United States Environmental Protection Agency (US EPA) leadership team to work with staff in US EPA offices and the Office of Environmental Justice to identify ways to ensure that the country's environmental laws – and the policies implemented under them – deliver benefits to all individuals and communities.
Using All Appropriate Injunctive Relief Tools in Civil Enforcement Settlements (April 26, 2021)	Office of Enforcement and Compliance Assurance	Link	This memorandum charges enforcement staff and case teams to appropriately use the full array of policy and legal tools available to ensure that the US's environmental laws – and the policies to implement them – deliver benefits to all individuals and communities. This memorandum supersedes and replaces both the 2018 (The Appropriate Use of Compliance Tools in Civil Enforcement Settlements; Bodine, 2018) and 2015 (Use of Next Generation Compliance Tools in Civil Enforcement Settlements; Giles, 2015). The first document, drafted by the Obama Administration, required that regulators should consider "innovative enforcement" activities including injunctive relief from violators in all cases. The second memorandum, issued under the Trump Administration, pulled back this policy and noted that there is "no default expectation that 'innovative enforcement' provisions will routinely be sought as injunctive relief."

Title	Authors	WebLink	Abstract
Strengthening Enforcement in Communities with Environmental Justice Concerns (April 30, 2021)	Office of Enforcement and Compliance Assurance	Link	This memorandum directed all US EPA offices to "strengthen enforcement of violations of cornerstone environmental statutes" in communities that are overburdened by pollution, which is consistent with Executive Order 14008. Goals outlined in this memorandum include increasing the number of facility inspections in overburdened communities, preventing further pollution, and obtaining restitution for victims of environmental crimes.
Strengthening Environmental Justice Through Criminal Enforcement	Office of Enforcement and Compliance Assurance	Link	This memorandum directed all US EPA offices to "strengthen enforcement of violations of cornerstone environmental statutes" in communities that are overburdened by pollution. It then sets out steps to advance these EJ goals by criminal enforcement work performed by the Office of Enforcement and Compliance Assurance. This criminal enforcement program can further EJ by strengthening tools to detect environmental crimes in overburdened communities.
EPA American Rescue Plan Funding	Not Named	Link	This fact sheet summarizes how 100 million dollars appropriated to the US EPA under the Federal Rescue Plan will be allocated to support EJ initiatives. The supported activities range across several policy activities, but with half of the funds focused on enhancing community air monitoring. Also included are funds for EJSCREEN, technical assistance for communities with "air and water issues," and expanding civil and criminal enforcement.
Interim Implementation Guidance for the Justice40 Initiative	Executive Office of the President, Office of Management and Budget	Link	This memorandum for heads of departments and agencies gives implementation guidance for the Justice40 Initiative. The actions outlined here include identifying the benefits of covered programs, determining how these programs allocate benefits, and then how to calculate and report on achieving the 40% goal outlined in the Justice40 Initiative.
Strengthening Environmental Justice Through Cleanup Enforcement Actions (July 1, 2021)	US EPA, Lawrence E. Starfield, Acting Assistant Administrator	Link	This memorandum "sets out steps to advance these environmental justice (EJ) goals through cleanup enforcement at private and federal facility sites, primarily through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA)." Specific actions that were addressed include requiring responsible parties to take early cleanup actions, ensuring prompt clean-up actions, enhancing enforcement tools/approaches, increased oversight of clean-up activities, and engaging in activities that build trust.

Title	Authors	WebLink	Abstract
DRAFT FY 2022-2026 EPA Strategic Plan (October 1, 2021)	US EPA	Link	US EPA's draft 2022-2026 strategic plan address several issues related to EJ, principally falling under Goal 2, "Take Decisive Action to Advance Environmental Justice and Civil Rights." Under this goal, US EPA developed long-term performance goals and strategic goals related to supporting community involvement, incorporating EJ into US EPA programs, policies, and activities, and strengthening compliance and enforcement in communities with EJ concerns. External factors and emerging issues were also highlighted. It should be noted that this was a draft document with several missing details.

1.2 Notable Definitions

The study of EJ issues has developed over the years, and with it, certain concepts and terminology have also evolved. Notable definitions of EJ-related terms are included in Appendix A. These terms include legislation (*i.e.*, Title VI of the Civil Rights Act of 1964) and EOs (*i.e.*, EO 12898 and EO 14008) related to EJ concerns, as well as terms that differentiate risk assessment concepts, such as "cumulative risk," "human health risk assessment," "risk communication," "risk characterization," and "risk management." A number of the notable definitions presented in Appendix A of this report come from different EJ tools and are presented to help understand the tools and how different indicators and metrics are defined. For example, California Environmental Protection Agency's (CalEPA) Office of Environmental Health Hazard Assessment's (CalOEHHA) CalEnviroScreen 4.0 (CalEPA and CalOEHHA, 2021) uses "education attainment" and "linguistic isolation" as socioeconomic indicators along with its "sensitive population" metric to calculate "Population Characteristics" scores, which is then combined with "Pollution Burden" to model cumulative impacts. Terms related to US EPA's EJSCREEN tool (*i.e.*, demographic indicators, environmental indicators, and EJ index) are also presented in Appendix A.

Key concepts on the identification and differentiation of EJ concerns and populations of concern are also included. For example, there are distinctions between the definitions of "stressor," "psychosocial stressor," and "non-chemical stressor." There are also a number of terms used to define different populations related to EJ, such as "indigenous peoples," "low-income populations," "community of color," "socially disadvantaged," "underserved communities," "minority populations," "subsistence populations," and "vulnerable populations." Many of these terms were identified and further clarified in US EPA's 2016 "Technical Guidance for Assessing Environmental Justice in Regulatory Analysis" (US EPA, 2016b) or WHEJAC's Interim Final Recommendations (WHEJAC, 2021). These resources reflect the most current terminology used to describe EJ-related concerns and populations. US EPA (2016b) and WHEJAC (2021) have almost identical definitions of EJ but differentiate between some terms. For example, WHEJAC (2021) uses the term "just treatment" in its definition of EJ, whereas US EPA (2016b) uses "fair treatment" in its definition. It is worth noting here that although WHEJAC defines the EJ community as "a geographic location with significant representation of persons of color, low-income persons, indigenous persons, or members of Tribal nations, where such persons experience, or are at risk of experiencing, higher or more adverse human health or environmental outcomes" (WHEJAC, 2021), US EPA has cautioned against the term "EJ community" to identify communities with features that may indicate EJ concerns, and the term is not widely used in current government reports and policies.

1.3 Introduction to Cumulative Risk Assessment and Non-chemical Stressors

EJ and Cumulative Risk Assessment

The bridge between EJ issues and human health risk assessment falls under the umbrella of cumulative risk assessment. As defined by US EPA (2003), cumulative risk assessment is "[a]n analysis, characterization, and possible quantification of the combined risks to health or the environment from multiple agents or stressors" (US EPA, 2003). US EPA's recognition of the importance of moving beyond single chemical exposures has existed in some form for many years. For example, a traditional risk assessment conducted under Risk Assessment Guidance for Superfund – which considers multiple chemical exposures, sensitive sub-populations, and multi-pathway evaluations – embodies some of the key facets of a cumulative risk assessment. Another example is the evaluation of aggregate exposures to pesticides mandated by the Food Quality Protection Act of 1996, which specifically states that pesticides with a common mechanism of action be evaluated for their cumulative health risks (*e.g.*, organophosphate pesticides risk assessment).

The assessment of multiple chemical exposures (in sensitive sub-populations) fits clearly within US EPA's existing human health risk assessment paradigm, but there has been an increased interest in evaluating human health risk more holistically and including non-chemical stressors as important public health determinants. Non-chemical stressors can include physical factors, such as noise and radiation, but the incorporation of non-chemical stressors into human health risk assessment has increasingly focused on how non-chemical social factors contribute to the uneven distribution of environmental health risk in communities with EJ concerns.

The incorporation of non-chemical risk stressors as part of the cumulative risk paradigm received some limited attention in a 1997 planning and scoping document issued by US EPA's Science Policy Council, but it was US EPA's (2003) "Framework for Cumulative Risk Assessment" report that was instrumental in formalizing the connection between more traditional chemical-related health evaluation and non-chemical stressors. Although no specific methodology was offered, the report explicitly promoted consideration of stressors in the risk assessment process that were not commonly within US EPA's regulatory purview, including the impacts of low income, limited access to health care, psychosocial stress, and other stressors commonly associated with EJ communities (US EPA, 2003). Some of the general approaches that were introduced include the possible use of biomarkers and finding common outcome metrics. Quality-adjusted life years (QALYs) and disability-adjusted life years (DALYs) were provided as an example metric that can be used to assess multiple factors that lead to a common adverse health outcome (US EPA, 2003).

In addition to the focus on non-chemical stressors, US EPA's 2003 guidance document proposed a shift in the conventional risk assessment paradigm by recommending that risk assessments focus on a more community-based approach rather than on hypothetical individual risks (for the reasonably maximally exposed individual from point sources). This approach, which was generally developed to be able to analyze more specific problems and deliver more targeted risk-based responses (*i.e.*, a fit-for purpose approach), also largely stemmed from the perceived need to address EJ concerns at the community level.

Both the consideration of non-chemical stressors and the shift to community-based assessment, as well as the explicit connection with EJ initiatives were further promoted in a 2004 report by the National Environmental Justice Advisory Council (NEJAC), which is group of multi-disciplinary experts who have advised US EPA on EJ issues since 1993 (NEJAC, 2004). In 2004, NEJAC published the report, "Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts," with key recommendations:

- To institutionalize a bias for action within EPA through the widespread utilization of an Environmental Justice Collaborative Problem-Solving Model;
- To fully utilize existing statutory authorities;
- To address and overcome programmatic and regulatory fragmentation within the nation's environmental protection regime;
- To fully incorporate the concept of vulnerability, especially its social and cultural aspects, into EPA's strategic plans and research agendas;
- To promote a paradigm shift to community-based approaches, particularly community-based participatory research and intervention;
- To incorporate social, economic, cultural, and community health factors, particularly those involving vulnerability, in EPA decision-making;
- To develop and implement efficient screening, targeting, and prioritization methods/tools to identify communities needing immediate intervention; and

- To address capacity and resource issues (human, organizational, technical, and financial) within EPA and the states, within impacted communities and tribes, and among all relevant stakeholders. (NEJAC, 2004)

This strategic shift was echoed in subsequent US EPA documents, as well as reports from other leading authoritative agencies (US EPA and US DOE, 2007; US EPA, 2012; NRC, 2009). In particular, the landmark 2009 Science and Decisions report from the National Research Council (NRC) affirmed that advances in risk assessment should have a community focus and incorporate non-chemical elements (NRC, 2009). In response to NRC's recommendations, US EPA issued the report, "Framework for Human Health Risk Assessment to Inform Decision Making" (US EPA, 2014), which provided a forward-looking vision to human health-based risk assessment at US EPA: one that clearly emphasized a community-based risk assessment approach that considers the fully endorsed, previously formulated concepts of cumulative risk assessment.

While the connection between cumulative risk assessment and addressing EJ concerns has been strategically visualized, the science-based application of cumulative risk assessment principles has been more elusive, hampering follow-up guidance from US EPA on the application of those principles to health-based regulations. In fact, risk assessment guidance in support of the 2003 cumulative risk framework has not yet been issued, even though US EPA planned for a release in 2013. In the interim, however, US EPA has published a key guidance document related to implementation of science-based approaches that address EJ issues in a regulatory context. This document, called, "Technical Guidance for Assessing Environmental Justice in Regulatory Analysis," outlines the importance of considering EJ issues during all regulatory determinations and stresses the importance of considering if any new actions worsen or improve issues in a community with possible EJ concerns. This document, however, falls short on introducing specific cumulative risk methodologies. In fact, the document states that "[e]stablished methods are not available for modeling the effects of many non-chemical stressors that are important to an analysis of potential EJ concerns. Such stressors (*e.g.*, nutritional deficits, stress) may interact with chemical stressors to exacerbate or mitigate health outcomes; the ability to model such interactions is still in the nascent stages of development" (US EPA, 2016b).

The intersection between environmental exposure and EJ-related, non-chemical stressors has been reiterated through US EPA's various strategic plans to advance EJ. The EJ 2020 report has some particularly relevant examples on how US EPA views the intersection of EJ-related, non-chemical stressors with specific environmental issues. For its initiative to reduce $PM_{2.5}$ emissions, US EPA noted the relevance to EJ (US EPA, 2016c):

> The impacts of fine particulate matter pollution are not evenly shared across all population groups. Low-income populations are among those most at-risk to adverse health effects from exposure to PM2.5. They have been generally found to have a higher prevalence of pre-existing diseases, limited access to medical treatment, and increased nutritional deficiencies, which can increase their risk of particle pollution-related effects. In addition, low-income populations often suffer from low educational attainment or disadvantageous residential location factors that can also contribute to an individual's higher exposure to air pollution.

Since the publication of US EPA's technical guidance document (US EPA, 2016b) and on the heels of research investment, most notably through the Science to Achieve Results (STAR) Program, there have been advances in quantitative methods that can be used to characterize risk from non-chemical stressors (see discussion on STAR research below). These advancements, in conjunction with the priorities related to addressing EJ concerns, have prompted US EPA to announce its plans to finally release its draft cumulative risk assessment guidance by the end of 2021. While, at the time of this report, it is not clear how prescriptive the guidance will be with regard to methodological approaches or areas of application, the release of further guidance will likely be an important next step in incorporating science-based approaches into EJ-based initiatives.

Current State of Science of Cumulative Risk Evaluation

Evaluating risk in communities with potential EJ concerns is often cast in terms of identifying and characterizing the risks of "vulnerable" populations. In its 2016 technical guidance document, US EPA (2016b) defined a vulnerability as, "physical, chemical, biological, social, and cultural factors that result in certain communities and population groups being more susceptible or more exposed to environmental toxins, or having compromised ability to cope with and/or recover from such exposure" (US EPA, 2016b). This constellation of environmental, biological, and behavioral/cultural factors is used to characterize vulnerability and understand cumulative risk. Significant research has been dedicated to defining the stressors in EJ communities and how these factors interact to affect health outcomes (*e.g.*, Lewis *et al.*, 2011; Burger and Gochfeld, 2011; Fox *et al.*, 2017; Payne-Sturges *et al.*, 2015). Example stressors compiled from several different resources are presented in Table 1.3. Although there is no definitive source for how to group these stressors, some useful categories are offered in Table 1.3; they include factors that characterize environmental burden, socioeconomic factors, susceptibility factors (innate biological characteristics), community issues, and climate-related factors. Collectively, many of these factors fall more broadly under the term of psychosocial stress, which is a term commonly used in the cumulative risk literature to describe the stress that comes from living in an under-resourced, low socioeconomic environment. Many of these factors have been incorporated into tools (*e.g.*, EJSCREEN) that are used to identify communities with EJ concerns (see Section 2). In particular, indicators related to socioeconomics, susceptibility, and environmental burden are well integrated into existing tools, while community and climate change indicators are being proposed as part of tool updates or for developing tools.

Table 1.3 Factors Used to Screen EJ Communities

Category	Example Stressors
Socioeconomic	Income, poverty rate, unemployment rate Racial and ethnic composition of population English proficiency Educational attainment Housing burdened (*i.e.*, communities that are low income and also spending more than half of income on housing)
Susceptibility	Age distribution (particularly % >65 years old and % <5 years old) Genetics
Environmental Burden	Air pollutant concentration data (*e.g.*, $PM_{2.5}$, ozone, toxic release inventory) Contaminants in water (*e.g.*, drinking water, surface water, location, and data from impaired water bodies) Contaminants in other environmental media (*e.g.*, contaminated fish/seafood, drinking water) Presence and density of industrial sites (*e.g.*, contaminated sites, dry cleaners, junkyards, power plants, incinerators, landfills) Compliance indicators (inspections, violations, actions at major facilities) Presence and density of other activities (*e.g.*, road traffic, mining, oil and gas extraction) Pesticide exposure (from agricultural and non-agricultural use)
Behavioral	Nutrition Obesity Drug/alcohol abuse

Category	Example Stressors
Community	Measures of violence/crime Access to health care Quality of housing and schools Law enforcement Disenfranchisement
Climate-related	Percent elderly living alone Tree canopy Coastal sea level rise and flooding risk Ocean acidity
Outcomes	
Public health measures	Infant mortality, low birth weights, mortality rates, birth defect rates Cancer incidence and death rates Asthma hospitalization and emergency visits (in children and/or adults) Incidence of cardiovascular disease Prevalence of hypertension Obesity

Notes:
EJ = Environmental Justice; $PM_{2.5}$ = Particulate Matter with Particle Size ≤2.5 µm in Diameter.
Information in this table was compiled and synthesized from the following sources: Lewis *et al*. (2011); US EPA and US DOE (2007); US EPA (2017); CalEPA and CalOEHHA (2017); KFTC (2016); and WHEJAC (2021).

Not surprisingly, the complexities involved in incorporating non-chemical stressors into risk assessment are manifold. Key questions relate to identifying the non-chemical stressors that have the most meaningful impacts, and then examining how these factors can be incorporated into the quantitative human health risk assessment structures that underlie health-based regulatory actions. US EPA has invested significant resources *via* research, grants, and expert conferences to understand how non-chemical and chemical stressors interact to affect health outcomes and how this information can be (quantitatively or semi-quantitatively) incorporated into human health risk assessments. Through sustained support for research in this area, the sciences are advancing. Payne-Sturges *et al*. (2018) summarized the key advances in evaluating the combined effects of chemical and non-chemical exposures:

- **The Use of Biomarkers to Measure Psychosocial Stress and Allostatic Load:** The use of biomarkers as a means to measure cumulative stress and physiological dysregulation has long been recognized as a promising strategy for characterizing cumulative risk. The concept of "allostatic load" revolves around the concept that stress leads to biological dysregulation and adverse health outcomes, and that perturbations can be assessed through a common set of biomarkers. The original 10 biomarkers of allostatic load include four primary mediators (dehydroepiandrosterone sulfate, cortisol, epinephrine, and norepinephrine) and six secondary outcomes of non-chemical stressors (systolic blood pressure, diastolic blood pressure, waist-hip ratio, high-density lipoprotein cholesterol, total cholesterol, and glycated hemoglobin) (Seeman *et al*., 1997). These 10 biomarkers were determined after studying a predominantly White sample population. More recent research conducted in representative and diverse populations has suggested the inclusion of additional biomarkers such as dopamine, insulin-like growth factor-1, fasting glucose, triglycerides, C-reactive protein, apolipoprotein A1, apolipoprotein B, body mass index, and waist circumference (Rodriquez *et al*., 2019).

  STAR program researchers have further explored possible biomarkers that can be used to assess adverse outcomes from chemical exposures. One particular study examined the relationship between carbon black emission from diesel trucks in a high-traffic area and childhood asthma in relation to psychosocial stress as measured through interviews, focus groups, and biomarkers of stress (*i.e.*, glucocorticoid and b2-adrenergic levels). The hypothesis was that chronic psychosocial factors would suppress the adaptive response to carbon black, which, over time, would cause increased susceptibility to carbon black-induced asthma. The study was met with significant challenges related to subject recruitment and retention because the study required "intensive, extensive periods of personal monitoring of children." According to Payne-Sturges *et al*. (2018), preliminary results of the analysis showed that "exposure to previous 24-h mean black carbon concentrations were positively associated with increased exhaled nitric oxide, a marker of airway inflammation, but chronic stress measured by interview did not modify this association." Results related to the biomarker analysis were not presented.

- **Identification of Relevant Cumulative Risk Assessment Stressors:** Several of the STAR research projects focused on interviews and focus groups to identify the stressors that are most critical to a cumulative risk assessment analysis. This included research on the most effective strategies to collect meaningful information as well as identifying key community stress factors. For example, the study by the University of Pittsburgh/West Harlem Environmental Action identified several novel community stressors (*e.g*., rats and vermin, graffiti, police-community dynamics, gentrification) that have not been traditionally recognized as meaningful sources of psychosocial stress.
- **Exposure Assessment of Non-chemical Stressors:** Efforts under the STAR Program to improve exposure analyses associated with non-chemical stressors has been focused on a few key areas. The first focus area was on the identification of relevant data sources that could be reliably used as a proxy for psychosocial stress. For example, one research program found that among common urban stressors, violent crime was most associated with "perceived neighborhood social disorder, perceived stress, anxiety, and depression" and that these stresses could be well characterized using the various statistics on violent crime in the community of interest.

  The second area of research has involved developing methodologies for spatial analyses that can more reliably identify and establish causal relationships among a large set of variables across a geographic region. A common critique of EJ research efforts is that census or other government boundaries fail to adequately capture the true community boundaries, and that because separate sources of data do not always geographically align, it is difficult to make reliable causal associations between different community stressors and outcomes. In response, STAR research projects have sought strategies to use community boundaries that enhance both analysis and, ultimately, any needed interventions. In several studies, researchers incorporated community members' perceptions of their neighborhood boundaries into spatial analyses *via* interview. For example, researchers asked participants to draw their neighborhoods on a map, and then reformulated non-chemical stressor information and applied this information to the approximated neighborhoods, in an attempt to correct some misalignment of certain stressor information.

  Another set of researchers (University of Pittsburgh) explored ways to optimize information from large geographic information system (GIS) datasets. One study used simultaneous autoregressive models to account for confounding across variables and issues with autocorrelation. Another research group used simulation methods to generate synthetic microdata (*i.e*., individual-level data) by correcting census-level demographic information collected from a set of random households in the actual area. The researchers then used multiregression models to predict chemical exposure and other important public health indicators as a function of the variables from microdata set across the same geographic area. Given the large, but inconsistent, amount of relevant information that can inform cumulative risk impacts across populations and communities, more reliable methods to analyze the inter-relationship between demographics, and chemical and non-chemical stressors is one of the more important cumulative research needs.

  Finally, it is noteworthy that much of the most recent research is highly focused on understanding the confounding that can occur spatially when conducting cumulative risk analysis; the recent

STAR research projects do not appear to be as focused on the uncertainty and misclassification that can result due to temporal variability across data sources. However, issues with disparate temporal information in establishing cumulative risk impacts is a noted area of uncertainty that warrants further consideration.

- **Statistical Methods for Understanding the Relative Contribution of Chemical and Non-chemical stressors:** Complex statistical modeling techniques are needed to more accurately reflect the convoluted nature of the relationships between multiple stressors and health outcomes, especially if relationships are nonlinear. Several STAR research projects have focused on statistical methods that could be used to more reliably understand the non-chemical stressors that affect health outcomes. For example, researchers from the University of Texas accounted for latent variables in modeling, which are variables that are not directly measured. The researchers identified three latent variables: place-based stressors, individual-level disadvantage, and psychosocial stress; these latent variables were hypothesized mediators between environmental exposures and health outcomes. As another example, another research group used structural equation modeling, which combines linear regression, path analysis, and factor analysis to determine if socioeconomic variables impact health outcomes or if they are mediated through environmental or psychosocial variables. Similar to the issues with spatial exposure analysis (described above), statistical methods to work out the relative contribution of chemical *vs.* non-chemical stressors to adverse health outcomes is an important research area that is needed to reliably advance cumulative risk assessment.
- **Animal Models of Stress:** While most of the efforts to establish relationship between chemical and non-chemical-stressors, and health outcomes are rooted in epidemiological analysis, animal models have been used to elucidate interactions between chemical exposures and stress and provide a biological basis for observations in epidemiological studies (Payne-Sturges *et al*., 2018). The University of Rochester School of Medicine and Dentistry has a long history of examining the interaction between animals and stress (as reviewed in Lewis *et al*., 2011). In the most recent research effort under the STAR program, the school investigated the effect of cumulative maternal toxicity and lifetime exposure to lead or developmental exposure to methylmercury, and stress in rats. The investigators found that combined exposure to metals and non-chemical stressors produced more pronounced adverse cognitive effects and/or "unmasked" effects of the chemical exposure (as summarized in Payne-Sturges *et al*., 2018). The study went on to further suggest that the effects were mediated through common pathways (*i.e*., the hypothalamic-pituitary-adrenal [HPA] and the brain mesocorticolimbic systems). Further research by the group demonstrated that postnatal exposure to stress could further enhance observed neurotoxicity in offspring and that there were sex-dependent responses to combined lead and stress exposures that were consistent with effects on the HPA axis.

  While animal models may play some role in understanding the biological underpinnings of the interaction between chemical exposures and stress, there is still significant uncertainty in how these models relate to humans. Payne-Sturges *et al*. (2018) suggest that the common animal model of stress, which usually involves restraint or heat- or footshock, may be less relevant than stresses related to resource deprivation, such as limiting access to nesting materials. However, the noted limitation of any animal study to characterize the complex interactions that occur in an underserved community is clear, and further validation of appropriate animal models is needed.

Given the challenges of quantifying the impact of non-chemical stressors on populations, current cumulative risk assessment efforts have been largely focused on identifying populations that may have both increased chemical exposure (*i.e*., are overburdened) and vulnerability based on a collection of the psychosocial factors listed in Table 1.3. EJ screening tools being developed at both the federal and state levels reflect this form of assessment. In general, these tools tend to focus on socioeconomic and environmental indicators, due, in large part, to their data accessibility. Many of these other factors may be harder to measure, but there is clear interest in expanding the number of indicators that can be used to identify vulnerable populations. For example, the climate and economic justice screening tool being proposed by WHEJAC includes indicator recommendations that go well beyond what is currently included in existing tools (see Section 3.2 for more details).

As noted in more detail throughout this report, although these tools represent significant efforts to advance an understanding of the overlap between socioeconomic factors and measures of environmental burden, the tools should not be construed as instruments of risk assessment. Rather, in both function and practice, the tools reflect semi-quantitative screening assessment methods that may help in identifying communities with possible EJ concerns. The identification of communities with potential EJ concerns may then spur on further action, which may come in many forms, including being prioritized for government programs, increased compliance and enforcement activities, or targeted support for community engagement. More information on the application of EJSCREEN is discussed in Section 2.5.

1.4 Intersection of EJ with Chemical Industry

The impact of EJ-related policies will crosscut industries. Because of the connection between EJ issues and climate change, the utility industry is likely an early focal point for the implementation of EJ-related initiatives. The research between non-chemical and chemical stressors is most robust with respect to criteria air pollutants, and there has already been some precedent for the consideration of EJ-related issues in regulatory decisions (*e.g.*, Clean Power Plan Rule; see Section 2.5). Resources have also been dedicated to creating the "Power Plants and Neighboring Communities" tool, which maps and analyzes the demographic make-up of communities within three miles of US power-generating facilities. EJ-related analyses conducted for utilities may serve as a bellwether for other industries.

For the chemical industry, the intersection between EJ-related issues and regulatory impacts is formative, with few existing actions to provide perspective on how EJ-related analyses will affect the activities of chemical manufacturers and marketers. Although speculative, presented below is discussion of how developing EJ policy and evaluation may affect the chemical industry. Overall, at least in the near term, it is likely that chemical manufacturers located in the vicinity of a community with potential EJ concerns might expect more scrutiny in the form of increased inspections and audits, and ensuring that any past non-compliance infractions are being addressed in a timely and effective manner.

As noted in Section 1.1, US EPA released several policy memoranda emphasizing the commitment to increased enforcement and compliance assurance in communities with potential EJ concerns, including a formalized plan for increasing the number of facility inspections in communities with potential EJ concerns (US EPA, 2021b,c). With an increase in inspections, US EPA has also proposed several steps to address environmental non-compliance, once identified. In a step that has the potential to carry significant implications for the chemical industry, US EPA's April 26, 2021, memorandum (US EPA, 2021d) rescinded a 2018 policy (Bodine, 2018) that restricted the use of "innovative enforcement" approaches. Instead, US EPA expanded the scope of possible injunctive relief tools "not only to return facilities to compliance but also to tailor the relief to address the underlying causes of the violations" (US EPA, 2021d). One of the highlighted tools that could be used as part of injunctive relief was "advanced monitoring," which could include point source and ambient monitoring of air and water releases. Other tools relate to third-party compliance audits that could extend beyond the scope of the violation at issue, increased reporting requirements, and greater public access to compliance data. US EPA noted how these tools can work together to further achieve goals. For example, fenceline monitoring, in combination with enhanced public transparency, was presented as an approach that could be "particularly effective," with US EPA (2021d) stating that "[f]acilities are more likely to take extra caution to self-police and ensure their operations are addressing pollution problems when the [air emission] information is transparent."

In addition to more robust injunctive relief tools, US EPA also provided policy direction on enhanced enforcement of environmental crimes (US EPA, 2021c). US EPA's stated goal is to "integrate crime victim and environmental justice considerations into every environmental criminal investigation and prosecution." The policy memorandum directed the use of EJSCREEN to improve outreach to possible victims of environmental crimes. One of the key facets of the policy is ensuring that punishments promote deterrence for future violations. This is expected to be achieved by the injunctive relief tools described above as well as seeking forms of financial restitution.

In its most recent memorandum, US EPA (2021e) focused attention on ensuring that site clean-up actions (under the Resource Conservation and Recovery Act [RCRA] and the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]) are expedited, utilize appropriate enforcement tools, and engage the surrounding community during the remedial process. These policies will be applicable to entities that are currently engaged in clean-up activities or might be in the future. This memorandum proposed a whole host of activities that help target more effective clean-up in overburdened communities, but of special note, the memorandum again emphasized active monitoring – in this case, to ensure compliance with remedial action objectives.

In conjunction with these strategic objectives, US EPA has highlighted several recent compliance and enforcement actions the reflect policy objectives. For example, there have been early actions against companies (in communities with EJ concerns) failing to comply with Section 112(r) of the 1990 Clean Air Act amendments, which requires facilities that store threshold quantities of certain chemicals to file a Response Management Plan (RMP). The enforcement actions, which were levied against a fertilizer and a seafood processing facility, included a mandate for corrective measures (*i.e.*, submit appropriate regulatory analysis) and fines (in excess of $100,000). Interestingly, US EPA has more generally identified the RMP rule, which was only recently updated in 2017, as an "action for review" because of the potential intersection with EJ issues (US EPA, 2021f). A press release by US EPA noted that improvements to the rule were being considered "so EPA can better address the impacts of climate change on facility safety and protect communities from chemical accidents, especially vulnerable and overburdened communities living near RMP facilities" (US EPA, 2021f). Because the Biden Administration has made its explicit goal to track EJ-related activities, it would not be surprising if a more complete accounting of compliance and enforcement action targeted at communities with EJ concerns becomes available in the near future.

The strategic objectives to increase compliance and enforcement activities in communities with EJ concerns is not specific to the chemical industry, but they certainly can affect different facets of facilities that manage chemicals, particularly if there are non-compliance issues (present or future). The call for increased air monitoring is a consistent theme within these efforts and reflects a broader effort to increase monitoring capabilities to ensure that air emissions are not contributing more risk to communities that are already considered overburdened. For example, the EJ 2020 plan identified several priority issues, and among them was a goal to achieve $PM_{2.5}$ standards in all low-income communities as early as practicable. Also, EO 14008 expressed the general goal to "create a community notification program to monitor and provide real-time data to the public on current environmental pollution, including emissions, criteria pollutants, and toxins, in frontline and fenceline communities—places with the most significant exposure to such pollution" (Biden, 2021).

Putting these principles into action is starting to take form in regulatory measures. Recently, a bill was introduced in the Senate that would designate 100 million dollars for US EPA to develop an air monitoring program in communities with EJ issues (US Congress, 2021). This reflects activities that are occurring on the state level; for example, New York State recently announced that it is initiating hyperlocal air quality assessments in communities historically overburdened by pollution to "reduce emissions in communities heavily impacted by air pollution and help to address the public health impacts due to this pollution, including higher rates of lung disease, asthma, heart disease, and premature death" (New York State Office of the Governor, 2021).

US EPA's Office of Chemical Safety and Pollution Prevention (OCSPP), which administrates the Toxic Substances Control Act (TSCA), has also started to consider how EJ issues may impact chemical safety assessment. Initiatives from this office have the potential to significantly and uniquely impact chemical and product manufacturers. While OCSPP has not released a strategic plan for evaluating EJ issues in programs under its purview, several recent actions and statements provide some perspective on how EJ might be considered in chemical safety assessments. Some of these early actions are highlighted below:

- In April 2021, US EPA announced plans to update the Toxics Release Inventory (TRI) in recognition of EJ issues. The updates included expanded reporting requirements for certain types of facilities (*i.e.*, ethylene oxide from sterilization facilities and chemical releases from natural gas processing facilities) and an increased number of chemicals eligible for reporting (*e.g.*, per- and polyfluoroalkyl substances [PFAS] and substances designated as high priority under TSCA). US EPA also developed goals around better communicating TRI information to affected communities through new tools and platforms (US EPA, 2021g).
- US EPA has announced series of consultation chemicals that are subject to a risk management actions under TSCA. At this point, the agency appears to be collecting input and has not indicated how EJ concerns could affect the assessments (US EPA, 2021h).[3] US EPA has also expressed interested in expanding evaluations on air emissions and water discharges from chemical manufacturing in areas with EJ concerns to other TSCA functions. According to a presentation given by Michal Freedhoff (Assistant Administrator of OCSPP) at the 2021 Product Stewardship Society Annual Meeting, US EPA will be releasing a tool (or tools) that can be used to assess chemical exposures *via* water and air in the context of TSCA assessments, with a focus on assessment of EJ-related issues. The exact nature and scope of the tool and in what circumstances it should be used have not been clarified, but there is some indication that it will be based on the current Risk Screening Environmental Indicators (RSEI) tool (see Appendix D for more information on RSEI) (*via* communication at the 2021 Product Stewardship Society Meeting, held in Anaheim, CA, on September 28-30, 2021).
- US EPA runs the SaferChoice Program, which encourages replacing more hazardous compounds with less hazardous ones in different product categories. US EPA has noted a connection between this program and EJ goals and is encouraging manufacturers and marketers to make SaferChoice products available in low-income communities. In a press release acknowledging US EPA's most valued SaferChoice partners, US EPA stated that "[a]pplicants for this year's awards were encouraged to show how their work with safer chemistry promotes environmental justice, bolsters resilience to the impacts of climate change, results in cleaner air or water, or improves drinking water quality" (US EPA, 2021i).

Compliance and enforcement actions and TSCA evaluations have seen some specific movement on integrating EJ issues into the regulatory framework. The scope of EJ consideration is likely to touch all facets of regulation. The US EPA (2016b) technical guidance was clear that proposed regulatory actions will need to address the following question: "For the regulatory option(s) under consideration, are potential EJ concerns created or mitigated compared to the baseline?"

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[3] Some examples of US EPA gathering information on EJ concerns can be found at: https://www.epa.gov/chemicals-under-tsca/pollution-prevention-and-toxics-news-stories.

An early example of an attempt to answer this question that is relevant to the chemical industry can be seen in the "Draft Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs)" (US EPA, 2021j). This report, which evaluated the economic impacts of phasing out HFCs and finding acceptable substitutes (as mandated by the American Innovation and Manufacturing [AIM] Act of 2020), included an extensive EJ analysis that examined current manufacturing conditions and implications for the use and production of alternative chemicals. Using exposure information from the RSEI tool, the National Air Toxics Assessment (NATA), and US census data, this report attempted to answer the question of whether this regulation would worsen or mitigate any existing EJ concerns. Specifically, the report combined RSEI toxicity weights for chemicals used in or released as a byproduct of HFC production with TRI information to identify facilities that released substantial quantities of chemicals with higher potential risks for cancer and non-cancer effects (US EPA, 2021j, Tables 6-6 and 6-7). Separately, the report relied on US census and NATA data to determine a) whether a greater percentage of population groups of concern (as determined by socioeconomic and demographic characteristics) live within 1 or 3 miles of an HFC production facility, and b) whether census tracts within those radii have greater cancer or respiratory risk due to air toxics exposure compared to census tracts outside those radii. The report was issued as a draft, and while there were data to suggest that a disproportionate number of Blacks or African-Americans lived in close proximity to existing HFC production facilities, and NATA data indicated the potential for an increased respiratory and cancer risk around a subset of facilities, the relationship of HFC production to health risk could not be established, nor could the potential impacts of possible chemical alternatives.

1.5 Key Literature for Environmental Justice

Gradient conducted a literature search focused on information related to the development of EJ tools, the application of EJ tools, and key information that will be used to support cumulative risk assessment methodology. We also identified key strategy and policy documents. To conduct this evaluation, we used PubMed, Scopus, Microsoft Academic, regulations.com, and Google Scholar to identify relevant information. We reviewed titles and abstracts related to EJ topics to identify relevant literature. We also reviewed the reference lists of many key EJ documents, such as US EPA (2016b), to identify literature (including books, book chapters, scientific reports, and peer-reviewed publications) to identify further relevant research. The resulting citations were then organized into the following topic areas:

- Key EJ Initiatives
- EJ Analytical Framework
- EJ Strategic Guidance Documents
- Cumulative Risk Assessment
- Risk Assessment Methodology
- Evaluated EJ Tools
- CalEnviroScreen Used or Critiqued
- US EPA EJSCREEN Used or Critiqued
- EJ Health Disparities
- Non-governmental Organization Reports
- Scientific literature on various other topics such as EJ-related variables, health risks, and health disparities

Appendix B presents the results of this literature review. Note that the literature was not comprehensive with respect to epidemiological studies that establish a relationship between EJ and health disparities. This research is voluminous and extends outside of traditional health research and into social science studies. There is also a large body of research on the intersection between chemical exposure and EJ-related variables. While we cover some of the key literature (as cited in key documents), this research would be better identified in the context of a more specific research question. One important reason for this is because many studies that examine the impact between chemicals and disease include consideration of socioeconomic status in the analysis, even when quantifying EJ impacts is not the focus of the study. It is also noteworthy that there is a large body of research examining the connection between climate change, EJ, and adverse health outcomes. This literature was not included in the search.

In addition to these documents, we also identified and reviewed the 47 public comments received by CalOEHHA as part of the public comment period following the release of the draft CalEnviroScreen version 4.0 (CalEPA and CalOEHHA, 2021). While this information is primarily discussed in Section 4 of this document, an index of these comments are provided in Appendix E, with a brief description of the contents of each document.

2 Environmental Justice: Federal EJ Tools

2.1 Overview of the EJSCREEN Tool

While efforts to incorporate cumulative risk assessment methodologies into a traditional quantitative risk framework have lagged, US EPA and several states have made significant progress in developing tools to help identify communities with possible EJ concerns. The 1994 EO (EO 12898) explicitly directed the federal agencies to "collect, maintain and analyze information assessing and comparing environmental and human health risks borne by populations identified by race, national origin or income" (Clinton, 1994). Since then, a number of different tools have been developed at the federal level – some publicly available and some used only internally at US EPA – but all coalesced around the common principle of using environmental indicators and other socioeconomic data to identify communities with possible EJ concerns.

Over the years, several public-facing tools have developed by US EPA including EJView and Community-Focused Exposure and Risk Screening Tool (C-FERST).[4] US EPA's Office of Enforcement and Compliance Assurance (OECA) also developed its own internal tool called EJSEAT, which was designed to help identify areas with possible EJ concerns using 18 select, federally recognized or managed databases, but this tool appears to have been discontinued (UNECE, 2021). Although the development of multiple tools helped refine the most effective approaches to identify communities with possible EJ Concerns, the use and maintenance of multiple tools created some level of confusion and did not efficiently leverage resources. A key goal of the EJ 2014 action plan was to develop a single, national, consistent tool that could be used where the public, regulators, and other key stakeholders could access a common dataset for evaluating possible EJ issues (US EPA, 2011). As a direct result of this plan, most of the other tools were eventually phased out and EJSCREEN was developed.

First released in 2015 and updated every year through 2022, EJSCREEN has emerged as the dominant tool used by the federal government to identify communities with EJ concerns. EJSCREEN is a publicly available mapping and screening tool developed by US EPA and is used to characterize areas based on specific demographic characteristics and indicators of environmental exposures. While EJSCREEN can be used to analyze and visualize a whole host EJ-related information, the function that is most widely used is the calculation "EJ indexes." Calculating EJ indexes involves the integration of environmental indicator data with demographic information (percent low income and percent minority). The average of these two indicators is expressed as the demographic index. The demographic index is then used in conjunction with environmental indicator data to derive an overall EJ index for each environmental indicator (see the equation below) across a census block group.[5] The population count for each census block group is also taken into account.

[4] EJView was the first publicly available web-based mapping tool that displayed demographic and environmental data; it did not include a methodology to identify a community with EJ concerns. C-FERST also allowed the user to look at a wider variety of data that may be relevant to EJ analyses (*e.g.*, NATA data for individual pollutants such as benzene; water quality monitoring data; location of and information regarding impaired water bodies; location of various facilities such as those regulated for radiation and radioactivity; and location of schools). However, C-FERST also did not include a methodology for identifying or assessing cumulative risks for EJ communities.

[5] A census *block* is the smallest unit for the tabulated data of a *full census* and is defined by visible (*e.g.*, streets) or invisible (*e.g.*, city limits) boundaries. A census *block group* is a group of census blocks (typically about 39) and each contains between 600 and 3,000 people. A census block group is the smallest unit for the tabulated data of a *survey* (*e.g.*, the American Community Survey [ACS] 5-year estimates).

EJ Index (for a Census Block Group) = (Environmental Indicator)
× (Demographic Index for Census Block Group - Demographic Index for US/Region/State)
× (Population Count for Census Block Group)

The census block group is the standard geographical unit for which an EJ index can be calculated and viewed on EJSCREEN maps. US EPA, however, notes that indices for census block groups are relatively uncertain because of their relatively small size. US EPA (2019) notes that the uncertainty can be reduced by looking at multiple census blocks or a larger geographical area using a buffer report. When using a larger area, the analysis relies on more detailed census block estimates on a per resident basis. The EJ index for a buffer analysis is calculated as the population-weighted average of the indicator values in the blocks contained in the buffer. In this analysis, each census block is assigned the indicator values associated with the larger block group.

As noted above, for the calculation of the demographic index, EJSCREEN uses measures of low income and percent minority. The specific definitions for these indicators are presented in Table 2.1. Also presented in the table are other demographic variables that can be viewed in EJSCREEN but are not used to calculate the EJ indexes.

Table 2.1 Demographic Indicators in EJSCREEN Version 2.0

Indicator	Use in EJ Index Calculation	Description (as presented in US EPA, 2019, 2022)
Low Income	Yes	The number or percent of a block group's population in households where the household income is less than or equal to twice the federal "poverty level.
Minority	Yes	The number or percent of individuals in a block group who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino. That is, all people other than non-Hispanic white-alone individuals. The word "alone" in this case indicates that the person is of a single race, since multiracial individuals are tabulated in another category – a non-Hispanic individual who is half white and half American Indian would be counted as a minority by this definition.
Unemployment Rate[6]	No	The percent of people in a block group that did not have a job at any point in the reporting period, made at least one specific active effector to find a job during the prior 4 weeks, and were available for work.
Less than a high school education	No	The number or percent of people age 25 and older in a block group who have less than a high school diploma.
Linguistic Isolation	No	The number or percent of people in a block group living in linguistically isolated households. A household in which all members age 14 years and over speak a non English language and also speak English less than "very well" (have difficulty with English) is linguistically isolated.
Individuals under age 5 and over age 64	No	The number or percent of people in a block group under the age of 5 or over age 65.

US EPA selected 12 environmental indicators to provide perspective on environmental burden, while also satisfying additional data availability and quality criteria. In particular, US EPA (2019) articulated four

[6] This is a new demographic indicator in EJSCREEN 2.0 for 2022 (US EPA, 2022a 222-6630).

criteria in the selection of environmental indicators: resolution, coverage, relevance to EJ, and public health significance. These criteria are described in more detail in Table 2.2 below.

Table 2.2 US EPA's Environmental Indicator Selection Criteria

Feature	Description
Resolution	Screening level data are available (or could be readily developed) at the block group level (or at least close to this resolution)
Coverage	Screening level data are available (or could be readily developed) for the entire United States (or with nearly complete coverage).
Relevance to EJ	Pollutants or impacts are relevant to EJ (*e.g.*, differences between groups have been indicated in exposures, susceptibility, or health endpoints associated with the exposures)
Public health significance	Pollutants or impacts are potentially important in the United States (*e.g.*, notable impacts estimated or significant concerns have been expressed, at least locally, or exposure has been linked to health endpoints with substantial impacts nationwide).

Source: US EPA (2019).

2.2 Environmental Indicators in EJSCREEN

Based on the four criteria described above, US EPA mostly selected indicators that could be analyzed with the use of existing datasets from US EPA programs, although data from the Department of Transportation and general census data were also included. The available data sources address multiple environmental media (*e.g.*, air, water) and include modeled environmental concentrations, direct estimates of risk, and more rough indicators of proximity to pollution sources or other hazards (*e.g.*, proximity to Superfund sites). Detailed information on the 12 environmental indicators used in EJSCREEN, including information on the data sources and calculation methods, are presented in Table 2.3. Table 2.4 presents a brief summary of the underlying data sources that are used to calculate the indicators. It is noteworthy, and discussed further in Section 4.3, that the indicators of environmental burden can be very broad and often represent a proxy for possible chemical exposure, but not a measured (or even modeled) exposure. For example, the presence and density of industrial sites (*e.g.*, Superfund sites, hazardous waste facilities) do not necessarily mean that a nearby community has exposure to chemicals from such facilities.

Some of the environmental indicators make an attempt to estimate a chemical-specific exposure point concentration and connect that concentration to some measure of risk. Specifically, the environmental indicators that rely on data from US EPA's AirToxScreen (*i.e.*, Air Toxics Cancer Risk, Air Toxics Respiratory Hazard Index, and Diesel PM) and US EPA's Office of Air and Radiation (*i.e.*, $PM_{2.5}$ and Ozone) have used underlying emission data to spatially estimate chemical air concentrations for about 180 chemicals (US EPA, 2022b). When possible, these estimated concentrations were expressed as a cancer or non-cancer risk. For the wastewater discharge indicator, EJSCREEN uses the analyses from the RSEI database (US EPA, 2020a). These results reflect toxicity-weighted concentrations in surface water downstream of a reported release (*i.e.*, releases based on TRI facility data). Interestingly, RSEI can also be used to determine toxicity-weighted concentrations in air, but these analyses are not used in EJSCREEN.

While some of the indicators express some form of risk, US EPA is clear that risk results from AirToxScreen (NATA in the previous version of EJSCREEN) / and RSEI are not substitutes for quantitative risk assessment. Results are better viewed for screening or in relative terms (*i.e.*, by comparing the community of interest to another community or another geographical area).

Because these tools are complex but are a central component of the EJ index, more information on NATA and RSEI is presented in Appendix D and below. It should be noted that one of the more substantive changes to EJSCREEN that occurred in the 2022 update was that data from the National Air Toxics Assessment (NATA) was superseded by the newer AirToxScreen (US EPA, 2022b, 2022c). NATA and AirToxScreen are conceptually similar in that both analyses evaluate outdoor air concentrations of hazardous air pollutants and develop screening risk estimates associated with those levels. Because of the timing of this report, a detailed review of NATA is included, but those observation are likely to extend to AirToxScreen. A more detailed review of any differences between NATA *vs*. AirToxScreen as they relate to EJSCREEN will be conducted at a later date. In the interim, a detailed discussed of NATA and its relationship to EJSCREEN and other US EPA tools is provided in this report.

Aside from the fact that RSEI accounts for surface water releases as well as air emissions, one of the key differences between the two databases is that RSEI evaluates point-source chemical releases from specific facilities (subject to TRI reporting). This allows for analyses that can be used to assess the environmental burden of a specific facility. In contrast, the NATA analysis calculates a combined chemical concentration in air across multiple emission sources (*i.e*., stationary point, point airports, point rail yards, stationary nonpoint, fires, biogenics, locomotives, commercial marine vessels, on-road, and nonroad), such that air concentration data are area- and not facility-specific. There are also differences in scope; for example, RSEI models for age- and sex-specific results, whereas NATA only models age-specific results. In addition, the results resolution for RSEI is census block level *versus* census tract level in NATA. RSEI results are released every year, whereas NATA is released every few years, and comparison between years is only possible in RSEI. In RSEI, results can "be filtered by one or more dimensions like industry, facility, chemical, year or state. Metrics are additive and comparable across any aggregations" (US EPA, 2021k). Due to differences in emission inventories submitted by state, local, and tribal agencies, NATA risk estimates are not as easily compared between states or regions. Toxicity assessment in RSEI is available for over 400 chemicals compared to 138 chemicals in NATA. NATA only estimates cancer risk and non-cancer hazards and does not use oral endpoints, such as reference dose (RfD) or oral slope factor (OSF), in its determinations. RSEI estimates a "Cancer Score," a "Non-Cancer Score," and an "RSEI Score." Like NATA, the toxicity values used to calculate cancer and non-cancer scores depend on the exposure pathway (*i.e*., inhalation unit risk [IUR] or reference concentration [RfC] is used to calculate risk-based results for the air pathway, and RfD and OSF are used to calculate risk-based results for the surface water pathway). To estimate the RSEI Score, if a chemical has no toxicity values in one exposure route, the toxicity values from the other exposure route are implemented. For example, if a chemical has no IUR or RfC, the higher toxicity weight calculated using either the RfD or OSF is used for air releases despite being oral endpoints. For a more detailed comparison of NATA and RSEI, see Appendix D. Note that information on the RSEI model for air is included, even though that function is not used in EJSCREEN. However, as noted in Section 1.4, RSEI, or some version of RSEI, may be used in future TSCA assessments to assess impacts from both air and water releases to better understand possible EJ implications of risk management decisions.

Table 2.3 Environmental Indicators in EJSCREEN Version 2.0, Their Data Sources, and Strengths/Weaknesses

Indicator	Value	Calculation Method	Data Source for Indicator[a]	Notes
Air Toxics Cancer Risk[7]	Lifetime inhalation cancer risk (cases per one million)	Value as reported in underlying source	US EPA AirToxics Data Update (2017) (Note: this source of air data replaced NATA in EJSCREEN 2.0)	▪ Based on combined information from three sources: National Emissions Inventory (NEI) data, Multipollutant Emissions Modeling Platform, and the Air Toxics Screening Assessment (AirToxScreen) ▪ NEI data are subject to uncertainty (updated every 3 years and compiled using information from US EPA, and state, local, and tribal agencies, whose data collection and presentation approaches may vary). ▪ AirToxScreen estimates are available at census-tract level, not block level, resolution, and even for the modeled results that are at the census tract level, US EPA cautions that this "approach is used only to determine geographic patterns of risks within counties, and not to pinpoint specific risk values for each census tract." (US EPA, 2022). ▪ This version of AirToxScreen estimated ambient concentrations of 180 hazardous air pollutants (HAPs) with quantitative health risk estimates provided for 127 of them. ▪ Background concentrations or ambient air are not accounted for in AirToxScreen
Air Toxics Respiratory Hazard Index[8]	Ratio of exposure concentration to health-based RfC	Value as reported in underlying source		
Diesel PM (DPM)[9]	Annual average DPM level in air, in µg/m^3	Value as reported in underlying source		

[7] This environmental indicator has new underlying source data in EJSCREEN 2.0 for 2022.
[8] This environmental indicator has new underlying source data in EJSCREEN 2.0 for 2022.
[9] This environmental indicator has new underlying source data in EJSCREEN 2.0 for 2022.

Indicator	Value	Calculation Method	Data Source for Indicator[a]	Notes
Particulate Matter ($PM_{2.5}$)	Annual average $PM_{2.5}$ levels in air, in $\mu g/m^3$	Value as reported in underlying source	US EPA Office of Air and Radiation monitoring data and modeling (2018)	▪ Relies on available air monitoring data with additional modeling (from Fused Air Quality Surface Using Downscaling (FAQSD) Files. ▪ Ambient $PM_{2.5}$ concentration is estimated by US EPA's Office of Research and Development using a Bayesian space-time downscaling fusion model approach. ▪ Limited geographic coverage (there are no results for Alaska or Hawaii, due to a lack of Community Multiscale Air Quality Modelling System[CMAQ] modeling for those states). ▪ Data are available at census-tract-level resolution, but it is difficult to estimate block-level concentrations for small blocks (*i.e.*, 1 sq. km). ▪ US EPA notes that the downscaling method is particularly strong for this indicator, as it estimates concentration at a specified point instead of as the average of a larger grid cell. ▪ Some small areas have used the high-resolution AERMOD model to estimate $PM_{2.5}$ concentrations; this method is not yet feasible for the entire US. ▪ It is important to note that the downscaling methods here do not describe all local variations in concentration. Rather, they find some additional variation that cannot be obtained from models or monitors alone. ▪ Additional data may be available from urban centers, which can be used for more refined estimates.
Ozone	Summer (May-September) average of daily maximum 8-hour concentrations of ozone in air, in ppb	Value as reported in underlying source		

Indicator	Value	Calculation Method	Data Source for Indicator[a]	Notes
Lead Paint Indicator	Percentage of occupied housing units built before 1960	Value as reported in underlying source	US Census/American Community Survey (ACS) data (data from 2015-2019; retrieved 2021)	▪ ACS survey has more limited data than the full US census. ▪ There is some debate over the use of 1960 *vs*. 1940 as the appropriate cutoff indicator for lead paint in houses. However, a cutoff of 1960 is consistent with US EPA lead paint-based data as well as window sill lead dust models. ▪ It is important to note that the presence of older housing on its own does not represent any exposure or risk. However, housing built before 1960 was 9 times as likely to have a significant lead-based paint hazard compared with housing built from 1960-1977. Among those with children, housing built before 1960 was 16 times as likely to pose a significant lead-based paint hazard.
Traffic Proximity and Volume	Population-weighted count of vehicles (average annual daily traffic) at major roads within 500 m of each census block centroid, divided by distance in meters and presented as a population-weighted average of blocks in each block group	Traffic Proximity is calculated by taking average annual daily traffic at major roads within 500 m of each census block centroid, divided by distance in meters and presented as a population-weighted average of blocks in each block group	US Department of Transportation (US DOT) 2019 traffic data (retrieved 2021)	▪ Cited epidemiological studies provide rationale for distance range (0-500 m). ▪ Closest traffic is given more weight to reflect evidence of higher toxics concentrations and epidemiological effects at shorter distances from sources. ▪ Focuses only on residential exposure; exposure may occur at work, school, during commute, *etc*. ▪ Does not account for wind direction and speed. ▪ More information on the Highway Performance Monitoring System can be found at http://fhwa.dot.gov/policyinformation/hpms.cfm

Indicator	Value	Calculation Method	Data Source for Indicator[a]	Notes
Wastewater Discharge (Stream Proximity and Toxicity-Weighted Concentration)	Population-weighted average RSEI modeled toxic concentrations at stream segments	Based on TRI chemical release data, RSEI model calculates weighted in-stream concentrations of chemicals. EJSCREEN then calculates these in-stream concentrations within 500 m of each census block centroid, divided by distance in kilometers and presented as a population-weighted average of blocks in each block group	Calculated from RSEI modeled toxicity-weighted stream concentrations (2021)	▪ Modeled toxicity-weighted concentrations (from TRI and POTW discharges). ▪ These modeled toxicity-weighted concentrations replaced the distance-weighted proximity indicator in the 2018 version of EJSCREEN (previously used in the 2015 version). ▪ Takes into account dilution in the stream and gives greater weight to downstream communities. ▪ Gives greater weight to releases of highly toxic chemicals through the calculation of toxicity weighting factors. ▪ No data are available for Alaska. ▪ Uses local information from RSEI Version 2.3.7 ▪ More information on RSEI modeling and output is presented in Appendix D.
Proximity to RMP Sites	Population-weighted count of RMP (potential chemical accident management plan) facilities	The proximity function is as follows: f(d) = 1/d, where d is the distance (km) from a block's centroid to the location of a facility within 5 km of the average resident in a block's centroid (or nearest one beyond 5 km), each divided by distance in kilometers	US EPA RMP database (2021)	▪ Tries to capture potential exposures from potential accidental releases. ▪ Does not take into account any additional details about the facilities (*e.g.*, compliance record). ▪ Radius of 5 km chosen to capture "the great majority of facilities or sites that could have a significant impact on local residents" (US EPA, 2017). ▪ Uses inverse distance weighting to account for the fact that impacts may be small for larger distances (>4 km). ▪ Does not take into account any additional details about the facilities/sites.
Proximity to Treatment, Storage and Disposal Facilities (TSDFs)	Population-weighted count of TSDFs (hazardous waste [TSDFs])	Proximity is calculated as f = 1/d, as above	TSDF data calculated from US EPA RCRAInfo database (2021)	▪ As with each of the proximity-based indicators, proximity alone may not represent any actual risk or exposure. ▪ The point data to show facility locations in "Map Supplementary Layers" is updated more often than the

Indicator	Value	Calculation Method	Data Source for Indicator[a]	Notes
Proximity to NPL Sites	Population-weighted count of proposed and listed NPL sites. within 5 km (or nearest one beyond 5 km) of a block's centroid, each divided by distance in kilometers and presented as population-weighted average of blocks in each block group	Proximity is calculated as f = 1/d, as above	US EPA CERCLIS database (2021)	database; sometimes (rarely) a facility may be in one data source but not in the other. ▪ Total of 20,368 RMP facilities were included in this version of EJSCREEN. ▪ Total of 17,306 TSDF facilities included. ▪ Total of 1,387 proposed and listed NPL sites included.
Underground Storage Tanks (UST) and Leaking UST (LUST)	Count of LUSTs and USTs within a 1,500-foot buffered block group	Based on UST and LUST data, EJSCREEN adds the number of USTs plus the number of LUSTs (multiplied by a factor of 7.7) for each census block.	EPA UST Finder (2021)	▪ Value and calculation method are not discussed in the currently available EJSCREEN Technical Document on the US EPA website – document has not been updated ▪ Census blocks are classified within EJScreen by national percentiles of USTs (less than 50%, 50-60%, 60-70%, 70-80%, 80-90%, 90-95%, and 95-100%)

Notes:
CERCLIS = Comprehensive Environmental Response, Compensation, and Liability Information System; LUST = Leaking Underground Storage Tank; NATA = National Air Toxics Assessment; NPL = National Priorities List; PM = Particulate Matter; $PM_{2.5}$ = Particulate Matter with Particle Size ≤2.5 µm in Diameter; POTW = Publicly Owned Treatment Works; ppb = Parts Per Billion; RCRA = Resource Conservation and Recovery Act; RfC = Reference Concentration; RMP = Risk Management Plan; RSEI = Risk Screening Environmental Indicators; TRI = Toxics Release Inventory; US EPA = United States Environmental Protection Agency; UST = Underground Storage Tank.
(a) Data sources were compiled from the latest available EJSCREEN documentation (US EPA, 2019) and the US EPA website for EJSCREEN (US EPA, 2020b, 2022a, 2022d).

Table 2.4 Key Data Sources Used in EJSCREEN

Data Source	Description	Reference
American Community Survey (ACS) 5-year Data	▪ Used for demographic indicators ▪ The ACS is an ongoing survey that provides information typically contained in the 10-year full US census on a yearly basis. ▪ Data for the ACS are collected *via* a survey sent to a subset of the US population (~3.5 million/year). ▪ Each year, the data for the previous 5 years are averaged and released at a census-block-group resolution.	**Homepage:** https://www.census.gov/programs-surveys/acs
US EPA Air Toxics Screening Assessment (AirToxScreen)	▪ AirToxScreen replaced US EPA's National Air Toxics Assessment (NATA) data in 2022. ▪ AirToxScreen datasets include concentrations and associated risks for various air toxics at the census-tract level. ▪ AirToxScreen air concentrations are calculated from air quality models (*i.e.*, AERMOD and CMAQ), meteorological data, and data from the National Emissions Inventory for point, nonpoint and mobile sources, and fires, as well as biogenic sources.	**Homepage:** https://www.epa.gov/AirToxScreen **Limitations:** https://www.epa.gov/AirToxScreen/airtoxscreen-limitations
US EPA National Air Toxics Assessment (NATA) (Note: This data source was retired by US EPA and replaced with AirToxScreen in 2022)	▪ NATA is an ongoing review of air toxics in the US. ▪ NATA datasets include concentrations and associated risks for various air toxics at the census-tract level. ▪ NATA air concentrations are calculated from air quality models and data from the National Emissions Inventory for stationary sources, on-road and non-road mobile sources, fires, as well as biogenic sources.	**Homepage:** https://www.epa.gov/national-air-toxics-assessment **Limitations:** https://www.epa.gov/national-air-toxics-assessment/nata-limitations

Data Source	Description	Reference
US EPA Office of the Air and Radiation (OAR)	▪ As part of its role in developing regulations for controlling air pollution, US EPA OAR compiles and reviews air pollution data and makes this information available to the public. ▪ US EPA OAR provides information on criteria pollutants such as ozone and $PM_{2.5}$ tabulated from public monitoring data, air modeling (*i.e.*, the Community Multiscale Air Quality Modelling System [CMAQ]), and a fusion model that combines the monitoring data and the model estimates.	**General Information:** https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information **Data for EJSCREEN:** https://www.epa.gov/green-book/green-book-pm-25-2012-area-information; https://www.epa.gov/hesc/rsig-related-downloadable-data-files
United States Department of Transportation (US DOT)	▪ US DOT maintains annual average daily traffic estimates collected from state traffic counts in its Highway Performance Monitoring System. ▪ EJSCREEN uses road traffic count data to estimate, for each census block, the distance-weighted average annual daily traffic within a 500 m radius .	**US DOT Shapefiles:** https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm
Risk Screening Environmental Indicators (RSEI)	▪ Under the RSEI program, US EPA takes data from the Toxics Release Inventory and combines them with modeling and information about chemicals' fate and transport to estimate toxicity-weighted concentrations in stream segments downstream of a discharge point. ▪ The 2018 version of EJSCREEN employs these toxicity-weighted concentrations in its "proximity to water discharges" indicator, replacing the previous distance-based approach used in the 2015 version.	**General Information:** https://www.epa.gov/rsei
US EPA Risk Management Plan (RMP) Database	▪ Database of facilities required to file an RMP with US EPA. Under the Clean Air Act, facilities must file an RMP with US EPA if they maintain certain high-toxicity, high-flammability, or high-explosive-potential substances above certain thresholds.	**RMP Program:** https://www.epa.gov/rmp/risk-management-plan-rmp-rule-overview **Data Source:** https://www.epa.gov/frs/frs-query
US EPA CERCLIS Database	▪ List of National Priorities List (NPL) sites (a subset of all Superfund sites) available from the Superfund Enterprise Management System (SEMS) database.	**SEMS Database:** https://www.epa.gov/enviro/sems-search

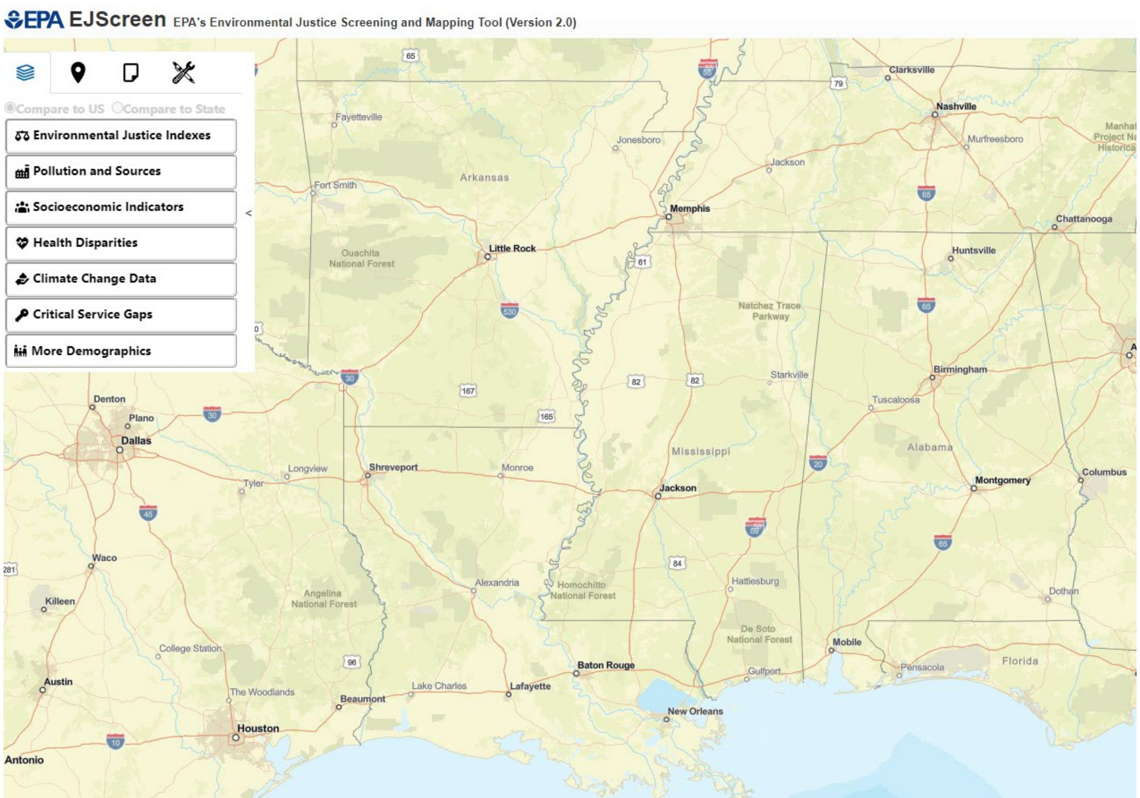
Data Source	Description	Reference
US EPA Biennial Hazardous Waste Report	▪ US EPA requires facilities considered to be large quantity generators (LQGs) of hazardous waste to submit a "Biennial Hazardous Waste Report" every two years that describes the types, amounts, and any treatment, storage, recycling and/or disposal protocols for hazardous waste generated at the facility.	**Report:** https://www.epa.gov/hwgenerators/biennial-hazardous-waste-report
US EPA Underground Storage Tanks (UST) Finder	▪ This database contains locations of and additional information on underground storage tanks (USTs) and leaking USTs from states, Tribal lands, and US territories.	**UST Finder:** https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=b03763d3f2754461adf86f121345d7bc
US EPA RCRAInfo Database	▪ This database contains locations of and additional information on active treatment, storage, and disposal facilities (TSDFs).	**RCRAInfo Database:** https://www3.epa.gov/enviro/facts/rcrainfo/search.html

Notes:
CERCLIS = Comprehensive Environmental Response, Compensation, and Liability Information System; $PM_{2.5}$ = Particulate Matter with Particle Size ≤2.5 µm in Diameter; RCRA = Resource Conservation and Recovery Act; US EPA = United States Environmental Protection Agency; UST = Underground Storage Tank.

2.3 EJ Screen Inputs and Outputs

EJSCREEN was designed to be applicable and accessible to all interested stakeholders, including regulators, community organizers, industry, and the public. Because of this, EJSCREEN is relatively user friendly and offers a range of evaluation and output options for viewing and analyzing results. Different outputs will better inform different research questions. Below are some screenshots related to the input and output for calculating EJ indexes for different environmental indicators. This is the function that will likely guide the application of EJSCREEN in a regulatory setting.

The EJSCREEN user interface allows the user to either select a specific location using a specific address, including city/town and ZIP code, or census block group number (Figure 2.1). When a specific location is selected, the default characterization is for a population in a one-mile radius. The user may also select a location based on a user-defined point, shape, or polygon. A larger area that covers more than one census block group is called a buffer report. A buffer report characterizes the average individual living in the selected area.



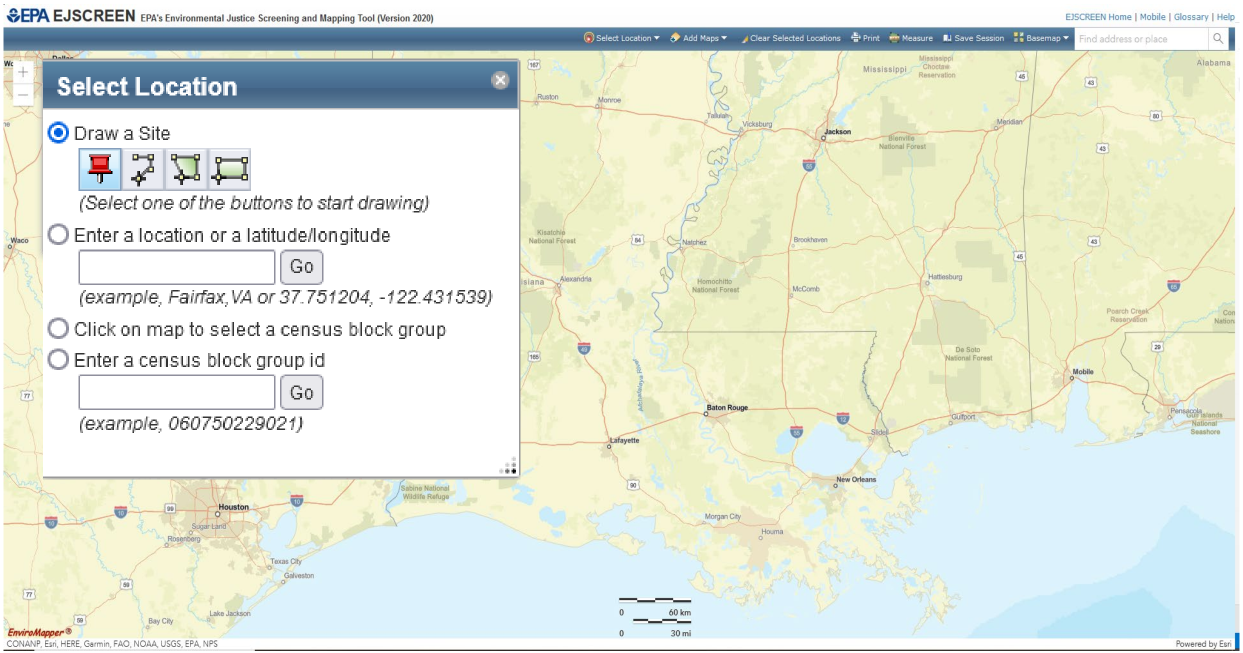


Figure 2.1 EJSCREEN Location Selection. (*Note: See Section 2.6 and Figured 2.9 and 2.10 for an updated example of this process in EJSCREEN 2.0*). Source: US EPA (2020b. https://ejscreen.epa.gov/mapper/).

The example below in Figure 2.2 shows a user-defined area (green box) surrounded by a user-defined buffer (yellow buffer surrounding green box). Buffer areas are selected to decrease uncertainty that can occur when small areas are evaluated. At the left of the screen, EJSCREEN provides a selector box for the environmental indicators. (See more detail in Figure 2.3).

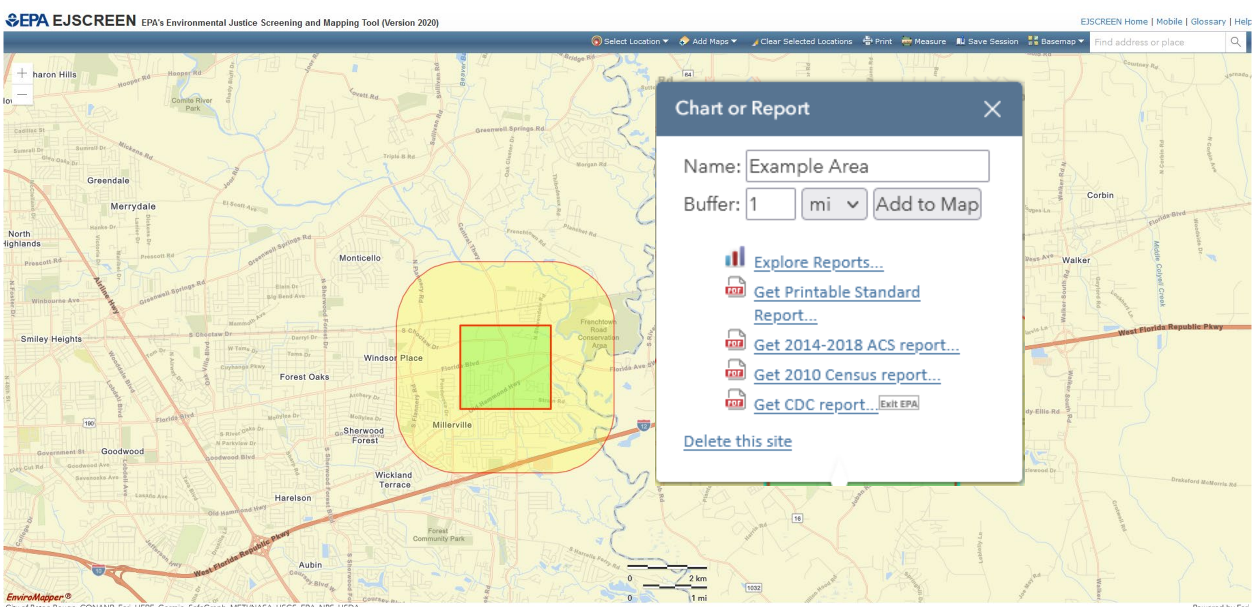


Figure 2.2 Selected Location and Buffer for Example Area. (*Note: See Section 2.6 and Figured 2.9 and 2.10 for an updated example of this process in EJSCREEN 2.0*) Source US EPA (2020b. https://ejscreen.epa.gov/mapper/).

Selection options for reports include a report for the environmental indicators raw data (12 variables), demographic indicators raw data (7 variables), and calculated EJ indexes (12 variables).

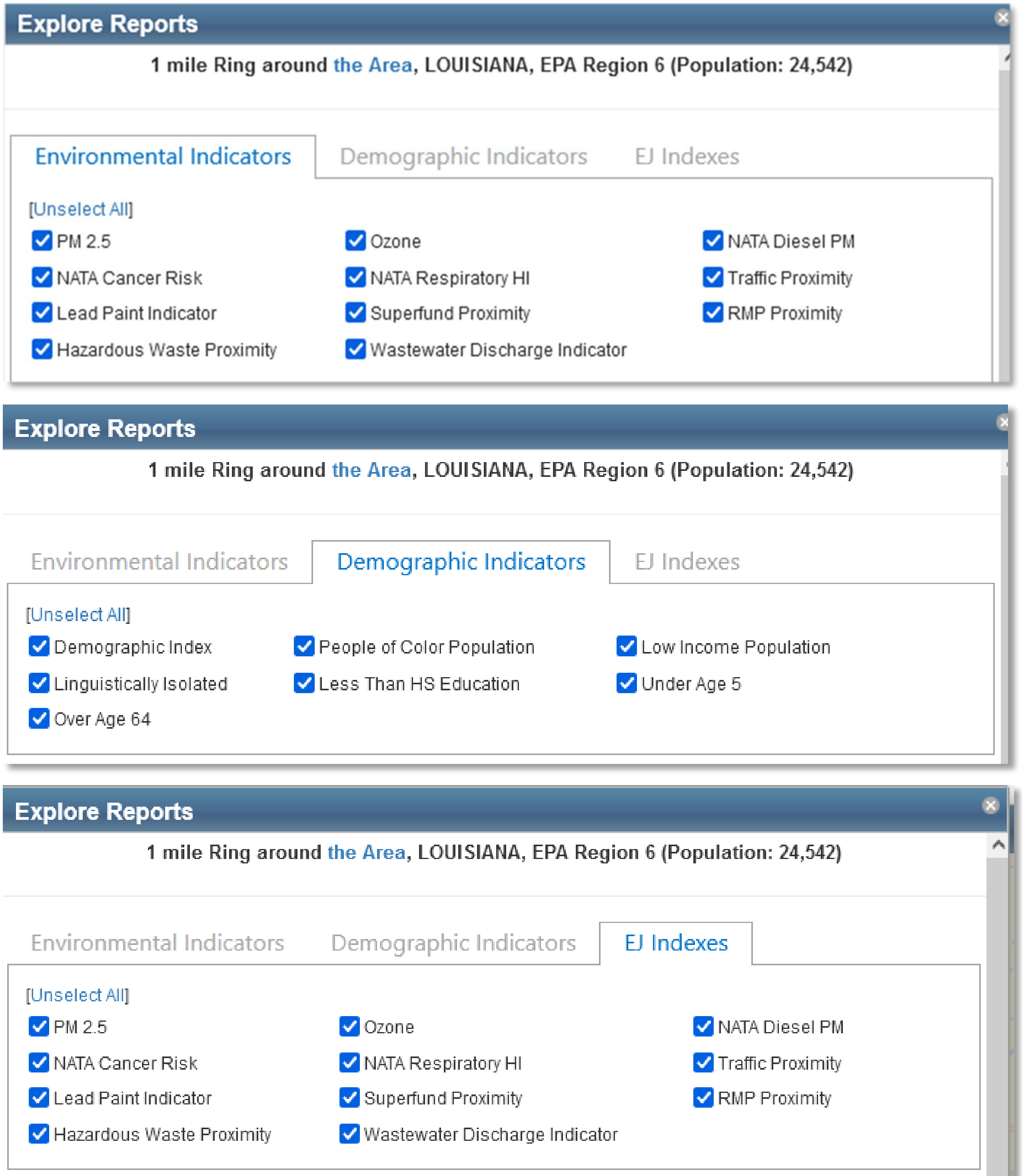


Figure 2.3 EJSCREEN Indicator Selection Options. Source: US EPA (2020b. https://ejscreen.epa.gov/mapper/).

The full report output is displayed below in Figures 2.4a-c.

EJSCREEN Report (Version 2020)

City: Jackson

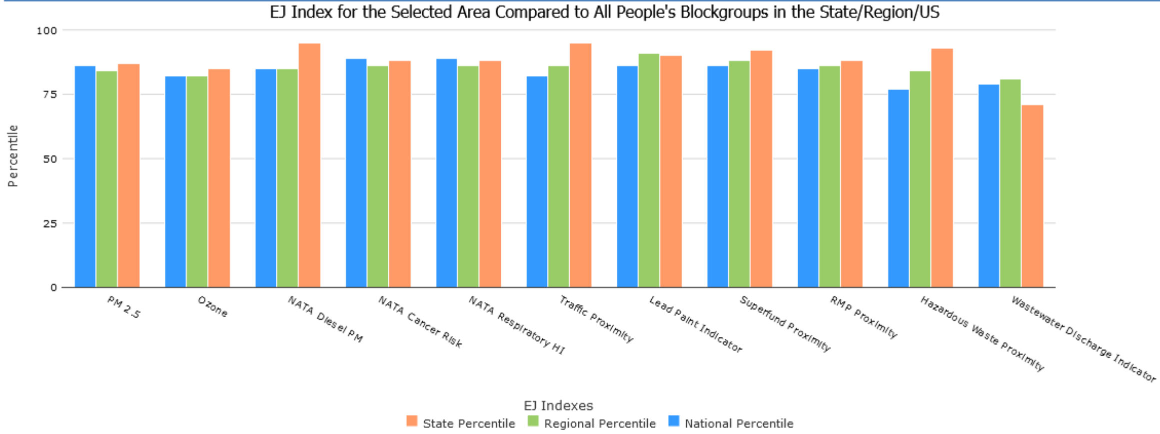
MISSISSIPPI, EPA Region 4

Approximate Population: 168,730

Input Area (sq. miles): 113.23

Selected Variables	Percentile in State	Percentile in EPA Region	Percentile in USA
EJ Indexes			
EJ Index for Particulate Matter (PM 2.5)	87	84	86
EJ Index for Ozone	85	82	82
EJ Index for NATA* Diesel PM	95	85	85
EJ Index for NATA* Air Toxics Cancer Risk	88	86	89
EJ Index for NATA* Respiratory Hazard Index	88	86	89
EJ Index for Traffic Proximity and Volume	95	86	82
EJ Index for Lead Paint Indicator	90	91	86
EJ Index for Superfund Proximity	92	88	86
EJ Index for RMP Proximity	88	86	85
EJ Index for Hazardous Waste Proximity	93	84	77
EJ Index for Wastewater Discharge Indicator	71	81	79

EJ Index for the Selected Area Compared to All People's Blockgroups in the State/Region/US



This report shows the values for environmental and demographic indicators and EJSCREEN indexes. It shows environmental and demographic raw data (e.g., the estimated concentration of ozone in the air), and also shows what percentile each raw data value represents. These percentiles provide perspective on how the selected block group or buffer area compares to the entire state, EPA region, or nation. For example, if a given location is at the 95th percentile nationwide, this means that only 5 percent of the US population has a higher block group value than the average person in the location being analyzed. The years for which the data are available, and the methods used, vary across these indicators. Important caveats and uncertainties apply to this screening-level information, so it is essential to understand the limitations on appropriate interpretations and applications of these indicators. Please see EJSCREEN documentation for discussion of these issues before using reports.

Figure 2.4a EJSCREEN Output for Each EJ Index. Bar chart and table of results are compared to state, regional, and national information.

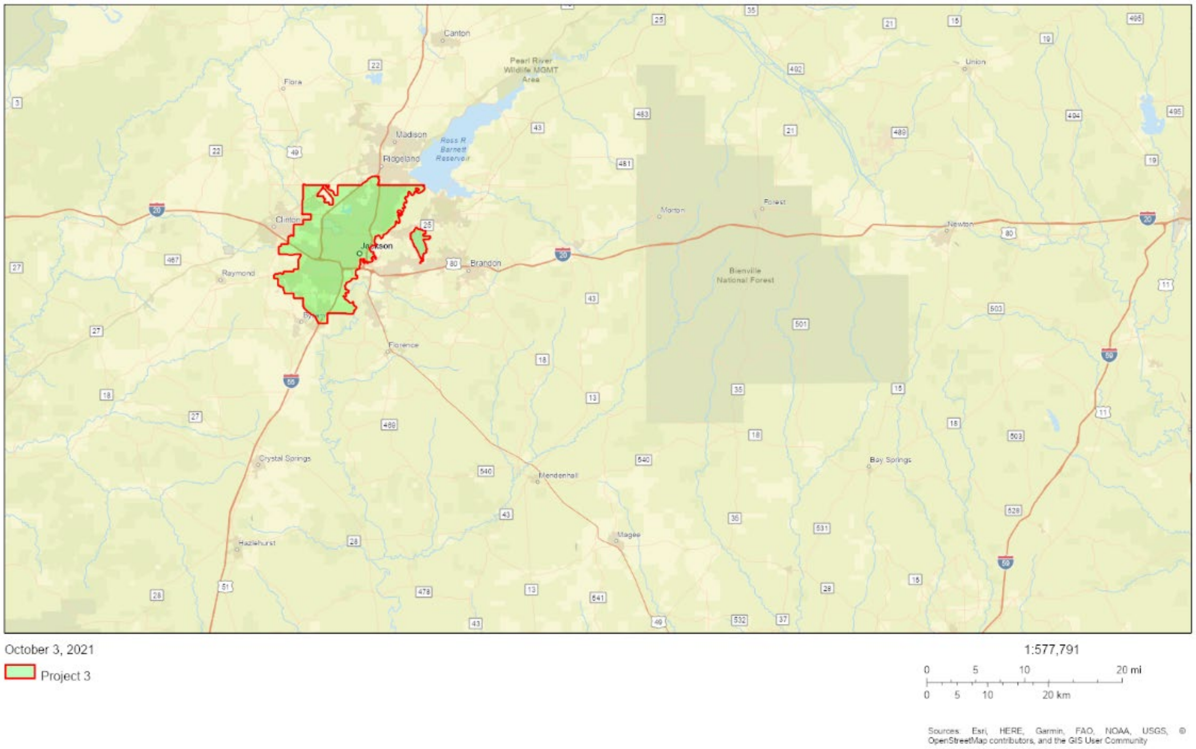


Figure 2.4b EJSCREEN Output for Selected Location. Map of the user-defined area.

Sites reporting to EPA	
Superfund NPL	0
Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)	10

Selected Variables	Value	State		EPA Region		USA	
		Avg.	%tile	Avg.	%tile	Avg.	%tile
Environmental Indicators							
Particulate Matter (PM 2.5 in µg/m³)	9.63	8.89	94	8.57	91	8.55	84
Ozone (ppb)	35.7	36.1	53	38	36	42.9	12
NATA* Diesel PM (µg/m³)	0.571	0.263	97	0.417	70-80th	0.478	70-80th
NATA* Air Toxics Cancer Risk (risk per MM)	46	39	96	36	90-95th	32	95-100th
NATA* Respiratory Hazard Index	0.65	0.56	91	0.52	90-95th	0.44	90-95th
Traffic Proximity and Volume (daily traffic count/distance to road)	430	120	93	350	78	750	65
Lead Paint Indicator (% pre-1960s housing)	0.31	0.15	87	0.15	85	0.28	63
Superfund Proximity (site count/km distance)	0.12	0.064	88	0.083	82	0.13	71
RMP Proximity (facility count/km distance)	0.76	0.54	81	0.6	75	0.74	69
Hazardous Waste Proximity (facility count/km distance)	1.4	0.46	90	0.91	79	5	57
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	3.3E-05	0.014	50	0.65	58	9.4	49
Demographic Indicators							
Demographic Index	68%	43%	81	37%	88	36%	88
People of Color Population	84%	43%	86	39%	88	39%	86
Low Income Population	51%	43%	64	36%	76	33%	80
Linguistically Isolated Population	0%	1%	80	3%	51	4%	45
Population with Less Than High School Education	14%	16%	47	13%	62	13%	67
Population under Age 5	7%	6%	64	6%	68	6%	66
Population over Age 64	12%	15%	35	17%	35	15%	39

*The National-Scale Air Toxics Assessment (NATA) is EPA's ongoing, comprehensive evaluation of air toxics in the United States. EPA developed the NATA to prioritize air toxics, emission sources, and locations of interest for further study. It is important to remember that NATA provides broad estimates of health risks over geographic areas of the country, not definitive risks to specific individuals or locations. More information on the NATA analysis can be found at: https://www.epa.gov/national-air-toxics-assessment.

For additional information, see: www.epa.gov/environmentaljustice

EJSCREEN is a screening tool for pre-decisional use only. It can help identify areas that may warrant additional consideration, analysis, or outreach. It does not provide a basis for decision-making, but it may help identify potential areas of EJ concern. Users should keep in mind that screening tools are subject to substantial uncertainty in their demographic and environmental data, particularly when looking at small geographic areas. Important caveats and uncertainties apply to this screening-level information, so it is essential to understand the limitations on appropriate interpretations and applications of these indicators. Please see EJSCREEN documentation for discussion of these issues before using reports. This screening tool does not provide data on every environmental impact and demographic factor that may be relevant to a particular location. EJSCREEN outputs should be supplemented with additional information and local knowledge before taking any action to address potential EJ concerns.

Figure 2.4c EJSCREEN Output for Raw Data for Environmental and Demographic Indicators. Results are presented separately for each EJ indicator, with the percentile for each indicator relative to state, regional, and national data.

2.4 Raw Data and the Example Calculation

This section provide some further insight into how the EJ indexes are and resulting percentiles are calculated.

2.4.1 Census Block Group Calculation

In this example (Figure 2.5), Blockgroup: 450570102004 is selected. This is an area in South Carolina in US EPA Region 4 with a population of 1,875. The census block group is the smallest unit that can be analyzed in EJSCREEN.

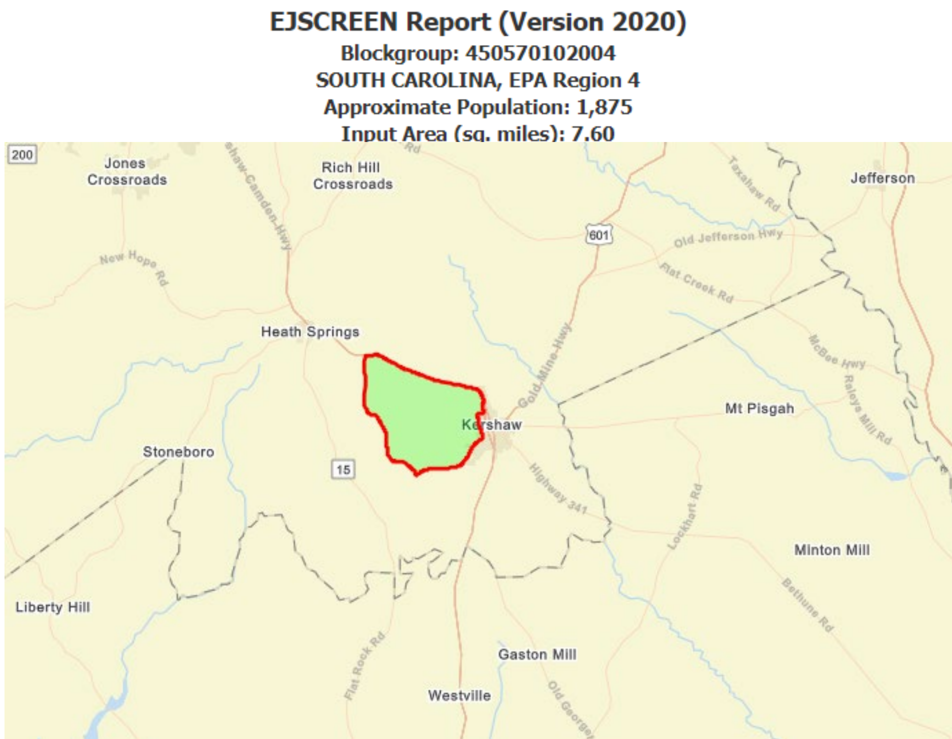


Figure 2.5 Example Raw Data and Calculation Location. Note: The raw data for this area are shown below in Figure 2.6.

Selected Variables	Value	State Avg.	%ile in State	EPA Region Avg.	%ile in EPA Region	USA Avg.	%ile in USA
Environmental Indicators							
Particulate Matter (PM 2.5 in $\mu g/m^3$)	8.08	8.51	20	8.57	25	8.55	33
Ozone (ppb)	41	39.1	69	38	61	42.9	35
NATA* Diesel PM ($\mu g/m^3$)	0.164	0.308	12	0.417	<50th	0.478	<50th
NATA* Cancer Risk (lifetime risk per million)	34	38	19	36	<50th	32	60-70th
NATA* Respiratory Hazard Index	0.48	0.53	18	0.52	<50th	0.44	60-70th
Traffic Proximity and Volume (daily traffic count/distance to road)	25	180	31	350	24	750	17
Lead Paint Indicator (% Pre-1960 Housing)	0.28	0.14	85	0.15	83	0.28	61
Superfund Proximity (site count/km distance)	0.048	0.094	45	0.083	57	0.13	40
RMP Proximity (facility count/km distance)	0.11	0.46	22	0.6	21	0.74	16
Hazardous Waste Proximity (facility count/km distance)	0.36	0.62	57	0.91	50	5	34
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	7.3E-05	0.38	47	0.65	62	9.4	52
Demographic Indicators							
Demographic Index	42%	36%	66	37%	64	36%	66
People of Color Population	34%	36%	55	39%	53	39%	53
Low Income Population	51%	36%	75	36%	75	33%	80
Linguistically Isolated Population	0%	1%	62	3%	51	4%	45
Population With Less Than High School Education	26%	13%	88	13%	87	13%	86
Population Under 5 years of age	7%	6%	69	6%	69	6%	66
Population over 64 years of age	6%	17%	5	17%	7	15%	10

Figure 2.6 Example Raw Data and Percentiles

As noted in Section 4.1, the EJ index for each environmental indicator is calculated using the following equation:

EJ Index (for a Census Block Group) = (Environmental Indicator)
× (Demographic Index for Census Block Group - Demographic Index for US/Region/State)
× (Population Count for Census Block Group)

The first step to calculating the EJ index is to calculate the census block group-specific demographic index. The demographic index is calculated as follows:

Demographic Index = (% minority + % low-income) ÷ 2

Thus, for the area above, the demographic index is:

Demographic Index for Census Block Group = (34% + 51%) ÷ 2 = 42% (see blue circle in Figure 2.6)

The demographic index for the US is 36% (see purple circle in Figure 2.6).[10]

With this information, the EJ index for each environmental variable can be calculated. An example with particulate matter ($PM_{2.5}$ in $\mu g/m^3$) in relation to the US is shown below. The particulate matter raw value is 8.08, which falls into the 33rd percentile nationally (green circles in Figure 2.6):

EJ Index = (Particulate Matter [8.08]
× (Demographic Index for Area [42%] - Demographic Index for US [36%])
× (Population Count for Census Block Group [1, 875])
EJ Index = 909

[10] Note that the EJSCREEN technical guidance states, repeatedly, that the US national demographic index is approximately 35%.

The value is a positive value, which means the selected census block group demographic index is above the US average. If the census block group demographic index were below the national demographic index, the value would be negative. Note that the EJ index value is not reported in individual reports. These values are compared to state, regional, and national distributions of the EJ indices to generate a relative percentile. The raw distribution tables and associated percentiles for each environmental indicator assigned to calculated values (such as in buffer reports) are compared to national, region-specific, and state-specific lookup tables.

In the example above, the raw particulate matter value of 8.08 is at the 33rd percentile compared to the US (green circles, Figure 2.6), and the demographic index is at the 66th percentile compared to the US (red circle, Figure 2.6). Based on this, the EJ index for particulate matter ($PM_{2.5}$) is at the 67th percentile (see purple circle, Figure 2.7, below). This example shows how a higher demographic index percentile shifted the particulate matter raw percentile data of 33 to a higher EJ index percentile of 67.

Selected Variables	State Percentile	EPA Region Percentile	USA Percentile
EJ Indexes			
EJ Index for PM2.5	68	64	67
EJ Index for Ozone	69	65	67
EJ Index for NATA* Diesel PM	64	60	63
EJ Index for NATA* Air Toxics Cancer Risk	67	64	68
EJ Index for NATA* Respiratory Hazard Index	67	64	68
EJ Index for Traffic Proximity and Volume	68	61	62
EJ Index for Lead Paint Indicator	81	80	76
EJ Index for Superfund Proximity	71	69	68
EJ Index for RMP Proximity	64	61	63
EJ Index for Hazardous Waste Proximity	73	67	65
EJ Index for Wastewater Discharge Indicator	74	81	79

Figure 2.7 Example EJ Index Results

2.5 Application of EJSCREEN Results

The application of EJSCREEN for addressing EJ issues is a developing practice, and at present, US EPA is more prescriptive on how EJSCREEN should not be used than how it should be used. According to documentation from multiple sources, US EPA provides the following caveats for using EJSCREEN (US EPA, 2019, 2021l):

- As noted in its name, EJSCREEN is a screening tool and should not be used in isolation to conclude that a community has EJ concerns or as the sole basis for any regulatory determinations. Instead, EJSCREEN should be used to identify communities that may warrant further investigation.
- Environmental indicators results should not be used as quantitative risk estimates. Most of the indictors are screening-level proxies for actual exposure and/or risk.
- There is significant uncertainty in the underlying data, particularly when results are applied to a small geographic area (*e.g.*, a single census block group). Expanding the area of analysis to include "buffer communities" will help to reduce uncertainty.
- Even for those indicators that are based on a more refined assessment of exposure, the data may not reflect current conditions.

- EJSCREEN should not be used to label/categorize a location and an EJ community.
- The environmental indicators are not meant to capture all possible environmental issues; a community may have specific chemical exposure concerns that will not be reflected in the environmental indicator data.

With these caveats in mind, US EPA has articulated that the general purpose of EJSCREEN is to help "highlight geographic areas and the extent to which they may be candidates for further review, including additional consideration, analysis or outreach" (US EPA, 2019). US EPA has further specified that the further analysis may be related to permitting, enforcement, and compliance actions (US EPA, 2018b). It has also suggested that EJSCREEN can be used to "to support educational programs, grant writing, community awareness efforts, and other purposes" (US EPA, 2018b). As noted above US EPA has been clear that the tool should not be used to label a community as an EJ community, but it is noteworthy that US EPA has suggested that results that fall in the 80th percentile may be a good "starting point of identifying geographic areas in the United States that may warrant further consideration, analysis, or outreach" (US EPA, 2016b).

A role for EJSCREEN in a regulatory initiatives has been recently re-affirmed by US EPA and the White House. A recent memorandum (US EPA, 2021b) issued by US EPA's OECA specially noted that EJSCREEN is an important tool to increase engagement with communities about enforcements issues. The memorandum also mentioned the use of "offsite compliance monitoring tools" to "strengthen enforcement in overburdened communities by resolving environmental noncompliance through remedies with tangible benefits for the communities." Although EJSCREEN was not specifically mentioned in this context in this memorandum, it is easy to envision a role for EJSCREEN in helping to determine whether a community is overburdened and for prioritizing enforcement actions. In fact, in a subsequent memorandum released on July 1, 2021 (US EPA, 2021e), EJSCREEN was specifically mentioned as an important facet in identifying communities that could benefit from clean-up enforcement action (specifically CERCLA and RCRA issues). More information on this memorandum and possible implications for the chemical industry is addressed in Section 1.4. A role for EJSCREEN in compliance was one of the few specific applications for EJSCREEN mentioned in US EPA's (draft) 2022-2026 strategic plan (US EPA, 2021c). Specifically, the strategic plan put forth goals to use EJSCREEN to identify communities where they can strengthen enforcement by:

- Preventing further pollution due to noncompliance, mitigating past impacts from pollution, and securing penalties to recapture economic benefit of noncompliance and deter future violations.
- Seeking early and innovative relief (*e.g.*, fenceline monitoring and transparency tools).
- Incorporating Supplemental Environmental Projects (SEPs) in settlements, where appropriate and to the extent permitted by law and policy.
- Seeking restitution for victims of environmental crimes.

As noted above, how EJSCREEN will be applied in regulatory contexts is developing. This developing nature of the application of EJSCREEN is evident in US EPA's most recent strategic plan, which states that a key part of addressing issues of "disproportionality" is to "ensure that all US EPA programs develop guidance on using EJ tools such as EJSCREEN to support their decision-making.

Although EJSCREEN is not yet widely used, below are some examples of how US EPA (and other entities) has used EJSCREEN. Interestingly, most of the applications have been restricted to the use of demographic indicators, without any further consideration of how environmental indicators relate to the demographic findings (*i.e.*, EJ indexes were not used). Example EJSCREEN applications include the following:

- In support of the Clean Power Plan Rule, which established guidelines for reducing carbon dioxide emissions, US EPA conducted an analysis of populations living with 3 miles of existing fossil fuel-fired electric power plants using demographic information from EJSCREEN. It determined that the percentage of low-income/minority populations living within 3 miles of these power plants was greater than national averages. This result was used to support the adoption of the rule by providing support that there would be a reduction in adverse health impacts (from non-carbon dioxide emissions) for low-income and minority communities in closest proximity to power plants (US EPA, 2016b).
- In July 2021, US EPA released the Power Plants and Neighboring Communities mapping tool , which is an interactive, web-based tool that leverages EJSCREEN demographic indicators to provide perspective on the types of communities living with 3 miles of power plants, with a specific emphasis on understanding if these plants were disproportionately located in communities with possible EJ concerns.
- In September 2021, US EPA and DOJ announced that they will be releasing a revised model agreement to be used by potentially responsible parties (PRPs) in reaching agreements for Superfund clean-up (US EPA, 2021m). The revised model agreement will include provisions for increased public engagement and will include information from EJSCREEN to be provided to the public.
- The North Carolina Department of Environmental Quality (NCDEQ) has used EJSCREEN (and other datasets) in the context of evaluating permitting for coal ash disposal activities. The analyses are conducted to determine if the proposed permitted facilities (and transportation routes associated with disposal) will cause a disproportionate impact to low-socioeconomic status/minority communities (note that other factors are also considered). The analysis seems to be mainly used to determine if the facilities will disproportionally impact low-income and minority populations and, if so, what additional action should be taken (see NCDEQ's "Environmental Justice Reports").
- In its 2022-2026 strategic plan (US EPA, 2021n), US EPA notes a specific role for EJSCREEN in identifying vulnerable communities with leaking underground storage tanks. EJSCREEN would be used to identify communities where clean-ups should be prioritized.

Although EJSCREEN has not been used specifically on the federal level to support rulemaking, US EPA (2016b) presented several examples of existing or proposed regulations that have considered EJ issues using census and geospatial information, similar to some of the information that is available in EJSCREEN. Notably, there is very little consistency among the analyses, in terms of the data sources, indicators, and application of results. Moreover, each proposed regulation required information that was very specific to the proposed rule and included endpoints that would not necessarily be captured in EJSCREEN. This highlights that US EPA's stated goal to integrate EJSCREEN into the federal rule decision-making is a work in progress and may require supplementary information or adaptations to be useful. Table 2.5 below presents the rules and proposed rules in which EJ-related analyses were used to inform rulemaking (more details on each of these analyses are in Appendix C of US EPA, 2016b). Most of these analyses were included in supporting regulatory impact analysis (RIAs) reports that quantify the risks and benefits to the US population and were used to determine whether the proposed rule would provide a disproportionate benefit to non-White/low-income populations.

Table 2.5 National Regulations that Have Conducted EJ Analyses as Presented in US EPA, 2016b, Appendix C

Year	Regulation or Proposed Regulation
2008	Lead Renovation, Repair, and Painting Program Rule
2011	Greenhouse Gas (GHG) Emission Standards for Medium-Heavy Duty Trucks
2011	National Pollutant Discharge Elimination System (NPDES) Concentrated Animal Feeding Operation (CAFO) Reporting Rule[a]
2011	Mercury and Air Toxics Standards (MATS)
2013	Formaldehyde Standards for Composite Wood Products Implementing Regulations Proposed Rule
2014	National Pollutant Discharge Elimination System – Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities; Final Rule
2015	Disposal of Coal Combustion Residuals from Electric Utilities Final Rule
2015	Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category, Final Rule
2015	Clean Power Plan Final Rule
2015	Agricultural Worker Protection Standard Revisions Final Rule
2014, 2015	Definition of Solid Waste Final Rule

Note:
(a) Rule was withdrawn.

2.6 Important Changes to EJSCREEN Version 2.0

US EPA released EJSCREEN Version 2.0 in February 2022. Important updates include an improved user interface and a new environmental indicator for underground storage tanks (USTs) and leaking underground storage tanks (LUSTs). Also, as mentioned earlier the NATA dataset was replaced by AirToxScreen.

The new indicator for Underground Storage Tanks and leaking USTs (LUSTs) helps identify tanks that have at least 10% of their volume underground and can present environmental risks if contents leak in to the environment. This indicator is the count of LUSTs (multiplied by a factor of 7.7) and the count of USTs within a 1,500-foot buffered census block group[11]. When this indicator has been selected on the map, its output shows census blocks that are classified within EJSCREEN by national percentiles of USTs (less than 50%, 50-60%, 60-70%, 70-80%, 80-90%, 90-95%, and 95-100%). This is the first environmental indicator within EJSCREEN that contains a multiplier to account for differences in the presence of UST compared to LUSTs that are leaking. As of the writing of this report (Summer 2022), the technical documentation for EJSCREEN 2.0 was not available, so US EPA has not provided additional information to evaluate the selected multiplier or any information on specific calculation methods.

In addition to this new UST indicator, EJSCREEN Version 2.0 provides an updated and more accessible user interface. The updated version contains menu options shown in a box where you can select everything this tool offers (Figure 2.8, below). There are four tabs that contain EJSCREEN 2.0's information: Maps. Places, Reports, and Tools.

[11] Basic information about this new EJSCREEN 2.0 environmental indicator is available here: https://www.epa.gov/ejscreen/overview-environmental-indicators-ejscreen.

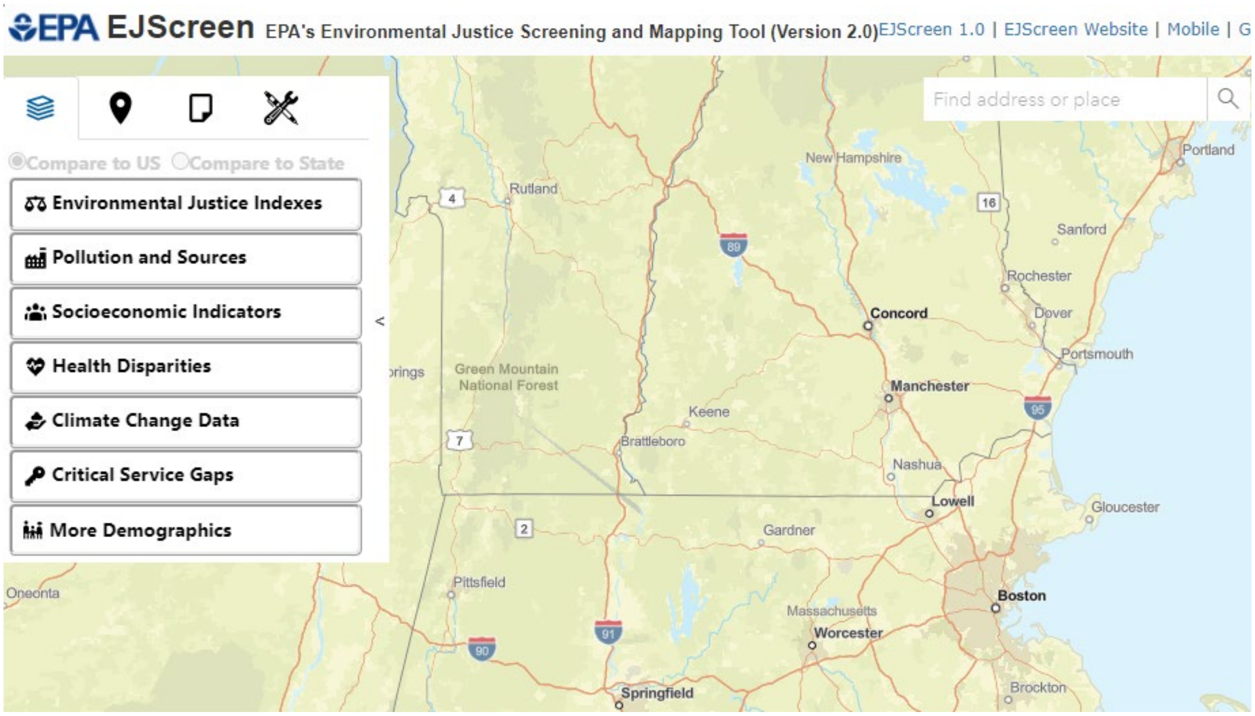


Figure 2.8: Updated EJSCREEN Interactive Menu. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

Many of the functionalities in this update remain the same as in the previous version. Users are still able to select a location of their choosing. To select a certain census tract or to draw an area of interest in this update, choose the Reports tab at the top of the white box, and the option to select any type of location will appear (see Figure 2.9 below). From this menu, users can drop a pin at a specific location, draw an area, or select a location by census tract, city, or county.

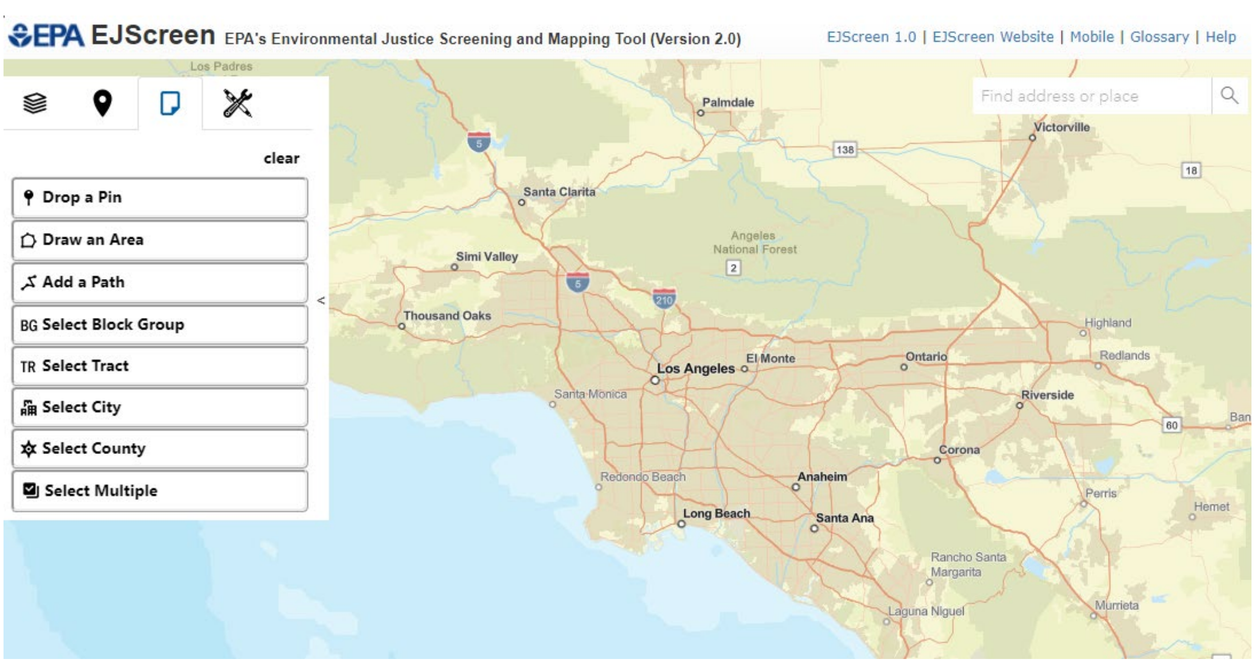


Figure 2.9: Selecting Location in the Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

Drawing an area in EJSCREEN 2.0 works similarly to the previous version of EJSCREEN. Once "Draw an Area" is selected on the Reports tab, the user needs to click each time they want to put down a marker. Once the user clicks on the first point again, their shape will be finalized (See Figure 2.10).

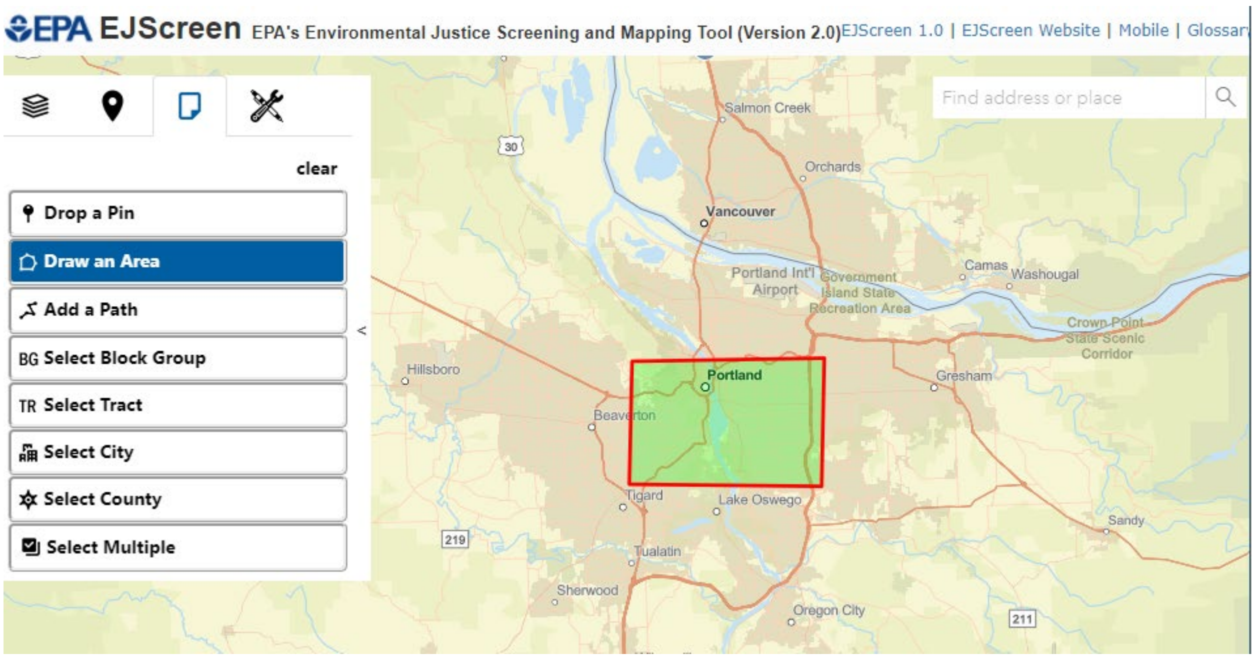


Figure 2.10: Drawing an Area in the Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

This updated version still allows for users to compare their indicator of interest with other locations at both the state and national level, often in terms of relative percentiles. For the map to update accurately, the user will have to re-select the indicator of interest switching between state and national comparisons.

Overall, this version appears to be much more user-friendly, with a clear organizational and functional advantage over the previous version. The original version had some functions hidden under multiple layers of menu without text, but EJSCREEN 2.0 is more streamlined and intuitive. This version also contains many new layers, making it a much more comprehensive tool for visualizing and considering issues of environmental justice.

2.6.1 Additional Map Layers

EJSCREEN 2.0 has added supplemental map layers (but not indicators) related to health disparities, climate change data, and critical service gaps.

- Health Disparities (Figures 2.11 – 2.13) layers include: Low Life Expectancy, Heart Disease, and Asthma.
- Climate Change (Figures 2.11 – 2.18) layers include Drought Risk, Wildfire Hazard Potential, Coastal Flood Hazard, 100-year Flood Plain, and Sea Level Rise.
- Critical Service Gaps (Figures 2.19 – 2.21) layers include: Broadband Gaps, Food Desert, and Medically Underserved.

<u>**Health Disparities Map Layers in EJSCREEN 2.0**</u>

Under the category of health disparities, EJSCREEN 2.0 contains layers for low life expectancy, heart disease, and asthma, all by census tract level. The low life expectancy layer depicts census tracts by life expectancy percentile (See Figure 2.11). The heart disease layer shows heart disease prevalence among adults 18 or older by census tract (See Figure 2.12). The asthma layer shows asthma prevalence among adults 18 or older by census tract (See Figure 2.13). These health disparities layers are derived from the CDC's U.S. Small-area Life Expectancy Estimates Project (USALEEP) and the CDC's Population Level Analysis and Community Estimates (PLACES) data.

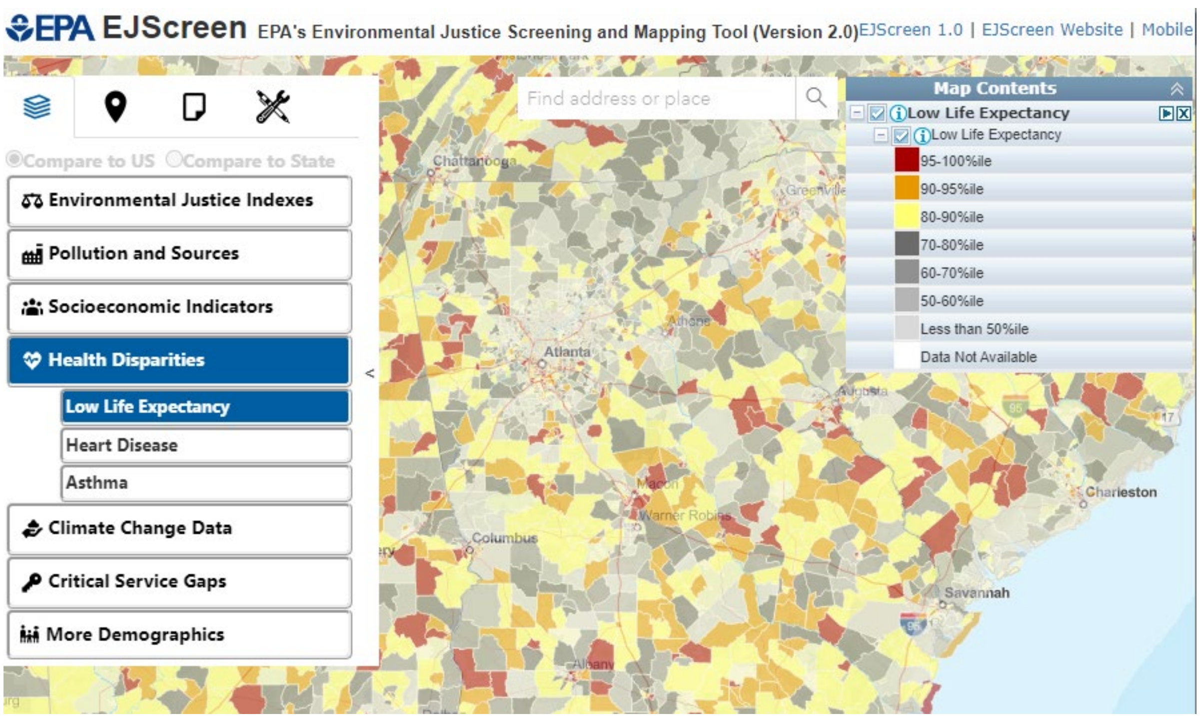


Figure 2.11: Low Life Expectancy Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

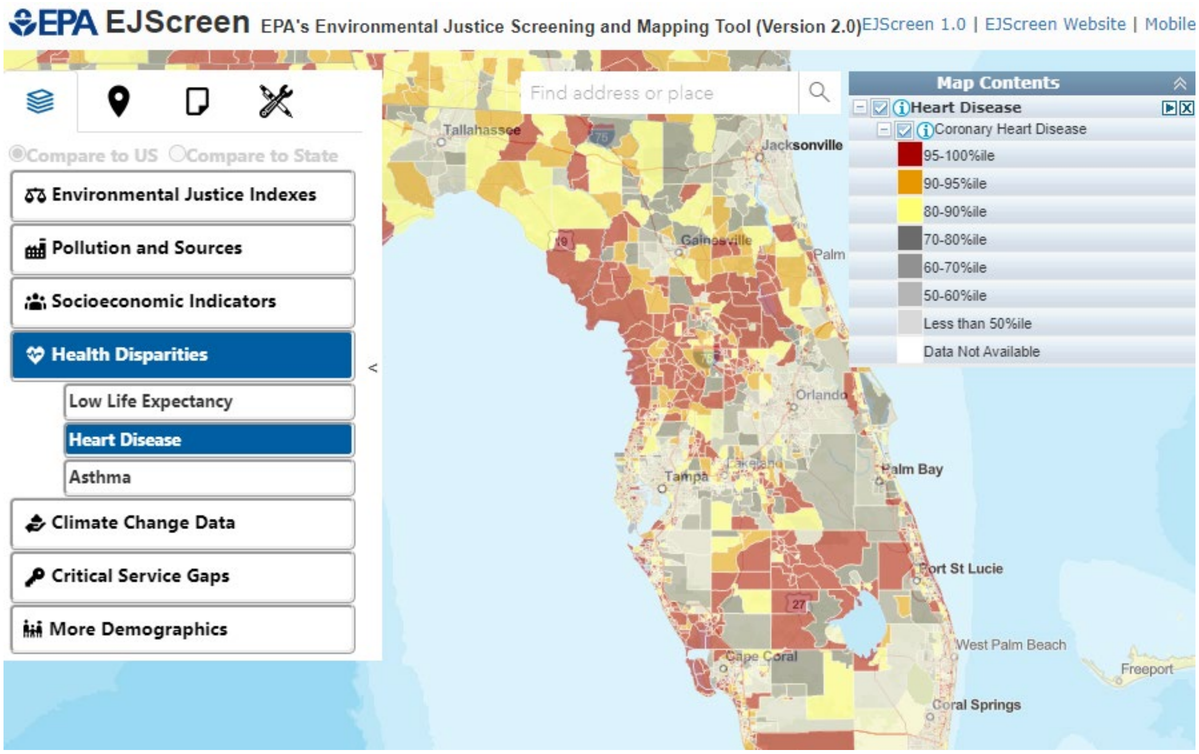


Figure 2.12: Heart Disease Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

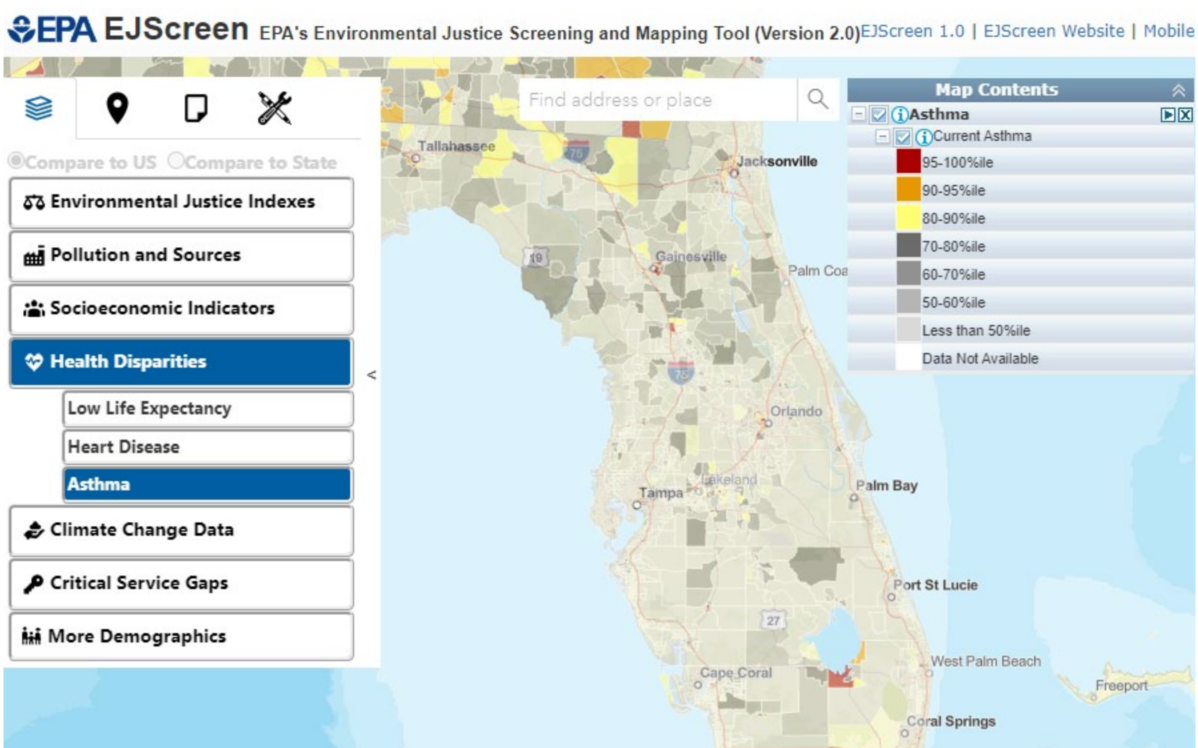


Figure 2.13: Asthma Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

Climate Change Map Layers in EJSCREEN 2.0

Climate change layers in EJSCREEN 2.0 include drought risk, wildfire hazard potential, coastal flood hazard, 100-year estimated flood plain, and estimates for sea level rise between one and six feet above current levels. The wildlife hazard potential layer quantifies the possibility of a wildfire that may be difficult to control (See Figure 2.14). The drought risk layer shows the average change in drought (5-year SPEI) for the contiguous 48 states (See Figure 2.15). The coastal flood hazard layer depicts areas in coastal counties along the Gulf of Mexico and Atlantic Ocean that are most prone to flood hazards (See Figure 2.16). The 100-year floodplain layer shows estimates for floodplains over the next 100 years and potentially vulnerable communities contained within them (See Figure 2.17). The sea level rise layer depicts land at risk of permanent flooding when sea level rises, with six layers for each scenario between one and six feet of sea rise (See Figure 2.18). These climate change layers are derived from data from the US Department of Agriculture, the US EPA's EnviroAtlas, and the National Oceanic and Atmospheric Administration (NOAA).

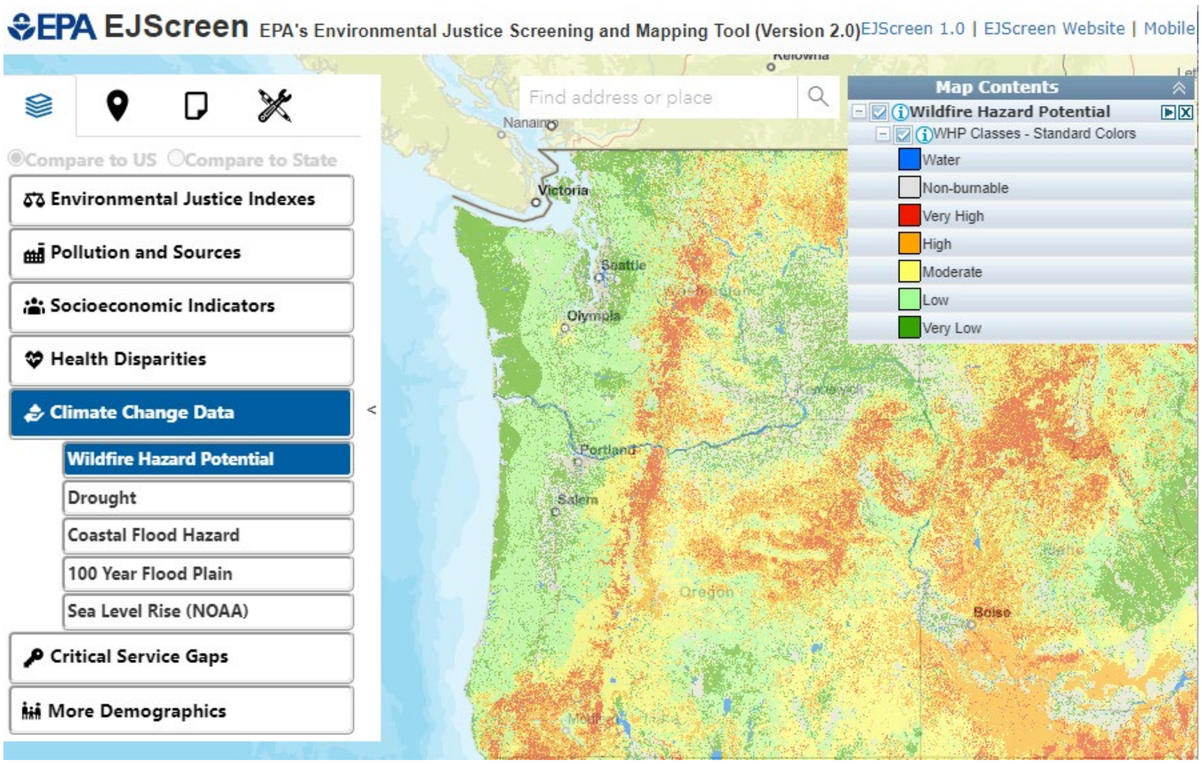


Figure 2.14: Wildfire Risk Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

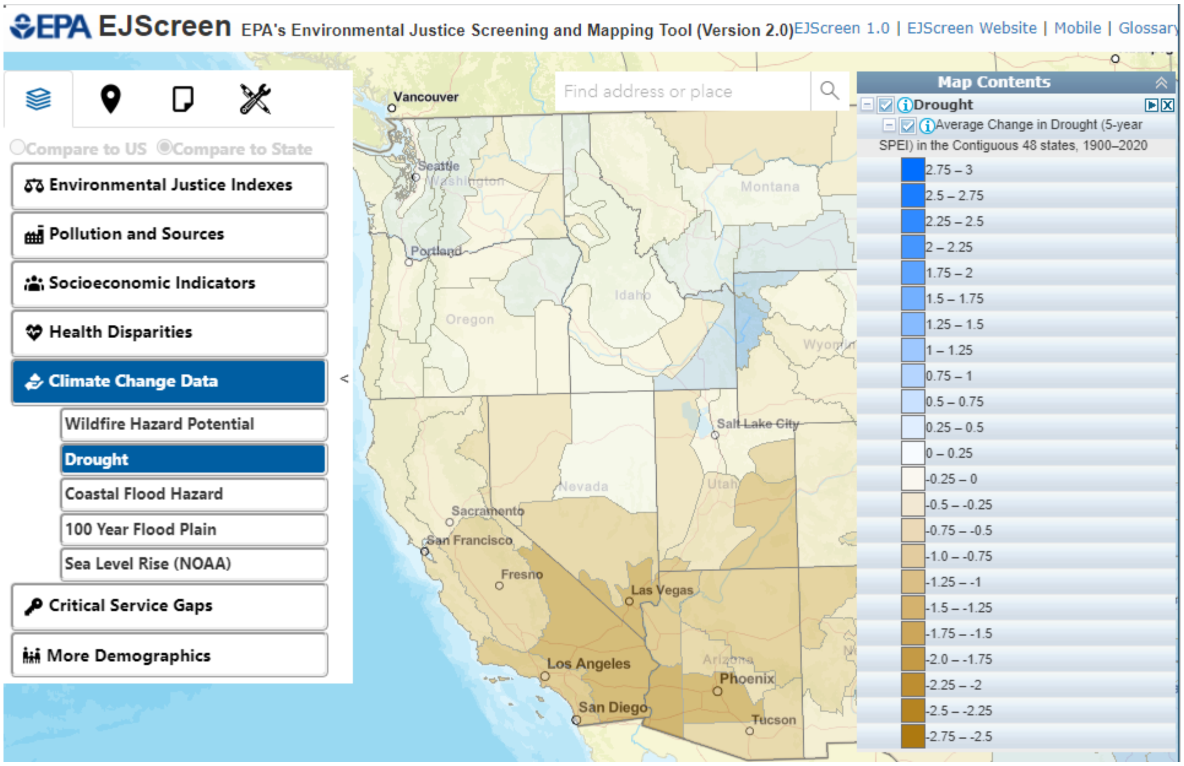


Figure 2.15: Drought Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

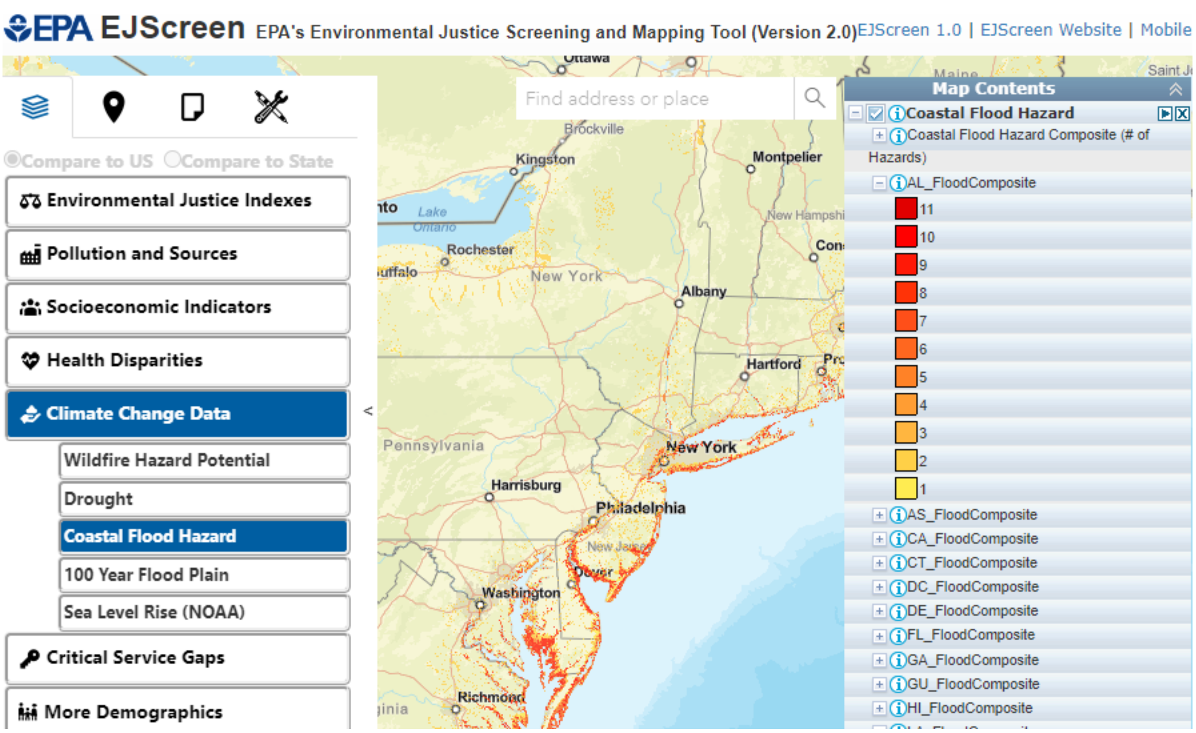


Figure 2.16: Coastal Flood Hazard Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

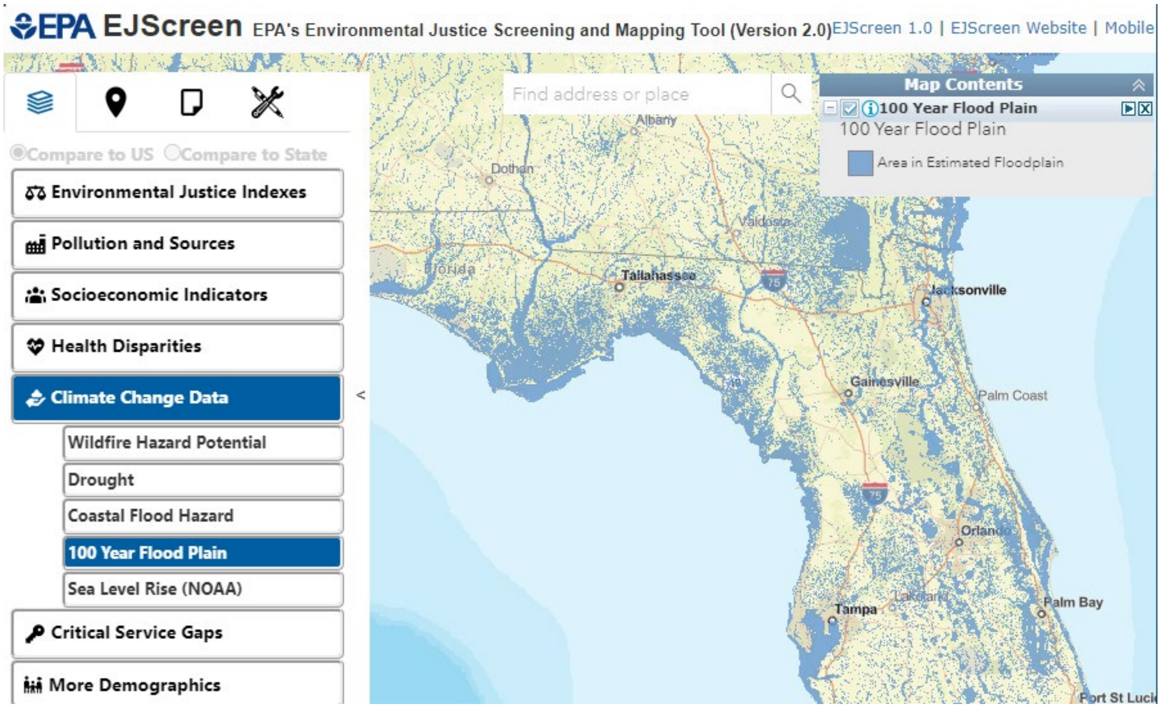


Figure 2.17: 100-Year Floodplain Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

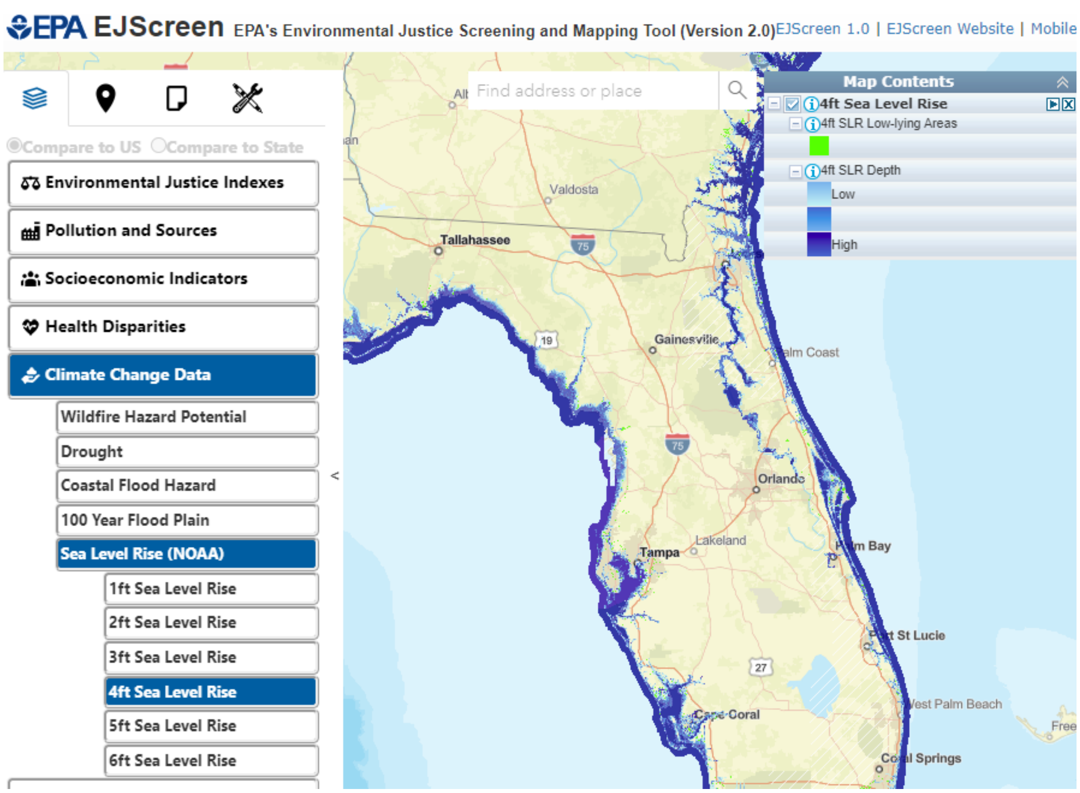


Figure 2.18: Sea Level Rise Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

Critical Service Gaps Map Layers in EJSCREEN 2.0

Under the category of critical service gaps, EJSCREEN 2.0 contains layers for broadband gaps, areas that are food deserts, and medically underserved areas. The broadband gap layer shows areas with lowest rate of households with broadband internet connection by census tract (See Figure 2.19). The food desert layer shows low income and low access tracts measured at 1 mile for urban areas and 10 miles for rural areas (See Figure 2.20). The medically underserved layer shows areas that are designated as having too few primary care providers, high infant mortality, high poverty, or a high elderly population (See Figure 2.21). These critical service gap layers are derived from data from the US Census/American Community Survey, the U.S. Department of Agriculture, and US Health Resources and Service Administration.

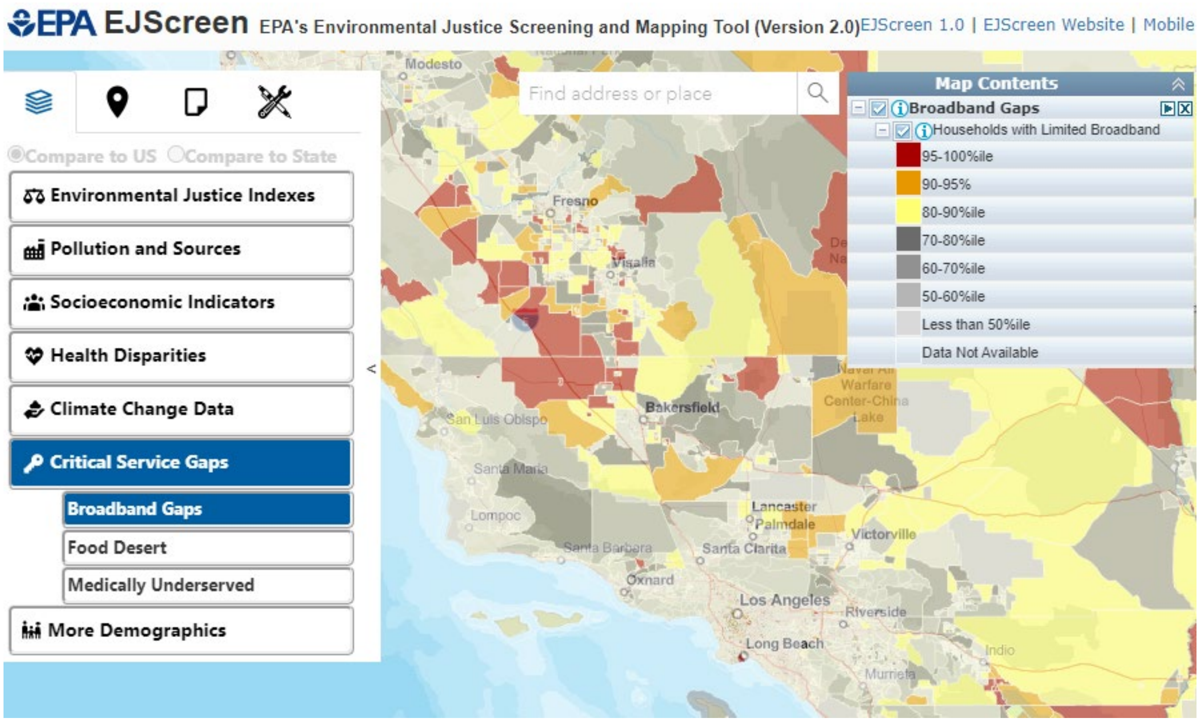


Figure 2.19: Broadband Internet Gap Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

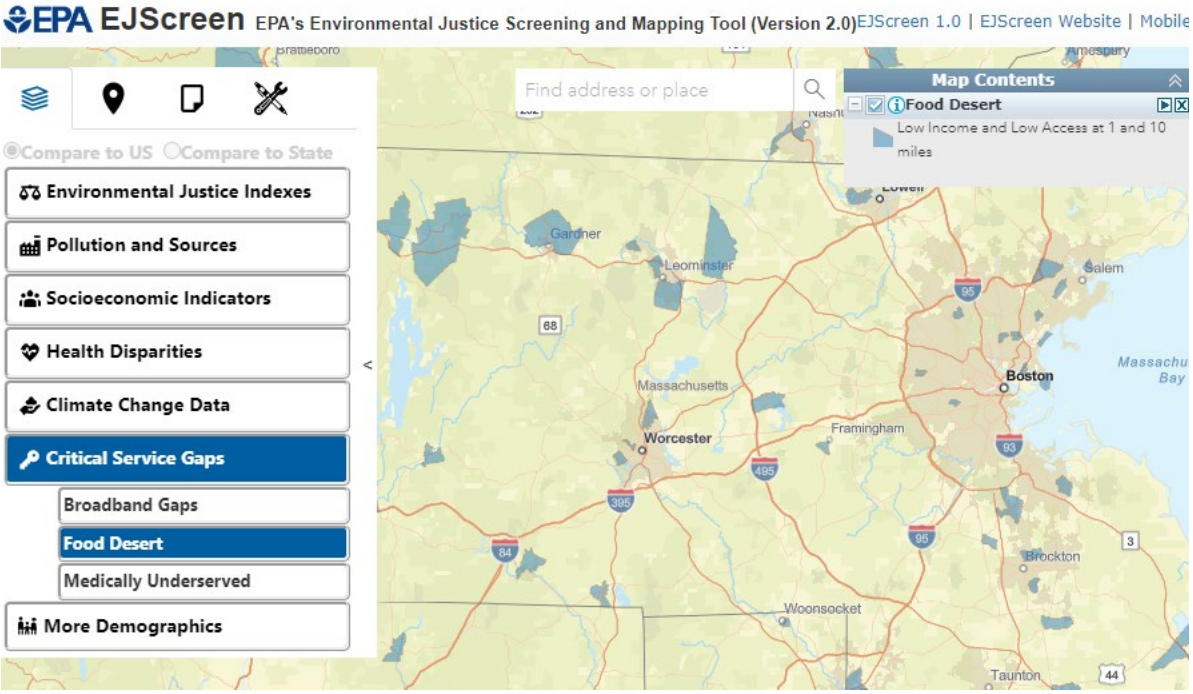


Figure 2.20: Food Desert Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

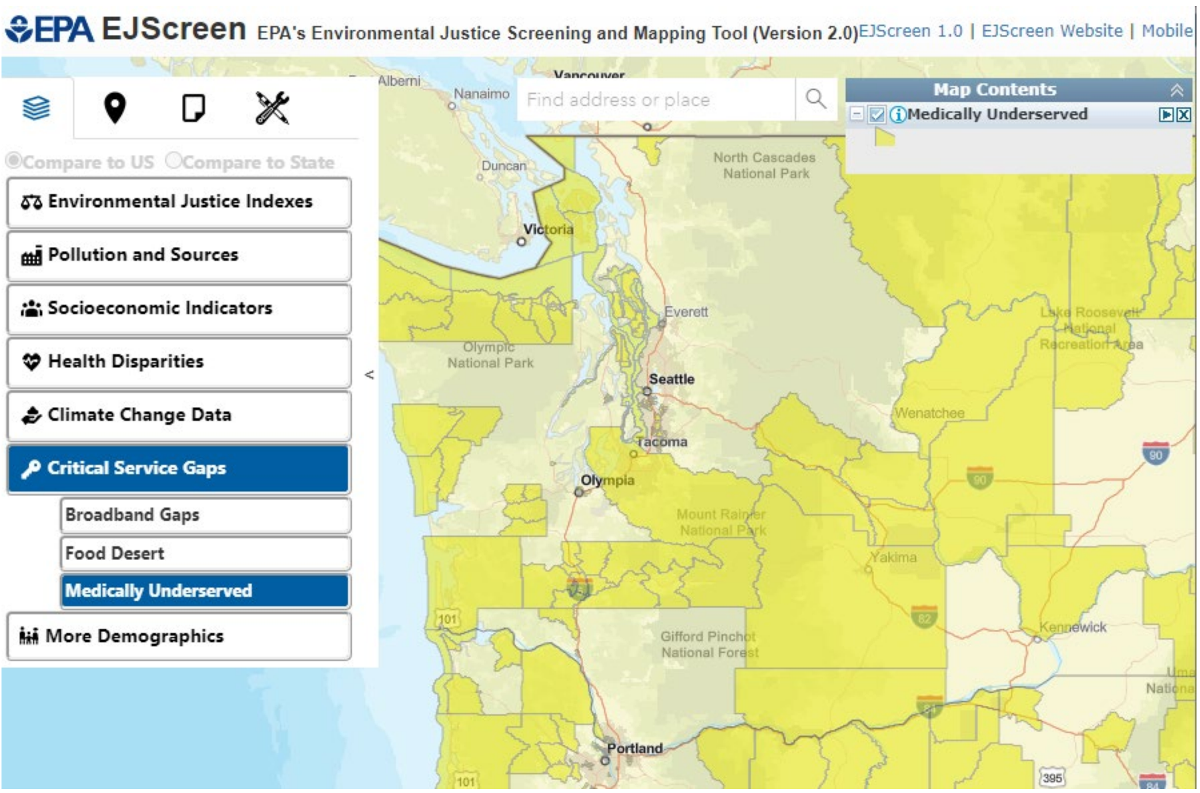


Figure 2.21: Medically Underserved Areas Representation in Updated EJSCREEN. Source US EPA (2022d. https://ejscreen.epa.gov/mapper/).

3 Environmental Justice: State EJ Tools

3.1 CalEnviroScreen

3.1.1 Overview and Development of CalEnviroScreen

Several states have developed or proposed tools for identification of potential EJ communities. One of the most comprehensive state tools is the California Communities Environmental Health Screening Tool, also known as "CalEnviroScreen" or "CES," developed by CalOEHHA within CalEPA. CalEnviroScreen identifies cumulative impacts of pollution burden, along with the modifying effects of socioeconomic stressors and health conditions among California communities, and provides a numerical ranking score for each community.

CalEnviroScreen final version 4.0 was released in October 2021 and was developed over the course of many years of interagency EJ collaboration, stakeholder involvement, and government legislation. In the early 2000s, California convened an EJ working group and a public advisory committee to assist CalEPA in developing an interagency EJ strategy and developed the CalEPA (2004) Environmental Justice Action Plan (CalEPA 2004; California, State Senate, 2000). In 2010, CalEPA and CalOEHHA (2010) proposed a scientific screening method for evaluating cumulative impacts on communities that would later form the basis for the first version of the CalEnviroScreen (version 1.0), which was released as a public comment draft in 2012 (CalOEHHA, 2013). CalEnviroScreen version 1.0 evaluated pollution and population data at the ZIP code level and was intended to help stakeholders focus resources and programs on communities in greater need of assistance (CalOEHHA, 2013). Subsequent iterations of the tool added census-tract-level capabilities, as well as additional indicators.

California has used each iteration of the tool to develop a list of disadvantage communities. In 2014, CalEPA first defined disadvantaged communities as census tracts scoring within the highest 25% in CalEnviroScreen 2.0 (CalEPA, 2017). Later, in 2017, the definition of disadvantaged communities expanded to include census tracts scoring within the highest 25%, as well as 22 census tracts scoring within the highest 5% of Pollution Burden in CalEnviroScreen and with potentially "unreliable socioeconomic or health data" (CalEPA, 2017). The updated list of disadvantaged communities for 2017 and 2018 was developed using CalEPA's CalEnviroScreen version 3.0. These disadvantaged communities in California represent census tracts scoring in the highest 25% from version 3.0, as well as other areas with high pollution and low populations. The most recent version of the preliminary list of disadvantaged communities, published in October 2021, is based on CalEnviroScreen 4.0; it includes the census tracts scoring in the highest 25% for overall score and the top 5% for the Pollution Burden indicator from version 4.0, any census tracts identified as disadvantaged based on CalEnviroScreen 3.0, and any federally recognized tribal lands (CalEPA, 2021a).

CalEnviroScreen and the lists of disadvantaged communities[12] developed using this EJ tool are used to target investment in these communities. Targeted investments are funded through the Cap-and-Trade Auction[13] (also known as California Climate Investments, or CCIs) and are aimed at improving health,

[12] This list is called the "Disadvantaged Communities List for Climate Investments."
[13] The Cap-and-Trade Program is administered by the California Air Resources Board (CARB). More information on this program can be found at https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

quality of life, and economic opportunity in disadvantaged communities (CalEPA, 2021b. https://calepa.ca.gov/EnvJustice/GHGInvest/). CCI funds in these communities have been used for projects such as energy efficiency, public transit, affordable housing, and low emissions transportation.

3.1.2 CalEnviroScreen: Indicators

One of the guiding principals for the CalEnviroScreen is the formula that "risk = threat × vulnerability." CalEnviroScreen's methodology implements this by multiplying Pollution Burden (Exposure and Environmental Effects) by Population Characteristics (Sensitive Populations and Socioeconomic Factors) (see Figure 3.1) (CalEPA, 2017; CalEPA and CalOEHHA, 2021a). Although the scoring system is less intuitive than simple addition, CalEPA selected the multiplication method because the scientific literature supports that socioeconomic factors and certain characteristics of sensitive populations can increase health impacts by 3-fold to 10-fold depending on the specific combination of factors (CalEPA and CalOEHHA, 2021). For example, CalEPA and CalOEHHA (2021a) noted one study indicating that asthmatics have a 7-fold greater sensitivity to air pollution compared to non-asthmatics.

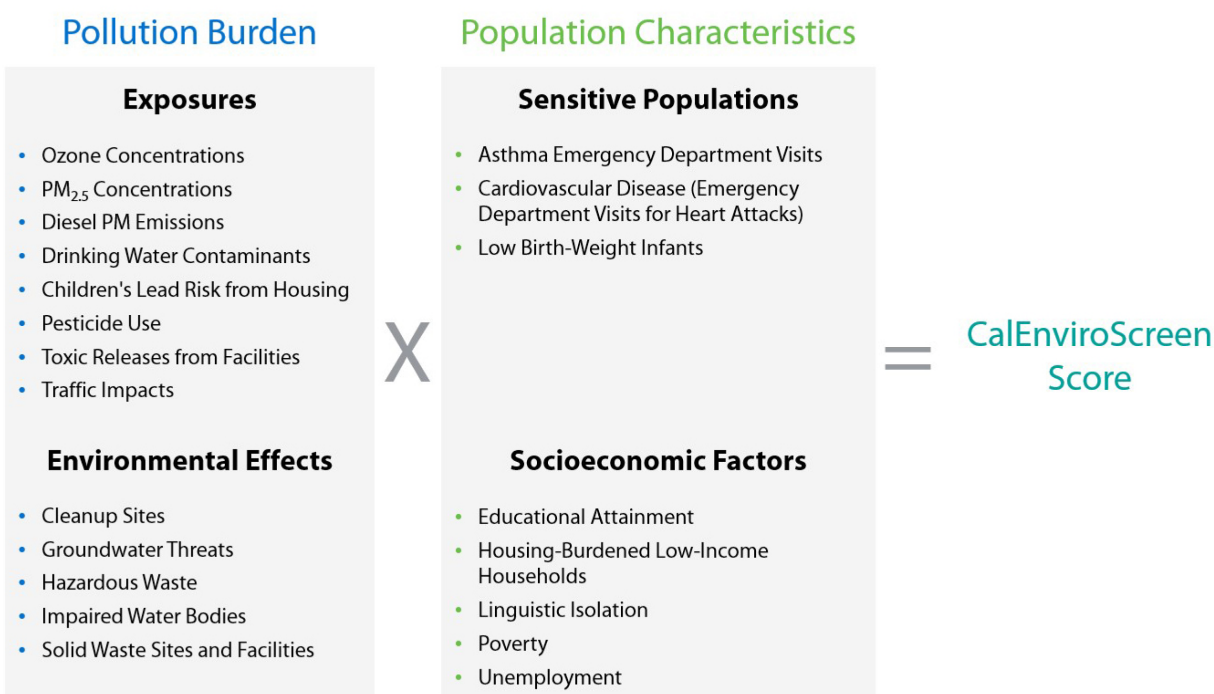


Figure 3.1 CalEnviroScreen Scoring Calculation Method. (Adapted from CalEnviroScreen Public Review Draft Feb 2021, p. 18). Note: The Environmental Effects Score is weighted half as much as the Exposures score (CalEPA and CalOEHHA, 2021a).

Cumulative impacts are assessed based on two broad categories – Pollution Burden and Population Characteristics:

- Pollution Burden is further divided into potential exposures (pollution sources, releases, and environmental concentrations) and environmental effects (environmental clean-up sites, hazardous waste facilities, solid waste facilities, and impaired water bodes). There are 13 indicators of Pollution Burden (see Figure 3.1).

- Population Characteristics is further divided into sensitive populations (measures of certain health conditions such as asthma, cardiovascular disease, and low birth weight that may result in increased vulnerability to pollution) and socioeconomic factors (community characteristics that may result in increased vulnerability such as poverty, low educational attainment, linguistic isolation, and unemployment). There are 8 indictors of Population Characteristics (see Figure 3.1).

CalEnviroScreen combines 21 indicators of Pollution Burden and Population Characteristics into a single score at the census tract scale. Each of the 21 indicators, along with its data sources and other helpful information, is provided in Table 3.1 below.

Table 3.1 Indicators in CalEnviroScreen Draft Version 4.0, Their Data Sources, and Strengths/Weaknesses, Compiled from CalEPA Documentation

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
Exposure Indicators	Air Quality: Ozone	Mean of daily maximum 8-hour ozone concentration	Daily maximum 8-hour average concentrations for all CA monitoring sites for summer months (May-October) for three years for center of each census tract	California Air Resources Board (CARB) Air Monitoring Network Data (2017-2019) Data are available at: http://arb.ca.gov/aqmis2/aqmis2.php	Ozone values at census tracts with centers farther than 50 km from nearest monitor were not estimated with the model. Ozone value at nearest air monitor used instead.
Exposure Indicators	Air Quality: PM2.5	Annual mean concentration of $PM_{2.5}$ over three years	Weighted average of measured monitor concentrations and satellite observations over three years	Air Monitoring Network, Satellite Remote Sensing Data, California Air Resources Board (CARB) (2015-2017) Data are available at: http://arb.ca.gov/aqmis2/aqmis2.php https://ww2.arb.ca.gov/resources/documents/air-quality-research-using-satellite-remote-sensing	
Exposure Indicators	Children's Lead Risk from Housing	Potential risk for lead exposure in children living in low-income communities with older housing	Combined percentage of homes with a high likelihood of lead-based paint (LBP) hazards and households that have both less than 80% of the county median family income and children under 6 years of age.	California Residential Parcel Data, Digital Map Products (2017) United States Census Bureau - American Community Survey (2014-2018) United States Department of Housing and Urban Development (HUD) – Comprehensive Housing Affordability Strategy (CHAS) (2013-2017) Data are available at: https://www.digmap.com/platform/smartparcels/ http://www.census.gov/acs/ https://data.census.gov/cedsci/ https://www.huduser.gov/portal/datasets/cp.html	

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
Exposure Indicators	Diesel Particulate Matter	Spatial distribution of gridded diesel PM emissions from on-road and non-road sources (tons/year).	County-wide diesel PM estimates were spatially distributed to 1 x 1 km grids and combined with transportation network and non-road emissions data. Weighted estimates were summed across census tracts and assigned percentiles.	EMission FACtors (EMFAC) model 2017 (2017) CEPAM v1.05 Inventory for criteria pollutants (2016) California Air Resources Board (CARB) California Emissions Inventory Development and Reporting System (CEIDARS) database (2012) Data available at the following links: http://www.arb.ca.gov/diesel http://arb.ca.gov/msei/modeling.htm https://ww2.arb.ca.gov/emission-inventory-data https://arb.ca.gov/emfac	The data source does not account for meteorological dispersion of emissions at the neighborhood scale, which can be prone to variability, or significant local spatial gradients that exist near major roadways or other sources of diesel PM.
Exposure Indicators	Drinking Water Contaminants	Drinking water contaminant index[a] for selected contaminants	Census tract-weighted average of water contaminant concentrations were assigned percentiles. Weighted contaminant index calculated as the sum of percentiles for all contaminants.	Tracking California - Water Boundary Tool (WBT): Public Land Survey System – Townships California State Water Resources Control Board (SWRCB) – Safe Drinking Water Information System (SDWIS) EDT Library and Water Quality Analyses Data and Download Page Permits, Inspections, Compliance, Monitoring and Enforcement (PICME) database, California Department of Public Health (database is no longer in active use)	The Water Boundary Tool was retired on July 1, 2020, yet still remains the most comprehensive tool for system boundaries at the time that CalEnviroScreen 4.0 was released.

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
				California State Water Resources Control Board (SWRCB) – Groundwater Ambient Monitoring and Assessment (GAMA) Program's Groundwater Information System: GAMA Aquifer Risk Map Depth Filter Dataset Data range from 2011-2019 Data available at the following links: https://trackingcalifornia.org/water-boundary-tool/water-boundary-tool-landing https://www.cdpr.ca.gov/docs/emon/grndwtr/gis_shapefiles.htm https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/EDTlibrary.html https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/Default.asp https://gispublic.waterboards.ca.gov/portal/home/item.html?id=55258176731a4cefb24fc571d8136276	
Exposure Indicators	Pesticide Use	Total pounds of 83 selected active pesticide ingredients (filtered for hazard and volatility) used in production-agriculture per square mile, averaged over three years	Census tract-weighted measure of pesticide use assigned percentile based on statewide distribution of values.	Pesticide Use Reporting, California Department of Pesticide Regulation (DPR) 2017-2019 Data are available at: http://www.DPR.ca.gov/docs/pur/purmain.htm	

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
Exposure Indicators	Toxic Releases from Facilities	Toxicity-weighted concentrations of modeled chemical releases to air from facility emissions and off-site incineration	RSEI model uses census-tract level estimates for hazard-weighted concentrations of toxic air releases. These were then assigned a percentile based on location in the distribution.	Toxics Release Inventory (TRI), US Environmental Protection Agency (US EPA) Mexico Registry of Emissions and Transfer of Contaminants (RETC) Risk Screening Environmental Indicators (RSEI), US Environmental Protection Agency (US EPA) Data averaged over 2017-2019 Data are available at: https://www.epa.gov/toxics-release-inventory-tri-program http://sinat.semarnat.gob.mx/retc/index.html https://www.epa.gov/rsei	
Exposure Indicators	Traffic Density	Sum of traffic volumes adjusted by road segment length (vehicle-kilometers per hour) divided by total road length (kilometers) within 150 meters of the census tract	Traffic impacts indicator (vehicles/hour) calculated by dividing the sum of length-adjusted traffic volumes within the buffered census tract (vehicle-km/hr) by the sum of the length of all road segments within the buffered census tract (in km). Traffic impacts (vehicles/hour) shows the number of vehicles (adjusted by road segment length in km) per hour per km of roadways within census tract.	TomTom Find/Route/Display TrafficMetrix® Traffic Count Database University of California, Riverside College of Engineering – Center for Environmental Research and Technology Bernie Beckerman, Ph.D., independent contractor US Customs and Border Protection, Border Crossing Entry Data; San Diego Association of Governments (SANDAG) Traffic Volume Estimates from 2017	

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
				Data are available at: https://www.adci.com/tomtom/gis/ https://explore.dot.gov/views/BorderCrossingData/Annual?:isGuestRedirectFromVizportal=y&:embed=y https://www.kalibrate.com/solutions/traffic-count-data https://www.cert.ucr.edu/ https://www.sandag.org/	
Environmental Effect Indicators	Cleanup Sites	Sum of weighted site scores[b] within each census tract	Cleanup sites were mapped in ArcGIS Pro, with polygon boundaries of California Superfund sites identified. Sites were scored on a weighted scale of 0 to 12, with higher weights assigned to more severe sites. Sites were weighted based on distance to nearest populated census blocks, scored, and assigned percentiles based on position in the distribution.	EnviroStor Cleanup Sites Database, Department of Toxic Substances Control (DTSC) US Environmental Protection Agency, Region 9 Region 9 NPL Sites (Superfund Sites) Polygons Data downloaded March 2020 Data are available at: http://www.envirostor.dtsc.ca.gov/public/ https://edg.epa.gov/clipship/	
Environmental Effect Indicators	Groundwater Threats	Sum of weighted scores[c] for sites within each census tract	Data on cleanup sites, storage tanks, produced water ponds, dairies, and feedlots were geocoded in ArcMap. The weights for all sites were adjusted based on distance from populated census blocks. Census tracts scored based on sum of adjusted weights for sites it contains.	GeoTracker Database, State Water Resources Control Board (SWRCB) California Integrated Water Quality System Project (CIWQS) SWRCB Data downloaded March 2020 Data are available at: https://geotracker.waterboards.ca.gov/ https://www.waterboards.ca.gov/water_issues/programs/ciwqs/	Facilities further than 1,000 m from any populated census blocks were excluded from the analysis.

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
Environmental Effect Indicators	Hazardous Waste Generators and Facilities	Sum of weighted scores[d] for permitted hazardous waste facilities, hazardous waste generators, and chrome plating facilities within each census tract.	Permitted hazardous waste facilities, hazardous waste generators, and chrome plating facilities were weighted based on their distance from populated census blocks. Census tracts were scored based on the sum of adjusted weights in ArcGIS Pro, sorted and assigned percentiles.	EnviroStor Hazardous Waste Facilities Database and Hazardous Waste Tracking System, Department of Toxic Substances Control (DTSC)Chrome Plating Airborne Toxics Control Measure, California Air Resources BoardPermitted hazardous waste facilities were downloaded June 2021, hazardous waste data are from 2018-2020, and chrome plating facilities are based on data from 2018. Data are available at: http://www.envirostor.dtsc.ca.gov/public/data_download.asp http://hwts.dtsc.ca.gov/https://ww2.arb.ca.gov/our-work/programs/chrome-plating-atcm	Facilities further than 1,000 m from any populated census blocks were excluded from the analysis.
Environmental Effect Indicators	Impaired Water Bodies	Summed number of pollutants across all water bodies designated as impaired within the area.	Bodies of water were identified in all census tracts in ArcGIS Pro. The number of pollutants listed in streams within 1 or 2 kilometers of a populated census block was counted. Pollutant counts were summed for all census tracts, which were then scored based on number of individual pollutants within or bordering it.	303(d) List of Impaired Water Bodies, State Water Resources Control Board (SWRCB) Data are from 2014-2016. Data are available at: http://www.waterboards.ca.gov/rwqcb2/water_issues/programs/TMDLs/303dlist.shtml	
Environmental Effect Indicators	Solid Waste Sites and Facilities	Sum of weighted scores[e] for solid waste sites and facilities.	Solid waste sites and facilities were weighted based on the distance they fell from populated census blocks. Census tracts were scored based on the sum of the adjusted weights for sites it	Solid Waste Information System (SWIS) and Closed, Illegal, and Abandoned (CIA) Disposal Sites Program, California Department of Resources Recycling and Recovery, CalRecycle	Facilities further than 1,000 m from any populated census blocks were excluded from the analysis, apart from odor analysis, which extends to 2,000 m.

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
			contains or is near. Summed census tract scores were assigned percentiles based on their position in the distribution.	Hazardous Waste Tracking System, Department of Toxic Substances Control (DTSC) Data were downloaded in July 2021. Data are available at: http://calrecycle.ca.gov/SWFacilities/Directory/ http://www.calrecycle.ca.gov/SWFacilities/CIA/ http://hwts.dtsc.ca.gov/	
Sensitive Population Indicators	Asthma	Spatially modeled, age-adjusted rate of emergency department (ED) visits for asthma per 10,000	Tracking California calculated age-adjusted rate of asthma ED visits for each zip code. These rates were then reapportioned to census tract rates. Census blocks were assigned the average rate of the ZIP code they intersected using areal apportionment, with census tract rates estimated by population-weighted averages.	Emergency Department and Patient Discharge Datasets from the State of California, Office of Statewide Health Planning and Development (OSHPD); Tracking California Data are from 2015-2017 Data are available at: https://oshpd.ca.gov/data-and-reports/ https://trackingcalifornia.org/asthma/query	
Sensitive Population Indicators	Cardiovascular Disease	Spatially modeled, age-adjusted rate of emergency department (ED) visits for acute myocardial infarction (AMI) per 10,000	Tracking California calculated age-adjusted rate of AMI ED visits for each zip code. These rates were then reapportioned to census tract rates. Census blocks were assigned the average rate of the ZIP code they intersected using areal apportionment, with census tract rates estimated by population-weighted averages.	Emergency Department and Patient Discharge Datasets from the State of California, Office of Statewide Health Planning and Development (OSHPD); Tracking California; (2015-2017) Data are available at: https://oshpd.ca.gov/data-and-reports/ https://trackingcalifornia.org/mi/query	

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
Sensitive Population Indicators	Low Birth Weight Infants	Percent low birth weight	Low birth weight (LBW) was calculated from CA birth records, which were then geocoded by mother's address at time of birth and assigned to a census tract. Averaged over several years.	California Department of Public Health (CDPH); Tracking California; (2009-2015) Data are available at: http://www.cdph.ca.gov/data/datareso urces/requests/Pages/BirthandFetalDea thFiles.aspx https://trackingcalifornia.org/	Multiple births (non-singletons) and births with an improbable combination of gestational age and birth weight were excluded. Out-of-state births, and births with no known residential address (including P.O. boxes) were also excluded. These exclusions lead to lower statewide LBW percentage than that reported by other organizations who do not apply this criterion. Estimates derived from places with few births are considered unreliable because they often produce extreme values much higher or lower than expected and can vary greatly from year to year. For this reason, census tracts with fewer than 50 live births over the seven years (2009-2015) were excluded.
Socioeconomic Factor Indicators	Educational Attainment	Percentage of the population over age 25 with less than a high school education.	Percentage of population over age 25 without a high school education was calculated and estimated by census tract.	American Community Survey, US Census Bureau (2015-2019) Data are available at: https://data.census.gov/cedsci/	

Environmental Category	Indicator	Value	Calculation Method	Data Source	Notes
Socioeconomic Factor Indicators	Housing Burden	Housing-Burdened Low-Income Households. Percent of households in a census tract that are both low income and severely burdened by housing costs.	Number of households that are both low-income (making less than 80% of the HUD Area Median Family Income) and severely burdened by housing costs (paying greater than 50% of their income to housing costs) estimated by census tract.	Housing and Urban Development,Comprehensive Housing Affordability Strategy (2013-2017) Data are available at: https://www.huduser.gov/portal/datasets/cp.html	
Socioeconomic Factor Indicators	Linguistic Isolation	Percentage of limited English-speaking households.	Percentage of households where no one age 14 and above speaks English well estimated by census tract.	American Community Survey, US Census Bureau (2015-2019) Data are available at: https://data.census.gov/cedsci/	
Socioeconomic Factor Indicators	Poverty	Percent of the population living below two times the federal poverty level.	Number of individuals below 200 percent of the federal poverty level divided by the total population estimated by census tract.	American Community Survey, US Census Bureau (2015-2019) Data are available at: https://data.census.gov/cedsci/	CalEnviroScreen uses a threshold of twice the federal poverty level because California's cost of living is higher than many other parts of the country. Methods for determining the federal poverty thresholds have not changed since the 1980s despite increases in the cost of living.
Socioeconomic Factor Indicators	Unemployment	Percentage of the population over the age of 16 that is unemployed and eligible for the labor force.	Percentage of the population over the age of 16 that is unemployed and eligible for the labor force estimated by census tract.	American Community Survey, US Census Bureau (2015-2019) Data are available at: https://data.census.gov/cedsci/	Excludes retirees, students, homemakers, institutionalized persons except prisoners, those not looking for work, and military personnel on active duty.

Notes:

(a) The drinking water contaminant index was calculated based on average concentrations for each detected contaminant for a single water system or township for one compliance cycle (currently, the data included range from 2011-2019). These average concentrations for a single water system or township were then extrapolated to cover the census tract, and census tracts were ranked to obtain percentiles for each contaminant and tract. The final drinking water contaminant index for each census tract was calculated as the sum of the percentiles for all contaminants. The primary drinking water and groundwater constituents that CalEPA highlighted include nitrate, perchlorate, arsenic, trihalomethanes, and lead, although many other contaminants are also included in the drinking water contaminant index (CalEPA, 2021). CalEPA notes that these scores are not indicative of exposures or of any impacts on human health and notes that "the drinking water score may not reflect the water that an *individual* resident of that track is drinking (CalEPA, 2021).

(b) Cleanup sites were assigned a weight between 0 and 12 based on site type (*e.g.*, Superfund site, school cleanup, state response, historical, evaluations, military site, and many other types) and site status (*e.g.,* active remediation, no state involvement, and other types) (CalEPA, 2021). Higher weights were assigned for Superfund sites, state cleanup sites, and sites undergoing active remediation compared to sites undergoing evaluation and those with no state involvement. Weights were then adjusted by factors of 1, 0.5, 0.25, and 0.1 for increasing distance from populated census blocks within a given census tract.

(c) Groundwater threats were assigned a weight between 0 and 15 based on site type (*e.g.*, land disposal site, military cleanup sites, leaking underground storage tank [LUST] sites) and site status, with open, active remediation sites receiving higher scores than closed or inactive sites or those undergoing monitoring (CalEPA, 2021). A chart detailing a specific weight for each site and status type is available in the CalEnviroScreen user guide (CalEPA, 2021). Weights were then adjusted by factors of 1, 0.5, 0.25, and 0.1 for increasing distance from populated census blocks within a given census tract.

(d) Hazardous waste generators and facilities were assigned a weight between 0 and 10 based on site type (*e.g.*, 10 for a permitted hazardous waste landfill, 7 for permitted treatment facility, 4 for permitted storage facility, and 2 for post-closure facility), with additional weights added for permit type (large facilities, Resource Conservation and Recovery Act [RCRA] facility, non-RCRA facility), and violation compliance tier. Hazardous waste generators and chrome plating facilities were also assigned weights of 0.1, 0.5, or 2 based on quantity of waste or permitted amperage hours (CalEPA, 2021).

(e) Solid Waste Sites and Facilities were assigned a weight between 0 and 13 based on site type (*e.g.*, higher scores for illegal or abandoned sites and large tonnage solid waste landfills; lower scores for facilities with inert debris, closed solid waste facilities), and history of violations within the last 12 months (CalEPA, 2021). According to CalEPA (2021, footnote 1), violation scores are assigned in a way that ensures that "only facilities that exhibit a pattern and practice of non-compliance receive a higher impact score and reduces point-in-time fluctuations." Explosive gas violations receive a score of 3, while violations with less potential environmental impacts, such as dust, noise, vectors (birds, animals), nuisance, and site security, receive scores of 1 each. The score for a specific facility within this indicator is the sum of the site type score and violations score. A chart detailing a specific weight for each site type and violation is available in the CalEnviroScreen user guide (CalEPA, 2021). Scores were then adjusted by factors of 1, 0.5, 0.25, and 0.1 for increasing distance from populated census blocks within a given census tract.

Sources:
CalOEHHA (2021a,b).

3.1.3 CalEnviroScreen Outputs

The CalEnviroScreen 4.0 tool provides results in two forms: as a mapping tool and as individual maps by indicator (CalEPA, 2021). The mapping tool provides cumulative results for California communities by census tract (Figure 3.2). Individual indicator maps provide detailed information on each indicator, the score for each census tract based on that indicator, and additional details or statistics related to the indicator. The mapping tool, indicator maps, and relative rankings of California communities are used by many state agencies in the implementation of different programs. Below are some screenshots related to the user interface and output for CalEnviroScreen 4.0.

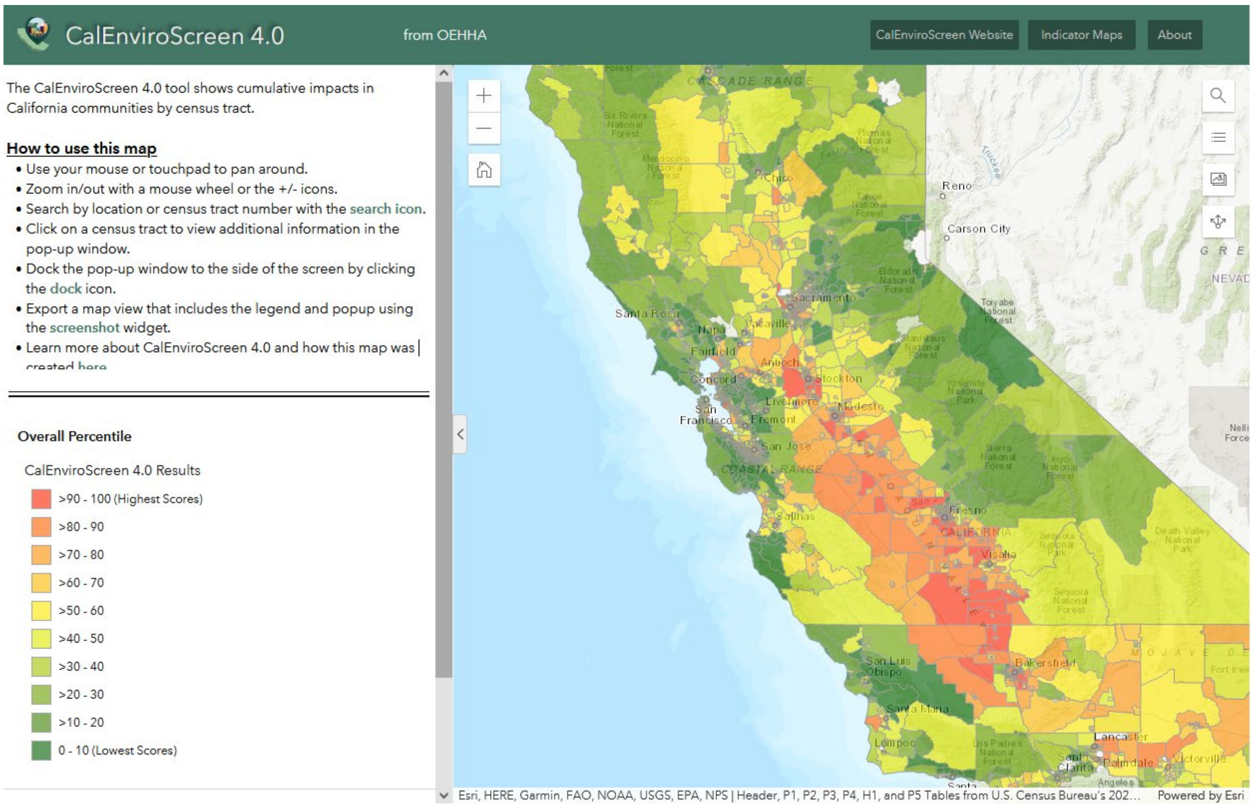


Figure 3.2 CalEnviroScreen Output. Source: CalOEHHA (2021c. https://oehha.ca.gov/calenviroscreen/report/draft-calenviroscreen-40).

The interactive mapping tool[14] allows the user to zoom to any area of California and select a census tract to see the overall CalEnviroScreen ranking (CalEnviroScreen 4.0 Percentile) and the rank for each of the 21 indicators[15] that make up the overall percentile (Figure 3.3). The screen capture icon ( ) allows the user to download a graphic file containing a map and the associated numerical information for the selected geographic area.

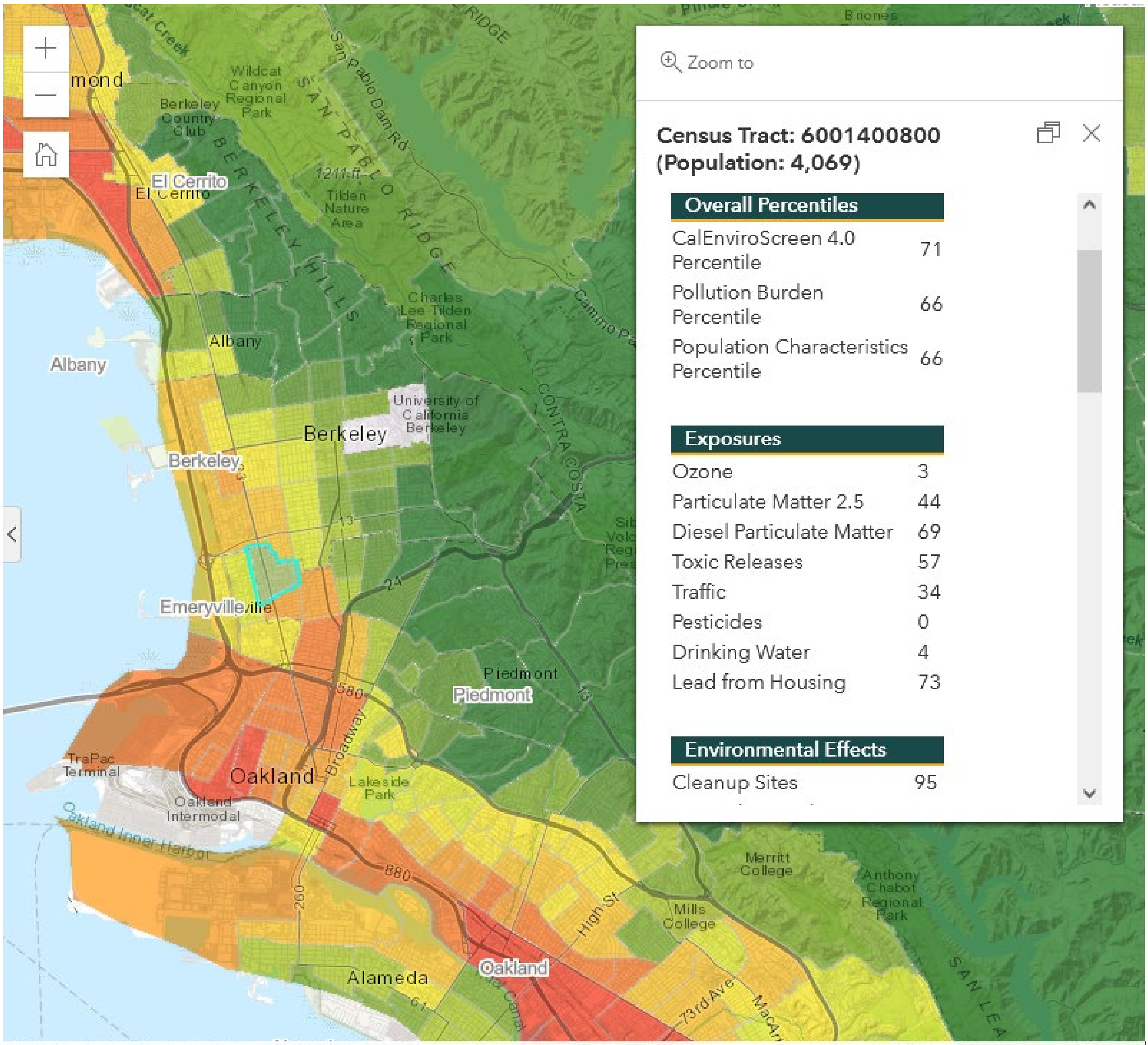


Figure 3.3 CalEnviroScreen Output Rankings for All Indicators. Source: CalOEHHA (2021c. https://oehha.ca.gov/calenviroscreen/report/draft-calenviroscreen-40).

[14] The CalEnviroScreen interactive mapping tool can be accessed at https://experience.arcgis.com/experience/11d2f52282a54ceebcac7428e6184203/.
[15] The CalEnviroScreen 4.0 indicators maps can be accessed at https://experience.arcgis.com/experience/ed5953d890384431dbf4f22ab9abfe40d/

This section of the CalEnviroScreen 4.0 portal contains individual maps for each of the 21 pollution or population indictors. Each indicator map can be accessed by first selecting the indicator category (pollution or population), then selecting the tab for the indicator of interest (ozone, $PM_{2.5}$, solid waste facilities, *etc.*) (Figure 3.4).

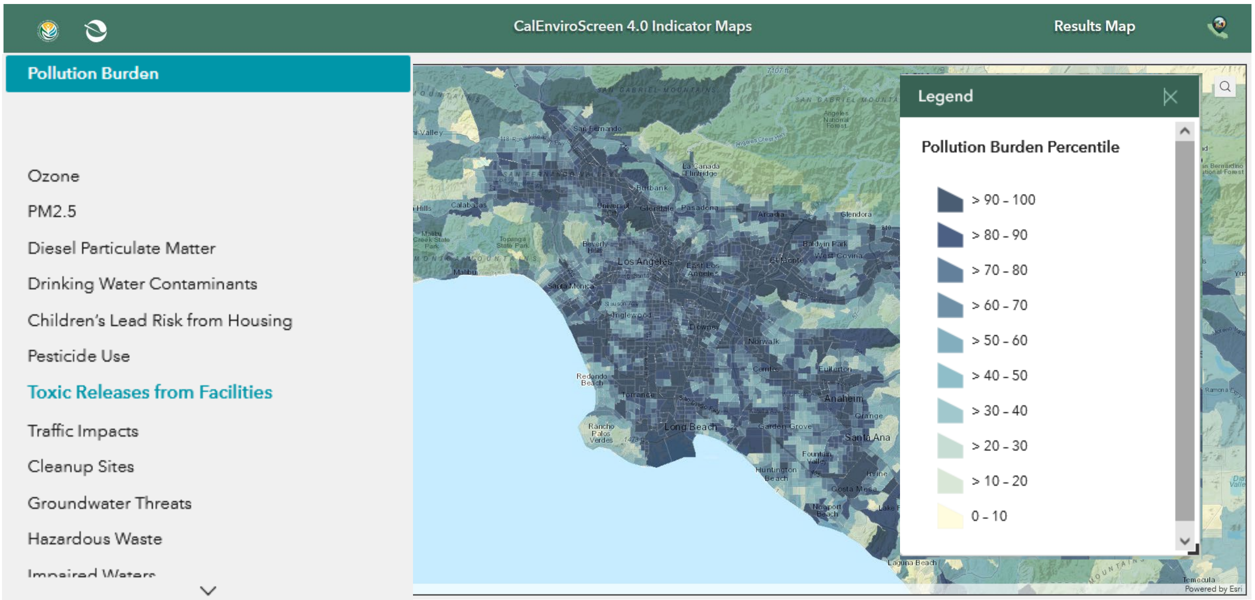


Figure 3.4 CalEnviroScreen Indicator Maps. Source: CalOEHHA (https://experience.arcgis.com/experience/ed5953d89038431dbf4f22ab9abfe40d/).

The individual maps also provide additional detail on each of the indicators listed. When a census tract is selected, each map provides a callout box describing the indicator and its potential impact on the population, as well as more detailed information to help the user understand the relative score. For example, the "Linguistic Isolation" indicator provides relative scoring for all census tracts in California, as well as additional information on the percent of homes in each census tract that do not speak English well and the top three non-English languages spoken in each census tract (Figure 3.5).

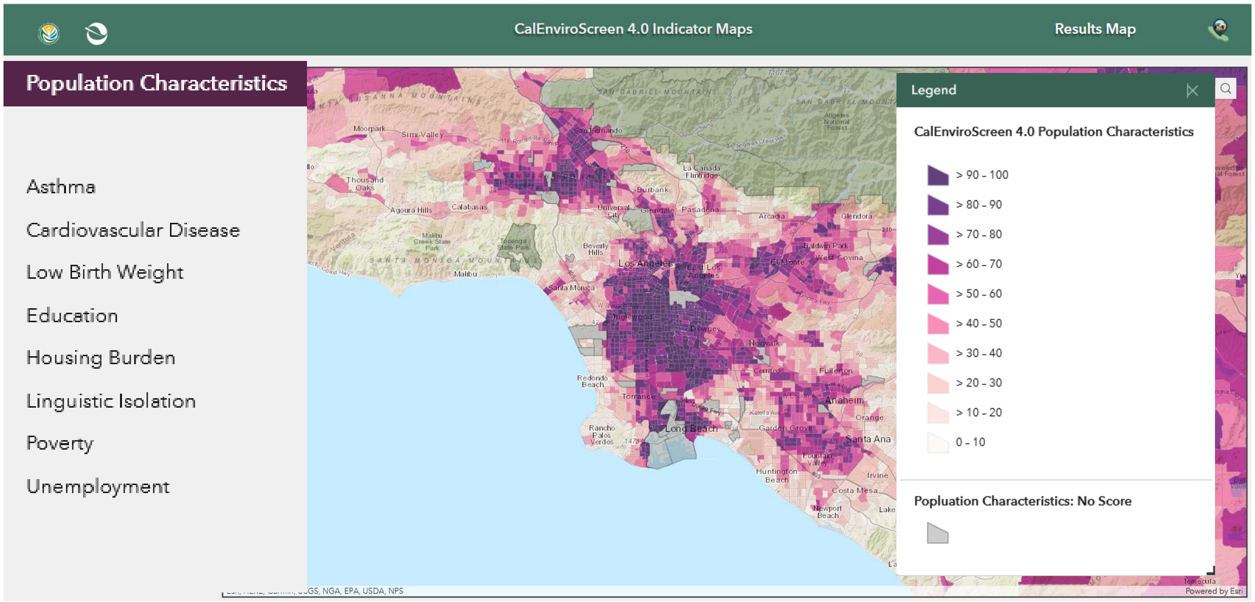


Figure 3.5 CalEnviroScreen Indicator Maps: Linguistic Isolation Example. Source: CalOEHHA (https://experience.arcgis.com/experience/5764b91c4c8a461693487c17b8859976/).

3.1.4 Applications of CalEnviroScreen

CalEnviroScreen is used to inform the implementation of many policies and programs in the state of California and primarily to direct targeted investments to the list of disadvantaged communities. Beginning in 2012, state legislation undertook a number of measures aimed at improving communities and the environment. These activities included the development of frameworks for appropriations to further reduce greenhouse gas emissions, the direction of CalEPA to identify disadvantaged communities, and the direction of funding towards such communities (CalEPA, 2017). For example, CalEPA was directed to allocate at least 25% of the Greenhouse Gas Reduction Fund (funded by the Cap-and-Trade Program) to projects that benefit disadvantaged communities, with at least 10%[16] of the projects required to be located in those communities (SB 1532 and SB 535 in 2012 and AB 1550 in 2016).

Most recently, under SB 673, DTSC has proposed using CalEnviroScreen in the permitting process for operating transfer, treatment, storage, and disposal hazardous waste facilities in California. Specifically, permits for proposed (or existing) hazardous waste facilities that achieve an aggregate score in CalEnviroScreen higher than the 60th percentile will be subject to further review. This further review, which will be tiered depending on risk potential (including further consideration of CalEnviroScreen scores), would result in public consultations and could result in mandates to improve facility operations (*e.g.*, enhance pollution controls, replace older trucks with more fuel efficient trucks) or monitor air and water quality. Depending on the plan developed with public input, the permit could be approved or denied/revoked (CalDTSC, 2021).

CalEPA maintains a growing list of the state entities that use CalEnviroScreen in their program implementation:

- CalEPA Environmental Justice and Compliance Enforcement Working Group
- California DTSC

[16] AB 1550, signed in 2016, increased the percentage from the original 10% designated by SB535 to 25% (CalEPA, 2017).

- GreenHouse Gas Reduction Fund Programs
- Sustainable Communities Planning Grants and Incentives Program
- Affordable Housing and Sustainable Communities
- Sustainable Agricultural Lands Conservation
- Transit and Intercity Rail Capital Program
- Low Carbon Transit Operations Program
- Weatherization Upgrades/Renewable Energy
- Sustainable Forests**,** Active Transportation Program (Caltrans)
- Green Tariff Shared Renewables Program

3.2 Other Relevant Federal EJ Tools

At the federal level, several interactive tools or data viewers have been developed to assist in the identification of vulnerable populations.

EnviroAtlas (https://www.epa.gov/enviroatlas)
US EPA's EnviroAtlas is a set of resources and interactive tools that provides information on ecosystem services, which are the benefits that people can receive from nature and natural resources. Benefits derived from ecosystem services are central to most aspects of human well-being, including access to food and water, security, health, and the economy. EnviroAtlas outlines seven broad categories to organize information on ecosystem service benefits: Clean Air; Clean and Plentiful Water; Natural Hazard Mitigation; Climate Stabilization; Recreation, Culture, and Aesthetics; Food, Fuel, and Materials; and Biodiversity Conservation.

EJSCREEN differs from EnviroAtlas in that it is more of a screening tool that combines demographic information with environmental data to highlight places that should be further reviewed for issues related to EJ. The outputs of these two tools differ slightly, as well. EJSCREEN outputs an interactive map with census tract resolution of air toxics emissions and estimates of cancer and non-cancer risks, among other values. EnviroAtlas, on the other hand, has demographic maps, community comparisons, and EJ indexes as its outputs. Both of these tools are screening indexes and are able to be connected to outside web service technology. However, only with EnviroAtlas does the user have the ability to add their own data and to download the data stored within the tool.

In sum, EJSCREEN is a tool meant to aid stakeholders in making informed decisions about potential EJ issues by finding locations of potentially vulnerable communities. EnviroAtlas's focus is to provide data, resources, and tools for broader understanding of community vulnerability and attributes.

Power Plants and Neighboring Communities Mapping Tool (https://experience.arcgis.com/experience/2e3610d731cb4cfcbcec9e2dcb83fc94)
US EPA's Power Plants and Neighboring Communities mapping tool is a recently released tool that combines the community demographic data from US EPA's EJSCREEN with locations of fossil fuel power plants, and emissions data (carbon dioxide, nitrogen oxides, sulfur dioxide). Developed by US EPA's Office of Air and Radiation and released in July 2021, this tool includes power plant characteristics, operating information, fuel use, and rates/types of emissions. The tool determines Block Groups within a 3-mile buffer of each of 3,477 fossil fuel-fired power plants within the US. The tool contains six community

demographic indicators in the broad categories of income, race/ethnicity, educational attainment, linguistic isolation, and age.

US EPA's tool also provides several static maps and graphs to highlight certain power plants located in areas with one or more of the six demographic indicators at or above the 80th percentile.

WHEJAC Tool – Climate and Economic Justice Screening Tool (https://screeningtool.geoplatform.gov)

In response to goals laid out in EO 14008, members of the Climate and Economic Justice Screen Tool (CEJST) Working Group within WHEJAC were tasked with providing recommendations for creating CEJST (WHEJAC, 2021). The charge included establishing the guiding principles for the tool, as well as identifying indicators that could be used to "publish interactive maps highlighting disadvantaged communities." WHEJAC's interim final recommendations were released in May 2021 (WHEJAC, 2021). The recommendations were expansive and not only reflected efforts to monitor indicators for identifying communities with potential EJ concerns, but also included plans for tracking progress and accountability related to EJ goals.

The White House's Council on Environmental Quality (CEQ) released the beta version of the CEJST in February 2022. The CEQ requested comments by May 2022 on the new tool's overall methodology, dataset, usability, and accessibility (Executive Office of the President of the United States, CEQ, 2022a,b). CEJST is a map-based tool that allows users to identify disadvantaged communities that are above 24 environmental, demographic, or economic thresholds in eight categories. Table 3.2 presents these categories and indicators that were incorporated into the CEQ's beta version of the CEJST.

Table 3.2 Indicators in the Beta Version of the Climate and Economic Justice Screening Tool (CEJST)

Climate and Economic Categories[a]	Indicator
▪ Climate Change	▪ Expected Agricultural Loss Rate
	▪ Expected Building Loss Rate
	▪ Expected Population Loss Rate
▪ Clean Energy and Energy Efficiency	▪ Energy Burden
	▪ PM2.5 in the air
▪ Clean Transit	▪ Diesel PM exposure
	▪ Traffic proximity and volume
▪ Affordable and Sustainable Housing	▪ Housing cost burden
	▪ Lead paint
	▪ Median home value
▪ Reduction and Remediation of Legacy Pollution	▪ Proximity to hazardous waste facilities
	▪ Proximity to National Priorities List (NPL) sites
	▪ Proximity to Risk Management Plan (RMP) facilities
▪ Critical Clean Water and Waste Infrastructure	▪ Wastewater discharge
▪ Health Burdens	▪ Asthma
	▪ Diabetes
	▪ Heart disease
	▪ Low life expectancy
▪ Training and Workforce Development	▪ Low median income
	▪ Linguistic isolation
	▪ Unemployment

	▪ Poverty
	▪ High school degree non-attainment

Notes:
NPL = National Priorities List; PM = Particulate Matter; RMP = Risk Management Plan.
(a) CEJST also includes two socioeconomic thresholds as part of each of the above categories: 1) Low income; 2) Higher education non-enrollment.
Source: CEQ (2022c).

The CEQ or the WHEJAC has not put forth specific information on how this tool will be used to support the Justice40 Initiative, and, thus, it is difficult to comment on the tool's effectiveness in supporting the Justice40 program. It will be important to consider how it will be used to further EJ-related goals beyond what can be accomplished with EJSCREEN.

3.3 State Tools

At the state level, progress on EJ initiatives has been mixed. Some states have no tools available at the state government level to identify EJ communities, some states only have EJ viewers (MA EJ Viewer, New York State Department of Environmental Conservation [NYSDEC] GIS layers, and Pennsylvania Environmental Justice Area Viewer), and other states or regions have made significant progress in EJ community identification or evaluation (California's CalEnviroScreen, NCDEQ's Community Mapping System, and Baltimore's EJSCREEN). Appendix C contains a list of many state or regional EJ tools, in alphabetical order by state. The state resources are useful for gaining a general understanding of the EJ data tools available in each state.

The list of state tools in Appendix C provides some indication of the states that have robust EJ regimes, including which ones have largely followed the federal government approach with reliance on EJSCREEN *versus* those that have devoted limited resources to addressing EJ issues and have simply installed Title VI officers to comply with their funding obligations. California, North Carolina, New York, and Maryland, are notable examples of locations with robust EJ programs and dedicated legislation and/or tools. States such as Rhode Island, Arizona, and Maine have fewer resources dedicated to developing legislation and guidance on EJ issues but still have relevant policies for assessing EJ and its impacts, and engaging communities in decision-making, while states such as Michigan have emerging EJ programs. North Dakota and Wyoming are examples of states that have devoted limited attention to EJ concerns.

Maryland and Baltimore
Maryland, a state identified as one of a few that have developed robust EJ screening tools, has two EJ screening tools available – one that covers the entire state of Maryland (Maryland's EJ Screen Mapper available at https://p1.cgis.umd.edu/ejscreen/) and another specifically limited to Baltimore County (Baltimore EJ Screen available). Development of these tools was funded by the Maryland Department of the Environment. Maryland's EJSCREEN borrows the basic methodology for scoring and board indicator categories from California's EJ screening tool (CalEnviroScreen), including the scoring system for census tracts within the tool. Maryland's development of its own tool was driven by a desire to customize the tool to address local community concerns (University of Maryland, 2020). Similar to CalEnviroScreen, Maryland's tool has 23 indicators divided into four broad categories: two categories for Pollution Burden (Exposure and Environmental Effects), which include indexes for NATA Air Toxics Cancer Risk, NATA Respiratory Hazard Index, NATA Diesel PM, $PM_{2.5}$, Ozone, Traffic Proximity and Volume, Lead Paint Risk, Proximity to Treatment, Storage, and Disposal Facilities, and Watershed Failure; and two categories for Population Characteristics (Sensitive Populations and Socioeconomic Factors), which include asthma emergency department discharges, myocardial infarction discharges, low birth weight infant data, as well as socioeconomic factors such as percent low-income, age, percent non-white, linguistic isolation, and

unemployment. Both the Maryland EJSCREEN Mapper and the Baltimore EJSCREEN include an additional category of layers not included in CalEnviroScreen – this is the Context Layers, which includes layers such as food access, point source water discharges, US EPA Superfund sites, and concentrated animal feeding operation (CAFO) locations. The Baltimore EJSCREEN tool is limited to the boundaries of Baltimore County, Maryland, but includes some additional context layers of local community concern such as areas with limited access to supermarkets and local public school system data.

In addition to this extra category of layers offered by the Maryland and Baltimore EJ tools, these two state tools also alter the EJ index score weighting from CalEnviroScreen. Within the Pollution Burden category, CalEnviroScreen weights Environmental Effects indicators at 50% of Exposure, whereas Maryland's EJSCREEN assigns equal weight between these two components of Pollution Burden (University of Maryland, 2020), resulting in equal weighting across the four categories (Exposure 25%, Environmental Effects 25%, Socioeconomic Factors 25%, and Sensitive Populations 25%).

North Carolina

North Carolina is also identified as a state that is developing additional EJ analytical capacity with EJ tools. The NCDEQ Community Mapping Tool includes environmental indicators but has no information on socioeconomic or health indictors at this time. NCDEQ's EJ webpage indicates that the Community Mapping Tool can be used "to inform some department decisions, such as specific plans for local outreach and public participation" (NCDEQ: https://deq.nc.gov/outreach-education/environmental-justice). The tool allows user-defined communities (a limitation of some other EJ tools like CalEnviroScreen) and provides several base maps, including street, satellite, and topographical maps. The goal of this tool is to inform stakeholders on EJ issues when addressing zoning and permitting issues throughout the state (NCDEQ, 2020). Environmental burden layers include air quality permit sites, animal feed operation sites, solid waste sites, hazardous sites, and petroleum-contaminated soil remediation sites. Layers are also available for conservation areas and effective flood zones. Summary information allows the user to view counts of all environmental burdens for a specific location by name, coordinates, or boundaries. This tool would require the use of health or socioeconomic data to provide relevant information for an EJ analysis.

New Jersey

New Jersey has been at the forefront of EJ legislation for the better part of the last two decades. In 2004, New Jersey's EO 96 created a statewide EJ policy, requiring Executive Branch bodies to provide opportunities for involvement in decisions that may impact environmental and public health. This EO also created a multi-agency task force called the Environmental Justice Task Force (McGreevey, 2004). New Jersey's EO 131, set forth in 2009, established the state Environmental Justice Advisory Council (Corzine, 2009). In 2011, EO 60 directed the New Jersey Department of Environmental Protection (NJDEP) and the New Jersey Department of Transportation (NJDOT) to establish a pilot program to reduce emissions from diesel-powered equipment in selected publicly funded state construction contracts in an effort to reduce respiratory health effects in overburdened communities (Christie, 2011). EO 23 in 2018 tasked NJDEP with developing EJ guidance for all state agencies (Murphy, 2018). After the passage of EO 23 in 2018, NJDEP's (2020) "Furthering the Promise" provided advice and timelines on furthering EJ initiatives throughout various state government agencies. NJDEP (2020) provides specific guidance for state agencies to assess their current and future impacts on EJ as well as action plans for agencies to integrate EJ issues into their functions.

On the heels of EO23, New Jersey has recently enacted the nation's first EJ-specific law. S232b (New Jersey State Legislature, 2020). New Jersey's S232 requires NJDEP to evaluate the environmental and public health impacts on these overburdened communities[17] when assessing permits for facilities that may burden nearby communities. Permitted facilities that may be subject to these new assessment requirements for new facilities or expansion on existing facilities include sewage plants, landfills, incinerators, and natural gas-run power plants. S232 calls for facilities seeking new permits or expansion on existing facilities to submit an environmental impact statement of the facility, which includes the environmental burden on the community, including cumulative impacts, adverse environmental effects that are unavoidable if the permit is granted, and the public health impact on the burdened community of the proposed facility. This also requires the applicants seeking this permit to conduct enhanced public participation (New Jersey State Legislature, 2020).

New Jersey has a robust legislative history, but a limited EJ tool compared to those from California, Maryland, and North Carolina, for example. The New Jersey Environmental Justice Mapping Tool, NJDEP's (2021a) interactive tool, allows users to identify and map overburdened communities and view various EJ criteria by block group. While other states' tools are interactive, with various environmental indicators divided into broad categories, New Jersey's tool color codes overburdened communities under the NJ Environmental Justice Law into six categories. There is one category each for communities that are only minority or only low-income, one for low income and minority, one for low income and limited English, another for minority and limited English, and the final category for communities that are low income, minority, and limited English (NJDEP, 2021b). NJDEP's tool lacks many of the environmental indictors or health effects indictors that are available in the California, Maryland, and North Carolina tools discussed earlier. NJDEP's Office of Environmental Justice website has additional spotlights emphasizing the EJ law, overburdened communities, addressing climate change, and site remediation in the community (NJDEP, 2021b). New Jersey has a robust program of EJ legislation and community engagement, but its tools could use some upgrading.

Colorado

The Colorado Department of Public Health and Environment (CDPHE) maintains several existing databases and visualization tools for health and environmental equity that can be used individually to view statewide data (CDPHE, 2021a. https://cdphe.colorado.gov/maps-and-gis-for-health-and-environment).

- The CDPHE Community Health Equity Map is an existing tool that uses 2013-2017 data from US Census Estimates to create map layers for "visualizing geographic disparities for selected social determinants of health, life expectancy estimates, and key health conditions/outcomes across Colorado," such as population density, education, poverty, heart disease, low birth weight and race/ethnicity (CDPHE, 2021b. http://www.cohealthmaps.dphe.state.co.us/cdphe_community_health_equity_map/).
- CDPHE Community Level Estimates (http://www.cohealthmaps.dphe.state.co.us/cdphe_community_level_estimates/) are data generated by statistical models that outline 18 important health conditions and risk behaviors for smaller geographies (census tracts) (CDPHE, 2021c). These estimates are produced "using a multilevel model that incorporates individual Colorado Behavioral Risk Factor Surveillance System (BRFSS) survey responses in addition to socio-demographic and contextual information from the U.S. Census."
- The CDPHE Open Data website (https://data-cdphe.opendata.arcgis.com/) is a library for geospatial data related to categories including demographics, facilities, environment, and health conditions (CDPHE, 2021d).

[17] New Jersey's S232 defines an overburdened community as any census block group where at least 35% of households are low-income, at least 40% of residents identify as minority or as members of a recognized tribal community, or at least 40% of the households have limited English proficiency (New Jersey State Legislature, 2020).

- CDPHE also reports environmental maps and GIS data for environmental cleanup sites such as dumps, landfills, superfund sites, and hazardous waste-producing locations (CDPHE, 2021e. https://cdphe.colorado.gov/hm-gis-data). Water quality data are also available, with access to various water maps (CDPHE, 2021f. https://cdphe.colorado.gov/clean-water-gis-maps).
- The Colorado Environmental Public Health Tracking Program is a web-based surveillance system that features health and environmental data (CDPHE, 2021g. https://coepht.colorado.gov/). Data are visualized through interactive maps, and statistics over time and against relevant demographics.
- The Visual Information System for Identifying Opportunities and Needs (VISION) is a tool with visualizations that provide data for prioritized chronic disease and behavioral health measures in Colorado. The purpose of VISION is to "provide data and visualizations for assessments and data driven public health planning and program work" (CDPHE, 2021h. https://cdphe.colorado.gov/vision-visual-information-system-for-identifying-opportunities-and-needs).
- The Climate Equity Data View is an EJ tool that uses "population and environmental factors to calculate climate equity score[s]" for each census block group in Colorado (CDPHE, 2021i. https://cdphe.maps.arcgis.com/apps/webappviewer/index.html?id=25d884fc249e4208a9c37a34a0d75235). The score considers environmental burden (including factors such as air pollution and proximity to traffic) and population characteristics (including factors such as health status, age, race/ethnicity and education). This tool can create a map-based community screening tool as well as a sortable table that allows the user to view and export information about communities. However, the tool cannot define areas that might be affected by environmental injustice or specific environmental burdens, or take all environmental exposures into account (such as water quality).

A primary limitation of many of these existing tools (other than the Climate Equity Data View tool) is that they mainly provide data visualization for individual statistics and do not allow users to bring together environmental and population indicators to identify disproportionately impacted communities. In order to address this, Colorado is developing a new EJ tool: EnviroScreen (https://cdphe.colorado.gov/enviroscreen; CDPHE, 2021j). The purpose of this tool is to "help Colorado address current and historic inequities by identifying and visualizing places with environmental health inequities in Colorado" and is intended to replace the Climate Equity Data View tool (https://chhs.source.colostate.edu/state-health-department-csu-team-start-work-on-environmental-justice-mapping-tool/). This tool is designed to pinpoint communities that are overburdened with environmental health risk with the goals of building public trust, empowering communities, and helping users target interventions. Colorado's EnviroScreen has only yet completed its first phase of development, gathering community and stakeholder input. The community engagement report for the first phase (Colorado State University, 2021) includes some high-priority indicators that are already being included in the tool. These are air pollution (ozone, $PM_{2.5}$, diesel PM, hazardous air pollutants, and other criteria air pollutants), environmental exposures (lead, traffic proximity, Risk Management Plan sites proximity, wastewater discharge, hazardous waste facilities, and oil and gas facilities), extractive and energy activities (National Priority List of contaminated sites, hazardous waste facilities, and coal power plants), socioeconomic factors (percentage of people of color, percentage low income, housing-cost burdened communities, linguistic isolation, percentage less than high school education), and health (asthma, cancer, heart disease, low birth weight). Following development, testing, and feedback, Colorado's EnviroScreen is predicted to launch in the summer of 2022.

4 Considerations for EJ Framework and Tools

4.1 Overview

Both EJSCREEN and CalEnviroScreen, plus many of the other EJ tools, are developed with a common purpose to identify a community with EJ concerns. Below are some overall observations on the available tools, with discussion of some of the advantages and limitation of specific approaches. Multiple rounds of public comment are available for CalEnviroScreen because CalEPA's cumulative impact framework and CalEnviroScreen have been available for nearly 10 years; therefore, discussion of CalEnviroScreen in this section focuses on more recent critiques and comments. EJSCREEN is newer and has had significantly less public review and critique.

4.2 Socioeconomic Indicators

The demographic information used in EJ tools is meant to capture the community characteristics that may leave the community underserved and disenfranchised. The most commonly used sociodemographic factors include some measure of income status and concentration of minority populations, although the specific measure and threshold value that is used to qualify an area as an EJ concern will vary across tools and policies. The most common source for income and race/ethnicity data are the US Census (available every 10 years) and the American Community Survey (available as a 5-year average of annual surveys conducted on a smaller subset of the population than the US Census). EJSCREEN uses incomes less than or equal to twice the federal poverty level as an indicator of low-income populations. This information, in conjunction with information on the percent minority (*i.e.*, individuals who list their racial status as other than white or list ethnicity as Hispanic or Latino), is used to calculate the demographic index. Other demographic information that can be important to an EJ analysis (*e.g.*, less than high school education, linguistic isolation, and individuals under 5 and over 64 years of age) can be mapped in EJSCREEN but are not included in the calculated indices. Many states with large immigrant populations use linguistic isolation information, based on state-specific concerns for unique challenges associated with engaging these communities in the public participation process.

Similarly, CalEnviroScreen uses the threshold of twice the federal poverty level, given that California's cost of living is higher than many other parts of the country. In contrast, CalEnviroScreen uses all of these metrics (except percent of population below 5 and above 64 years of age), plus measures of unemployment and being "housing burdened"[18] to quantify socioeconomic impacts. CalEnviroScreen's guidance provides scientific support for the inclusion of each of these factors (*e.g.*, for educational attainment, it cites studies indicating an increased risk of air pollution-related mortality for individuals without a high school education) and also points to some studies offering information on potential correlations between educational attainment, health, and race/ethnicity (CalEPA and CalOEHHA, 2021a).

WHEJAC suggested a number of additional indicators for inclusion in CEJST, including home ownership rates, presence of redlining, and gentrification pressure. Several commenters on the draft CalEnviroScreen 4.0 requested the addition of a layer related to historical geographic zoning discrimination *via* redlining.

[18] CalEPA identifies households as "housing burdened" based on having income less than 80% of the United States Department of Housing and Urban Development (HUD) Area Median Family Income and paying greater than 50% of their household income to housing costs.

While these measures may be relevant factors in EJ communities, the added value associated with inclusion of these additional metrics will have to be evaluated in the context of how the tool is ultimately used, and specifically if the tool will be an informational resource or will be used in a decision-making capacity.

4.3 Health Indicators

Unlike EJSCREEN, CalEnviroScreen uses public health data in its EJ screening assessment. Guidance documents from CalEnviroScreen specify that indicators such as incidence of asthma, cardiovascular disease, and low birth weight may be better metrics of a population's sensitivity to chemical exposures compared to previously used metrics of sensitive populations, such as percentage of elderly individuals or percentage of children in the population (CalEPA and CalOEHHA, 2017). Age distribution indicators were employed in previous versions of CalEnviroScreen but were removed in version 3.0 because they were found to highlight census tracts that contain large retired populations with longer life expectancy as opposed to elderly populations with early mortality. For this reason, the age distribution alone was not a reliable indictor of population vulnerability. Other population characteristics such as certain health conditions or socioeconomic factors are preferred indicators of potential community vulnerability.

Studies have found that indicators such as prevalence of asthma, cardiovascular disease, and low birth weight can be correlated with environmental exposure, but they also indicate increased vulnerability of individuals or populations to adverse impacts from chemical exposures. For example, air pollutants can both cause and exacerbate asthma (CDPH, 2010, as cited in CalEPA and CalOEHHA, 2017). Maryland's EJSCREEN also recognized the importance of public health data for assessing the current incidence of exposure-related health problems in a population. In its EJ analysis, Maryland's EJSCREEN considered asthma emergency department discharges, myocardial infarction discharges, and low birth weight infant data. Public health data are also available for other states (*e.g.*, Colorado includes typical health indicators such as asthma, diabetes, cardiovascular disease, and low birth weight infant data, as well as those of local interest, such as data on drug overdoses, teen fertility, and suicide, in an online interactive map – see the Colorado state listing in Appendix B for more information), but such data have not yet been incorporated into other states' EJ analyses.

Recent comments on the draft CalEnviroScreen version 4.0 also highlighted opportunities to include additional Population Characteristic indicators to help better identify sensitive populations or disadvantaged communities within California. Recent indicator suggestions from commenters that would also fall under the health indicator category are renal disease burden and COVID-19 burden. (See public comment submissions online at: https://oehha.ca.gov/calenviroscreen/comments/comment-submissions-draft-calenviroscreen-40, or see the summary in Appendix E.) Many of these same indicators have been suggested for the WHEJAC tool. Some additional proposed indicators not included in the other tools include measures of obesity, percent of the population that is disabled, and rates of opioid addiction.

4.4 Exposure/Environmental Indicators

The selection of factors to include in an EJ analysis depends on the specific concerns of local communities, as well as the availability and quality of data. The most commonly used exposure and environmental factors included in EJ screening tools and approaches (EJSCREEN, as well as state-level EJ tools/definitions/analyses) are direct exposures to air (ozone and participate matter), water (groundwater threats, contaminants in drinking water or groundwater, and discharges to surface water), and dust/soil (lead paint in homes). The most commonly used datasets for these environmental exposure data are ACS, NATA, and RSEI (see Table 2.3 for descriptions of these data sources). EJSCREEN includes 11 environmental indicators, while CalEnviroScreen considers 13 environmental indicators.

EJ screening tools use several indirect indictors of exposures that are based on distance or proximity to a potential source of chemical release (*e.g.*, an environmental cleanup site, a hazardous waste facility, a landfill, an agricultural feedlot) and these proximity indicators are questionable measures of exposure or risk. Indirect indictors of exposure are used because "[n]o data are available statewide that provide direct information on exposures" (CalOEHHA, 2021a). However, the proximity indicators fail to account for pathways (or lack of pathways) of human exposure. For example, CalEnviroScreen documentation indicates rather weak evidence for the Hazardous Waste Generator and Facility Indicator – stating nothing about exposure potential for populations and only that "health effects that come from living near hazardous waste disposal sites have been examined in a number of studies" and that ingestion or inhalation of chromium from active chrome plating facilities can result in health effects (CalOEHHA, 2021a). For permitted hazardous waste facilities (which account for only 1% of all the hazardous waste facilities evaluated within CalEnviroScreen), CalEnviroScreen includes a measure of past violations scored as either "conditionally acceptable" or "unacceptable" based on past scores from the California Department of Toxic Substances Control (CalOEHHA, 2021a). Application of additional weighting factors to account for pollution control measures, operational procedures, and facility compliance are useful for refining EJ screening tools.

EJSCREEN's indicators cover a variety of media (e.g., air, water) and examine both direct estimates of risk (*e.g.*, NATA lifetime inhalation cancer risk) and crude indicators of potential exposure, such as proximity to pollution sources or other hazards (e.g., proximity to Superfund sites, hazardous waste facilities, traffic). Significant uncertainty in the underlying data exists even for EJSCREEN exposure indicators that are considered to be more direct estimates of exposure and risk. For example, NATA's lifetime inhalation cancer risks are based on modeled, not measured, air concentrations, which are obtained from several sources of air toxics emissions inventories. Other indicators like ozone and $PM_{2.5}$ are based on a combination of modeling and monitoring data and have limited geographic coverage (with no coverage for Alaska and Hawaii). A recent study specifically examined how closely EJSCREEN's indicator for estimated roadway air pollution concentrations correlated with more detailed modelling estimates of on-road vehicle emissions. The study found a poor correlation using the existing methodology in EJSCREEN.[19] Applying the screen at the census block level and correcting for the roadway length improved, however, gave more reliable results (Rowangould *et al*., 2018). More studies like this will be useful in refining EJSCREEN and increasing confidence (or exposing limitations) in results.

Another example of significant uncertainty in the underlying data can be identify within the Hazardous Waste indicator within CalEnviroScreen. CalEnviroScreen documentation indicates that 97% of hazardous waste released nationwide originates from small hazardous waste generators and facilities, yet CalEnviroScreen limits data to large quantity generators and facilities: "Only large quantity generators (>1,000 kg per month or >13.2 tons per year) that produce RCRA waste were included due to the large number of hazardous waste generators producing small amounts of less hazardous types of waste" (CalEPA and CalOEHHA, 2021).

A key issue to keep in mind is that high EJ indicators and EJ indexes bear little association to actual risk estimates, or even relative risk. Table 4.1 below presents the distribution of various environmental indicators with health benchmarks. A few key observations are as follows:

- Even at the 99th percentile, $PM_{2.5}$ levels, ozone levels, and NATA respiratory risk are below the acceptable health-based benchmark and would not be considered to pose a risk.

[19] The effect of traffic in EJSCREEN is currently calculated by taking average annual daily traffic at major roads within 500 m of each census block centroid, divided by distance in meters and presented as a population-weighted average of blocks in each block group.

- Conversely, even at the 25th percentile, all NATA cancer risks are above the benchmark (using 1×10^{-5} (*i.e.*, 10 in 1,000,000 as a benchmark).
- Interestingly, although the difference between a 25th percentile result and a 90th percentile result in an EJSCREEN analysis is likely to be quite consequential, the difference between the raw data 25th and 95th percentile are fairly small and inconsequential from a risk standpoint. For example, NATA respiratory risk values in the 25th percentile are very unlikely to trigger a further concern, while those values in the 95th percentile are very likely to trigger an EJ concern once demographics are considered. In terms of risk, though, the difference between a hazard index (HI) of 0.34 and an HI of 0.68 is negligible.

Table 4.1 Raw Data Distribution for Environmental Indicators with Health-Based Benchmarks

Environmental Indicator	Health Benchmark	25th Percentile	50th Percentile	80th Percentile	95th Percentile	99th Percentile
$PM_{2.5}$ (μg/m^3)	12 μg/m^3	7.41	8.3	9.34	10.58	12.11
Ozone (ppb)	70 ppb[a]	38.93	43.03	46.72	53.47	60.61
NATA Cancer Risk (1 in 1,000,000)	1 in 100,000 (or 10 in 1,000,000)	25.72	43.03	38.21	53.47	60.61
NATA Respiratory (hazard index [HI])	HI = 1	0.34	0.43	0.55	0.68	0.77

Notes:
NATA = National Air Toxics Assessment; $PM_{2.5}$ = Particulate Matter with Particle Size ≤2.5 μm in Diameter; ppb = Parts Per Billion.
(a) The fourth-highest daily maximum 8-hour concentration, averaged across three consecutive years.

A common critique of EJ screening tools is the limited inclusion of exposure or environmental factors compared to the widespread availability of such data. For CalEnviroScreen, one of the most frequent comments on the most recent draft version was a request to include additional exposure or environmental effects indicators to allow for improved identification of disadvantaged communities within California. Many commenters included recommendations to consider additional environmental data, including drinking water, climate change risks, legacy mining lands, noise, surface water flow characteristics, pesticide data for new or emerging compounds of public interest, air quality from growth in border crossings, and many others. Commenters indicate that the addition of exposure or environmental datasets to the EJ screening tool would identify additional disadvantaged communities within California.

4.5 Community Indicators

EJSCREEN and CalEnviroScreen do not currently contain indicators that could be considered to fall into the "community" category. These indicators mainly relate to community level features that may individuals in those community more vulnerable to environmental exposures. There is a clear interest to expand tools to account for these features. For example, recent comments on the draft CalEnviroScreen version 4.0 suggested the addition of measures of access to healthcare (including staffing levels of medical professionals, medically underserved areas), tobacco use or sales data, community access to parks and green spaces, and proximity to transit and schools. (See public comment submissions online at: https://oehha.ca.gov/calenviroscreen/comments/comment-submissions-draft-calenviroscreen-40, or see the summary in Appendix E.) Similarly, WHEJAC members have suggested similar indicators. Some additional indicators are access to mental health systems and care and proximity and availability of fresh food (WHEJAC, 2021). WHEJAC has also called out factors more directed at climate change including, indicators related to the extent of tree canopy, and impervious surfaces, amount of green space, and measures of coastal sea level rise and flooding risk. As noted above the Baltimore and Maryland tools has already incorporated some of these community level factors in its newly developed tool. The Baltimore and Maryland EJSCREEN tools include important community factors such as segregation, limited access to supermarkets, locations of supermarkets, locations of small grocers and corner stores, urban heat islands, Health Professional Shortage Areas (HPSAs), and local public school system data.

4.6 Differences in Data Presentation

Of the many currently available EJ tools, most do not calculate scores or rankings, but rather present visual displays or comparisons to a specific criterion. CalEnviroScreen is a notable exception that provides data and relative ranking information for each individual indicator and also compiles the 21 EJ indicators into a single score for each census tract. This allows users to review and analyze specific indicators, determine indicators that are providing higher contributions to the overall score, and quickly identify disadvantaged communities. However, as noted previously, there are limitations based on CalOEHHA's approach for determining and weighting each indicator.

There are many differences in the way the various EJ screening tools combine and summarize the various factors used for screening. CalEnviroScreen combines each input into a percentile score, then combines these into a final EJ score inclusive of sociodemographic, health, and environmental factors. Even though these data are compiled into a single EJ score, detailed data for each indicator are still available for user review and analysis. The demographic data for CalEnviroScreen are censored (*i.e.*, by removing demographic data for census tracts for which the relative standard error is greater than half the estimate or for which the standard error is greater than the mean standard error for all California census tracts) and further adjust proximity-type indicators based on the status of the site, facility, *etc*.

EJSCREEN differs from CalEnviroScreen in that EJSCREEN offers an EJ index (as a percentile) for each of the 11 environmental indicators, although the underlying raw data for each indicator are also available. The presented percentile is based on comparison of the EJ index in the selected study area to a distribution of that same indicator on the state, regional, or national level. EJSCREEN technical guidance indicates that certain indicators with highly skewed underlying distributions should be interpreted with caution (US EPA, 2019, p. 26-27): "For example, block groups in the top 5% (shown in red on maps and reports) have traffic, NPL [National Priorities List], and TSDF [treatment, storage and disposal facility] proximity indicators on average that are about three times as high as in the next 5% (shown in orange on the maps). These differences are far less extreme in the cases of $PM_{2.5}$ and lead paint indicators, which don't vary as much across block groups." More information on the nature of the underlying distribution and impact on interpretation is discussed in Section 4.7.

Several commenters on CalEnviroScreen's most recent version focused on the need for additional research or documentation to support the underlying data distributions, calculations, and methodology for CalEnviroScreen EJ Scoring. For example, documentation is lacking for calculations that weight the Exposure component twice as much as the Environmental Effects component of the EJ analysis. While it is not surprising that Exposure indicators, such as ozone, PM, and drinking water contaminants, may contribute more to population exposures than a specific hazardous waste generator or cleanup site, additional documentation or support for the specific 50% weighting would be helpful.

A common and basic critique of many EJ screening tools is the general ease-of-use for these EJ Screening tools. For CalEnviroScreen, some recent public comments centered on requests for more functionality for users to make custom maps or labels or to increase readability by changing font colors or accounting for colorblind users. An additional longstanding critique of the tool has been the inability of the user to define their community. Unlike tools like EJSCREEN and North Carolina's Community Mapping System, where a user can select the borders of their community, CalEnviroScreen users are limited to communities defined by census tract designations. In many cases, census tracts may not account for EJ communities or populations that represent smaller divisions or different borders than those represented by the census tract boundaries.

4.7 Sensitivity in Each Tool

The process for generating EJ indexes, which are the cornerstone of an EJ assessment, is straightforward, with limited opportunities for user input. Consequently, the EJSCREEN output is not particularly sensitive to user assumptions. One user input that can influence results (and the subsequent interpretation of results) is the selection of the study area of interest. Because of the variability that may exist among census block groups, a single census block group may not be representative of the nearby larger community. For this reason, US EPA (2019) noted that it is important to examine surrounding communities (*i.e.*, look at a buffer area) to ensure that results make sense in the context of nearby communities. In contrast, if the user examines an area that is too large, small pockets of susceptible sub-populations may be missed because of the averaging that occurs. Because of this, it is important to consider analysis objectives when selecting a study area of interest and to examine underlying raw data where there is evidence of significant inter-census block variability.

Besides the selection of the study area of interest, EJ indexes are not influenced by any other user input. EJ indexes are calculated for each environmental indicator, and since they are not combined into a common metric, all results have equal weight. In fact, according to US EPA (2019, Appendix H), if any one indicator exceeds the 80th percentile, the community warrants further consideration as a community with potential EJ concerns. Because each environmental indictor has its own index and because each score has equal weight, EJ analysis results are not sensitive to the types of environmental variables that are examined, and the uncertainty in one indicator does not affect any other indicators.

Although the EJSCREEN program is not sensitive to analysis assumptions, the data that underlie the environmental indicators have been generated using a multitude of assumptions that can have a significant impact on the resulting data distributions. US EPA (2019) notes that "[e]ven for the indicators that directly estimate risks or hazards, as with the air toxics cancer risk indicator, estimates have substantial uncertainty because emissions, ambient levels in the air, exposure of individuals, and toxicity are uncertain."

The assumptions that are used to generate the environmental indicator data vary by indicator but include time periods of interest, emissions data, air and water modeling assumptions, toxicity criteria selection, and receptor exposure assumptions. While any assumption has the potential to influence results, these assumptions cannot be changed during an EJSCREEN evaluation. While one could examine the methodology underlying the environmental indictor data generation and identify the assumptions that most significantly affect the data distributions (both within the indicator and among indicators), such an analysis would be a large undertaking and would best be accomplished through a targeted case study. Moreover, because data in EJSCREEN analyses are presented as a relative measure of concern and not a raw level of risk, it is likely that any exposure/modeling assumptions will affect calculations in the same way. Thus, while the raw environmental indicator distributions may change, the changes on the relative percentiles (*i.e.*, EJ indexes) would be expected to be negligible.

Environmental Indicator	Missing	Minimum	25%ile	50%ile (median)	*Pop. Mean*	75%ile	80%ile	90%ile	95%ile	99%ile
PM 2.5	1664	3.04	7.41	8.30	9.14	9.13	9.34	9.95	10.58	12.11
Ozone	1664	25.27	38.93	43.03	38.4	46.12	46.72	49.21	53.47	60.61
NATA DPM	542	4.8E-06	0.23	0.38	0.48	0.60	0.66	0.85	1.05	1.73
NATA cancer risk	542	6.13	25.72	31.16	31.92	36.85	38.21	41.72	44.53	49.55
NATA respiratory HI	542	0.06	0.34	0.43	0.44	0.52	0.55	0.62	0.68	0.77
% pre-1960 (lead paint)	0	0	.04	0.17	0.28	0.46	0.54	0.72	0.83	0.92
Proximity Traffic	0	-	50.15	203.95	753.67	654.58	849.77	1691.71	2862.75	6046.43
Proximity NPL	0	0	2.8E-02	6.0E-02	0.13	0.13	0.15	0.24	0.42	0.88
Proximity RMP	0	0	0.14	0.30	0.74	0.90	1.11	2.53	2.71	4.05
Proximity TSDF	0	0	0.14	0.42	3.95	1.64	2.17	4.31	7.45	45.46
Wastewater Discharge	534	-	-	2.5E-05	13.60	3.65E-03	8.91E-03	7.65E-02	0.51	6.56

Figure 4.1 Underlying data for EJSCREEN's Environmental Indicators. Source: US EPA (2020b).

Similarly, CalEnviroScreen offers limited opportunities for user input. For CalEnviroScreen, both the calculation method and the scoring method within the indicators offer opportunities to assess tool sensitivity, but these methods cannot be altered by a user in the tool itself and would require significant effort to obtain underlying data sets, recalculate individual site or facility scores, and adjust overall weighting of components of the final CalEnviroScreen score.

A main source of potential sensitivity in the CalEnviroScreen Score[20] calculation method is that CalEPA weights the Environment Effects component score half as much as the Exposures score. In practice, this means that CalEPA assumes that Exposures Indicators (*e.g.*, PM, Diesel PM, Ozone, Lead Risk, Pesticide Use) better represent "presence of pollutants in a community" rather than the Environmental Effects (such as cleanup sites, groundwater threats, impaired water bodies). Notably, CalEPA does note that either measure is a measure of actual exposure to pollutants in a community.

An additional important source of potential sensitivity in CalEnviroScreen is the calculation of the raw scores for the individual indictors. Unlike EJSCREEN, many of the CalEnviroScreen indicator raw scores include weighting values to address site status or size, violation history, proximity, and many other factors that CalEPA includes to determine the magnitude of the threat to a community (see description of weighting in notes of Table 3.1). In all, Environmental Effects indictors (except the Impaired Water Bodies Indicator), facilities are assigned scores by CalEPA, these raw scores are then calculated on the census tract level and ranked to assign percentiles for each census tract, and then percentiles are averaged to produce combined scores for each component of the overall census tract CalEnviroScreen Score. CalEnviroScreen's weighting and scoring methodologies for both the indicator score and the final calculation provide significant opportunities for exploration of alteration of facility or site weights and the resulting impacts on individual census tracts.

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[20] The overall CalEnviroScreen Score is a combination of the percentile rankings from the four components: Exposure Indicators, Environmental Effects Indicators, Sensitive Population Indicators, and Socioeconomic Factor Indicators.

5 Application of EJ Tools

5.1 Case Study #1: EJSCREEN *vs* CalEnviroScreen

Different EJ tools do not always yield consistent results. As an example, the predominant federal EJ tool, EJSCREEN (Section 2), and the California-specific CalEnviroScreen (Section 3.1) were both run for the same census block for an urban area in central California (Figure 5.1) with a population of more than 3,000.

Figure 5.1 Case Study Census Block Area. Source: Google (2021).

EJSCREEN reported that for the 10 EJ indexes with available data, the census block ranked at or above the 70th percentile in the state for all 10 indexes. Nationally, the census block ranked at or above the 87th percentile for all 10 indexes (Table 5.1 and Figure 5.2). In contrast, CalEnviroScreen puts the same census block at, overall, just the 47th percentile in the state, with a pollution burden at the 33rd percentile. The exposure results from CalEnviroScreen are shown in Table 5.2.

Table 5.1 EJ Screen Indexes for Selected Case Study Census Block

EJ Indexes	Percentile in State	Percentile in US EPA Region	Percentile in US
EJ Index for Particulate Matter ($PM_{2.5}$)	87	89	96
EJ Index for Ozone	70	72	88
EJ Index for NATA Diesel PM	99	99	99
EJ Index for NATA Air Toxics Cancer Risk	89	90	95
EJ Index for NATA Respiratory Hazard Index	91	92	97
EJ Index for Traffic Proximity and Volume	99	99	99
EJ Index for Lead Paint Indicator	97	98	99
EJ Index for Superfund Proximity	85	88	93
EJ Index for RMP Proximity	71	75	87
EJ Index for Hazardous Waste Proximity	98	99	98
EJ Index for Wastewater Discharge Indicator	N/A	N/A	N/A

Notes:
EJ = Environmental Justice; N/A = Not Applicable; NATA = National Air Toxics Assessment; PM = Particulate Matter; $PM_{2.5}$ = Particulate Matter with Particle Size ≤2.5 µm in Diameter; RMP = Risk Management Plan; US EPA = United States Environmental Protection Agency.
Data obtained by running EJ Screen for the selected case study census block.

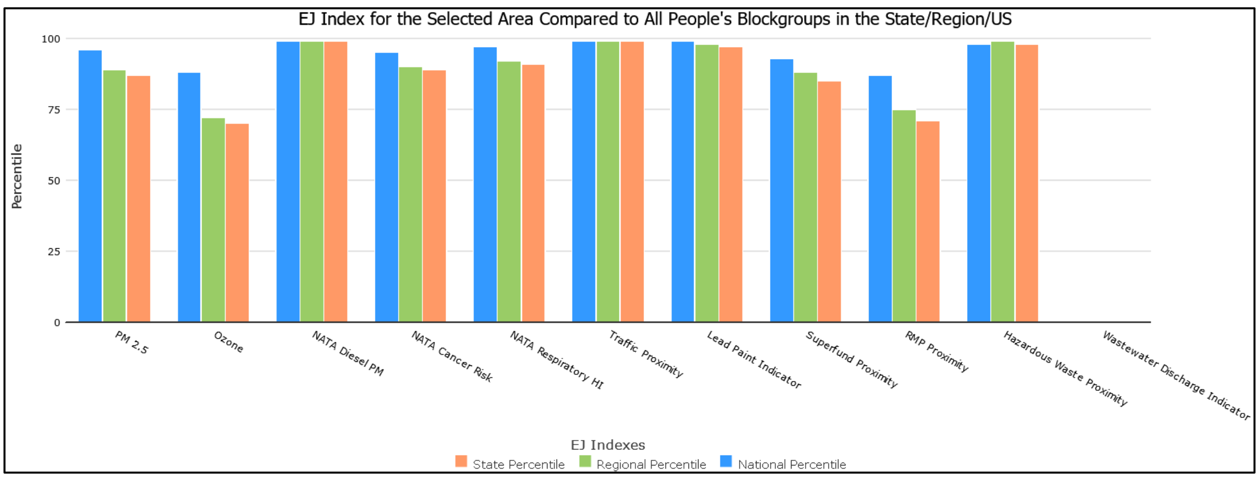

Figure 5.2 EJ Screen Results for Selected Case Study Census Block

Table 5.2 CalEnviroScreen Results for Selected Case Study Census Tract

Exposure	Percentile (State)
Ozone	2
Particulate Matter ($PM_{2.5}$)	29
Diesel Particulate Matter	100
Toxic Releases	50
Traffic	65
Pesticides	0
Drinking Water	14
Lead from Housing	67

Notes:
Data obtained by running CalEnviroScreen for the selected case study census tract.

Using EJ Screen exclusively, an analysis could conclude that the case study census block warrants consideration as an EJ community, since every indicator is above the 80th percentile nationally (see discussion in Section 2.4). Conversely, using CalEnviroScreen exclusively, an analysis could conclude that the case study census block does not warrant further consideration, since the overall CalEnviroScreen percentile is below the median in the state. The disagreement between the tools points to the need for continued EJ tool refinement, as well as the need for EJ analyses to be aware of cases where multiple EJ tools may cover the same geographic area and to screen communities using all of the available tools.

5.2 Case Study #2: EJ Indexes Driven by Demographics and not Environmental Burden

When using EJSCREEN it is important to understand the basis for the EJ index and whether the score is being driven by environmental burden or is simply a function of demographics. These distinctions become important if decision are being made about where to direct resources to mitigate chemical exposures. The example below shows an area in North Carolina, where most of the environmental indicators (Figure 5.3a) are below the 50th percentile, but most of the calculated EJ indexes (Figure 5.3b) are above 80%, qualifying this area for "further review." These results would indicate the area has demographic profile consistent with EJ concerns, but the environmental indicators do not suggest an environmental overburden.

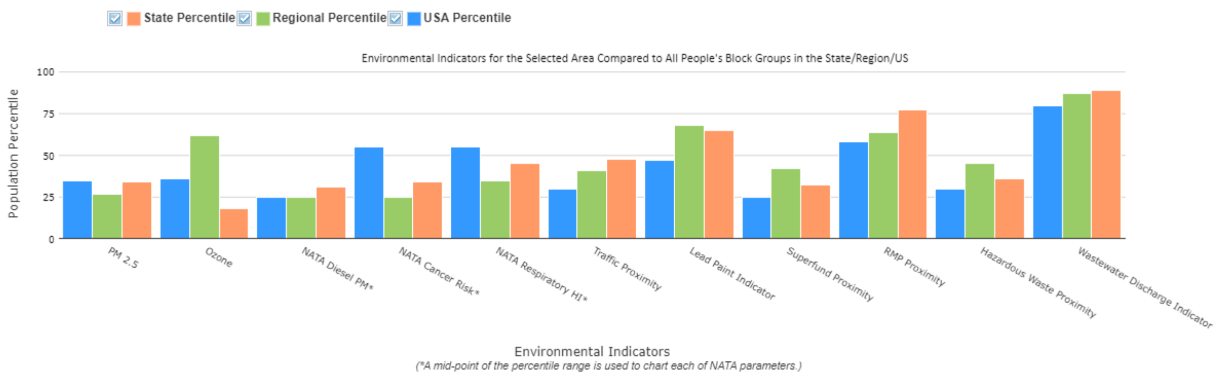

Figure 5.3a EJSCREEN Results - Environmental Indicators for Rural North Carolina

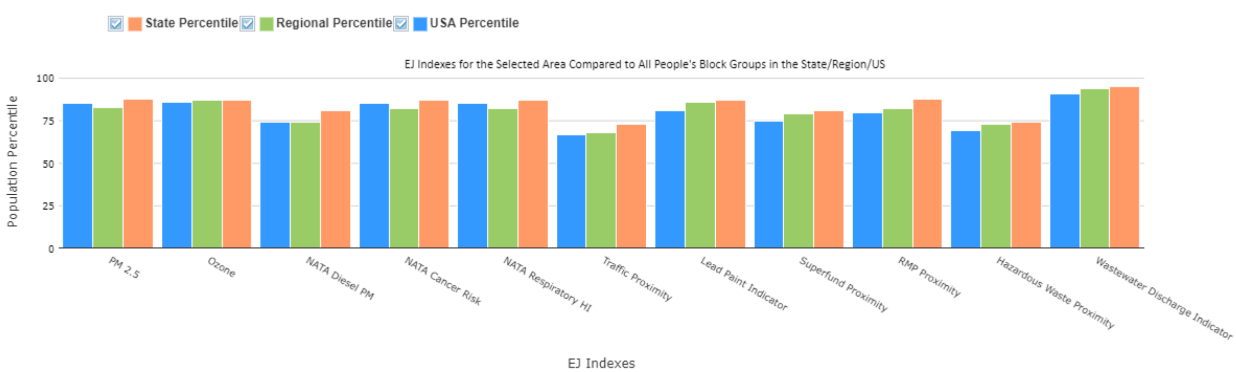

Figure 5.3b EJSCREEN Results - EJ Indexes for Rural North Carolina

Conversely, areas that score relatively high in area of environmental burden may not be triggered for further follow-up. In the example below a community outside NYC, has several environmental indicators above the 80th percentile (Figure 5.4a), but almost all EJ indexes are below the 80th percentile (Figure 5.4b).

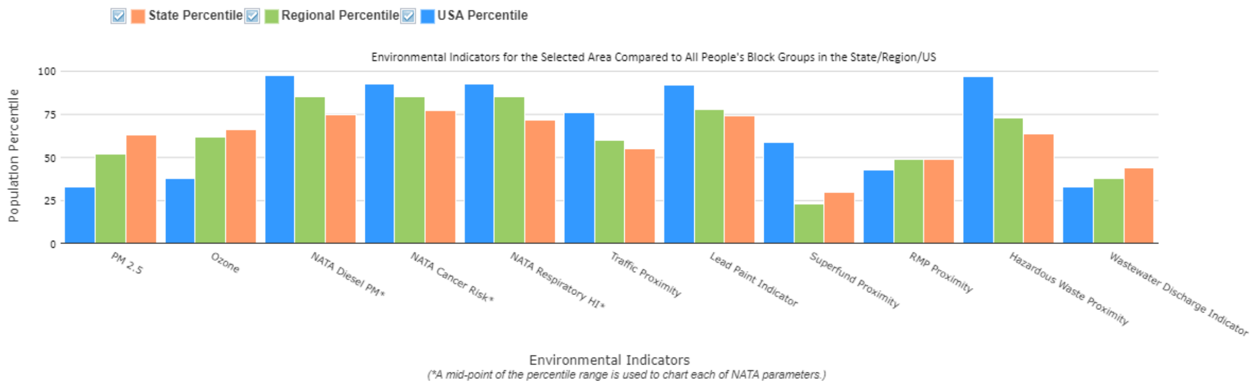

Figure 5.4a EJSCREEN Results -Environmental Indicators for Urban Community Outside New York City

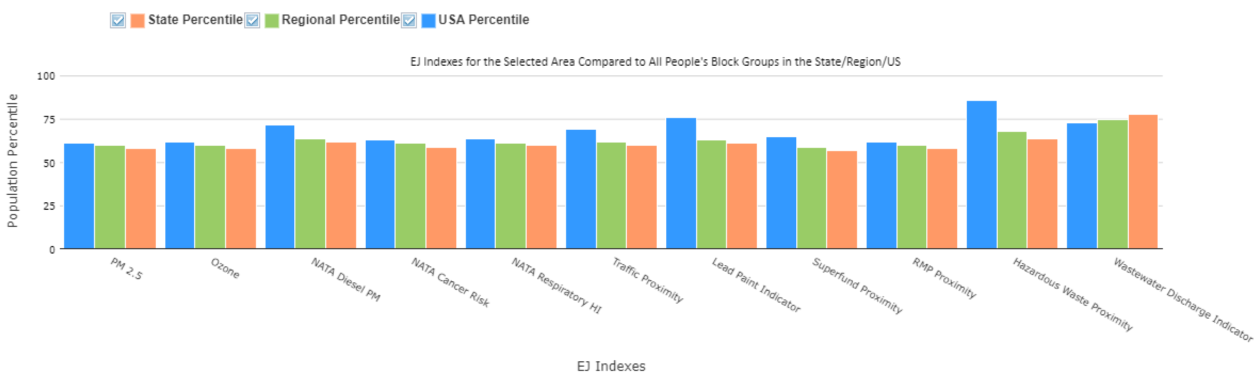

Figure 5.4b EJSCREEN Results - EJ Indexes for Urban Community Outside New York City

5.3 Case Study #3: Determine Facilities Siting Based on EJ Communities

Given the developing science and policy related to evaluation of EJ concerns, there are many different approaches that have been used to incorporate EJ initiatives into state-level programs and regulations. One example of EJ used in practice comes as part of rulemaking for renewable energy subsidies and siting of wood-burning biomass plants in Massachusetts.

In Massachusetts, the Renewable Energy Portfolio Standard (RPS) program requires a certain percentage of the state's electricity to come from renewable energy (MassDOER, 2021a). Recent rulemaking related to the RPS program sets limits on the locations of facilities that qualify for the RPS based on proximity to EJ communities. As part of 225 CMR 14.00, facilities using biomass fuel shall not qualify for subsidies if they are located in or within 5 miles of an EJ population (MassDOER, 2021b).

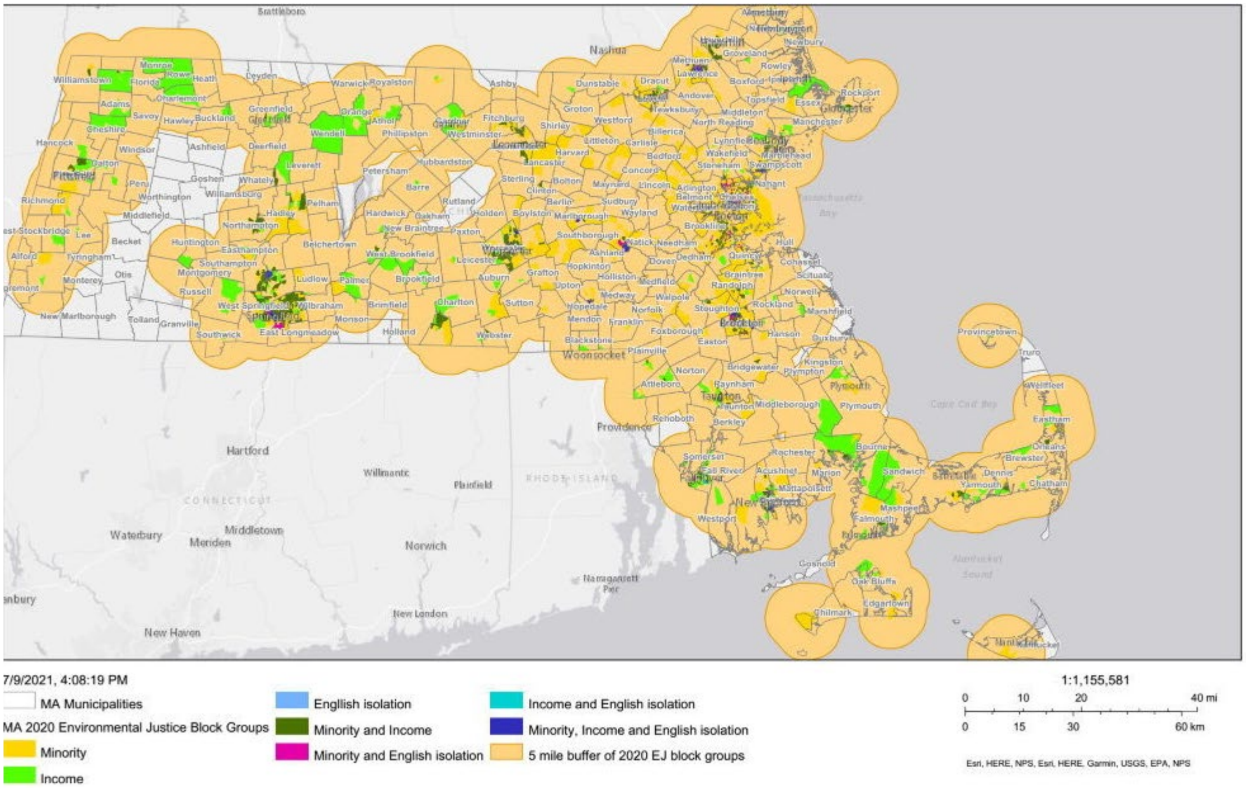

Figure 5.5 Massachusetts Environmental Justice Populations with 5-Mile Buffer. Source: MassDOER (2021, as cited in Young, 2021).

The Massachusetts Department of Energy Resources (MassDOER) produced the map (Young, 2021) above identifying EJ communities and a 5-mile buffer around such communities (Figure 5.5). EJ communities are identified consistent with Massachusetts's EJ policy (Massachusetts Executive Office of Energy and Environmental Affairs, 2021) designating EJ communities as those that meet one or more of the criteria based on low income, high minority population, and lack of English proficiency. Notably, a new addition to the state's EJ policy allows the Secretary of Environmental Affairs to designate additional areas or small portions of communities as EJ populations (Massachusetts Executive Office of Energy and Environmental Affairs, 2021). MassDOER also applied a 5-mile buffer around each EJ block group, with no justification provided in the new regulations for the selection of this 5-mile buffer distance. The resulting map of buffered EJ communities identifies very limited areas (~10-15% of total area) within the state where facilities using biomass fuel could be sited, including portions of approximately 40 communities out of the 351 cities and towns in Massachusetts (Young, 2021). This approach to facility siting can result in the perception of a disproportionate burden of large wood-burning facilities on less populated areas of the state (Western Massachusetts) that may not meet the limited demographic indictors used to identify overburdened communities.

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Appendix A

Notable Definitions

1. **Aggregating effects:** The effect of aggregation on the results. According to US EPA (2016b, p. 56), "[r]esults may differ depending on the unit of analysis; small geographical units (e.g., census tract) may provide different results than when results are aggregated across units." Therefore, the spatial unit used in the analysis should be specific to both the pollutant and the data (*i.e.*, air or water data).

2. **Allostatic load:** The aggregated physiological effect of chronic adaptation to stress that occurs at the cellular and intracellular level. Negative health outcomes, such as cardiovascular disease or depression may result from consistent secretion of stress-related hormones and resulting allostatic overload in the human body (Mauss *et al*., 2015).

3. **Analysis plan:** The "final stage of problem formulation," which details the intentions and technical aspects of the risk assessment (US EPA, 2016b, p. 38). These steps include "(a) the assessment design and rationale for selecting specific pathways to include in the risk assessment; (b) a description of the data, information, methods, and models to be used in the analyses (including uncertainty analyses), as well as intended outputs (e.g., risk metrics); (c) quality assurance and quality control measures; and (d) the associated data gaps and limitations."

4. **BIPOC:** Black, Indigenous and People of Color (US EPA, 2020c, p. 18).

5. **Community of color:** "[A] geographically distinct area in which the population of any of the following categories of individuals, individually or in combination, is higher than the average population of that category for the State in which the community is located:

   a. Black;

   b. African American;

   c. Asian;

   d. Pacific Islander;

   e. Other Non-White race;

   f. Hispanic;

   g. Latino;

   h. Indigenous or members of a Tribe; and

   i. Linguistically isolated." (WHEJAC, 2021, p. 78-79)

6. **Community outreach:** To strengthen Human Health Risk Assessment to consider environmental justice, US EPA (2016b) recommends that "community-generated information" be collected and implemented in regulatory analyses. This requires community outreach, and therefore, the study of how to effectively reach out to these communities.

7. **Comparison population group:** US EPA (2016b, p. 66) defines comparison group as "other groups about which information is presented, in relation to population groups of concern, in order to describe impacts of a regulatory action." US EPA (2016b, p. 54) explains that comparison groups can be "individuals with similar socioeconomic characteristics across different areas in the state, region or nation (i.e., within-group comparison)" or "individuals with different socioeconomic characteristics within an affected area (i.e., across-group comparison)."

8. **Cumulative risk:**

   a. US EPA (US EPA, 2016b, p. 18) defines cumulative risk as the risk of adverse effects "associated with **multiple stressors** from one **or more** pollution sources or exposure pathways."

b. CalOEHHA (2021d, p. 10) defines cumulative impacts as "exposures, public health or environmental effects from the combined emissions and discharges, in a geographic area, including environmental pollution from all sources, whether single or multi-media, routinely, accidentally, or otherwise released. Impacts will take into account sensitive populations and socioeconomic factors, where applicable and to the extent data are available."

9. **Cumulative risk assessment:**

   a. US EPA (2016b, p. 66) defines cumulative risk assessment as "an analysis, characterization, and possible quantification of the combined risks to human health or the environment from multiple agents or stressors."

   b. NRC (2009, as cited in US EPA, 2016b, p. 66) defines cumulative risk assessment as "evaluating an array of stressors (chemical and non-chemical) to characterize – quantitatively to the extent possible – human health and ecologic effects, taking into account factors such as vulnerability and background exposures."

10. **Demographic indicators:** Demographic indicators are demographic factors "often used as proxies for a community's health status and potential susceptibility to pollution" (US EPA, 2015, p. 8). The EJSCREEN tool (US EPA, 2021o) incorporates six demographic indicators that are measured per census block group and are described as "very general indicators":

    a. Percent low-income;

    b. Percent people of color;

    c. Less than high school education;

    d. Linguistic isolation;

    e. Percent of people under the age of five years; and

    f. Percent of people over the age of 64 years.

11. **Differential impacts:** Differential impacts are described as "discernible distinction in impacts or risks across population groups" (US EPA, 2016b, p. 4) or "differences in anticipated impacts across population groups of concern for both the baseline and proposed regulatory options" (US EPA, 2016b, p. 4). According to US EPA (2016b, p. 11), differential impacts are used to answer the following three questions:

    a. "Are there potential EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern in the baseline?";

    b. "Are there potential EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern for the regulatory option(s) under consideration?"; and

    c. "For the regulatory option(s) under consideration, are potential EJ concerns created or mitigated compared to the baseline?"

12. **Disproportionate impacts:** US EPA (2016b, p. 66) defines disproportionate impacts as "differences in impacts or risks that are extensive enough that they may merit Agency action." Disproportionate impacts are informed by analysis but are policy judgements, and therefore, "the responsibility of the decision maker" (US EPA, 2016b, p. 4).

13. **Educational attainment**: Educational attainment is an important predictor of health as it is associated with the degree of indoor and outdoor pollution exposure as well as "susceptibility to the health impacts of environmental pollutants" (CalEPA and CalOEHHA, 2021, p. 161). In California's CalEnviroScreen (version 4.0) screening tool, educational attainment is measured by

the "percentage of the population over age 25 with less than a high school education" (CalEPA and CalOEHHA, 2021, p. 161). This percentage is a 5-year estimate using 2014-2018 data and is one of the five socioeconomic indicators used in the screening tool to calculate 'Population Characteristics' scores, which range from 0.10 to 10 (CalEPA and CalOEHHA, 2021, p. 161, 192). CalEPA and CalOEHHA (2021, p. 162) list the following ways in which lower educational attainment can decrease health status: "economic hardship, stress, fewer occupational opportunities, lack of social support, and reduced access to health-protective resources such as medical care, prevention and wellness initiatives, and nutritious food."

14. **Effect modifiers**: US EPA (2016b, p. 66) defines effect-modifiers (also known as risk-modifiers) as "factors that may influence susceptibility, and may include genetics, diet, nutritional status, pre-existing disease, psychological stress, co-exposure to similarly-acting toxics, and cumulative burden of disease resulting from exposure to all stressors throughout the course of life." Effect-modifiers can "influence the health-related outcome of exposure through biological interactions at the individual level" (US EPA, 2016b, p. 19).

15. **Effects assessment**: Effects assessment is a step of the 'classic risk assessment process' and includes hazard identification and dose-response assessment (US EPA, 2016b, p. 22). Hazard identification is defined as the "process of identifying the type of hazard to human health (e.g., cancer, birth defects) posed by the exposure of interest," whereas "dose-response assessment addresses the relationship between the exposure or dose of a contaminant and the occurrence of particular health effects or outcomes" (US EPA, 2016b, p. 61). In the context of EJ, it is not only important to identify the health problems caused and at what exposures. Differences in the type and/or incidence of health problems in populations of concern, as well as the response of these populations to either the environmental stressors that cause the health problems or the health problems themselves, must be determined (US EPA, 2016b, p. 61). According to US EPA (2016b, p. 61), the "range of population-specific risk distributions along the dose-response curve" should be considered.

16. **EJ community:** WHEJAC (2021, p. 79) defines an EJ community as "a geographic location with significant representation of persons of color, low-income persons, indigenous persons, or members of Tribal nations, where such persons experience, or are at risk of experiencing, higher or more adverse human health or environmental outcomes."

17. **EJ index:** US EPA (2021p) creates EJ indexes by combining environmental and demographic information to summarize how a single "environmental indicator and demographics come together in the same location." Using the concept of 'excess risk,' EJSCREEN implements the following equation to calculate EJ index: Environmental Indicator × (Demographic Index for Block Group - Demographic Index for US) × Population count for Block Group. According to US EPA (2021p), "[t]his formula for the EJ Index is useful because for each environmental factor it finds the block groups that contribute the most toward the national disparity in that environmental factor. It can highlight which locations are driving the overall net disparity." See 'Environmental Indicators' for the eleven environmental indicators that are represented by EJ indexes in EJSCREEN.

18. **EJ tools:** EJ tools use environmental and demographic data to identify and compare areas with potential EJ concerns. For example, US EPA's environmental justice screening map and mapping tool, EJSCREEN, can compare "locations to the rest of the state, EPA region, or the nation" (US EPA, 2021q). EJ tools can be used to support research and policy goals.

    a. According to US EPA (2021q), EJSCREEN is used to identify areas with "[m]inority and/or low-income populations," "[p]otential environmental quality issues," a "combination of environmental and demographic indicators that is greater than usual," and "[o]ther factors that may be of interest" (US EPA, 2021q).

b. CalEPA and CalOEHHA (2021, p. 6) describes its EJ tool, CalEnviroScreen (v. 4.0), as "a science-based method for identifying impacted communities by taking into consideration pollution exposure and its effects, as well as health and socioeconomic status, at the census-tract level."

19. **Environmental burden:** Environmental burden is the relative share or distribution of environmental effects such as pollutant concentrations, presence and density of industrial sites (*e.g.*, contaminated sites, dry cleaners, junkyards, power plants, incinerators, landfills), presence and prevalence of lead paint, and impaired groundwater/surface water.

20. **Environmental indicators:** US EPA (2015, p. 8) describes environmental indicators as "direct or proxy estimates of risk, pollution levels or potential exposure (e.g., due to nearby facilities)." According to US EPA (2021r), environmental indicators can be used to "quantify proximity to and the numbers of certain types of potential sources of exposure to environmental pollutants, such as nearby hazardous waste sites or traffic." US EPA (2021q) lists the eleven environmental indicators[21] in EJSCREEN as follows:

    a. National Scale Air Toxics Assessment Air Toxics Cancer Risk;

    b. National Scale Air Toxics Assessment Respiratory Hazard Index;

    c. National Scale Air Toxics Assessment Diesel PM;

    d. Particulate Matter ($PM_{2.5}$);

    e. Ozone;

    f. Lead Paint Indicator;

    g. Traffic Proximity and Volume;

    h. Proximity to Risk Management Plan Sites;

    i. Proximity to Treatment Storage and Disposal Facilities;

    j. Proximity to National Priorities List Sites; and

    k. Wastewater Discharge Indicator.

21. **Environmental justice:**

    a. US EPA (2016b, p. 66) 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."

    b. WHEJAC (2021, p. 79) defines environmental justice as "the just treatment and meaningful involvement of all people regardless of race, color, national origin, or income, or ability, with respect to the development, implementation, enforcement, and evaluation of laws, regulations, programs, policies, practices, and activities, that affect human health and the environment."

22. **Environmental stressor:** According to US EPA (2016b, p. 69), an environmental stressor "is any physical, chemical, or biological entity that can induce an adverse response. Stressors may adversely affect specific natural resources or entire ecosystems, including plants and animals, as well as the environment with which they interact." In US EPA's Technical Guidance for Assessing Environmental Justice in Regulatory Analysis, the term environmental stressor "is used to

[21] For details on the environmental indicators see https://www.epa.gov/ejscreen/overview-environmental-indicators-ejscreen or https://www.epa.gov/sites/default/files/2015-05/documents/ejscreen_technical_document_20150505.pdf

encompass the range of chemical, physical, or biological agents, contaminants, or pollutants that may be subject to a rulemaking" (US EPA, 2016b, p. 69).

23. **EO 12898:** *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (Clinton, 1994, p. 7629). According to US EPA (2016b, p. 1), this EO "calls on each covered Federal agency to make achieving environmental justice part of its mission 'by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities" on populations of concern including minority populations and low-income populations.

24. **EO 14008:** *Tackling the Climate Crisis at Home and Abroad* was issued by President Biden "to increase the Federal Government's efforts to address environmental injustice" (WHEJAC, 2021, p. 10). WHEJAC (see definition below) was established under this EO to strengthen environmental justice monitoring and enforcement (WHEJAC, 2021, p. 10). EO 14008 required a Climate and Economic Justice Screening Tool be established by July 2021 (WHEJAC, 2021, p. 13). For more information see https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.

25. **Exposure assessment:** US EPA (2016b, p. 67) defines exposure assessment as "an identification and evaluation of the human population exposed to a contaminant or stressor, describing its composition and size, as well as the type, magnitude, frequency, route and duration of exposure."

26. **Fair treatment:** US EPA (2016b, p. 67) defines fair treatment as "the principle that no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental, and commercial operations or programs and policies." Therefore, "the distribution of reductions in risk from EPA actions" is also considered (US EPA, 2016b, p. 1). The term 'just treatment' is used by WHEJAC (2021) and is defined below.

27. **Health Impact Assessment:** US EPA (2016b, p. 67) defines Health Impact Assessment as "a systematic process that uses an array of data sources and analytic methods, and considers input from stakeholders to identify the potential effects of a proposed regulatory action, policy, or project on the health of a population and the distribution of those effects within the population."

28. **Hot spots:** US EPA (2016b, p. 67) defines a hot spot as "a geographic area with a high level of pollution/contamination within a larger geographic area of lower or more "normal" environmental quality."

29. **Human Health Risk Assessment:** US EPA (2016b, p. 67) defines Human Health Risk Assessment (HHRA) as "the process used to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals or other stressors in contaminated environmental media, now or in the future."

30. **Indigenous peoples/Tribal and indigenous community:**

    a. US EPA (2016b, p. 67) gives the following definition for indigenous peoples: "state-recognized tribes; indigenous and tribal community-based organizations; individual members of federally recognized tribes, including those living on a different reservation or living outside Indian country; individual members of state-recognized tribes; Native Hawaiians; Native Pacific Islanders; and individual Native Americans. A reference to populations characterized by Native American or other pre-European North American ethnicity or cultural traits."

    b. WHEJAC (2021, p. 81) defines a tribal and indigenous community as "a population of people who are members of:

    (i) a federally recognized Indian Tribe;

(ii) a State-recognized Indian Tribe;

(iii) an Alaska Native or Native Hawaiian community or organization; and

(iv) any other community of indigenous people located in a State, including indigenous persons residing in urban communities."

31. **Just treatment:** WHEJAC (2021, p. 80) defines just treatment as "the conduct of a program, policy, practice or activity by a Federal agency in a manner that ensures that no group of individuals (including racial, ethnic, or socioeconomic groups) experience a disproportionate burden of adverse human health or environmental outcomes resulting from such program, policy, practice, or activity, as determined through consultation with, and with the meaningful participation of, individuals from the communities affected by a program, policy, practice, or activity of a Federal agency, and to ensure that each person enjoys, at a minimum:

    a. the full degree of protection from environmental and health hazards, especially where disproportionate human health and environmental impacts are demonstrably greater;

    b. equitable access to any Federal agency action, including decision-making processes, actions, resources, and benefits, to build and ensure healthy, culturally vibrant, sustainable, and resilient environments for all people to live, learn, work, worship, recreate, and practice their cultures;

    c. elimination of systemic racism and other structural barriers to achieving healthy, culturally vibrant, sustainable, and resilient communities for all people, which contribute to disproportionate human health and environmental impacts on the basis of race, color, national origin, income, and disability; and

    d. improvement in human health and environmental outcomes in communities disproportionately impacted by environmental and health hazards, including the improvement of environmental outcomes that protect cultural practices, the maintenance and restoration of cultural heritage, and the cultural bases of human health."

32. **Justice40:** A work group has been tasked with the Justice40 Initiative (EO 14008 Sec. 223), which requires that "[w]ithin 120 days of the date of this order, the Chair of the Council on Environmental Quality, the Director of the Office of Management and Budget, and the National Climate Advisor, in consultation with the Advisory Council, shall jointly publish recommendations on how certain Federal investments might be made toward **a goal that 40 percent of the overall benefits flow to disadvantaged communities**. The recommendations shall focus on investments in the areas of clean energy and energy efficiency; clean transit; affordable and sustainable housing; training and workforce development; the remediation and reduction of legacy pollution; and the development of critical clean water infrastructure. The recommendations shall reflect existing authorities the agencies may possess for achieving the 40-percent goal as well as recommendations on any legislation needed to achieve the 40-percent goal" (emphasis in original; WHEJAC, 2021, p. 11). According to WHEJAC (2021, p. 11), the 'highest goal' of the initiative is to "ensure that more investments are directed into historically overburdened and underserved communities."

33. **Linguistic isolation:** Linguistic isolation is one of the five socioeconomic indicators used in California's CalEnviroScreen (version 4.0) screening tool to calculate 'Population Characteristics' scores, which range from 0.10 to 10 (CalEPA and CalOEHHA, 2021, pp. 161, 192). According to CalEPA and CalOEHHA (2021, p. 174), "[t]he US Census Bureau uses the term 'linguistic isolation' to measure households where all members 14 years of age or above have at least some difficulty speaking English." Linguistic isolation was selected as a socioeconomic indicator, because "[a] high degree of linguistic isolation among members of a community raises concerns about access to health information and public services, and effective engagement with regulatory

processes" (CalEPA and CalOEHHA, 2021, p. 174). EJSCREEN also tracks linguistic isolation but does not use it to calculate the EJ index score.

34. **Low-income populations:** Low-income populations are "characterized by limited economic resources" (US EPA, 2016b, p. 67). Low-income populations are defined by the Census Bureau's annual poverty measures.
    a. According to US EPA (2016b, p. 7), the Census Bureau "uses a set of income thresholds that vary by family size and composition to determine the households that live in poverty. If a family's total income falls below the threshold, then that family and every individual in it is defined as being in poverty."
    b. WHEJAC (2021, p. 80) defines a low-income community as "any census block group in which 30 percent or more of the population are individuals with an annual household income equal to, or less than, the greater of:

       (i) an amount equal to 80 percent of the median income of the area in which the household is located, as reported by the Department of Housing and Urban Development; or

       (ii) 200 percent of the Federal poverty line."
35. **Majority minority communities:** A majority minority community is a community in which the majority of the community is comprised of minority populations, and is considered an underserved community by WHEJAC (2021, p. 64). See definition of minority populations.
36. **Meaningful involvement:** According to US EPA (2016b, p. 67), meaningful involvement "indicates that potentially affected populations have an appropriate opportunity to participate in decisions about a proposed activity (i.e., in [the Technical Guidance for Assessing Environmental Justice in Regulatory Analysis document] rulemaking) that will affect their environment and/or health; the population's contribution can influence the EPA's regulatory action decisions; the concerns of all participants involved will be considered in the decision-making process; and the EPA will seek out and facilitate the involvement of population's potentially affected by the EPA's regulatory action development process."
37. **Meaningful participation:** According to WHEJAC (2021, p. 80), meaningful participation "means that potentially affected populations have an opportunity to participate in decisions that will affect their health or environment, that the population's contributions can influence the agency's decisions, that the viewpoints of all participants involved will be considered in the decision-making process, and that the agency will seek out and facilitate the involvement of the population potentially affected, including consultation with Tribal and indigenous communities and by providing culturally appropriate information, access for people with disabilities, and language access for persons with Limited English Proficiency (LEP), considering issue of access raised by location, transportation, and other factors affecting participation, and by making available technical assistance to build community-based capacity for participating."
38. **Minority populations:** According to US EPA (2016b, p. 67), minority populations consist "of individuals who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic."
39. **Non-chemical stressor:** Non-chemical stressors are stressors that are not physical chemicals or pollutants, but can "interact with chemical stressors to exacerbate or mitigate health outcomes" (US EPA, 2016b, p. 25). Examples of non-chemical stressors include crime, nutritional deficits, and stress (US EPA, 2016b, pp. 18, 25).
40. **Overburdened community:** "Minority, low-income, tribal, or indigenous populations or geographic locations in the United States that potentially experience disproportionate environmental harms and risks. This disproportionality can be as a result of greater vulnerability

to environmental hazards, lack of opportunity for public participation, or other factors. Increased vulnerability may be attributable to an accumulation of negative or lack of positive environmental, health, economic, or social conditions within these populations or places. The term describes situations where multiple factors, including both environmental and socio-economic stressors, may act cumulatively to affect health and the environment and contribute to persistent environmental health disparities" (EJ 2020; US EPA, 2016a).

41. **Psychosocial stressors:** Psychosocial stressors are stressful relationships and living conditions, such as "social crowding, social/family disorder, racial discrimination, and economic insecurity" (CalEPA and CalOEHHA, 2021, p. 182). Psychosocial stressors "are more common in low-income neighborhoods" and "combine to create environmental health disparities in low-income communities" (CalEPA and CalOEHHA, 2021, p. 182).

42. **Population characteristics:** According to US EPA (2016b, p. 37), "[p]opulation characteristics refer to those attributes shared by individuals within a population group that influence the likelihood of exposure to the stressor and the risk of an adverse health outcome from this exposure." Population characteristics can have direct effects (*i.e.*, age, pre-existing disease conditions, chronic disease, immune status, and medication status) or indirect influences (*i.e.*, negative social conditions, poor educational status, income status, lack of access to resources, "age of housing as a function of race/ethnicity and income") (US EPA, 2016b, p. 37).

43. **Population groups of concern:** US EPA (2016b, p. 68) defines population groups of concern as "minority populations, low-income populations, and indigenous peoples in the United States and its territories and possessions."

44. **Redlined or redlining:** Formerly redlined refers to those communities that were identified as minority communities, and therefore, outlined in red on publicly available maps in the United States during the 20th century (US EPA, 2020c, p. 47-48). This "discriminatory geographic zoning" practice "discouraged mortgage investments in minority communities based on race and ethnicity" (US EPA, 2020c, p. 47). According to US EPA (2020c, p. 48), "[m]any redlined areas continue to endure financial, social, and environmental inequities linked to redline-related discrimination", and therefore, formerly redlined is considered an underserved community by WHEJAC (2021, p. 64).

45. **Risk characterization:** Risk characterization is the "final step in the risk assessment paradigm" and "strives to provide a clear and integrated discussion of the overall findings, key areas of uncertainty, overall data quality, and data deficiencies that may affect methodology development and the overall conclusion" (US EPA, 2016b, p. 62). According to US EPA (2016b, p. 22), risk characterization "provides the basis for communicating the results to decision makers and the public." For more information see US EPA's Risk Characterization Handbook.

46. **Risk communication:** Communicating risk to people and communities (*i.e.*, risk communication) produces "an informed public that is involved, interested, reasonable, thoughtful, solution-oriented, and collaborative" (US EPA, 2016b, p. 32). According to US EPA (2016b, p. 33), "[e]ffective risk communication can assist in and is essential to identifying and addressing potential EJ concerns and can ensure that relevant information is accessible to affected communities and population groups of concern who may not be familiar with the data and analyses used by the EPA to evaluate public health risks." For more information see US EPA's Seven Cardinal Rules for Risk Communication.

47. **Risk management:** US EPA (2016b, p. 68) defines risk management as "a decision-making process that accounts for political, social, economic and engineering implications together with risk-related information in order to develop, analyze and compare management options and select the appropriate managerial response to a potential chronic health hazard."

48. **Sensitive population:** CalEPA and CalOEHHA (2021, p. 16) defines sensitive populations as populations with physiological conditions (*i.e.*, heart disease, asthma) or "lower protective biological mechanisms due to genetic factors" "that result in increased vulnerability to pollutants." Sensitive population is one of the four components used in CalEnviroScreen to model cumulative impacts and is averaged with Socioeconomic Factors to produce a Population Characteristics score (CalEPA and CalOEHHA, 2021, p. 10, 19). The three indicators used in CalEnviroScreen to represent sensitive populations are asthma, cardiovascular disease, and low birth weight (CalEPA and CalOEHHA, 2021, p. 192).

49. **Social context:** US EPA (2016b, p. 68) defines social context as "all social and political mechanisms that generate, configure, and maintain social hierarchies. These mechanisms can include the labor market, the educational system, political institutions, and cultural and societal values."

50. **Socially disadvantaged:** WHEJAC (2021, p. 57) refers to 'socially disadvantaged' in respect to farmers. NSAC (2021) defines a socially-disadvantaged farmer or rancher, or 'SDA,' as a "farmer or rancher who is a member of a group whose members have been subjected to racial or ethnic (and in some cases gender) prejudice because of his or her identity as a member of the group."

51. **Sociodemographic:** Sociodemographic refers to the combination of social and demographic factors. Examples include education, English proficiency, race and ethnicity, unemployment rate, poverty rate, income, and age distribution (particularly the percentage of population over 65 years old and under 5 years old).

52. **Spatial identification:** Spatial identification is required to "aggregate affected and unaffected (i.e., comparison group) populations" when human health outcomes are spatially distributed, which is "a relevant consideration for some regulatory actions, such as those that reduce emissions from point sources that have fairly localized effects" (US EPA, 2016b, p. 55).

53. **Stakeholders:** US EPA (2016b, p. 68) defines stakeholders as "interested persons concerned with the decisions made about how a risk may be avoided, mitigated, or eliminated, as well as those who may be affected by regulatory decisions."

54. **Stressor:** US EPA (2016b, p. 69) defines stressor as "any physical, chemical, or biological entity that can induce an adverse response. Stressors may adversely affect specific natural resources or entire ecosystems, including plants and animals, as well as the environment with which they interact. In this document, the term is used to encompass the range of chemical, physical, or biological agents, contaminants, or pollutants that may be subject to a rulemaking."

55. **Subsistence populations:** Subsistence populations are defined by US EPA (2016b, p. 69) as "minority populations, low-income populations, or indigenous peoples (or subgroups of such populations) subsisting on indigenous fish, vegetation and/or wildlife, as the principal portion of their diet." This includes self-caught fish and wildlife.

56. **Title VI of the Civil Rights Act of 1964:** Title VI "prohibits discrimination on the basis of race, color, and national origin in programs and activities receiving federal financial assistance" (US Commission On Civil Rights, 2016, p. 157). Title VI authority can be used to address EJ concerns, applying to agency-funded activities that affect human health and the environment (US EPA, 2014).

57. **Underserved communities:** According to WHEJAC (2021, p. 64), underserved communities include majority minority communities, communities with high rate of health disparities, communities that do not attain clean air and water standards, formerly redlined communities, communities with food insecurity that do not reach child nutrition levels, communities with children enrolled in their school lunch program, communities with low education attainment and low high school graduation rates, communities with high maternal and infant mortality rates,

communities with high asthma rates and deaths, communities that lack grocery stores and where there is a proliferation of "cent stores and fast-food outlets," communities with "[p]oorly maintained stock of housing," communities where income and percentage of households are on supplementary income benefits, and communities where there are a number of "superfund, waste, landfills and toxic facilities."

58. **Vulnerable populations:** Vulnerable populations (*i.e.*, children and the elderly) are characterized by "physical, chemical, biological, social, and cultural factors that result in certain communities and population groups being more susceptible or more exposed to environmental toxins, or having compromised ability to cope with and/or recover from such exposure" (US EPA, 2016b, p. 69).

59. **WHEJAC:** The White House Environmental Justice Advisory Council (WHEJAC) was established under EO 14008 (see EO 14008 for more information). "WHEJAC's efforts will include a broad range of strategic, scientific, technological, regulatory, community engagement, and economic issues related to environmental justice" (WHEJAC, 2021, p. 10).

60. **WHEJIC:** The White House Environmental Justice Interagency Council (WHEJIC) works with WHEJAC "to increase the Federal Government's efforts to address environmental injustice" (WHEJAC, 2021, p. 10).

Appendix B

Literature Review for Environmental Justice Publications

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
Key Initiatives	Executive Order 12898 - Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations	The White House	1994	Government Document	https://www.archives.gov/files/federal-register/executive-orders/pdf/12898.pdf	Executive Order (E.O.) 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* , directs all Federal agencies to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations," including tribal populations.
EJ Strategic Guidance Documents	Environmental Justice-Guidance Under the National Environmental Policy Act	Council on Environmental Quality	1997	Government Document	https://www.epa.gov/sites/default/files/2015-02/documents/ej_guidance_nepa_ceq1297.pdf	This document provides guidance under the National Environmental Policy Act on what EO 12898 entails and how agencies should act in accordance with its guidelines. It says as well that federal agencies should apply the guidance within this document flexibly and should consider its terms as a point of departure rather than conclusive direction in applying the terms of the Executive Order.
Cumulative Risk Assessment	Guidance on Cumulative Risk Assessment, Part 1: Planning and Scoping.	US EPA	1997	Government Document	https://www.epa.gov/sites/default/files/2015-01/documents/cumrisk2_0.pdf	This report offers guidance on the planning and scoping of cumulative risk assessments, which focus on integrating assessments for multiple possible pollutants with multiple paths of exposure and the variety of adverse effects on the health of humans, animals, and ecological systems.
EJ Analytical Framework	Application of health information to hazardous air pollutants modeled in EPA's Cumulative Exposure Project	Caldwell, JC; Woodruff, TJ; Morello-Frosch, R; Axelrad DA.	1998	*Toxicol. Ind. Health* 1998 May-Jun; 14(3):429-54	https://pubmed.ncbi.nlm.nih.gov/9569448/	Relatively little is known about the spectrum of health effects, and the scope and level of ambient air concentrations of those pollutants regulated under the Clean Air Act as "hazardous air pollutants". The U.S. Environmental Protection Agency's Cumulative Exposure Project uses currently available emissions inventories, from a variety of source types, and an atmospheric dispersion model to provide estimates of ambient concentrations for 148 hazardous air pollutants (HAPs) in over 60,000 census tracts for the year 1990. This paper uses currently available hazard information for those pollutants and provides a database of potential regulatory threshold concentrations of concern, or "benchmark concentrations," and a methodology for prioritizing and characterizing the quality of the data. In order to demonstrate application of the database and prioritization scheme to outputs from the Cumulative Exposure Project, comparisons were made with the maximum modeled concentration of each individual hazardous air pollutant across the census tracts. Of the 197 benchmark concentrations for cancer and non-cancer (long- and short-term exposures) effects compiled for the study, approximately one half were exceeded with a predominance of exceedance of cancer benchmarks. While the number of benchmark concentrations available to fully characterize potential health effects of these pollutants was limited (approximately 80 percent of HAPs identified as cancer concerns had benchmark concentrations for cancer and 50 percent of all HAPs had non-cancer benchmark concentrations) and there was greater uncertainty in derivation of maximum modeled air concentrations than other levels, the comparison between the two was a useful approach for providing an indication of public health concern from hazardous air pollutants.
EJ Strategic Guidance Documents	EPA Statutory and Regulatory Authorities Under Which Environmental Justice Issues May Be Addressed in Permitting	Gary S. Guzy, Office of General Counsel	2000	Government Document	https://www.epa.gov/sites/default/files/2015-02/documents/ej_permitting_authorities_memo_120100.pdf	This memorandum analyzes a significant number of statutory and regulatory authorities under the Resource Conservation and Recovery Act, the Clean Water Act, the Safe Drinking Water Act, the Marine Protection, Research, and Sanctuaries Act, and the Clean Air Act that the Office of General Counsel believes are available to address environmental justice issues during permitting. The use of EPA's statutory authorities, as discussed herein, may in some cases involve new legal and policy interpretations that could require further Agency regulatory or interpretive action. Although the memorandum presents interpretations of EPA's statutory authority and regulations that we believe are legally permissible, it does not suggest that such actions would be uniformly practical or feasible given policy or resource considerations or that there are not important considerations of legal risk that would need to be evaluated.
SES and Health Risks	Race, gender, and social status as modifiers of the effects of PM10 on mortality	Zanobetti, A; Schwartz, J.	2000	*J. Occup. Environ. Med.* 42(5): 469-474	https://pubmed.ncbi.nlm.nih.gov/10824299/	Interest has recently been focused on which populations are most at risk of premature mortality induced by air pollution. This coincides with greater concern about environmental justice. We analyzed total mortality in the four largest US cities with daily measurements of particulate matter less than 10 microns (PM10) and combined the results to determine whether race, sex, and education are potential modifiers of the effects of PM10 on mortality. We computed daily counts of deaths stratified by sex, race, and education in each city and investigated their associations with PM10 in a Poisson regression model. We combined the results by using inverse variance weighted averages. We found evidence of effect modification by sex, with the slope in female deaths one third larger than in male deaths, whereas for social factors and race we found only weak evidence of effect modification. In general, the effect modification appeared modest compared with other reports of substantial effect modification by medical conditions.
EJ Strategic Guidance Documents	Opportunities for Advancing Environmental Justice: An Analysis of US EPA Statutory Authorities	Environmental Law Institute	2001	Environmental Law Institute Research Report	https://www.epa.gov/sites/default/files/2015-02/documents/eli-opportunities4ej.pdf	This report reviews the provisions contained in the principal federal environmental laws administered by EPA, in order to identify authorities that potentially could be used to advance a variety of environmental justice goals in the agency's programs. While there also are significant opportunities for action to be taken by other federal, state, tribal and local agencies, this report considers only EPA's authorities and actions. The report aims to present an expansive view of the relevant statutory provisions, in order to further public understanding of the range of actions that can be considered. The report does not discuss all of the legal arguments that might be framed in support of or against the analysis presented in the following chapters, nor does the report attempt to predict how these arguments would be resolved in a particular case. Moreover, the report does not assess the practical viability of using these statutory authorities to address environmental justice issues. Implementation of any of the authorities discussed here will require consideration of a mix of scientific, political, financial and other factors, depending on the program and type of action involved. It is hoped that the discussion of authorities in this report can provide a starting point for such inquiry by individuals and groups, both public and private, interested in advancing environmental justice goals in specific areas of EPA regulatory activity.
EJ Health Disparities	Environmental Justice and Southern California's "Riskscape": The Distribution of Air Toxics Exposures and Health Risks among Diverse Communities	Morello-Frosch, R; Pastor, M; Sadd, J.	2001	*Urban Affairs Review* 36:551-578	https://journals.sagepub.com/doi/10.1177/10780870122184993	Past research on "environmental justice" has often failed to systematically link hazard proximity with quantifiable health risks. The authors employ recent advances in air emissions inventories and modeling techniques to consider a broad range of outdoor air toxics in Southern California and to calculate the potential lifetime cancer risks associated with these pollutants. They find that such risks are attributable mostly to transportation and small-area sources and not the usually targeted large-facility pollution emissions. Multivariate regression suggests that race plays an explanatory role in risk distribution even after controlling for other economic, land-use, and population factors. This pattern suggests the need for innovative emissions reduction efforts as well as specific strategies to alter the spatial and racial character of the environmental "riskscape" in urban centers.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
EJ Health Disparities	The Locality of Waste Sites within the City of Chicago: a Demographic, Social, and Economic Analysis.	Baden, BM; Coursey, D.	2002	*Resource and Energy Economics* 24:53-93	https://www.sciencedirect.com/science/article/abs/pii/S0928765501000604	In 1987, the United Church of Christ (UCC) released Toxic Waste and Race in the United States: A National Report on the Racial and Socio-economic Characteristics of Communities with Hazardous Waste Sites (1987) which stimulated substantial research and activism concerning the disproportionate exposure of minorities to environmental hazards. The current study responds to many of the deficiencies of previous research by integrating the demographic history with an empirical analysis of the distribution of hazardous waste in a major American industrial city. Two hypothesis are tested: (1) contemporaneous disproportionate exposure, and (2) discriminatory intent in waste siting decisions. Interestingly, there is evidence that Hispanics are disproportionately exposed, but there is not evidence of disproportionate exposure to the most dangerous hazards for African Americans either currently or historically.
EJ Health Disparities	Unequal exposure to ecological hazards: environmental injustices in the Commonwealth of Massachusetts.	Faber, DR; Krieg, EJ.	2002	*Environ. Health Perspect.* 110(S2):277-288	https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.02110s2277	This study analyzes the social and geographic distribution of ecological hazards across 368 communities in the Commonwealth of Massachusetts. Combining census data with a variety of environmental data, we tested for and identified both income-based and racially based biases to the geographic distribution of 17 different types of environmentally hazardous sites and industrial facilities. We also developed a composite measure of cumulative exposure to compare the relative overall risks characteristic of each community. To the best of our knowledge, this point system makes this the first environmental justice study to develop a means for measuring and ranking cumulative exposure for communities. The study also controls for the intensity of hazards in each community by accounting for the area across which hazards are distributed. The findings indicate that ecologically hazardous sites and facilities are disproportionately located and concentrated in communities of color and working-class communities. The implication of this research for policymakers and citizen advocates is that cumulative exposure of residents to environmentally hazardous facilities and sites should receive greater consideration regarding community demographics and environmental health indicators. We conclude that the provision of additional resources for environmental monitoring and ranking, as well as yearly progress reports, is necessary for communities and state agencies to achieve equal access to clean and healthy environments for all residents.
Cumulative Risk Assessment	Evaluating Cumulative Risk Assessment for Environmental Justice: A Community Case Study	Fox, MA; Groopman, JD; Burke, TA.	2002	*Environ. Health Perspect.* 110(2):203-209	https://pubmed.ncbi.nlm.nih.gov/11929729/	A key feature of cumulative risk assessment (CRA) is the ability to estimate differential health risks from environmental exposures within populations. Identifying populations at increased risk from environmental exposures is the first step toward mitigating such risks as required by the fair treatment mandate of environmental justice. CRA methods remain under development except for a limited application in pesticide regulations. The goals of this research were to advance CRA methods and to test their application in a community case study. We compared cumulative risk and health assessments for South and Southwest Philadelphia communities. The analysis found positive correlations between cumulative risk and mortality measurements for total mortality in Whites and non-Whites when we conducted the risk assessment using a multi-end point toxicological database developed for this project. Cumulative risk scores correlated positively with cause-specific mortality in non-Whites. Statistically significant increases in total and respiratory mortality rates were associated with incremental increases in the hazard ratio cumulative risk scores, with ranges of 2-6% for total and 8-23% for respiratory. Regression analyses controlled for percent non-White population and per capita income, indicating that risk scores represent an environmental effect on health independent of race and income. This case study demonstrated the successful application of CRA at the community level. CRA adds a health dimension to pollutant concentrations to produce a more comprehensive understanding of environmental inequities that can inform decision making. CRA is a viable tool to identify high-risk areas and to guide surveillance, research, or interventions.
EJ Analytical Framework	Environmental justice and regional inequality in southern California: implications for future research	Morello-Frosch, R Pastor, M Jr; Porras, C; Sadd, J.	2002	*Environ. Health Perspect.* Apr; 110 Suppl 2(Suppl 2):149-54	https://pubmed.ncbi.nlm.nih.gov/11929723/	Environmental justice offers researchers new insights into the juncture of social inequality and public health and provides a framework for policy discussions on the impact of discrimination on the environmental health of diverse communities in the United States. Yet, causally linking the presence of potentially hazardous facilities or environmental pollution with adverse health effects is difficult, particularly in situations in which diverse populations are exposed to complex chemical mixtures. A community-academic research collaborative in southern California sought to address some of these methodological challenges by conducting environmental justice research that makes use of recent advances in air emissions inventories and air exposure modeling data. Results from several of our studies indicate that communities of color bear a disproportionate burden in the location of treatment, storage, and disposal facilities and Toxic Release Inventory facilities. Longitudinal analysis further suggests that facility siting in communities of color, not market-based "minority move-in," accounts for these disparities. The collaborative also investigated the health risk implications of outdoor air toxics exposures from mobile and stationary sources and found that race plays an explanatory role in predicting cancer risk distributions among populations in the region, even after controlling for other socioeconomic and demographic indicators. Although it is unclear whether study results from southern California can be meaningfully generalized to other regions in the United States, they do have implications for approaching future research in the realm of environmental justice. The authors propose a political economy and social inequality framework to guide future research that could better elucidate the origins of environmental inequality and reasons for its persistence.
EJ Health Disparities	Traffic density in California: socioeconomic and ethnic differences among potentially exposed children	Guinier, RB; Hertz, A; Von Behren, J; Reynolds, P.	2003	*Journal of Exposure Analysis and Environmental Epidemiology* 13(3):240-246	https://www.nature.com/articles/7500276	Motor vehicles are the main source of many hazardous air pollutants in California. Previous studies have shown that low-income and minority populations are more likely to live near industrial sources of pollution and in areas that do not meet national air quality standards. We estimated neighborhood exposures to motor vehicle emissions from a road network with daily traffic counts using a geographic information system. To calculate traffic density, we summed the average daily vehicle miles of travel per square mile of land area for each census block group in the state. We used 1990 census data to characterize the population by age, race and socioeconomic status in block groups with high traffic density. Block groups with more than 500,000 vehicle miles of travel per square mile were defined to be high traffic density. Statewide, about 5% of all block groups met this criterion and more than 215,000 children under 15 years of age lived in these high traffic density areas. Block groups in the lowest quartile of median family income were three times more likely to have high traffic density than block groups in the highest income quartile. The percentage of children living in high traffic density block groups increased with decreasing median family income for all race and ethnicities except White. Overall, children of color were about three times more likely to live in high-traffic areas than were white children. Based on this analysis, low-income and children of color have higher potential exposure to vehicle emissions. Future exposure assessment studies should target the highest traffic density areas, and health studies should consider the differences by income and race or ethnicity during design.

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Cumulative Risk Assessment	Framework for Cumulative Risk Assessment (EPA-630-P-02-001F).	US EPA	2003	Government Document	https://www.epa.gov/sites/default/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf	This report is part of a long-term effort to develop cumulative risk assessment guidelines. Its main goal is to provide a simple and flexible framework for cumulative risk assessments in the US EPA. This framework describes three phases to a cumulative risk assessment. The first step is planning, scoping, and problem formation, the second step is analysis, and the third step is risk characterization.
EJ Strategic Guidance Documents	Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Impacts/Risks	National Environmental Justice Advisory Council	2004	Government Document	https://www.epa.gov/sites/default/files/2015-02/documents/nejac-cum-risk-rpt-122104.pdf	This report, prepared by the NEJAC after request from US EPA, is meant to provide advice on the following question from the EPA: In order to ensure environmental justice for all communities and tribes, what short-term and long-term actions should the Agency take in proactively implementing the concepts contained in its Framework for Cumulative Risk Assessment? The authors provide the final paragraph of this document to serve as a summary: "The issue of cumulative risks/impacts is a unifying one, because it is a vehicle through which the impressive array of tools now available to ensure pollution prevention and risk reduction can be brought together and applied in new, innovative, and more effective ways. Exciting new approaches, partnerships, and models will surely emerge. Ensuring that these new possibilities will blossom will require a critical appraisal of past Agency policies and practices. Ensuring that this new day in environmental protection will come to pass will require committed individuals willing and able to provide foresight, analysis, and leadership."
EJ Strategic Guidance Documents	Toolkit for Addressing Environmental Justice Assessment	US EPA	2004	Government Document	https://www.epa.gov/sites/default/files/2015-02/documents/ej-toolkit.pdf	The Office of Environmental Justice has developed this Toolkit to serve two overarching purposes. The first is to provide a conceptual and substantive framework for understanding the Agency's environmental justice program. The second goal is to present a systematic approach with reference tools that can be used and adapted to assess and respond to potential allegations of environmental injustice as they occur, or to prevent injustices from occurring in the first place. This document is intended to promote a common understanding and provide a flexible framework for assessing situations of EJ concerns.
EJ Health Disparities	Environmental Health Disparities: A Framework Integrating Psychosocial and Environmental Concepts	Gee, GC; Payne-Sturges, DC.	2004	*Environ. Health Perspect.* 112(17):1645-1653	https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.7074?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed	Although it is often acknowledged that social and environmental factors interact to produce racial and ethnic environmental health disparities, it is still unclear how this occurs. Despite continued controversy, the environmental justice movement has provided some insight by suggesting that disadvantaged communities face greater likelihood of exposure to ambient hazards. The exposure–disease paradigm has long suggested that differential "vulnerability" may modify the effects of toxicants on biological systems. However, relatively little work has been done to specify whether racial and ethnic minorities may have greater vulnerability than do majority populations and, further, what these vulnerabilities may be. We suggest that psychosocial stress may be the vulnerability factor that links social conditions with environmental hazards. Psychosocial stress can lead to acute and chronic changes in the functioning of body systems (e.g., immune) and also lead directly to illness. In this article we present a multidisciplinary framework integrating these ideas. We also argue that residential segregation leads to differential experiences of community stress, exposure to pollutants, and access to community resources. When not counterbalanced by resources, stressors may lead to heightened vulnerability to environmental hazards.
EJ Health Disparities	Structural Disparities of Urban Traffic in Southern California: Implications for Vehicle-Related Air Pollution Exposure in Minority and High-Poverty Neighborhoods	Houston, D; Wu, J; Ong, P; Winer, A.	2004	*Journal of Urban Affairs* 26(5):565-592	https://onlinelibrary.wiley.com/doi/full/10.1111/j.0735-2166.2004.00215.x	Structural inequalities provide an important context for understanding and responding to the impact of high traffic densities on disadvantaged neighborhoods. Emerging atmospheric science and epidemiological research indicates hazardous vehicle-related pollutants (e.g., diesel exhaust) are highly concentrated near major roadways, and the prevalence of respiratory ailments and mortality are heightened in these high-traffic corridors. This article builds on recent findings that low-income and minority children in California disproportionately reside in high-traffic areas by demonstrating how the urban structure provides a critical framework for evaluating the causes, characteristics, and magnitude of traffic, particularly for disadvantaged neighborhoods. We find minority and high-poverty neighborhoods bear over two times the level of traffic density compared to the rest of the Southern California region, which may associate them with a higher risk of exposure to vehicle-related pollutants. Furthermore, these areas have older and more multifamily housing, which is associated with higher rates of indoor exposure to outdoor pollutants, including intrusion of motor vehicle exhaust. We discuss the implications of these patterns on future planning and policy strategies for mitigating the serious health consequences of exposure to vehicle-related air pollutants.
Risk Assessment Methodology	Personal exposure meets risk assessment: a comparison of measured and modeled exposures and risks in an urban community	Payne-Sturges, DC; Burke, TA; Breysse, P; Diener-West, M; Buckley, TJ.	2004	*Environ Health Perspect.* Apr; 112(5):589-98	https://pubmed.ncbi.nlm.nih.gov/15064166/	Human exposure research has consistently shown that, for most volatile organic compounds (VOCs), personal exposures are vastly different from outdoor air concentrations. Therefore, risk estimates based on ambient measurements may over- or underestimate risk, leading to ineffective or inefficient management strategies. In the present study we examine the extent of exposure misclassification and its impact on risk for exposure estimated by the U.S. Environmental Protection Agency (U.S. EPA) Assessment System for Population Exposure Nationwide (ASPEN) model relative to monitoring results from a community-based exposure assessment conducted in Baltimore, Maryland (USA). This study is the first direct comparison of the ASPEN model (as used by the U.S. EPA for the Cumulative Exposure Project and subsequently the National-Scale Air Toxics Assessment) and human exposure data to estimate health risks. A random sampling strategy was used to recruit 33 nonsmoking adult community residents. Passive air sampling badges were used to assess 3-day time-weighted-average personal exposure as well as outdoor and indoor residential concentrations of VOCs for each study participant. In general, personal exposures were greater than indoor VOC concentrations, which were greater than outdoor VOC concentrations. Public health risks due to actual personal exposures were estimated. In comparing measured personal exposures and indoor and outdoor VOC concentrations with ASPEN model estimates for ambient concentrations, our data suggest that ASPEN was reasonably accurate as a surrogate for personal exposures (measured exposures of community residents) for VOCs emitted primarily from mobile sources or VOCs that occur as global "background" source pollutant with no indoor source contributions. Otherwise, the ASPEN model estimates were generally lower than measured personal exposures and the estimated health risks. ASPEN's lower exposures resulted in proportional underestimation of cumulative cancer risk when pollutant exposures were combined to estimate cumulative risk. Median cumulative lifetime cancer risk based on personal exposures was 3-fold greater than estimates based on ASPEN-modeled concentrations. These findings demonstrate the significance of indoor exposure sources and the importance of indoor and/or personal monitoring for accurate assessment of risk. Environmental health policies may not be sufficient in reducing exposures and risks if they are based solely on modeled ambient VOC concentrations. Results from our study underscore the need for a coordinated multimedia approach to exposure assessment for setting public health policy.

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Risk Assessment Methodology	Toxicological resources for cumulative risk: an example with hazardous air pollutants	Fox, MA; Tran, NL; Groopman, JD; Burke, TA.	2004	*Regul. Toxicol. Pharmacol.* Dec; 40(3):305-11	https://pubmed.ncbi.nlm.nih.gov/15546684/	Cumulative risk assessment, concerned with the multiple health effects of chemical mixtures, challenges the utility of existing single-chemical regulatory references. We compare example cumulative risk assessments for 40 HAPs; one based on single-effect toxicological data from EPA, and another based on a multiple-effect toxicological database we developed. For the 40-chemical HAP subset, the multiple effect database contains information on approximately seven effects per chemical and contains a total of 290 toxicological values. Seven health effects are represented in the IRIS data. Seventeen health effects are represented in the multiple-effect data. Respiratory and neurological effects ranked first and second in both cumulative analyses, regardless of the source data. In addition to respiratory and neurological effects, gastro-intestinal/hepatic, renal/kidney, and immunologic effects were identified as effects of concern on the basis of the multiple effect data. Immunologic effects are not found in the 40-chemical IRIS dataset. Cumulative risk assessment has the potential to expand our understanding of the public health impacts of environmental exposures. Advancements in toxicological resources will improve cumulative risk assessment. Cumulative risk assessment will reduce risks to the extent that it can be integrated into prevention strategies to track and protect the public's health.
EJ Health Disparities	Socioeconomic and Racial Disparities in Cancer Risk from Air Toxics in Maryland.	Apelberg, BJ; Buckley, TJ; White, RH.	2005	*Environ. Health Perspect.* 113(6):693-699.	https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.7609?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed	We linked risk estimates from the U.S. Environmental Protection Agency's National Air Toxics Assessment (NATA) to racial and socioeconomic characteristics of census tracts in Maryland (2000 Census) to evaluate disparities in estimated cancer risk from exposure to air toxics by emission source category. In Maryland, the average estimated cancer risk across census tracts was highest from on-road sources (50% of total risk from non-background sources), followed by on-road (25%), area (23%), and major sources (< 1%). Census tracts in the highest quartile defined by the fraction of African-American residents were three times more likely to be high risk (> 90th percentile of risk) than those in the lowest quartile (95% confidence interval, 2.0–5.0). Conversely, risk decreased as the proportion of whites increased ($p < 0.001$). Census tracts in the lowest quartile of socioeconomic position, as measured by various indicators, were 10–100 times more likely to be high risk than those in the highest quartile. We observed substantial risk disparities for on-road, area, and on-road sources by socioeconomic measure and on-road and area sources by race. There was considerably less evidence of risk disparities from major source emissions. We found a statistically significant interaction between race and income, suggesting a stronger relationship between race and risk at lower incomes. This research demonstrates the utility of NATA for assessing regional environmental justice, identifies an environmental justice concern in Maryland, and suggests that on-road sources may be appropriate targets for policies intended to reduce the disproportionate environmental health burden among economically disadvantaged and minority populations.
EJ Health Disparities	Unequal Exposure to Ecological Hazards 2005: Environmental Injustices in the Commonwealth of Massachusetts: A Report by the Philanthropy and Environmental Justice Research Project.	Faber, DR; Krieg, EJ.	2005	Boston, MA: Northeastern University.	https://web.northeastern.edu/ejresearchnetwork/wp-content/uploads/2014/10/Final-Unequal-Exposure-Report-2005-10-12-05.pdf	Classification of Massachusetts' 362 communities by class and racial composition. Comparisons of low-to-high income communities and low minority-to-high minority status communities are made in terms of the location of environmentally hazardous industrial facilities and pollution releases, hazardous waste sites, power plants, incinerators, trash transfer stations, and landfills of all types. Environmentally hazardous sites and facilities of all kinds are disproportionately located in working class towns and communities of color.
EJ Health Disparities	Racial/Ethnic Disparities in Prevalence, Treatment, and Control of Hypertension -- United States, 1999--2002	Glover, MJ; Greenlund, KJ; Ayala, C; Croft, JB.	2005	*Morbidity and Mortality Weekly Report* 54(1):7-9	https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5401a3.htm	High blood pressure (HBP) is a major risk factor for heart disease and stroke, end-stage renal disease, and peripheral vascular disease and is a chief contributor to adult disability. Approximately one in four adults in the United States has hypertension. Although effective therapy has been available for more than 50 years, most persons with hypertension do not have their blood pressure (BP) under control. National health objectives for 2010 include reducing the proportion of adults with HBP to 16% (baseline: 28%), increasing the proportion of adults with hypertension who are taking action to control it to 95% (baseline: 82%), and increasing the proportion of adults with controlled BP to 50% (baseline: 18%). During 1990--2000, the prevalence of hypertension, the percentage of those with hypertension who were aware of their condition, and treatment and control of hypertension increased among non-Hispanic whites, non-Hispanic blacks, and Hispanics. CDC analyzed data from the National Health and Nutrition Examination Surveys (NHANES) for 1999--2002. This report summarizes the results of that analysis, which determined that racial/ethnic disparities in awareness of, treatment for, and control of hypertension persist. If national health objectives are to be met, public health efforts must continue to focus on the prevention of HBP and must improve awareness, treatment, and control of hypertension among minority populations.
EJ Health Disparities	Assessing Evidence of Environmental Inequities: A Meta-Analysis.	Ringquist, E.	2005	*Journal of Policy Analysis and Management* 24(2):223-247	https://onlinelibrary.wiley.com/doi/10.1002/pam.20088	Over the past decade activists, academics, and policymakers have devoted a great deal of attention to "environmental equity," or the notion that sources of potential environmental risk may be concentrated among racial and ethnic minorities and the poor. Despite these efforts, the existence and extent of environmental inequities is still the subject of intense scholarly debate. This manuscript reports the results from a meta-analysis of 49 environmental equity studies. The analysis demonstrates that while there is ubiquitous evidence of environmental inequities based upon race, existing research does not support the contention that similar inequities exist with respect to economic class.
EJ Health Disparities	Reassessing racial and socioeconomic disparities in environmental justice research	Mohai, P; Saha, R.	2006	*Demography* 43(2):383-399	https://read.dukeupress.edu/demography/article/43/2/383/170125/Reassessing-racial-and-socioeconomic-disparities	The number of studies examining racial and socioeconomic disparities in the geographic distribution of environmental hazards and locally unwanted land uses has grown considerably over the past decade. Most studies have found statistically significant racial and socioeconomic disparities associated with hazardous sites. However there is considerable variation in the magnitude of racial and socioeconomic disparities found; indeed, some studies have found none. Uncertainties also exist about the underlying causes of the disparities. Many of these uncertainties can be attributed to the failure of the most widely used method for assessing environmental disparities to adequately account for proximity between the hazard under investigation and nearby residential populations. In this article, we identify the reasons for and consequences of this failure and demonstrate ways of overcoming these shortcomings by using alternate, distance-based methods. Through the application of such methods, we show how assessments about the magnitude and causes of racial and socioeconomic disparities in the distribution of hazardous sites are changed. In addition to research on environmental inequality, we discuss how distance-based methods can be usefully applied to other areas of demographic research that explore the effects of neighborhood context on a range of social outcomes.

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EJ Health Disparities	Separate and Unequal: Residential Segregation and Estimated Cancer Risks Associated with Ambient Air Toxics in U.S. Metropolitan Areas.	Morello-Frosch, R; Jesdale, BM.	2006	*Environ. Health Perspect.* 114(3):386-393	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1392233/	This study examines links between racial residential segregation and estimated ambient air toxics exposures and their associated cancer risks using modeled concentration estimates from the U.S. Environmental Protection Agency's National Air Toxics Assessment. We combined pollutant concentration estimates with potencies to calculate cancer risks by census tract for 309 metropolitan areas in the United States. This information was combined with socioeconomic status (SES) measures from the 1990 Census. Estimated cancer risks associated with ambient air toxics were highest in tracts located in metropolitan areas that were highly segregated. Disparities between racial/ethnic groups were also wider in more segregated metropolitan areas. Multivariate modeling showed that, after controlling for tract-level SES measures, increasing segregation amplified the cancer risks associated with ambient air toxics for all racial groups combined [highly segregated areas: relative cancer risk (RCR) = 1.04; 95% confidence interval (CI), 1.01–107; extremely segregated areas: RCR = 1.32; 95% CI, 1.28–1.36]. This segregation effect was strongest for Hispanics (highly segregated areas: RCR = 1.09; 95% CI, 1.01–1.17; extremely segregated areas: RCR = 1.74; 95% CI, 1.61–1.88) and weaker among whites (highly segregated areas: RCR = 1.04; 95% CI, 1.01–1.08; extremely segregated areas: RCR = 1.28; 95% CI, 1.24–1.33), African Americans (highly segregated areas: RCR = 1.09; 95% CI, 0.98–1.21; extremely segregated areas: RCR = 1.38; 95% CI, 1.24–1.53), and Asians (highly segregated areas: RCR = 1.10; 95% CI, 0.97–1.24; extremely segregated areas: RCR = 1.32; 95% CI, 1.16–1.51). Results suggest that disparities associated with ambient air toxics are affected by segregation and that these exposures may have health significance for populations across racial lines.
SES and Health Risks	The environmental "riskscape" and social inequality: implications for explaining maternal and child health disparities	Morello-Frosch, R; Shenassa, ED.	2006	*Environ. Health Perspect.* Aug; 114(8):1150-3	https://pubmed.ncbi.nlm.nih.gov/16882517/	Background: Research indicates that the double jeopardy of exposure to environmental hazards combined with place-based stressors is associated with maternal and child health (MCH) disparities. Objective and discussion: Our aim is to present evidence that individual-level and place-based psychosocial stressors may compromise host resistance such that environmental pollutants would have adverse health effects at relatively lower doses, thus partially explaining MCH disparities, particularly poor birth outcomes. Allostatic load may be a physiologic mechanism behind the moderation of the toxic effect of environmental pollutants by social stressors. We propose a conceptual framework for holistic approaches to future MCH research that elucidates the interplay of psychosocial stressors and environmental hazards in order to better explain drivers of MCH disparities. Conclusion: Given the complexity of the link between environmental factors and MCH disparities, a holistic approach to future MCH research that seeks to untangle the double jeopardy of chronic stressors and environmental hazard exposures could help elucidate how the interplay of these factors shapes persistent racial and economic disparities in MCH.
SES and Health Risks	Separate and unequal: residential segregation and estimated cancer risks associated with ambient air toxics in U.S. metropolitan areas	Morello-Frosch, R; Jesdale, BM.	2006	*Environ. Health Perspect.* Mar; 114(3):386-93	https://pubmed.ncbi.nlm.nih.gov/16507462/	This study examines links between racial residential segregation and estimated ambient air toxics exposures and their associated cancer risks using modeled concentration estimates from the U.S. Environmental Protection Agency's National Air Toxics Assessment. We combined pollutant concentration estimates with potencies to calculate cancer risks by census tract for 309 metropolitan areas in the United States. This information was combined with socioeconomic status (SES) measures from the 1990 Census. Estimated cancer risks associated with ambient air toxics were highest in tracts located in metropolitan areas that were highly segregated. Disparities between racial/ethnic groups were also wider in more segregated metropolitan areas. Multivariate modeling showed that, after controlling for tract-level SES measures, increasing segregation amplified the cancer risks associated with ambient air toxics for all racial groups combined [highly segregated areas: relative cancer risk (RCR) = 1.04; 95% confidence interval (CI), 1.01-107; extremely segregated areas: RCR = 1.32; 95% CI, 1.28-1.36]. This segregation effect was strongest for Hispanics (highly segregated areas: RCR = 1.09; 95% CI, 1.01-1.17; extremely segregated areas: RCR = 1.74; 95% CI, 1.61-1.88) and weaker among whites (highly segregated areas: RCR = 1.04; 95% CI, 1.01-1.08; extremely segregated areas: RCR = 1.28; 95% CI, 1.24-1.33), African Americans (highly segregated areas: RCR = 1.09; 95% CI, 0.98-1.21; extremely segregated areas: RCR = 1.38; 95% CI, 1.24-1.53), and Asians (highly segregated areas: RCR = 1.10; 95% CI, 0.97-1.24; extremely segregated areas: RCR = 1.32; 95% CI, 1.16-1.51). Results suggest that disparities associated with ambient air toxics are affected by segregation and that these exposures may have health significance for populations across racial lines.
EJ Analytical Framework	The riskscape and the color line: examining the role of segregation in environmental health disparities	Morello-Frosch, R; Lopez, R.	2006	*Environ Res.* Oct; 102(2):181-96	https://pubmed.ncbi.nlm.nih.gov/16828737/	Environmental health researchers, sociologists, policy-makers, and activists concerned about environmental justice argue that communities of color who are segregated in neighborhoods with high levels of poverty and material deprivation are also disproportionately exposed to physical environments that adversely affect their health and well-being. Examining these issues through the lens of racial residential segregation can offer new insights into the junctures of the political economy of social inequality with discrimination, environmental degradation, and health. More importantly, this line of inquiry may highlight whether observed pollution--health outcome relationships are modified by segregation and whether segregation patterns impact diverse communities differently. This paper examines theoretical and methodological questions related to racial residential segregation and environmental health disparities. We begin with an overview of race-based segregation in the United States and propose a framework for understanding its implications for environmental health disparities. We then discuss applications of segregation measures for assessing disparities in ambient air pollution burdens across racial groups and go on to discuss the applicability of these methods for other environmental exposures and health outcomes. We conclude with a discussion of the research and policy implications of understanding how racial residential segregation impacts environmental health disparities.

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EJ Analytical Framework	Racial Inequality in the Distribution of Hazardous Waste: A National-Level Reassessment	Mohai, P; Saha, R.	2007	*Social Problems* 54(3):343-370	https://www.jstor.org/stable/10.1525/sp.2007.54.3.343	National-level studies examining racial disparities around hazardous waste treatment, storage, and disposal facilities have been very influential in defining the academic and political debates about the existence and importance of "environmental injustice." However, these studies tend to employ methods that fail to adequately control for proximity between environmentally hazardous sites and nearby residential populations. By using GIS and applying methods increasingly used in environmental inequality research that better control for proximity, we conduct a comprehensive reassessment of racial inequality in the distribution of the nation's hazardous waste facilities. We compare the magnitude of racial disparities found with those of prior studies and test competing racial, economic, and sociopolitical explanations for why such disparities exist. We find that the magnitude of racial disparities around hazardous waste facilities is much greater than what previous national studies have reported. We also find these disparities persist even when controlling for economic and sociopolitical variables, suggesting that factors uniquely associated with race, such as racial targeting, housing discrimination, or other race-related factors are associated with the location of the nation's hazardous waste facilities. We further conclude that the more recent methods for controlling for proximity yield more consistent and definitive results than those used previously, and therefore argue for their wider utilization in environmental inequality research.
EJ Health Disparities	Synergistic Effects of Traffic-Related Air Pollution and Exposure to Violence on Urban Asthma Etiology	Clougherty, JE; Levy, JI; Kubzansky, LD; Ryan, PB; Suglia, SF; Canner, MJ; Wright, RJ.	2007	*Environ. Health Perspect.* 115(8):1140-1146	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1940095/	**Background:** Disproportionate life stress and consequent physiologic alteration (i.e., immune dysregulation) has been proposed as a major pathway linking socioeconomic position, environmental exposures, and health disparities. Asthma, for example, disproportionately affects lower-income urban communities, where air pollution and social stressors may be elevated. **Objectives:** We aimed to examine the role of exposure to violence (ETV), as a chronic stressor, in altering susceptibility to traffic-related air pollution in asthma etiology. **Methods:** We developed geographic information systems (GIS)–based models to retrospectively estimate residential exposures to traffic-related pollution for 413 children in a community-based pregnancy cohort, recruited in East Boston, Massachusetts, between 1987 and 1993, using monthly nitrogen dioxide measurements for 13 sites over 18 years. We merged pollution estimates with questionnaire data on lifetime ETV and examined the effects of both on childhood asthma etiology. **Results:** Correcting for potential confounders, we found an elevated risk of asthma with a 1-SD (4.3 ppb) increase in NO2 exposure solely among children with above-median ETV [odds ratio (OR) = 1.63; 95% confidence interval (CI), 1.14–2.33)]. Among children always living in the same community, with lesser exposure measurement error, this association was magnified (OR = 2.40; 95% CI, 1.48–3.88). Of multiple exposure periods, year-of-diagnosis NO2 was most predictive of asthma outcomes. **Conclusions:** We found an association between traffic-related air pollution and asthma solely among urban children exposed to violence. Future studies should consider socially patterned susceptibility, common spatial distributions of social and physical environmental factors, and potential synergies among these. Prospective assessment of physical and social exposures may help determine causal pathways and critical exposure periods.
Risk Assessment Methodology	Predicting residential indoor concentrations of nitrogen dioxide, fine particulate matter, and elemental carbon using questionnaire and geographic information system based data	Baxter, LK; Clougherty, JE; Paciorek, CJ; Wright, RJ; Levy, JI.	2007	*Atmos Environ (1994)* Oct; 41(31):6561-6571	https://pubmed.ncbi.nlm.nih.gov/19830252/	Previous studies have identified associations between traffic-related air pollution and adverse health effects. Most have used measurements from a few central ambient monitors and/or some measure of traffic as indicators of exposure, disregarding spatial variability and/or factors influencing personal exposure-ambient concentration relationships. This study seeks to utilize publicly available data (i.e., central site monitors, geographic information system (GIS), and property assessment data) and questionnaire responses to predict residential indoor concentrations of traffic-related air pollutants for lower socioeconomic status (SES) urban households. As part of a prospective birth cohort study in urban Boston, we collected indoor and outdoor 3-4 day samples of nitrogen dioxide (NO(2)) and fine particulate matter (PM(2.5)) in 43 low SES residences across multiple seasons from 2003 - 2005. Elemental carbon concentrations were determined via reflectance analysis. Multiple traffic indicators were derived using Massachusetts Highway Department data and traffic counts collected outside sampling homes. Home characteristics and occupant behaviors were collected via a standardized questionnaire. Additional housing information was collected through property tax records, and ambient concentrations were collected from a centrally-located ambient monitor. The contributions of ambient concentrations, local traffic and indoor sources to indoor concentrations were quantified with regression analyses. PM(2.5) was influenced less by local traffic but had significant indoor sources, while EC was associated with traffic and NO(2) with both traffic and indoor sources. Comparing models based on covariate selection using p-values or a Bayesian approach yielded similar results, with traffic density within a 50 m buffer of a home and distance from a truck route as important contributors to indoor levels of NO(2) and EC, respectively. The Bayesian approach also highlighted the uncertainty in the models. We conclude that by utilizing public databases and focused questionnaire data we can identify important predictors of indoor concentrations for multiple air pollutants in a high-risk population.

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Risk Assessment Methodology	Synergistic effects of traffic-related air pollution and exposure to violence on urban asthma etiology	Clougherty, JE; Levy, JI; Kubzansky, LD; Ryan, PB; Suglia, SF; Canner, MJ; Wright, RJ.	2007	*Environ. Health Perspect.* Aug; 115(8):1140-6	https://pubmed.ncbi.nlm.nih.gov/17687439/	Background: Disproportionate life stress and consequent physiologic alteration (i.e., immune dysregulation) has been proposed as a major pathway linking socioeconomic position, environmental exposures, and health disparities. Asthma, for example, disproportionately affects lower-income urban communities, where air pollution and social stressors may be elevated. Objectives: We aimed to examine the role of exposure to violence (ETV), as a chronic stressor, in altering susceptibility to traffic-related air pollution in asthma etiology. Methods: We developed geographic information systems (GIS)-based models to retrospectively estimate residential exposures to traffic-related pollution for 413 children in a community-based pregnancy cohort, recruited in East Boston, Massachusetts, between 1987 and 1993, using monthly nitrogen dioxide measurements for 13 sites over 18 years. We merged pollution estimates with questionnaire data on lifetime ETV and examined the effects of both on childhood asthma etiology. Results: Correcting for potential confounders, we found an elevated risk of asthma with a 1-SD (4.3 ppb) increase in NO(2) exposure solely among children with above-median ETV [odds ratio (OR) = 1.63; 95% confidence interval (CI), 1.14-2.33)]. Among children always living in the same community, with lesser exposure measurement error, this association was magnified (OR = 2.40; 95% CI, 1.48-3.88). Of multiple exposure periods, year-of-diagnosis NO(2) was most predictive of asthma outcomes. Conclusions: We found an association between traffic-related air pollution and asthma solely among urban children exposed to violence. Future studies should consider socially patterned susceptibility, common spatial distributions of social and physical environmental factors, and potential synergies among these. Prospective assessment of physical and social exposures may help determine causal pathways and critical exposure periods.
Risk Assessment Methodology	Comparative assessment of air pollution-related health risks in Houston	Sexton, K; Linder, SH; Marko, D; Bethel, H; Lupo, PJ.	2007	*Environ. Health Perspect.* Oct; 115(10):1388-93	https://pubmed.ncbi.nlm.nih.gov/17938725/	Background: Airborne emissions from numerous point, area, and mobile sources, along with stagnant meteorological conditions, contribute to frequent episodes of elevated air pollution in Houston, Texas. To address this problem, decision makers must set priorities among thousands of individual air pollutants as they formulate effective and efficient mitigation strategies. Objectives: Our aim was to compare and rank relative health risks of 179 air pollutants in Houston using an evidence-based approach supplemented by the expert judgment of a panel of academic scientists. Methods: Annual-average ambient concentrations by census tract were estimated from the U.S. Environmental Protection Agency's National-scale Air Toxics Assessment and augmented with measured levels from the Houston monitoring network. Each substance was assigned to one of five risk categories (definite, probable, possible, unlikely, uncertain) based on how measured or monitored concentrations translated into comparative risk estimates. We used established unit risk estimates for carcinogens and/or chronic reference values for noncarcinogens to set thresholds for each category. Assignment to an initial risk category was adjusted, as necessary, based on expert judgment about the quality and quantity of information available. Results: Of the 179 substances examined, 12 (6.7%) were deemed definite risks, 9 (5.0%) probable risks, 24 (13.4%) possible risks, 16 (8.9%) unlikely risks, and 118 (65.9%) uncertain risks. Conclusions: Risk-based priority setting is an important step in the development of cost-effective solutions to Houston's air pollution problem.
Risk Assessment Methodology	Assessing cumulative health risks from exposure to environmental mixtures - three fundamental questions	Sexton, K; Hattis, D.	2007	*Environ. Health Perspect.* May; 115(5):825-32	https://pubmed.ncbi.nlm.nih.gov/17520074/	Differential exposure to mixtures of environmental agents, including biological, chemical, physical, and psychosocial stressors, can contribute to increased vulnerability of human populations and ecologic systems. Cumulative risk assessment is a tool for organizing and analyzing information to evaluate the probability and seriousness of harmful effects caused by either simultaneous and/or sequential exposure to multiple environmental stressors. In this article we focus on elucidating key challenges that must be addressed to determine whether and to what degree differential exposure to environmental mixtures contributes to increased vulnerability of exposed populations. In particular, the emphasis is on examining three fundamental and interrelated questions that must be addressed as part of the process to assess cumulative risk: a) Which mixtures are most important from a public health perspective? and b) What is the nature (i.e., duration, frequency, timing) and magnitude (i.e., exposure concentration and dose) of relevant cumulative exposures for the population of interest? c) What is the mechanism (e.g., toxicokinetic or toxicodynamic) and consequence (e.g., additive, less than additive, more than additive) of the mixture's interactive effects on exposed populations? The focus is primarily on human health effects from chemical mixtures, and the goal is to reinforce the need for improved assessment of cumulative exposure and better understanding of the biological mechanisms that determine toxicological interactions among mixture constituents.

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Risk Assessment Methodology	Vulnerability as a function of individual and group resources in cumulative risk assessment	DeFur, PL; Evans, GW; Cohen Hubal, EA; Kyle, AD; Morello-Frosch, RA; Williams, DR.	2007	*Environ. Health Perspect.* May; 115(5):817-24	https://pubmed.ncbi.nlm.nih.gov/17520073/	Background: The field of risk assessment has focused on protecting the health of individual people or populations of wildlife from single risks, mostly from chemical exposure. The U.S. Environmental Protection Agency recently began to address multiple risks to communities in the "Framework for Cumulative Risk Assessment" [EPA/630/P02/001F. Washington DC: Risk Assessment Forum, U.S. Environmental Protection Agency (2003)]. Simultaneously, several reports concluded that some individuals and groups are more vulnerable to environmental risks than the general population. However, vulnerability has received little specific attention in the risk assessment literature. Objective: Our objective is to examine the issue of vulnerability in cumulative risk assessment and present a conceptual framework rather than a comprehensive review of the literature. In this article we consider similarities between ecologic and human communities and the factors that make communities vulnerable to environmental risks. Discussion: The literature provides substantial evidence on single environmental factors and simple conditions that increase vulnerability or reduce resilience for humans and ecologic systems. This observation is especially true for individual people and populations of wildlife. Little research directly addresses the topic of vulnerability in cumulative risk situations, especially at the community level. The community level of organization has not been adequately considered as an end point in either human or ecologic risk assessment. Furthermore, current information on human risk does not completely explain the level of response in cumulative risk conditions. Ecologic risk situations are similarly more complex and unpredictable for cases of cumulative risk. Conclusions: Psychosocial conditions and responses are the principal missing element for humans. We propose a model for including psychologic and social factors as an integral component of cumulative risk assessment.
EJ Analytical Framework	A framework for assessing the impact of land use policy on community exposure to air toxics	Willis, MR; Keller, AA.	2007	*J. Environ. Manage.* Apr; 83(2):213-27	https://pubmed.ncbi.nlm.nih.gov/16842900/	Our research focuses on the linkage between land use planning policy and the spatial pattern of exposure to air toxics emissions. Our objective is to develop a modeling framework for assessment of the community health risk implications of land use policy. The modeling framework is not intended to be a regulatory tool for small-scale land use decisions, but a long-range planning tool to assess the community health risk implications of alternative land use scenarios at a regional or subregional scale. This paper describes the development and application of an air toxic source model for generating aggregate emission factors for industrial and commercial zoning districts as a function of permitted uses. To address the uncertainty of estimating air toxics emission rates for planned general land use or zoning districts, the source model uses an emissions probability mass function that weights each incremental permitted land use activity by the likelihood of occurrence. We thus reduce the uncertainty involved in planning for development with no prior knowledge of the specific industries that may locate within the land use district. These air toxics emission factors can then be used to estimate pollutant atmospheric mass flux from land use zoning districts, which can then be input to air dispersion and human health risk assessment models to simulate the spatial pattern of air toxics exposure risk. The model database was constructed using the California Air Toxics Inventory, 1997 US Economic Census, and land assessment records from several California counties. The database contains information on more than 200 air toxics at the 2-digit Standard Industrial Classification (SIC) level. We present a case study to illustrate application of the model. LUAIRTOX, the interactive spreadsheet model that applies our methodology to the California data, is available at http://www2.bren.ucsb.edu/~mwillis/LUAIRTOX.htm.
EJ Strategic Guidance Documents	EPA's Environmental Justice Collaborative Problem-Solving Model	US EPA	2008	Government Document	https://www.epa.gov/sites/default/files/2015-02/documents/cps-manual-12-27-06.pdf	This document is designed to give its readers a basic understanding of the Collaborative Problem-Solving (CPS) model and how it can be used to address local environmental and/or public health issues. It provides an overview of the model and its relationship to the Environmental Justice Collaborative Problem-Solving Cooperative Agreement Program. It is intended for a wide array of EJ stakeholders, including community-based organizations, government entities, industry, NGOs, and academia. It provides insights on how these entities can work together to address environmental and/or public health issues in local communities.
EJ Health Disparities	Where We Live Matters for Our Health: The Links Between Housing and Health.	Commission to Build a Healthier America	2008	Robert Wood Johnson Foundation	http://www.commissiononhealth.org/PDF/888f4a18-eb90-45be-a2f8-159e84a55a4c/Issue%20Brief%203%20Sept%2008%20-%20Neighborhoods%20and%20Health.pdf	Where we live is at the very core of our daily lives. For most Americans, home represents a place of safety, security, and shelter, where families come together. Housing generally represents an American family's greatest single expenditure, and, for homeowners, their most significant source of wealth. Given its importance, it is not surprising that factors related to housing have the potential to help—or harm—our health in major ways. This issue brief examines the many ways in which housing can influence health and discusses promising strategies to improve America's health by ensuring that all Americans have healthy homes.
EJ Analytical Framework	Is epidemiology the key to cumulative risk assessment?	Levy, JL.	2008	*Risk Analysis* 28(6):1507-13	https://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2008.01121.x	Although cumulative risk assessment by definition evaluates the joint effects of chemical and nonchemical stressors, studies to date have not considered both dimensions, in part because toxicological studies cannot capture many stressors of interest. Epidemiology can potentially include all relevant stressors, but developing and extracting the necessary information is challenging given some of the inherent limitations of epidemiology. In this article, I propose a conceptual framework within which epidemiological studies could be evaluated for their inclusion into cumulative risk assessment, including a problem formulation/planning and scoping step that focuses on stressors meaningful for risk management decisions, extension of the chemical mixtures framework to include nonchemical stressors, and formal consideration of vulnerability characteristics of the population. In the long term, broadening the applicability and informativeness of cumulative risk assessment will require enhanced communication and collaboration between epidemiologists and risk assessors, in which the structure of social and environmental epidemiological analyses may be informed in part by the needs of cumulative risk assessment.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
EJ Analytical Framework	A Framework for Examining Social Stress and Susceptibility to Air Pollution in Respiratory Health	Clougherty, JE; Kubzansky, LD.	2009	*Environ. Health Perspect.* 117(9):1351-1358	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2737009/	**Objective:** There is growing interest in disentangling the health effects of spatially clustered social and physical environmental exposures and in exploring potential synergies among them, with particular attention directed to the combined effects of psychosocial stress and air pollution. Both exposures may be elevated in lower-income urban communities, and it has been hypothesized that stress, which can influence immune function and susceptibility, may potentiate the effects of air pollution in respiratory disease onset and exacerbation. In this paper, we attempt to synthesize the relevant research from social and environmental epidemiology, toxicology, immunology, and exposure assessment to provide a useful framework for environmental health researchers aiming to investigate the health effects of environmental pollution in combination with social or psychological factors. **Data synthesis:** We review the existing epidemiologic and toxicological evidence on synergistic effects of stress and pollution, and then describe the physiologic effects of stress and key issues related to measuring and evaluating stress as it relates to physical environmental exposures and susceptibility. Finally, we identify some of the major methodologic challenges ahead as we work toward disentangling the health effects of clustered social and physical exposures and accurately describing the interplay among these exposures. **Conclusions:** There is still tremendous work to be done toward understanding the combined and potentially synergistic health effects of stress and pollution. As this research proceeds, we recommend careful attention to the relative temporalities of stress and pollution exposures, to nonlinearities in their independent and combined effects, to physiologic pathways not elucidated by epidemiologic methods, and to the relative spatial distributions of social and physical exposures at multiple geographic scales.
EJ Strategic Guidance Documents	Interim Guidance on Considering Environmental Justice During the Development of an Action	US EPA	2010	Government Document	https://www.epa.gov/sites/default/files/2015-03/documents/considering-ej-in-rulemaking-guide-07-2010.pdf	This guide is meant to help EPA staff consider EJ concerns during the development of actions under the Agency's ADP, consistent with existing environmental and civil rights laws and their implementing regulations, as well as Executive Order (EO) 12898. As working groups use this Interim Guide, the experiences and lessons they learned will be considered in both the development of the new technical guidance and in revising this guide later on.
Risk Assessment Methodology	A framework for examining social stress and susceptibility to air pollution in respiratory health	Clougherty, JE; Kubzansky, LD.	2010	*Cien Saude Colet.* Jul; 15(4):2059-74	https://pubmed.ncbi.nlm.nih.gov/20694328/	There is growing interest in disentangling the health effects of spatially clustered social and physical environmental exposures and in exploring potential synergies among them, with particular attention directed to the combined effects of psychosocial stress and air pollution. Both exposures may be elevated in lower-income urban communities, and it has been hypothesized that stress, which can influence immune function and susceptibility, may potentiate the effects of air pollution in respiratory disease onset and exacerbation. In this paper, we review the existing epidemiologic and toxicological evidence on synergistic effects of stress and pollution, and describe the physiologic effects of stress and key issues related to measuring and evaluating stress as it relates to physical environmental exposures and susceptibility. Finally, we identify some of the major methodologic challenges ahead as we work toward disentangling the health effects of clustered social and physical exposures and accurately describing the interplay among these exposures. As this research proceeds, we recommend careful attention to the relative temporalities of stress and pollution exposures, to nonlinearities in their independent and combined effects, to physiologic pathways not elucidated by epidemiologic methods, and to the relative spatial distributions of social and physical exposures at multiple geographic scales.
Risk Assessment Methodology	The role of cumulative risk assessment in decisions about environmental justice	Sexton, K; Linder, SH.	2010	*Int. J. Environ. Res. Public Health* Nov; 7(11):4037-49	https://pubmed.ncbi.nlm.nih.gov/21139875/	There is strong presumptive evidence that people living in poverty and certain racial and ethnic groups bear a disproportionate burden of environmental health risk. Many have argued that conducting formal assessments of the health risk experienced by affected communities is both unnecessary and counterproductive-that instead of analyzing the situation our efforts should be devoted to fixing obvious problems and rectifying observable wrongs. We contend that formal assessment of cumulative health risks from combined effects of chemical and nonchemical stressors is a valuable tool to aid decision makers in choosing risk management options that are effective, efficient, and equitable. If used properly, cumulative risk assessment need not impair decision makers' discretion, nor should it be used as an excuse for doing nothing in the face of evident harm. Good policy decisions require more than good intentions; they necessitate analysis of risk-related information along with careful consideration of economic issues, ethical and moral principles, legal precedents, political realities, cultural beliefs, societal values, and bureaucratic impediments. Cumulative risk assessment can provide a systematic and impartial means for informing policy decisions about environmental justice.
EJ Strategic Guidance Documents	Memorandum of Understanding on Environmental Justice and Executive Order 12898	Interagency Group of 17 agencies and offices	2011	Government Document	https://www.epa.gov/sites/default/files/2015-02/documents/ej-mou-2011-08.pdf	Applies to 17 federal agencies or offices. Highlights the continued importance of identifying and addressing environmental justice considerations in agency programs, policies, and activities as provided in Executive Order 12898, including as to agencies not already covered by the Order.
EJ Strategic Guidance Documents	Plan EJ 2014	US EPA	2011	Government Document	https://nepis.epa.gov/Exe/ZyPDF.cgi/P100DFCQ.PDF?Dockey=P100DFCQ.PDF	Plan EJ 2014, which is meant to mark the 20th anniversary of the signing of EO 12898 on environmental justice, is the EPA's overarching strategy for advancing environmental justice. It seeks to protect the environment and health in overburdened communities, empower communities to take action to improve their health and environment, and to establish partnerships with local, state, tribal, and federal governments and organizations to achieve healthy and sustainable communities.
EJ Health Disparities	Residential Proximity to Environmental Hazards and Adverse Health Outcomes	Brender, JD; Maantay, JA; Chakraborty, J.	2011	*American Journal of Public Health* 101(S1):S37-S52	https://ajph.aphapublications.org/doi/pdfplus/10.2105/AJPH.2011.300183	How living near environmental hazards contributes to poorer health and disproportionate health outcomes is an ongoing concern. We conducted a substantive review and critique of the literature regarding residential proximity to environmental hazards and adverse pregnancy outcomes, childhood cancer, cardiovascular and respiratory illnesses, end-stage renal disease, and diabetes. Several studies have found that living near hazardous wastes sites, industrial sites, cropland with pesticide applications, highly trafficked roads, nuclear power plants, and gas stations or repair shops is related to an increased risk of adverse health outcomes. Government agencies should consider these findings in establishing rules and permitting and enforcement procedures to reduce pollution from environmentally burdensome facilities and land uses.

Appendix B: Literature Review for Environmental Justice Publications

Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
EJ Health Disparities	Strengthening community capacity to participate in making decisions to reduce disproportionate environmental exposures	Freudenberg, N; Pastor, M; Israel, B.	2011	*American Journal of Public Health* 101(S1):S123-130	https://ajph.aphapublications.org/doi/10.2105/AJPH.2011.300265?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub++0pubmed	Environmental exposures impose a disproportionate health burden on low-income populations and communities of color. One contributing factor may be the obstacles such communities face to full participation in making policy decisions about environmental health. This study described and analyzed the characteristics that contributed to communities' capacity to participate in making environmental decisions and suggested steps public agencies could take to achieve more meaningful participation. By strengthening community capacity, advancing authentic participation, and building democratic power, it might be possible to alter current patterns of health inequities. Strengthening participation by working with communities to develop the capacities needed to be effective in such processes is a key role for local, state, and national environmental agencies.
EJ Health Disparities	Drinking water infrastructure and environmental disparities: evidence and methodological considerations	VanDerslice, J.	2011	*American Journal of Public Health* 101(S1):S109-114	https://ajph.aphapublications.org/doi/full/10.2105/AJPH.2011.300189	Potable drinking water is essential to public health; however, few studies have investigated income or racial disparities in water infrastructure or drinking water quality. There were many case reports documenting a lack of piped water or serious water quality problems in low income and minority communities, including tribal lands, Alaskan Native villages, colonies along the United States-Mexico border, and small communities in agricultural areas. Only 3 studies compared the demographic characteristics of communities by the quality of their drinking water, and the results were mixed in these studies. Further assessments were hampered by difficulties linking specific water systems to the sociodemographic characteristics of communities, as well as little information about how well water systems operated and the effectiveness of governmental oversight.
EJ Analytical Framework	Conceptual Environmental Justice Model for Evaluating Chemical Pathways of Exposure in Low-Income, Minority, Native American, and Other Unique Exposure Populations	Burger, J; Gochfeld, M.	2011	*American Journal of Public Health* 101(S1):S64-73	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3222515/	Risk assessment determines pathways, and exposures that lead to poor health. For exposures that fall disproportionately on urban low-income communities, minorities, and Native Americans, these pathways are often more common than in the general population. Although risk assessors often evaluate these pathways on an ad hoc basis, a more formal way of addressing these nonstandard pathways is needed to adequately inform public health policy. A conceptual model is presented for evaluating nonstandard, unique, or excessive exposures, particularly for environmental justice communities that have an exposure matrix of inhalation, dermal, ingestion, and injection. Risk assessment can be improved by including nonstandard and unique exposure pathways as described in this conceptual model.
EJ Analytical Framework	Proximity Analysis for Exposure Assessment in Environmental Health Justice Research	Chakraborty, J; Maantay, JA; Brender, J.	2011	Geospatial Analysis of Environmental Health, volume in series "Geotechnologies and the Environment" Springer-Verlag, pp. 111-138 (book)	https://link.springer.com/chapter/10.1007%2F978-94-007-0329-2_5	This chapter provides a historical overview and constructive critique of analytical approaches and methods that have been used to measure proximity to environmental health hazards and potential exposure to their adverse effects in the environmental justice (EJ) research literature. After providing an introduction to environmental health justice research and key findings, we examine how quantitative EJ analysis has emerged from comparing the prevalence of minority or low-income populations in spatial units hosting environmental hazards and circular buffer zones to more advanced techniques that utilize GIS, pollution plume models, and estimates of health risk from ambient exposure to multiple pollutants and emission sources. We also review spatial analytical approaches used in previous studies to determine the demographic and socioeconomic characteristics of people residing in areas potentially exposed to environmental hazards, as well as newly emerging geostatistical techniques that are more appropriate for spatial analysis of EJ than conventional statistical methods used in prior research. The concluding section focuses on highlighting the key limitations and identifying future research needs associated with assessment of environmental health justice.
EJ Analytical Framework	Maximizing health benefits and minimizing inequality: incorporating local-scale data in the design and evaluation of air quality policies	Fann, N; Roman, HA; Fulcher, CM; Gentile, MA; Hubbell, BJ; Wesson, K; Levy, JI.	2011	*Risk Analysis* 31(6):908-922	https://onlinelibrary.wiley.com/doi/full/10.1111/j.1539-6924.2011.01629.x	The U.S. Environmental Protection Agency undertook a case study in the Detroit metropolitan area to test the viability of a new multipollutant risk-based (MP/RB) approach to air quality management, informed by spatially resolved air quality, population, and baseline health data. The case study demonstrated that the MP/RB approach approximately doubled the human health benefits achieved by the traditional approach while increasing cost less than 20%--moving closer to the objective of Executive Order 12866 to maximize net benefits. Less well understood is how the distribution of health benefits from the MP/RB and traditional strategies affect the existing inequalities in air-pollution-related risks in Detroit. In this article, we identify Detroit populations that may be both most susceptible to air pollution health impacts (based on local-scale baseline health data) and most vulnerable to air pollution (based on fine-scale PM(2.5) air quality modeling and socioeconomic characteristics). Using these susceptible/vulnerable subpopulation profiles, we assess the relative impacts of each control strategy on risk inequality, applying the Atkinson Index (AI) to quantify health risk inequality at baseline and with either risk management approach. We find that the MP/RB approach delivers greater air quality improvements among these subpopulations while also generating substantial benefits among lower-risk populations. Applying the AI, we confirm that the MP/RB strategy yields less PM(2.5) mortality and asthma hospitalization risk inequality than the traditional approach. We demonstrate the value of this approach to policymakers as they develop cost-effective air quality management plans that maximize risk reduction while minimizing health inequality.
EJ Analytical Framework	Comparing Distributions of Environmental Outcomes for Regulatory Environmental Justice Analysis	Maguire, K; Sheriff, G.	2011	*International Journal of Environmental Research and Public Health* 8:1707-1726	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3108136/	Economists have long been interested in measuring distributional impacts of policy interventions. As environmental justice (EJ) emerged as an ethical issue in the 1970s, the academic literature has provided statistical analyses of the incidence and causes of various environmental outcomes as they relate to race, income, and other demographic variables. In the context of regulatory impacts, however, there is a lack of consensus regarding what information is relevant for EJ analysis, and how best to present it. This paper helps frame the discussion by suggesting a set of questions fundamental to regulatory EJ analysis, reviewing past approaches to quantifying distributional equity, and discussing the potential for adapting existing tools to the regulatory context.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
EJ Analytical Framework	Improving Health in the United States: The Role of Health Impact Assessment.	NRC	2011	National Academy Press	https://www.nap.edu/catalog/13229/improving-health-in-the-united-states-the-role-of-health	Factoring health and related costs into decision making is essential to confronting the nation's health problems and enhancing public well-being. Some policies and programs historically not recognized as relating to health are believed or known to have important health consequences. For example, public health has been linked to an array of policies that determine the quality and location of housing, availability of public transportation, land use and street connectivity, agricultural practices and the availability of various types of food, and development and location of businesses and industry. Improving Health in the United States: The Role of Health Impact Assessment offers guidance to officials in the public and private sectors on conducting HIAs to evaluate public health consequences of proposed decisions -- such as those to build a major roadway, plan a city's growth, or develop national agricultural policies -- and suggests actions that could minimize adverse health impacts and optimize beneficial ones. Several approaches could be used to incorporate aspects of health into decision making, but HIA holds particular promise because of its applicability to a broad array of programs, consideration of both adverse and beneficial health effects, ability to consider and incorporate various types of evidence, and engagement of communities and stakeholders in a deliberative process. The report notes that HIA should not be assumed to be the best approach to every health policy question but rather should be seen as part of a spectrum of public health and policy-oriented approaches. The report presents a six-step framework for conducting HIA of proposed policies, programs, plans, and projects at federal, state, tribal, and local levels, including within the private sector. In addition, the report identifies several challenges to the successful use of HIA, such as balancing the need to provide timely information with the realities of varying data quality, producing quantitative estimates of health effects, and engaging stakeholders.
EJ Analytical Framework	Symposium on Integrating the Science of Environmental Justice into Decision-Making at the Environmental Protection Agency: An Overview	Nweke, OC; Payne-Sturges, D; Garcia, L; Lee, C; Zenick, H; P. Grevatt, P; Sanders, WH; Case, H; Dankwa-Mullan, I.	2011	*American Journal of Public Health* 101(S1):S19-26	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3222477/	The symposium provided a forum for discourse on the state of scientific knowledge about factors identified by EPA that may contribute to higher burdens of environmental exposure or risk in racial/ethnic minorities and low-income populations. Also featured were discussions on how environmental justice considerations may be integrated into EPA's analytical and decision-making frameworks and on research needs for advancing the integration of environmental justice into environmental policymaking. We summarize key discussions and conclusions from the symposium and briefly introduce the articles in this issue.
EJ Analytical Framework	Exploring potential sources of differential vulnerability and susceptibility in risk from environmental hazards to expand the scope of risk assessment	Schwartz, J; Bellinger, D; Glass, T.	2011	*American Journal of Public Health* 101(Suppl 1):S94-101	https://ajph.aphapublications.org/doi/10.2105/AJPH.2011.300272?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub++0pubmed	Genetic factors, other exposures, individual disease states and allostatic load, psychosocial stress, and socioeconomic position all have the potential to modify the response to environmental exposures. Moreover, many of these modifiers covary with the exposure, leading to much higher risks in some subgroups. These are not theoretical concerns; rather, all these patterns have already been demonstrated in studies of the effects of lead and air pollution. However, recent regulatory impact assessments for these exposures have generally not incorporated these findings. Therefore, differential risk and vulnerability is a critically important but neglected area within risk assessment, and should be incorporated in the future.
EJ Analytical Framework	Expanding the Scope of Risk Assessment: Methods of Studying Differential Vulnerability and Susceptibility	Schwartz, J; Bellinger, D; Glass, T.	2011	*American Journal of Public Health* 101:S102-S109	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3222483/	Several methodological issues have been identified in analysis of epidemiological data to better assess the distributional effects of exposures and hypotheses about effect modification. We discuss the hierarchical mixed model and some more complex methods. Methods of capturing inequality are a second dimension of risk assessment, and simulation studies are important because plausible choices for air pollution effects and effect modifiers could result in extremely high risks in a small subset of the population. Future epidemiological studies should explore contextual and individual-level factors that might modify these relationships. The Environmental Protection Agency should make this a standard part of their risk assessments whenever the necessary information is available.
Cumulative Risk Assessment	Non-Chemical Stressors and Cumulative Risk Assessment: An Overview of Current Initiatives and Potential Air Pollutant Interactions	Lewis, AS; Sax, SN; Wason, SC; Campleman, SL.	2011	*Int. J. Environ. Res. Public Health*	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3138011/	Regulatory agencies are under increased pressure to consider broader public health concerns that extend to multiple pollutant exposures, multiple exposure pathways, and vulnerable populations. Specifically, cumulative risk assessment initiatives have stressed the importance of considering both chemical and non-chemical stressors, such as socioeconomic status (SES) and related psychosocial stress, in evaluating health risks. The integration of non-chemical stressors into a cumulative risk assessment framework has been largely driven by evidence of health disparities across different segments of society that may also bear a disproportionate risk from chemical exposures. This review will discuss current efforts to advance the field of cumulative risk assessment, highlighting some of the major challenges, discussed within the construct of the traditional risk assessment paradigm. Additionally, we present a summary of studies of potential interactions between social stressors and air pollutants on health as an example of current research that supports the incorporation of non-chemical stressors into risk assessment. The results from these studies, while suggestive of possible interactions, are mixed and hindered by inconsistent application of social stress indicators. Overall, while there have been significant advances, further developments across all of the risk assessment stages (i.e., hazard identification, exposure assessment, dose-response, and risk characterization) are necessary to provide a scientific basis for regulatory actions and effective community interventions, particularly when considering non-chemical stressors. A better understanding of the biological underpinnings of social stress on disease and implications for chemical-based dose-response relationships is needed. Furthermore, when considering non-chemical stressors, an appropriate metric, or series of metrics, for risk characterization is also needed. Cumulative risk assessment research will benefit from coordination of information from several different scientific disciplines, including, for example, toxicology, epidemiology, nutrition, neurotoxicology, and the social sciences.

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EJ Health Disparities	Using geographically weighted regression for environmental justice analysis: Cumulative cancer risks from air toxics in Florida	Gilbert, A; Chakraborty, J.	2011	*Social Science Research* 40(1): 273-286	https://www.sciencedirect.com/science/article/abs/pii/S0049089X10001754	Previous quantitative research on environmental justice has been limited by simplistic assumptions used to measure health risks and traditional regression techniques that fail to discern spatial variations in statistical relationships. We address these gaps through a case study that examines: (a) whether potential health risks from exposure to hazardous air pollutants in Florida are related to race/ethnicity and socioeconomic status, and (b) how the significance of statistical associations between health risk and race/ethnicity or socioeconomic status vary across the state. This study integrates census tract level estimates of cumulative cancer risk compiled by the EPA with Census 2000 data and a spatial statistical technique known as geographically weighted regression that allows us to explore spatial variability in analytical results. Our findings indicate that while race and ethnicity are significantly related to cancer risks in Florida, conventional regression can hide important local variations in statistical relationships relevant to environmental justice analysis.
Risk Assessment Methodology	Cumulative risk assessment for combined health effects from chemical and nonchemical stressors	Sexton, K; Linder, SH.	2011	*Am. J. Public Health* Dec; 101 Suppl 1(Suppl 1):S81-8	https://pubmed.ncbi.nlm.nih.gov/21551386/	Cumulative risk assessment is a science policy tool for organizing and analyzing information to examine, characterize, and possibly quantify combined threats from multiple environmental stressors. We briefly survey the state of the art regarding cumulative risk assessment, emphasizing challenges and complexities of moving beyond the current focus on chemical mixtures to incorporate nonchemical stressors, such as poverty and discrimination, into the assessment paradigm. Theoretical frameworks for integrating nonchemical stressors into cumulative risk assessments are discussed, the impact of geospatial issues on interpreting results of statistical analyses is described, and four assessment methods are used to illustrate the diversity of current approaches. Prospects for future progress depend on adequate research support as well as development and verification of appropriate analytic frameworks.
Risk Assessment Methodology	Conceptual models for cumulative risk assessment	Linder, SH; Sexton, K.	2011	*Am. J. Public Health* Dec; 101 Suppl 1(Suppl 1):S74-81	https://pubmed.ncbi.nlm.nih.gov/22021317/	In the absence of scientific consensus on an appropriate theoretical framework, cumulative risk assessment and related research have relied on speculative conceptual models. We argue for the importance of theoretical backing for such models and discuss 3 relevant theoretical frameworks, each supporting a distinctive "family" of models. Social determinant models postulate that unequal health outcomes are caused by structural inequalities; health disparity models envision social and contextual factors acting through individual behaviors and biological mechanisms; and multiple stressor models incorporate environmental agents, emphasizing the intermediary role of these and other stressors. The conclusion is that more careful reliance on established frameworks will lead directly to improvements in characterizing cumulative risk burdens and accounting for disproportionate adverse health effects.
Risk Assessment Methodology	Leveraging Epidemiology to Improve Risk Assessment	Nachman, KE; Fox, MA; Sheehan, MC; Burke, TA; Rodricks, JV; Woodruff, TJ.	2011	*Open Epidemiol. J.* 4:3-29	https://pubmed.ncbi.nlm.nih.gov/31341519/	The field of environmental public health is at an important crossroad. Our current biomonitoring efforts document widespread exposure to a host of chemicals for which toxicity information is lacking. At the same time, advances in the fields of genomics, proteomics, metabolomics, genetics and epigenetics are yielding volumes of data at a rapid pace. Our ability to detect chemicals in biological and environmental media has far outpaced our ability to interpret their health relevance, and as a result, the environmental risk paradigm, in its current state, is antiquated and ill-equipped to make the best use of these new data. In light of new scientific developments and the pressing need to characterize the public health burdens of chemicals, it is imperative to reinvigorate the use of environmental epidemiology in chemical risk assessment. Two case studies of chemical assessments from the Environmental Protection Agency Integrated Risk Information System database are presented to illustrate opportunities where epidemiologic data could have been used in place of experimental animal data in dose-response assessment, or where different approaches, techniques, or studies could have been employed to better utilize existing epidemiologic evidence. Based on the case studies and what can be learned from recent scientific advances and improved approaches to utilizing human data for dose-response estimation, recommendations are provided for the disciplines of epidemiology and risk assessment for enhancing the role of epidemiologic data in hazard identification and dose-response assessment.
Risk Assessment Methodology	Cumulative risk assessment: an overview of methodological approaches for evaluating combined health effects from exposure to multiple environmental stressors	Sexton, K.	2012	*Int. J. Environ. Res. Public Health* Feb; 9(2):370-90	https://pubmed.ncbi.nlm.nih.gov/22470298/	Systematic evaluation of cumulative health risks from the combined effects of multiple environmental stressors is becoming a vital component of risk-based decisions aimed at protecting human populations and communities. This article briefly examines the historical development of cumulative risk assessment as an analytical tool, and discusses current approaches for evaluating cumulative health effects from exposure to both chemical mixtures and combinations of chemical and nonchemical stressors. A comparison of stressor-based and effects-based assessment methods is presented, and the potential value of focusing on viable risk management options to limit the scope of cumulative evaluations is discussed. The ultimate goal of cumulative risk assessment is to provide answers to decision-relevant questions based on organized scientific analysis; even if the answers, at least for the time being, are inexact and uncertain.
Risk Assessment Methodology	Integrating susceptibility into environmental policy: an analysis of the national ambient air quality standard for lead	Chari, R; Burke, TA; White, RH; Fox, MA.	2012	*Int. J. Environ. Res. Public Health* Apr; 9(4):1077-96	https://pubmed.ncbi.nlm.nih.gov/22690184/	Susceptibility to chemical toxins has not been adequately addressed in risk assessment methodologies. As a result, environmental policies may fail to meet their fundamental goal of protecting the public from harm. This study examines how characterization of risk may change when susceptibility is explicitly considered in policy development; in particular we examine the process used by the U.S. Environmental Protection Agency (EPA) to set a National Ambient Air Quality Standard (NAAQS) for lead. To determine a NAAQS, EPA estimated air lead-related decreases in child neurocognitive function through a combination of multiple data elements including concentration-response (CR) functions. In this article, we present alternative scenarios for determining a lead NAAQS using CR functions developed in populations more susceptible to lead toxicity due to socioeconomic disadvantage. The use of CR functions developed in susceptible groups resulted in cognitive decrements greater than original EPA estimates. EPA's analysis suggested that a standard level of 0.15 µg/m(3) would fulfill decision criteria, but by incorporating susceptibility we found that options for the standard could reasonably be extended to lower levels. The use of data developed in susceptible populations would result in the selection of a more protective NAAQS under the same decision framework applied by EPA. Results are used to frame discussion regarding why cumulative risk assessment methodologies are needed to help inform policy development.

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Risk Assessment Methodology	Differential exposure to hazardous air pollution in the United States: a multilevel analysis of urbanization and neighborhood socioeconomic deprivation	Young, GS; Fox, MA; Trush, M; Kanarek, N; Glass, TA; Curriero, FC.	2012	*Int. J. Environ. Res. Public Health* Jun;9 (6):2204-25	https://pubmed.ncbi.nlm.nih.gov/22829799/	Population exposure to multiple chemicals in air presents significant challenges for environmental public health. Air quality regulations distinguish criteria air pollutants (CAPs) (e.g., ozone, PM2.5) from hazardous air pollutants (HAPs)-187 chemicals which include carcinogens and others that are associated with respiratory, cardiovascular, neurological and numerous other non-cancer health effects. Evidence of the public's cumulative exposure and the health effects of HAPs are quite limited. A multilevel model is used to assess differential exposure to HAP respiratory, neurological, and cancer hazards (2005) related to the Townsend Index of Socioeconomic Deprivation (TSI), after adjustment for regional population size and economic activity, and local population density. We found significant positive associations between tract TSI and respiratory and cancer HAP exposure hazards, and smaller effects for neurological HAPs. Tracts in the top quintile of TSI have between 38%-60% higher HAP exposure than the bottom quintile; increasing population size from the bottom quintile to the top quintile modifies HAP exposure hazard related to TSI, increasing cancer HAP exposure hazard by 6% to 20% and increasing respiratory HAP exposure hazard by 12% to 27%. This study demonstrates the value of social epidemiological methods for analyzing differential exposure and advancing cumulative risk assessment.
Cumulative Risk Assessment	Epigenome: biosensor of cumulative exposure to chemical and nonchemical stressors related to environmental justice	Olden, K; Lin, Y; Gruber, D; Sonawane, B.	2014	*Toxicol. Ind. Health* May-Jun 14(3):429-54.	https://pubmed.ncbi.nlm.nih.gov/9569448/	Relatively little is known about the spectrum of health effects, and the scope and level of ambient air concentrations of those pollutants regulated under the Clean Air Act as "hazardous air pollutants". The U.S. Environmental Protection Agency's (US EPA) Cumulative Exposure Project uses currently available emissions inventories, from a variety of source types, and an atmospheric dispersion model to provide estimates of ambient concentrations for 148 hazardous air pollutants (HAPs) in over 60,000 census tracts for the year 1990. This paper uses currently available hazard information for those pollutants and provides a database of potential regulatory threshold concentrations of concern, or "benchmark concentrations," and a methodology for prioritizing and characterizing the quality of the data. In order to demonstrate application of the database and prioritization scheme to outputs from the Cumulative Exposure Project, comparisons were made with the maximum modeled concentration of each individual hazardous air pollutant across the census tracts. Of the 197 benchmark concentrations for cancer and non-cancer (long- and short-term exposures) effects compiled for the study, approximately one half were exceeded with a predominance of exceedance of cancer benchmarks. While the number of benchmark concentrations available to fully characterize potential health effects of these pollutants was limited (approximately 80 percent of HAPs identified as cancer concerns had benchmark concentrations for cancer and 50 percent of all HAPs had non-cancer benchmark concentrations) and there was greater uncertainty in derivation of maximum modeled air concentrations than other levels, the comparison between the two was a useful approach for providing an indication of public health concern from hazardous air pollutants.
EJ Strategic Guidance Documents	EJ Legal Tools	US EPA	2014	Government Document	https://www.epa.gov/sites/default/files/2015-02/documents/ej-legal-tools.pdf	This document is designed to identify legal tools to help the U.S. Environmental Protection Agency (EPA) advance its goal of environmental justice in the United States. It provides an overview of a number of discretionary legal authorities that are or may be available to EPA to address environmental justice considerations under federal statutes and programs. It grows out of EPA's renewed commitment to environmental justice embodied in Plan EJ 2014, which marks the forthcoming 20th anniversary of Executive Order 12898, entitled "Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations". In response to Plan EJ 2014, this document consolidates, updates, and expands on the Office of General Counsel's past work on the subject of environmental justice. Significantly, EJ Legal Tools is not a document prescribing when and how the Agency should undertake specific actions. It is not an exhaustive inventory of every conceivable legal authority; rather, it attempts to identify some of the leading opportunities that may have viability both in terms of legal
CalEnviroScreen used	CalEnviroScreen: A pathway to address environmental justice issue in California	Alexeeff, G; Mataka, AY.	2014	*EM: Air and Waste Management Association's Magazine for Environmental Managers*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-84892753560&partnerID=40&md5=be7346adb58fc9f6bc869b6e3782636e	A look at CalEnviroScreen, an environmental health screening tool designed to help decision makers focus time, resources, and programs to improve the environmental health of Californians living in areas of the state disproportionately burdened by multiple sources of pollution. Copyright © 2014 Air & Waste Management Association.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
EJ Health Disparities	Social stressors and air pollution across New York City communities: a spatial approach for assessing correlations among multiple exposures	Shmool, JLC; Kubzansky, LD; Newman, OD; Spengler, J; Shepard, P; Clougherty, JE.	2014	*Environ. Health* 13:91	https://pubmed.ncbi.nlm.nih.gov/25374310/	**Background:** Recent toxicological and epidemiological evidence suggests that chronic psychosocial stress may modify pollution effects on health. Thus, there is increasing interest in refined methods for assessing and incorporating non-chemical exposures, including social stressors, into environmental health research, towards identifying whether and how psychosocial stress interacts with chemical exposures to influence health and health disparities. We present a flexible, GIS-based approach for examining spatial patterns within and among a range of social stressors, and their spatial relationships with air pollution, across New York City, towards understanding their combined effects on health. **Methods:** We identified a wide suite of administrative indicators of community-level social stressors (2008-2010), and applied simultaneous autoregressive models and factor analysis to characterize spatial correlations among social stressors, and between social stressors and air pollutants, using New York City Community Air Survey (NYCCAS) data (2008-2009). Finally, we provide an exploratory ecologic analysis evaluating possible modification of the relationship between nitrogen dioxide (NO2) and childhood asthma Emergency Department (ED) visit rates by social stressors, to demonstrate how the methods used to assess stressor exposure (and/or consequent psychosocial stress) may alter model results. **Results:** Administrative indicators of a range of social stressors (e.g., high crime rate, residential crowding rate) were not consistently correlated (rho = - 0.44 to 0.89), nor were they consistently correlated with indicators of socioeconomic position (rho = - 0.54 to 0.89). Factor analysis using 26 stressor indicators suggested geographically distinct patterns of social stressors, characterized by three factors: violent crime and physical disorder, crowding and poor access to resources, and noise disruption and property crimes. In an exploratory ecologic analysis, these factors were differentially associated with area-average NO2 and childhood asthma ED visits. For example, only the 'violent crime and disorder' factor was significantly associated with asthma ED visits, and only the 'crowding and resource access' factor modified the association between area-level NO2 and asthma ED visits. **Conclusions:** This spatial approach enabled quantification of complex spatial patterning and confounding between chemical and non-chemical exposures, and can inform study design for epidemiological studies of separate and combined effects of multiple urban exposures.
Risk Assessment Methodology	Integrated assessment of risk and sustainability in the context of regulatory decision making	Sexton, K; Linder, SH.	2014	*Environ. Sci. Technol.* 48(3):1409-18	https://pubmed.ncbi.nlm.nih.gov/24417344/	Risk assessment is a decision-making tool used by the U.S. Environmental Protection Agency and other governmental organizations to organize and analyze scientific information so as to examine, characterize, and possibly quantify threats to human health and/or ecologic resources. Sustainability evaluation is a process for organizing and analyzing scientific and technical information about nature-society interactions in order to help decision-makers determine whether taking or avoiding certain actions will make society more sustainable. Although development and application of these two methodologies have progressed along distinct and unconnected pathways, the National Research Council recently recommended that the U.S. Environmental Protection Agency adopt the concept of "sustainability" as both a process and a goal, and that risk assessment be incorporated, when appropriate, as a key input into decision-making about sustainability. The following discussion briefly reviews these two analytic approaches and examines conceptual frameworks for integrating assessments of risk and sustainability as a component of regulatory decision-making.
Risk Assessment Methodology	Social Determinants of Health in Environmental Justice Communities: Examining Cumulative Risk in Terms of Environmental Exposures and Social Determinants of Health	Prochaska, JD; Nolen, AB; Kelley, H; Sexton, K; Linder, SH; Sullivan, J.	2014	*Hum. Ecol. Risk Assess.* 20(4):980-994	https://pubmed.ncbi.nlm.nih.gov/24771993/	Residents of environmental justice (EJ) communities may bear a disproportionate burden of environmental health risk, and often face additional burdens from social determinants of health. Accounting for cumulative risk should include measures of risk from both environmental sources and social determinants. This study sought to better understand cumulative health risk from both social and environmental sources in a disadvantaged community in Texas. Key outcomes were determining what data are currently available for this assessment, clarifying data needs, identifying data gaps, and considering how those gaps could be filled. Analyses suggested that the traditionally defined EJ community in Port Arthur may have a lower environmental risk from air toxics than the rest of the City of Port Arthur (although the entire city has a higher risk than the average for the state), but may have a larger burden from social determinants of health. However, the results should be interpreted in light of the availability of data, the definitions of community boundaries, and the areal unit utilized. Continued focus on environmental justice communities and the cumulative risks faced by their residents is critical to protecting these residents and, ultimately, moving towards a more equitable distribution and acceptable level of risk throughout society.
EJ Strategic Guidance Documents	Guidance on Considering Environmental Justice During the Development of Regulatory Actions	US EPA	2015	Government Document	https://www.epa.gov/sites/default/files/2015-06/documents/considering-ej-in-rulemaking-guide-final.pdf	This guide is meant to help EPA rule-writers consider environmental justice during the development of regulatory actions under the Agency's Action Development Process, consistent with existing environmental and civil rights laws and their implementing regulations, as well as EO 12898. This guide also helps to identify key steps throughout the ADP where environmental justice should be considered, including in the development of risk assessments, analytical tools, guidance documents, and more.
CalEnviroScreen used	Racial/ethnic disparities in cumulative environmental health impacts in California: Evidence from a statewide environmental justice screening tool (CalEnviroScreen 1.1)	Cushing, L; Faust, J; August, LM; Cendak, R; Wieland, W; Alexeeff G.	2015	*American Journal of Public Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-84943764372&doi=10.2105%2fAJPH.2015.302643&partnerID=40&md5=92fe066cc60be741d41b8c2ad002bb5f	Objectives. We used an environmental justice screening tool (CalEnviroScreen 1.1) to compare the distribution of environmental hazards and vulnerable populations across California communities. Methods. CalEnviroScreen 1.1 combines 17 indicators created from 2004 to 2013 publicly available data into a relative cumulative impact score. We compared cumulative impact scores across California zip codes on the basis of their location, urban or rural character, and racial/ethnic makeup. We used a concentration index to evaluate which indicators were most unequally distributed with respect to race/ ethnicity and poverty. Results. The unadjusted odds of living in one of the 10% most affected zip codes were 6.2, 5.8, 1.9, 1.8, and 1.6 times greater for Hispanics, African Americans, Native Americans, Asian/Pacific Islanders, and other or multiracial individuals, respectively, than for non-Hispanic Whites. Environmental hazards were more regressively distributed with respect to race/ethnicity than poverty, with pesticide use and toxic chemical releases being the most unequal. Conclusions. Environmental health hazards disproportionately burden communities of color in California. Efforts to reduce disparities in pollution burden can use simple screening tools to prioritize areas for action.

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EJ Analytical Framework	Evaluating Environmental Justice: Analytic Lessons from the Academic Literature and in Practice	Shadbegian, R; Wolverton, A.	2015	In Konisky, D. (Ed.). Failed Promises: Evaluating the Federal Government's Response to Environmental Inequity. (book)	https://mitpress.universitypressscholarship.com/view/10.7551/mitpress/9780262028837.001.0001/upso-9780262028837-chapter-005	This chapter examines several issues relevant to the analysis of environmental justice, how they have been treated in the academic literature, and what approaches have been taken to address them in practice. In particular, we discuss the geographic scope and scale of the analysis, the identification of potentially affected populations, the selection of a comparison group, and how exposure or risk is proxied in an analysis. For each issue, we examine how it is treated in five recently proposed or final EPA rulemakings to illustrate the key similarities and differences in how these issues are treated within the context of an ex-ante analysis compared to the typical ex-post analyses found in the academic literature. We end with a discussion of several areas for future research on analytic issues that are recognized in the literature and by EPA but are often quite challenging to address.
EJ Analytical Framework	Engaging Communities in Research on Cumulative Risk and Social Stress-Environment Interactions: Lessons Learned from EPA's STAR Program	Payne-Sturges, DC; Korfmacher, KS; Cory-Slechta, DA; Jimenez, M; Symanski, E; Carr Shmool, JL; Dotson-Newman, O; Clougherty, JE; French, R; Levy, JI; Laumbach, R; Rodgers, K; Bongiovanni, R; Scammell, MK.	2015	*Environmental Justice* 8(6)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4981147/pdf/env.2015.0025.pdf	Studies have documented cumulative health effects of chemical and nonchemical exposures, particularly chronic environmental and social stressors. Environmental justice groups have advocated for community participation in research that assesses how these interactions contribute to health disparities experienced by low-income and communities of color. In 2009, the U.S. Environmental Protection Agency issued a request for research applications (RFA), ''Understanding the Role of Nonchemical Stressors and Developing Analytic Methods for Cumulative Risk Assessments.'' Seven research projects were funded to help address this knowledge gap. Each engaged with communities in different ways. We describe the community engagement approaches of the seven research projects, which ranged from outreach through shared leadership/ participatory. We then assess the experiences of these programs with respect to the community engagement goals of the RFA. We present insights from these community engagement efforts, including how the grants helped to build or enhance the capacity of community organizations in addition to contributing to the research projects. Our analysis of project proposals, annual grantee reports, and participant observation of these seven projects suggests guidelines for the development of future funding mechanisms and for conducting community engaged research on cumulative risk involving environmental and social stressors including: 1) providing for flexibility in the mode of community engagement; 2) addressing conflict between research timing and engagement needs, 3) developing approaches for communicating about the uniquely sensitive issues of nonchemical stressors and social risks; and 4) encouraging the evaluation of community engagement efforts.
EJ Health Disparities	Identifying Perceived Neighborhood Stressors Across Diverse Communities in New York City	Shmool, JL; Yonas, MA; Newman, OD; Kubzansky, LD; Joseph, E; Parks, A; Callaway, C; Chubb, LG; Shepard, P; Clougherty, JE.	2015	*Am. J. Community Psychol.* Sep; 56(1-2):145-55	https://pubmed.ncbi.nlm.nih.gov/26148979/	There is growing interest in the role of psychosocial stress in health disparities. Identifying which social stressors are most important to community residents is critical for accurately incorporating stressor exposures into health research. Using a community-academic partnered approach, we designed a multi-community study across the five boroughs of New York City to characterize resident perceptions of key neighborhood stressors. We conducted 14 community focus groups; two to three in each borough, with one adolescent group and one Spanish-speaking group per borough. We then used systematic content analysis and participant ranking data to describe prominent neighborhood stressors and identify dominant themes. Three inter-related themes regarding the social and structural sources of stressful experiences were most commonly identified across neighborhoods: (1) physical disorder and perceived neglect, (2) harassment by police and perceived safety and (3) gentrification and racial discrimination. Our findings suggest that multiple sources of distress, including social, political, physical and economic factors, should be considered when investigating health effects of community stressor exposures and psychological distress. Community expertise is essential for comprehensively characterizing the range of neighborhood stressors that may be implicated in psychosocial exposure pathways.
Risk Assessment Methodology	Area-level socioeconomic deprivation, nitrogen dioxide exposure, and term birth weight in New York City	Shmool, JL; Bobb, JF; Ito, K; Elston, B; Savitz, DA; Ross, Z; Matte, TD; Johnson, S; Dominici, F; Clougherty, JE.	2015	*Environ. Res.* Oct; 142:624-32	https://pubmed.ncbi.nlm.nih.gov/26318257/	Numerous studies have linked air pollution with adverse birth outcomes, but relatively few have examined differential associations across the socioeconomic gradient. To evaluate interaction effects of gestational nitrogen dioxide (NO2) and area-level socioeconomic deprivation on fetal growth, we used: (1) highly spatially-resolved air pollution data from the New York City Community Air Survey (NYCCAS); and (2) spatially-stratified principle component analysis of census variables previously associated with birth outcomes to define area-level deprivation. New York City (NYC) hospital birth records for years 2008-2010 were restricted to full-term, singleton births to non-smoking mothers (n=243,853). We used generalized additive mixed models to examine the potentially non-linear interaction of nitrogen dioxide (NO2) and deprivation categories on birth weight (and estimated linear associations, for comparison), adjusting for individual-level socio-demographic characteristics and sensitivity testing adjustment for co-pollutant exposures. Estimated NO2 exposures were highest, and most varying, among mothers residing in the most-affluent census tracts, and lowest among mothers residing in mid-range deprivation tracts. In non-linear models, we found an inverse association between NO2 and birth weight in the least-deprived and most-deprived areas (p-values<0.001 and 0.05, respectively) but no association in the mid-range of deprivation (p=0.8). Likewise, in linear models, a 10 ppb increase in NO2 was associated with a decrease in birth weight among mothers in the least-deprived and most-deprived areas of -16.2g (95% CI: -21.9 to -10.5) and -11.0 g (95% CI: -22.8 to 0.9), respectively, and a non-significant change in the mid-range areas [β=0.5 g (95% CI: -7.7 to 8.7)]. Linear slopes in the most- and least-deprived quartiles differed from the mid-range (reference group) (p-values<0.001 and 0.09, respectively). The complex patterning in air pollution exposure and deprivation in NYC, however, precludes simple interpretation of interactive effects on birth weight, and highlights the importance of considering differential distributions of air pollution concentrations, and potential differences in susceptibility, across deprivation levels.
EJ Health Disparities	Race, deprivation, and immigrant isolation: The spatial demography of air-toxic clusters in the continental United States	Liévanos, RS.	2015	*Soc. Sci. Res.* Nov; 54:50-67	https://pubmed.ncbi.nlm.nih.gov/26463534/	This article contributes to environmental inequality outcomes research on the spatial and demographic factors associated with cumulative air-toxic health risks at multiple geographic scales across the United States. It employs a rigorous spatial cluster analysis of census tract-level 2005 estimated lifetime cancer risk (LCR) of ambient air-toxic emissions from stationary (e.g., facility) and mobile (e.g., vehicular) sources to locate spatial clusters of air-toxic LCR risk in the continental United States. It then tests intersectional environmental inequality hypotheses on the predictors of tract presence in air-toxic LCR clusters with tract-level principal component factor measures of economic deprivation by race and immigrant status. Logistic regression analyses show that net of controls, isolated Latino immigrant-economic deprivation is the strongest positive demographic predictor of tract presence in air-toxic LCR clusters, followed by black-economic deprivation and isolated Asian/Pacific Islander immigrant-economic deprivation. Findings suggest scholarly and practical implications for future research, advocacy, and policy.

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EJ Strategic Guidance Documents	Promising Practices for EJ Methodologies in NEPA Reviews	Federal Interagency Working Group on Environmental Justice & NEPA Committee	2016	Government Document	https://www.epa.gov/sites/default/files/2016-08/documents/nepa_promising_practices_document_2016.pdf	The NEPA Committee seeks to improve the effective, efficient and consistent consideration of environmental justice issues in the NEPA process through the sharing of best practices, lessons learned, research, analysis, training, consultation, and other experiences of federal NEPA practitioners. This is a work product of the Federal Interagency Working Group on Environmental Justice (EJ IWG) produced by the NEPA Committee represents the professional experience, knowledge, and expertise of the individuals participating in the NEPA Committee.
EJ Strategic Guidance Documents	Environmental Justice: Examining the Environmental Protection Agency's Compliance and Enforcement of Title VI and Executive Order 12,898	The United States Commission on Civil Rights	2016	Government Document	https://www.usccr.gov/pubs/2016/Statutory_Enforcement_Report2016.pdf	This report assesses whether the EPA is complying with its EJ obligations. Through testimony from the EPA as well as experts in the field, there were many findings. Some findings include that racial minorities and low income communities are disproportionately affected by the location of waste disposal facilities and often lack the capability to properly bargain with polluters when seeking action. This report also finds that the EPA has a track record of being unable to meet its regulatory deadlines and there are extreme delays in the EPA's response to Title VI complaints having to do with EJ. Among the many recommendations in this report, the authors find that the EPA should include affected communities in settlement processes and it should bring on additional staff to meet current and future needs.
EJ Strategic Guidance Documents	EJ 2020 Action Agenda (EJ 2020): The U.S. Environmental Protection Agency's Environmental Justice Strategic Plan for 2016-2020	US EPA	2016	Government Document	https://www.epa.gov/sites/default/files/2016-05/documents/052216_ej_2020_strategic_plan_final_0.pdf	This is the EPA's strategic plan for advancing environmental justice from the years 2016-2020. There are three goals outlined in this report. Goal I is to deepen environmental justice practice within EPA programs to improve the health and environment of overburdened communities. Goal II is to work with partners to expand positive impact within overburdened communities. Goal III is to demonstrate progress on significant national environmental justice challenges.
EJ Strategic Guidance Documents	EJ 2020 Action Agenda (EJ 2020): NATIONAL MEASURES TECHNICAL APPENDIX Significant National Environmental Justice Challenges: Measures Technical Information	US EPA	2016	Government Document	https://www.epa.gov/sites/default/files/2016-05/documents/052216_ej2020_national_measures_technical_appendix_final.pdf	This appendix outlines various goals, metrics, and EJ relevance to each of the five national EJ measures. The five national EJ measures are blood lead level disparities, small water systems, tribal drinking water systems, fine particle air pollution, and hazardous waste sites.
EJ Strategic Guidance Documents	Technical Guidance for Assessing Environmental Justice in Regulatory Actions	US EPA	2016	Government Document	https://www.epa.gov/sites/default/files/2016-06/documents/ejtg_5_6_16_v5.1.pdf	This document is meant to outline technical approaches and methods to help EPA analysts assess potential EJ concerns for regulatory actions.
CalEnviroScreen used	A framework for siting and dispatch of emerging energy resources to realize environmental and health benefits: Case study on peaker power plant displacement	Krieger, EM; Casey, JA; Shonkoff, SBC.	2016	*Energy Policy*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-84973597863&doi=10.1016%2fj.enpol.2016.05.049&partnerID=40&md5=c816578b7cc36412d78b5b4419a04271	Emerging grid resources such as energy storage and demand response have the potential to provide numerous environmental and societal benefits, but are primarily sited and operated to provide grid-specific services without optimizing these co-benefits. We present a four-metric framework to identify priority regions to deploy and dispatch these technologies to displace marginal grid air emissions with high environmental and health impacts. To the standard metrics of total mass and rate of air pollutant emissions we add location and time, to prioritize emission displacement near densely populated areas with poor air quality, especially at times when air pollutant concentrations exceed regulatory standards. We illustrate our framework with a case study using storage, demand response, and other technologies to displace peaker power plants, the highest-rate marginal emitters on the California grid. We combine spatial-temporal data on plant electricity generation, air quality standard exceedance days, and population characteristics available from environmental justice screening tool CalEnviroScreen 2.0 to determine where emissions reductions may have the greatest marginal benefit. This screening approach can inform grid siting decisions, such as storage in lieu of peaker plants in high impact regions, or dispatch protocol, such as triggering demand response instead of peaker plants on poor air quality days. © 2016 Elsevier Ltd.
EJ Health Disparities	Cumulative Environmental Impacts: Science and Policy to Protect Communities	Solomon, GM; Morello-Frosch, R; Zeise, L; Faust, JB.	2016	*Annual Review of Public Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-84982845561&doi=10.1146%2fannurev-publhealth-032315-021807&partnerID=40&md5=ac5395794d192aea4fc79a86e3d05962	Many communities are located near multiple sources of pollution, including current and former industrial sites, major roadways, and agricultural operations. Populations in such locations are predominantly low-income, with a large percentage of minorities and non-English speakers. These communities face challenges that can affect the health of their residents, including limited access to health care, a shortage of grocery stores, poor housing quality, and a lack of parks and open spaces. Environmental exposures may interact with social stressors, thereby worsening health outcomes. Age, genetic characteristics, and preexisting health conditions increase the risk of adverse health effects from exposure to pollutants. There are existing approaches for characterizing cumulative exposures, cumulative risks, and cumulative health impacts. Although such approaches have merit, they also have significant constraints. New developments in exposure monitoring, mapping, toxicology, and epidemiology, especially when informed by community participation, have the potential to advance the science on cumulative impacts and to improve decision making. Copyright © 2016 by Annual Reviews. All rights reserved.
EJ Analytical Framework	Review of EJ Literature and Screening Tools & Recommendations for Alternative EJ Definitions (Revised Draft Report)	Industrial Economics, Incorporated	2016	White Paper	http://www.aqmd.gov/docs/default-source/Agendas/STMPR-Advisory-Group/april-2016/scaqmd-ej-literature_screening-tools-and-definitions-report_4_8_2016.pdf	IEc has conducted an analysis that reviews the existing literature for working definitions of EJ communities, evaluates screening tools that have been developed to help identify EJ communities, and assesses how these definitions impact the policy maker's ability to compare and contrast regulations. Based on these reviews, we recommend alternative sets of criteria SCAQMD could apply to define EJ communities as a sensitivity analysis of SCAQMD's current EJ definition to evaluate socioeconomic impacts of air quality management policies. In the remainder of this report, we first describe our approach to this analysis, then summarize our results and present our recommendations.

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Cumulative Risk Assessment	A framework for cumulative risk assessme	Moretto, A; Bachman, A; Boobis, A; Solomon, KR; Pastoor, TP; Wilks, MF; Embry, MR.	2016	*Crit. Rev. Toxicol.* 47(2):85-97	https://www.tandfonline.com/doi/full/10.1080/10408444.2016.1211618	The ILSI Health and Environmental Sciences Institute (HESI) has developed a framework to support a transition in the way in which information for chemical risk assessment is obtained and used (RISK21). The approach is based on detailed problem formulation, where exposure drives the data acquisition process in order to enable informed decision-making on human health safety as soon as sufficient evidence is available. Information is evaluated in a transparent and consistent way with the aim of optimizing available resources. In the context of risk assessment, cumulative risk assessment (CRA) poses additional problems and questions that can be addressed using the RISK21 approach. The focus in CRA to date has generally been on chemicals that have common mechanisms of action. Recently, concern has also been expressed about chemicals acting on multiple pathways that lead to a common health outcome, and non-chemical other conditions (non-chemical stressors) that can lead to or modify a common outcome. Acknowledging that CRAs, as described above, are more conceptually, methodologically and computationally complex than traditional single-stressor risk assessments, RISK21 further developed the framework for implementation of workable processes and procedures for conducting assessments of combined effects from exposure to multiple chemicals and non-chemical stressors. As part of the problem formulation process, this evidence-based framework allows the identification of the circumstances in which it is appropriate to conduct a CRA for a group of compounds. A tiered approach is then proposed, where additional chemical stressors and/or non-chemical modulating factors (ModFs) are considered sequentially. Criteria are provided to facilitate the decision on whether or not to include ModFs in the formal quantitative assessment, with the intention to help focus the use of available resources to have the greatest potential to protect public health.
EJ	A novel mobile monitoring approach to characterize spatial and temporal variation in traffic-related air pollutants in an urban community	Yu, CH; Fan, Z; Lioy, PJ; Baptista, A; Greenberg, M; Laumbach, RJ.	2016	*Atmospheric Environment* 141:161-173	https://www.sciencedirect.com/science/article/pii/S1352231016304770?casa_token=-_DotuFBBUgAAAAA:PT2eTlcKoPtVIYCoSIgkrLVRwr6ea_JVe3zsAYX9M3gFe1kveaf54GkmsaAVnd48nwrbr0C66dk	Air concentrations of traffic-related air pollutants (TRAPs) vary in space and time within urban communities, presenting challenges for estimating human exposure and potential health effects. Conventional stationary monitoring stations/networks cannot effectively capture spatial characteristics. Alternatively, mobile monitoring approaches became popular to measure TRAPs along roadways or roadsides. However, these linear mobile monitoring approaches cannot thoroughly distinguish spatial variability from temporal variations in monitored TRAP concentrations. In this study, we used a novel mobile monitoring approach to simultaneously characterize spatial/temporal variations in roadside concentrations of TRAPs in urban settings. We evaluated the effectiveness of this mobile monitoring approach by performing concurrent measurements along two parallel paths perpendicular to a major roadway and/or along heavily trafficked roads at very narrow scale (one block away each other) within short time period (<30 min) in an urban community. Based on traffic and particulate matter (PM) source information, we selected 4 neighborhoods to study. The sampling activities utilized real-time monitors, including battery-operated PM2.5 monitor (SidePak), condensation particle counter (CPC 3007), black carbon (BC) monitor (Micro-Aethalometer), carbon monoxide (CO) monitor (Langan T15), and portable temperature/humidity data logger (HOBO U12), and a GPS-based tracker (Trackstick). Sampling was conducted for ~3 h in the morning (7:30-10:30) in 7 separate days in March/April and 6 days in May/ June 2012. Two simultaneous samplings were made at 5 spatially-distributed locations on parallel roads, usually distant one block each other, in each neighborhood. The 5-min averaged BC concentrations (AVG ± SD, [range]) were 2.53 ± 2.47 [0.09-16.3] mg/m3, particle number concentrations (PNC) were 33,330 ± 23,451 [2512-159,130] particles/cm3, PM2.5 mass concentrations were 8.87 ± 7.65 [0.27-46.5] mg/m3 , and CO concentrations were 1.22 ± 0.60 [0.22-6.29] ppm in the community. The traffic-related air pollutants, BC and PNC, but not PM2.5 or CO, varied spatially depending on proximity to local stationary/mobile sources. Seasonal differences were observed for all four TRAPs, significantly higher in colder months than in warmer months. The coefficients of variation (CVs) in concurrent measurements from two parallel routes were calculated around 0.21 ± 0.17, and variations were attributed by meteorological variation (25%), temporal variability (19%), concentration level (6%), and spatial variability (2%), respectively. Overall study findings suggest this mobile monitoring approach could effectively capture and distinguish spatial/temporal characteristics in TRAP concentrations for communities impacted by heavy motor vehicle traffic and mixed urban air pollution sources.
Risk Assessment Methodology	Ambient Fine Particulate Matter, Nitrogen Dioxide, and Preterm Birth in New York City	Johnson, S; Bobb, JF; Ito, K; Savitz, DA; Elston, B; Shmool, JL; Dominici, F; Ross, Z; Clougherty, JE; Matte, T.	2016	*Environ. Health Perspect.* 124:1283-1290	https://pubmed.ncbi.nlm.nih.gov/26862865/	Background: Recent studies have suggested associations between air pollution and various birth outcomes, but the evidence for preterm birth is mixed. Objective: We aimed to assess the relationship between air pollution and preterm birth using 2008-2010 New York City (NYC) birth certificates linked to hospital records. Methods: We analyzed 258,294 singleton births with 22-42 completed weeks gestation to nonsmoking mothers. Exposures to ambient fine particles (PM2.5) and nitrogen dioxide (NO2) during the first, second, and cumulative third trimesters within 300 m of maternal address were estimated using data from the NYC Community Air Survey and regulatory monitors. We estimated the odds ratio (OR) of spontaneous preterm (gestation < 37 weeks) births for the first- and second-trimester exposures in a logistic mixed model, and the third-trimester cumulative exposures in a discrete time survival model, adjusting for maternal characteristics and delivery hospital. Spatial and temporal components of estimated exposures were also separately analyzed. Results: PM2.5 was not significantly associated with spontaneous preterm birth. NO2 in the second trimester was negatively associated with spontaneous preterm birth in the adjusted model (OR = 0.90; 95% CI: 0.83, 0.97 per 20 ppb). Neither pollutant was significantly associated with spontaneous preterm birth based on adjusted models of temporal exposures, whereas the spatial exposures showed significantly reduced odds ratios (OR = 0.80; 95% CI: 0.67, 0.96 per 10 µg/m3 PM2.5 and 0.88; 95% CI: 0.79, 0.98 per 20 ppb NO2). Without adjustment for hospital, these negative associations were stronger. Conclusion: Neither PM2.5 nor NO2 was positively associated with spontaneous preterm delivery in NYC. Delivery hospital was an important spatial confounder.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
Risk Assessment Methodology	Framework for using deciduous tree leaves as biomonitors for intraurban particulate air pollution in exposure assessment	Gillooly, SE; Shmool, JL; Michanowicz, DR; Bain, DJ; Cambal, LK; Shields, KN; Clougherty, JE.	2016	*Environ. Monit. Assess.* Aug; 188(8):479	https://pubmed.ncbi.nlm.nih.gov/27450373/	Fine particulate matter (PM2.5) air pollution, varying in concentration and composition, has been shown to cause or exacerbate adverse effects on both human and ecological health. The concept of biomonitoring using deciduous tree leaves as a proxy for intraurban PM air pollution in different areas has previously been explored using a variety of study designs (e.g., systematic coverage of an area, source-specific focus), deciduous tree species, sampling strategies (e.g., single day, multi-season), and analytical methods (e.g., chemical, magnetic) across multiple geographies and climates. Biomonitoring is a low-cost sampling method and may potentially fill an important gap in current air monitoring methods by providing low-cost, longer-term urban air pollution measures. As such, better understanding of the range of methods, and their corresponding strengths and limitations, is critical for employing the use of tree leaves as biomonitors for pollution to improve spatially resolved exposure assessments for epidemiological studies and urban planning strategies.
Risk Assessment Methodology	Spatio-temporal ozone variation in a case-crossover analysis of childhood asthma hospital visits in New York City	Shmool, JL; Kinnee, E; Sheffield, PE; Clougherty, JE.	2016	*Environ. Res.* May; 147:108-14	https://pubmed.ncbi.nlm.nih.gov/26855129/	Background: Childhood asthma morbidity has been associated with short-term air pollution exposure. To date, most investigations have used time-series models, and it is not well understood how exposure misclassification arising from unmeasured spatial variation may impact epidemiological effect estimates. Here, we develop case-crossover models integrating temporal and spatial individual-level exposure information, toward reducing exposure misclassification in estimating associations between air pollution and child asthma exacerbations in New York City (NYC). Methods: Air pollution data included: (a) highly spatially-resolved intra-urban concentration surfaces for ozone and co-pollutants (nitrogen dioxide and fine particulate matter) from the New York City Community Air Survey (NYCCAS), and (b) daily regulatory monitoring data. Case data included citywide hospital records for years 2005-2011 warm-season (June-August) asthma hospitalizations (n=2353) and Emergency Department (ED) visits (n=11,719) among children aged 5-17 years. Case residential locations were geocoded using a multi-step process to maximize positional accuracy and precision in near-residence exposure estimates. We used conditional logistic regression to model associations between ozone and child asthma exacerbations for lag days 0-6, adjusting for co-pollutant and temperature exposures. To evaluate the effect of increased exposure specificity through spatial air pollution information, we sequentially incorporated spatial variation into daily exposure estimates for ozone, temperature, and co-pollutants. Results: Percent excess risk per 10 ppb ozone exposure in spatio-temporal models were significant on lag days 1 through 5, ranging from 6.5 (95% CI: 0.2-13.1) to 13.0 (6.0-20.6) for inpatient hospitalizations, and from 2.9 (95% CI: 0.1-5.7) to 9.4 (6.3-12.7) for ED visits, with strongest associations consistently observed on lag day 2. Spatio-temporal excess risk estimates were consistently but not statistically significantly higher than temporal-only estimates on lag days 0-3. Conclusion: Incorporating case-level spatial exposure variation produced small, non-significant increases in excess risk estimates. Our modeling approach enables a refined understanding of potential measurement error in temporal-only versus spatio-temporal air pollution exposure assessments. As ozone generally varies over much larger spatial scales than that observed within NYC, further work is necessary to evaluate potential reductions in exposure misclassification for populations spanning wider geographic areas, and for other pollutants.
Risk Assessment Methodology	Cumulative Environmental Impacts: Science and Policy to Protect Communities	Solomon, GM; Morello-Frosch, R; Zeise, L; Faust, JB.	2016	*Annu. Rev. Public Health* 37:83-96	https://pubmed.ncbi.nlm.nih.gov/26735429/	Many communities are located near multiple sources of pollution, including current and former industrial sites, major roadways, and agricultural operations. Populations in such locations are predominantly low-income, with a large percentage of minorities and non-English speakers. These communities face challenges that can affect the health of their residents, including limited access to health care, a shortage of grocery stores, poor housing quality, and a lack of parks and open spaces. Environmental exposures may interact with social stressors, thereby worsening health outcomes. Age, genetic characteristics, and preexisting health conditions increase the risk of adverse health effects from exposure to pollutants. There are existing approaches for characterizing cumulative exposures, cumulative risks, and cumulative health impacts. Although such approaches have merit, they also have significant constraints. New developments in exposure monitoring, mapping, toxicology, and epidemiology, especially when informed by community participation, have the potential to advance the science on cumulative impacts and to improve decision making.

Appendix B: Literature Review for Environmental Justice Publications

Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
CalEnviroScreen used	A multivariate analysis of CalEnviroScreen: Comparing environmental and socioeconomic stressors versus chronic disease	Greenfield, BK; Rajan, J; McKone, TE.	2017	*Environmental Health: A Global Access Science Source*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85037841316&doi=10.1186%2fs12940-017-0344-z&partnerID=40&md5=00a8edc5767a831521d6ac32c39c1e09	Background: The health-risk assessment paradigm is shifting from single stressor evaluation towards cumulative assessments of multiple stressors. Recent efforts to develop broad-scale public health hazard datasets provide an opportunity to develop and evaluate multiple exposure hazards in combination. Methods: We performed a multivariate study of the spatial relationship between 12 indicators of environmental hazard, 5 indicators of socioeconomic hardship, and 3 health outcomes. Indicators were obtained from CalEnviroScreen (version 3.0), a publicly available environmental justice screening tool developed by the State of California Environmental Protection Agency. The indicators were compared to the total rate of hospitalization for 14 ICD-9 disease categories (a measure of disease burden) at the zip code tabulation area population level. We performed principal component analysis to visualize and reduce the CalEnviroScreen data and spatial autoregression to evaluate associations with disease burden. Results: CalEnviroScreen was strongly associated with the first principal component (PC) from a principal component analysis (PCA) of all 20 variables (Spearman ρ = 0.95). In a PCA of the 12 environmental variables, two PC axes explained 43% of variance, with the first axis indicating industrial activity and air pollution, and the second associated with ground-level ozone, drinking water contamination and PM2.5. Mass of pesticides used in agriculture was poorly or negatively correlated with all other environmental indicators, and with the CalEnviroScreen calculation method, suggesting a limited ability of the method to capture agricultural exposures. In a PCA of the 5 socioeconomic variables, the first PC explained 66% of variance, representing overall socioeconomic hardship. In simultaneous autoregressive models, the first environmental and socioeconomic PCs were both significantly associated with the disease burden measure, but more model variation was explained by the socioeconomic PCs. Conclusions: This study supports the use of CalEnviroScreen for its intended purpose of screening California regions for areas with high environmental exposure and population vulnerability. Study results further suggest a hypothesis that, compared to environmental pollutant exposure, socioeconomic status has greater impact on overall burden of disease. © 2017 The Author(s).
CalEnviroScreen used	Impact of community disadvantage and air pollution burden on geographic disparities of ovarian cancer survival in California	Vieira, VM; Villanueva, C; Chang, J; Ziogas, A; Bristow, RE.	2017	*Environmental Research*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85017095990&doi=10.1016%2fj.envres.2017.03.057&partnerID=40&md5=17b5925027320ae5e0bcffaa5b79ec91	Ovarian cancer survival varies geographically throughout California. The objective of this study is to determine the impact of living in disadvantaged communities on spatial patterns of survival disparities. Including a bivariate spatial smooth of geographic location within the Cox proportional hazard models is an effective approach for spatial analyses of cancer survival. Women diagnosed with advanced Stage IIIC/IV epithelial ovarian cancer (1996–2006) were identified from the California Cancer Registry. The impact of living in disadvantaged communities, as measured by the California Office of Environmental Health Hazard Assessment cumulative CalEnviroScreen 2.0 score, on geographic disparities in survival was assessed while controlling for age, tumor characteristics, quality of care, and race. Community-level air quality indicators and socioeconomic status (SES) were also independently examined in secondary analyses. The Cox proportional hazard spatial methods are available in the MapGAM package implemented in R. An increase in the community disadvantage from the 5th (less disadvantage) to the 95th percentile (more disadvantage) was significantly associated with poorer ovarian cancer survival (hazard ratio [HR], 1.16; 95% confidence interval [CI], 1.07–1.26). Ozone levels and SES were the most influential indicators on geographic disparities that warrant further investigation. The use of a bivariate smoother of location within the survival model allows for more advanced spatial analyses for exploring potential air quality-related predictors of geographic disparities. © 2017
CalEnviroScreen used	A comparison of Major Environmental Justice Screening and Mapping Tools	Kuruppuarachchi, LN; Kumar, A; Franchetti, M.	2017	*Environmental Management and Sustainable Development*	https://www.macrothink.org/journal/index.php/emsd/article/view/10914/8726	The concept of Environmental Justice (EJ) has evolved in United Sates for more than 30 years. Since then most empirical studies have shown that low-income and minority neighborhoods are disproportionately exposed to environmental hazards. Across the world, communities are struggling to protect their land, air, water, forests, and their livelihoods from damaging projects and activities with heavy environmental and social impacts. A Number of tools already exist to identify and map those areas with potential environmental justice concerns. This paper presents a comparison of the three major EJ tools; EJSCREEN (version 2016), **CalEnviroScreen** 2.0, EJ Atlas and their methodologies. There are some common parameters across these tools in presenting Environmental Justice and in identifying environmentally burdened communities, socially burdened communities, or both. Environmental burdens can include any environmental pollutant, hazard or disadvantage that compromises the health of a community. The tools are expected to help in understanding and studying the distribution of environmental benefits and burdens, decision making for disadvantaged communities in certain areas and in setting up environmental policies and planning.
Risk Assessment Methodology	An Overview of Literature Topics Related to Current Concepts, Methods, Tools, and Applications for Cumulative Risk Assessment (2007-2016)	Fox, MA; Brewer, LE; Martin, L.	2017	*Int. J. Environ. Res. Public Health* Apr 7;14(4):389	https://pubmed.ncbi.nlm.nih.gov/28387705/	Cumulative risk assessments (CRAs) address combined risks from exposures to multiple chemical and nonchemical stressors and may focus on vulnerable communities or populations. Significant contributions have been made to the development of concepts, methods, and applications for CRA over the past decade. Work in both human health and ecological cumulative risk has advanced in two different contexts. The first context is the effects of chemical mixtures that share common modes of action, or that cause common adverse outcomes. In this context two primary models are used for predicting mixture effects, dose addition or response addition. The second context is evaluating the combined effects of chemical and nonchemical (e.g., radiation, biological, nutritional, economic, psychological, habitat alteration, land-use change, global climate change, and natural disasters) stressors. CRA can be adapted to address risk in many contexts, and this adaptability is reflected in the range in disciplinary perspectives in the published literature. This article presents the results of a literature search and discusses a range of selected work with the intention to give a broad overview of relevant topics and provide a starting point for researchers interested in CRA applications.

Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
EJ Analytical Framework	Concepts for Studying Urban Environmental Justice	Corburn, J.	2017	*Curr. Environ. Health Rep.* Mar; 4(1):61-67	https://pubmed.ncbi.nlm.nih.gov/28101730/	Purpose of review: This paper offers research frameworks for understanding and acting to address urban environmental justice. Urban neighborhoods tend to concentrate and colocate vulnerable people and toxic environments. Cities are also where the poor and people of color tend to be disproportionately exposed to environmental hazards, such as air pollution, lead in paint and water, and polluting industries. Recent findings: Researchers and government agencies are increasingly recognizing the need to document cumulative exposures that the urban poor and people of color experience in addition to environmental hazards. These "toxic stressors" can exacerbate the health impacts of pollution exposures and include such social and economic factors as discrimination, racism, linguistic isolation, and political exclusion. Urban environmental justice research can benefit from a structural racism approach, which requires documenting the historical decisions, institutions, and policies that contribute to today's cumulative exposures. Key research frameworks and methods utilizing this approach for urban environmental justice include community-based participatory research, measuring cumulative stressors, and community-based asset and hazard mapping.
CalEnviroScreen - critique	Carbon trading, co-pollutants, and environmental equity: Evidence from California's cap-and-trade program (2011± 2015)	Cushing, L; Blaustein-Rejto, D; Wander, M; Pastor,M; Sadd, J; Zhu, A; Morello-Frosch, R.	2018	*PLoS Med*	https://doi.org/10.1371/journal.pmed.1002604	Author summary Why was this study done? Climate change policies to reduce greenhouse gas (GHG) emissions can also reduce emissions of hazardous co-pollutants, such as air toxics and particulate matter. Decreases in GHG emissions are therefore also likely to provide health benefits by improving local air quality to communities near regulated facilities. Globally, socioeconomically disadvantaged communities are often disproportionately exposed to hazardous air pollutants due to emissions from facilities nearby. We examined temporal patterns in GHG and co-pollutant emissions with respect to neighborhood demographics under California's cap-and-trade program—the world's fourth largest carbon trading market. What did the researchers do and find? We assessed GHG and co-pollutant (particulate matter, nitrogen oxides, sulfur oxides, volatile organic compounds, and air toxics) emission patterns and the social equity implications of California's cap-and-trade program before (2011–2012) and after (2013–2015) the initiation of carbon trading. Facilities regulated under California's cap-and-trade program are disproportionately located in disadvantaged neighborhoods. Statistical analysis found that co-pollutant emissions from regulated facilities were temporally correlated with GHG emissions, and most regulated facilities (52%) reported higher annual average local (in-state) GHG emissions after the initiation of trading, even though total emissions remained well under the cap established by the program. Since California's cap-and-trade program began, neighborhoods that experienced increases in annual average GHG and co-pollutant emissions from regulated facilities nearby had higher proportions of people of color and poor, less educated, and linguistically isolated residents, compared to neighborhoods that experienced decreases in GHGs. What do these findings mean? To our knowledge, this is the first study to assess social disparities in GHG and co-pollutant emissions under an existing carbon trading program. Although GHG emission reductions could bring about significant air quality and health benefits for California's disadvantaged residents, thus far the state's cap-and-trade program has yet to yield such localized improvements in
CalEnviroScreen used	Investigation of association between environmental and socioeconomic factors and preterm birth in California	Huang, H; Woodruff, TJ; Baer, RJ; Bangia, K; August, LM; Jellife-Palowski, LL; Padula, AM; Sirota, M.	2018	*Environment International*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85059338918&doi=10.1016%2fj.envint.2018.07.027&partnerID=40&md5=3cc8ae146b2479c0e23fca713f4d99ba	Background: Preterm birth (PTB),2 defined as birth at gestational age <37 weeks, is a major public health concern. Infants born prematurely, comprising of about 10% of the US newborns, have elevated risks of neonatal mortality and a wide array of health problems. Although numerous clinical, genetic, environmental and socioeconomic factors have been implicated in PTB, very few studies investigate the impacts of multiple pollutants and social factors on PTB using large scale datasets. Objectives: To evaluate association between environmental and socioeconomic factors and PTB in California. Methods: We linked the birth cohort file maintained by the California Office of Statewide Health Planning and Development from 2009 to 2012 years across 1.8 million births and the CalEnviroScreen 3.0 dataset from California Communities Environmental Health Screening Tool at the census tract level for 56 California counties. CalEnviroScreen contains 7 exposure and 5 environmental effects variables that constitute the Pollution Burden variable, and 5 socioeconomic variables. We evaluated relationships between environmental exposures and the risk of PTB using hierarchical clustering analyses and GIS-based visualization. We also used logistic regression to evaluate the relationship between specific pollutant and exposure indicators and PTB, accounted for socio-demographic determinants such as maternal race/ethnicity, maternal age, maternal education and payment of delivery costs. Results: There exists geographic variability in PTB for groups of counties with similar environmental and social exposure profiles. We found an association between Pollution Burden, particulate matter ≤2.5 μm (PM2.5), and Drinking Water Scores and PTB (adjusted odds ratios were 1.03 (95% Confidence Interval (CI): 1.01, 1.04), 1.03 (95% CI: 1.02,1.04), and 1.04 (95% CI: 1.03,1.05), respectively). Additional findings suggest that certain drinking water contaminants such as arsenic and nitrate are associated with PTB in California. Conclusions: CalEnviroScreen data combined with birth records offer great opportunity for revealing novel exposures and evaluating cumulative exposures related to PTB by providing useful environmental and social information. Certain drinking water contaminants such as arsenic and nitrate are potentially associated with PTB in California and should be investigated further. Small association signals may involve sizeable population impacts. © 2018

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
CalEnviroScreen used	Retooling CalEnviroScreen: Cumulative pollution burden and race-based environmental health vulnerabilities in California	Liévanos, RS.	2018	*International Journal of Environmental Research and Public Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85045682505&doi=10.3390%2fijerph15040762&partnerID=40&md5=4f80ba5ce06637cddf52b3642fce9957	The California Community Environmental Health Screening Tool (CalEnviroScreen) advances research and policy pertaining to environmental health vulnerability. However, CalEnviroScreen departs from its historical foundations and comparable screening tools by no longer considering racial status as an indicator of environmental health vulnerability and predictor of cumulative pollution burden. This study used conceptual frameworks and analytical techniques from environmental health and inequality literature to address the limitations of CalEnviroScreen, especially its inattention to race-based environmental health vulnerabilities. It developed an adjusted measure of cumulative pollution burden from the CalEnviroScreen 2.0 data that facilitates multivariate analyses of the effect of neighborhood racial composition on cumulative pollution burden, net of other indicators of population vulnerability, traffic density, industrial zoning, and local and regional clustering of pollution burden. Principal component analyses produced three new measures of population vulnerability, including Latina/o cumulative disadvantage that represents the spatial concentration of Latinas/os, economic disadvantage, limited English-speaking ability, and health vulnerability. Spatial error regression analyses demonstrated that concentrations of Latinas/os, followed by Latina/o cumulative disadvantage, are the strongest demographic determinants of adjusted cumulative pollution burden. Findings have implications for research and policy pertaining to cumulative impacts and race-based environmental health vulnerabilities within and beyond California. © 2018 by the author. Licensee MDPI, Basel, Switzerland.
CalEnviroScreen used	Community-based cumulative impact assessment: California's approach to integrating nonchemical stressors into environmental assessment practices	Murphy, SR; Prasad, SB; Faust, JB; Alexeeff, GV.	2018	*Chemical Mixtures and Combined Chemical and Nonchemical Stressors: Exposure, Toxicity, Analysis, and Risk*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85046052721&doi=10.1007%2f978-3-319-56234-6_18&partnerID=40&md5=c4f73e45e536f602720ed49784fa6d17	Risk assessment is complex and challenges assessors to expand its utility and bridge data gaps to better account for human health risk. Mixtures complicate the assessment landscape because cumulative chemical exposures occur at the nexus of nonchemical stressors that can influence adverse health outcomes. Traditional risk assessment approaches typically use comprehensive data sources and quantitative methods but have a limited capacity to account for or include nonchemical stressors. In contrast, community-based cumulative impact assessments utilize different types of data and apply both quantitative and semiquantitative methods. Recently, multiple approaches for cumulative impact assessment have been developed. One such example is the California Communities Environmental Health Screening Tool: CalEnviroScreen. CalEnviroScreen has been successful in evaluating the cumulative pollution burden at a census tract scale across the state, based on 12 pollution indicators. It also characterizes population vulnerabilities at the same scale, based on intrinsic and extrinsic factors (three health and four socioeconomic status indicators). The two indices are combined in a way that allows one to screen and identify communities across California at above or below various thresholds in the scale. CalEnviroScreen allows one to understand the similarities and differences between the most disadvantaged communities having similar scores. CalEnviroScreen has been instrumental in (a) identifying the disadvantaged communities across California that receive prioritized funding from Greenhouse Gas Reduction Funds derived from the cap-and-trade program, (b) prioritizing areas for targeted multimedia enforcement action, and (c) assisting California Environmental Protection Agency boards and departments with planning community engagement and outreach efforts. © Springer International Publishing AG 2018. All rights reserved.
EJ Analytical Framework	Evaluating Environmental Impact of Traffic Congestion in Real Time Based on Sparse Mobile Crowd-sourced Data	Hao, P; Wang, C.	2018	*Research Papers in Economics*	https://escholarship.org/uc/item/7q6760rz	Traffic congestion at arterial intersections and freeway bottlenecks degrades the air quality and threatens the public health. Conventionally, air pollutants are monitored by sparsely distributed Quality Assurance Air Monitoring Sites. Sparse mobile crowd-sourced data, such as cellular network and Global Positioning System (GPS) data, contain large amount of traffic information, but have low sampling rate and penetration rate due to the cost limit on data transmission and archiving. The sparse mobile data provide a supplement or alternative approach to evaluate the environmental impact of traffic congestion. This research establishes a framework for traffic-related air pollution evaluation using sparse mobile data and traffic volume data from California Performance Measurement System (PeMS) and Los Angeles Department of Transportation (LADOT). The proposed framework integrates traffic state model, emission model and dispersion model. An effective tool is developed to evaluate the environmental impact of traffic congestion for both arterials and freeways in an accurate, timely and economic way. The proposed methods have good performance in estimating monthly peak hour fine particulate matter (PM 2.5) concentration, with error of 2 ug/m3 from the measurement from monitor sites. The estimated spatial distribution of annual PM 2.5 concentration also matches well with the concentration map from California Communities Environmental Health Screening Tool (**CalEnviroScreen**), but with higher resolution. The proposed system will help transportation operators and public health officials alleviate the risk of air pollution, and can serve as a platform for the development of other potential applications. View the NCST Project Webpage
Cumulative Risk Assessment	Methods for Evaluating the Combined Effects of Chemical and Nonchemical Exposures for Cumulative Environmental Health Risk Assessment	Payne-Sturges, DC; Scammell, MK; Levy, JI; Cory-Slechta, DA; Symanski, E; Carr Shmool, JL; Laumbach, R; Linder, S; Clougherty, JE.	2018	*Int. J. Environ. Res. Public Health* 15:2797	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6313653/pdf/ijerph-15-02797.pdf	Cumulative risk assessment (CRA) has been proposed as a means of evaluating possible additive and synergistic effects of multiple chemical, physical and social stressors on human health, with the goal of informing policy and decision-making, and protecting public health. Routine application of CRA to environmental regulatory and policy decision making, however, has been limited due to a perceived lack of appropriate quantitative approaches for assessing combined effects of chemical and nonchemical exposures. Seven research projects, which represented a variety of disciplines, including population health science, laboratory science, social sciences, geography, statistics and mathematics, were funded by the US Environmental Protection Agency (EPA) to help address this knowledge gap. We synthesize key insights from these unique studies to determine the implications for CRA practice and priorities for further research. Our analyses of these seven projects demonstrate that the necessary analytical methods to support CRA are available but are ultimately context-dependent. These projects collectively provided advancements for CRA in the areas of community engagement, characterization of exposures to nonchemical stressors, and assessment of health effects associated with joint exposures to chemical and psychosocial stressors.
Modeling of EJ-related variable	It's not easy assessing greenness: A comparison of NDVI datasets and neighborhood types and their associations with self-rated health in New York City	Reid, CE; Kubzansky, LD; Li, J; Shmool, JL; Clougherty, JE.	2018	*Health Place* Nov; 54:92-101	https://pubmed.ncbi.nlm.nih.gov/30248597/	Growing evidence suggests that exposure to greenness benefits health, but studies assess greenness differently. We hypothesize greenness-health associations vary by exposure assessment method. To test this, we considered four vegetation datasets (three Normalized Difference Vegetation Index datasets with different spatial resolutions and a finely-resolved land cover dataset), and six aggregation units (five radial buffer sizes and self-described neighborhoods) of each dataset. We compared associations of self-rated health and these metrics of greenness among a sample of New York City residents. Associations with self-rated health varied more by aggregation unit than by vegetation dataset; larger buffers and self-described neighborhoods showed more positive associations. Researchers should consider spatial exposure misclassification in future greenness and health research.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
Risk Assessment Methodology	Building Healthy Community Environments: A Public Health Approach	Koehler, K; Latshaw, M; Matte, T; Kass, D; Frumkin, H; Fox, M; Hobbs, BF; Wills-Karp, M; Burke, TA.	2018	*Public Health Rep.* Nov/Dec; 133(1_suppl):35S-43S	https://pubmed.ncbi.nlm.nih.gov/30426875/	Environmental quality has a profound effect on health and the burden of disease. In the United States, the environment-related burden of disease is increasingly dominated by chronic diseases. At the local level, public health practitioners realize that many policy decisions affecting environmental quality and health transcend the authorities of traditional health department programs. Healthy decisions about the built environment, including housing, transportation, and energy, require broad collaborative efforts. Environmental health professionals have an opportunity to address the shift in public health burden toward chronic diseases and play an important role in the design of healthy communities by bringing data and tools to decision makers. This article provides a guide for community leaders to consider the public health effects of decisions about the built environment. We present a conceptual framework that represents a shift from compartmentalized solutions toward an inclusive systems approach that encourages partnership across disciplines and sectors. We discuss practical tools to assist with environmental decision making, such as Health Impact Assessments, environmental public health tracking, and cumulative risk assessment. We also identify priorities in research, practice, and education to advance the role of public health in decision making to improve health, such as the Health Impact Assessment, as a core competency for environmental health practitioners. We encourage cross-disciplinary communication, research, and education that bring the fields of planning, transportation, and energy in closer collaboration with public health to jointly advance the systems approach to today's environmental challenges.
Risk Assessment Methodology	Assessing health risks from multiple environmental stressors: Moving from G×E to I×E	McHale, CM; Osborne, G; Morello-Frosch, R; Salmon, AG; Sandy, MS; Solomon, G; Zhang, L; Smith, MT; Zeise, L.	2018	*Mutat. Res. Rev. Mutat. Res.* Jan-Mar; 775:11-20	https://pubmed.ncbi.nlm.nih.gov/29555026/	Research on disease causation often attempts to isolate the effects of individual factors, including individual genes or environmental factors. This reductionist approach has generated many discoveries, but misses important interactive and cumulative effects that may help explain the broad range of variability in disease occurrence observed across studies and individuals. A disease rarely results from a single factor, and instead results from a broader combination of factors, characterized here as intrinsic (I) and extrinsic (E) factors. Intrinsic vulnerability or resilience emanates from a variety of both fixed and shifting biological factors including genetic traits, while extrinsic factors comprise all biologically-relevant external stressors encountered across the lifespan. The I×E concept incorporates the multi-factorial and dynamic nature of health and disease and provides a unified, conceptual basis for integrating results from multiple areas of research, including genomics, G×E, developmental origins of health and disease, and the exposome. We describe the utility of the I×E concept to better understand and characterize the cumulative impact of multiple extrinsic and intrinsic factors on individual and population health. New research methods increasingly facilitate the measurement of multifactorial and interactive effects in epidemiological and toxicological studies. Tiered or indicator-based approaches can guide the selection of potentially relevant I and E factors for study and quantification, and exposomics methods may eventually produce results that can be used to generate a response function over the life course. Quantitative data on I×E interactive effects should generate a better understanding of the variability in human response to environmental factors. The proposed I×E concept highlights the role for broader study design in order to identify extrinsic and intrinsic factors amenable to interventions at the individual and population levels in order to enhance resilience, reduce vulnerability and improve health.
EJ Health Disparities	Neighborhood language isolation and depressive symptoms among elderly U.S. Latinos	Ward, JB; Albrecht, SS; Robinson, WR; Pence, BW; Maselko, J; Haan, MN; Aiello, AE.	2018	*Ann. Epidemiol.* Nov; 28(11):774-782	https://pubmed.ncbi.nlm.nih.gov/30201290/	Purpose: Neighborhood segregation related to cultural factors, such as language use, may influence elderly Latino depression. We examined the association between neighborhood-level Spanish language segregation and individual depressive symptoms among elderly Latinos. Methods: We linked U.S. Census language use data with geocoded population-based data from 1789 elderly Latinos (mean age = 70.6 years) participating in the Sacramento Area Latino Study on Aging (1998-2008). Neighborhood language segregation was measured with the Index of Concentration at the Extremes, which demonstrates the extent to which residents are concentrated at extremes of deprivation and privilege. We fit two-level generalized linear-mixed models with random intercepts for census tracts to quantify the association between neighborhood-level language segregation and depressive symptoms, adjusting for identified confounders. Results: After adjusting for age, sex, and nativity, residents of highly segregated Spanish-speaking neighborhoods had more depressive symptoms than those in highly segregated English-only-speaking neighborhoods (β = -4.410; 95% confidence interval [CI] = -6.851 to -1.970). This association was largely attenuated upon adjustment for individual-level education (β = -2.119; 95% CI = -4.650 to 0.413). Conclusions: Linguistically segregated communities may benefit from targeted outreach given the high depression prevalence in these neighborhoods. Furthermore, our findings suggest that limited access to fundamental social protections, such as education, may drive the segregation-depression association among U.S. Latinos.
EJ Tools	EJSCREEN Technical Documentation	US EPA	2019	Guidance Document	https://www.epa.gov/sites/default/files/2021-04/documents/ejscreen_technical_document.pdf	This document describes EJSCREEN within the context of EPA's EJ program, and provides details on the data and methods used to create the indicators and indexes in EJSCREEN. The Appendices in this document provide additional detail on data and methods for interested users.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
US EPA EJSCREEN used	Application of the Public Health Exposome Framework to Estimate Phenotypes of Resilience in a Model Ohio African-American Women's Cohort	Cifuentes, P; Reichard, J; Im, W; Smith, S; Colen, C; Giurgescu, C; Williams, KP; Gillespie, S; Juarez, PD; Hood, DB.	2019	*Journal of Urban Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85061642842&doi=10.1007%2fs11524-018-00338-w&partnerID=40&md5=6c978149be5bac598a581f8ec6be0d01	We report integration of the United States Environmental Protection Agency's (USEPA) United States Environmental Justice Screen (EJSCREEN) database with our Public Health Exposome dataset to interrogate 9232 census blocks to model the complexity of relationships among environmental and socio-demographic variables toward estimating adverse pregnancy outcomes [low birth weight (LBW) and pre-term birth (PTB)] in all Ohio counties. Using a hill-climbing algorithm in R software, we derived a Bayesian network that mapped all controlled associations among all variables available by applying a mapping algorithm. The results revealed 17 environmental and socio-demographic variables that were represented by nodes containing 69 links accounting for a network with 32.85% density and average degree of 9.2 showing the most connected nodes in the center of the model. The model predicts that the socio-economic variables low income, minority, and under age five populations are correlated and associated with the environmental variables; particulate matter (PM 2.5) level in air, proximity to risk management facilities, and proximity to direct discharges in water are linked to PTB and LBW in 88 Ohio counties. The methodology used to derive significant associations of chemical and non-chemical stressors linked to PTB and LBW from indices of geo-coded environmental neighborhood deprivation serves as a proxy for design of an African-American women's cohort to be recruited in Ohio counties from federally qualified community health centers within the 9232 census blocks. The results have implications for the development of severity scores for endo-phenotypes of resilience based on associations and linkages for different chemical and non-chemical stressors that have been shown to moderate cardio-metabolic disease within a population health context. © 2019, The New York Academy of Medicine.
US EPA EJScreen used	Validating and refining EPA's traffic exposure screening measure	Rowangould, D; Rowangould, G; Craft, E; Niemeier, D.	2019	*International Journal of Environmental Research and Public Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85058920697&doi=10.3390%2fijerph16010003&partnerID=40&md5=16a069f9ab5ff6de22d4184b62edf570	Exposure to high air pollutant concentrations results in significant health risks. Many communities of color and low-income communities face disproportionately higher levels of air pollution exposure. Environmental justice (EJ) screening tools play a critical role in focusing early attention on areas with a high likelihood of disparate health impacts. In 2015, the United States Environmental Protection Agency (US EPA) released EJScreen, a screening tool with indicators of a range of pollution burdens across the US. However, little is known about the accuracy of the screening estimates of pollution exposure. This study compares EJScreen's traffic proximity air quality metric to dispersion modeling results. Using the area around the Houston Ship Channel, we conduct fine-grained air pollution dispersion modeling to evaluate how closely EJScreen's indicator approximates estimated roadway air pollution concentrations. We find low correlation between modeled concentrations and the EJScreen roadway air pollution indicator. We extend EJScreen's roadway air pollution screening method in three ways: (1) using a smaller unit of analysis, (2) accounting for the length of each road segment, and (3) accounting for wind direction. Using the Houston region, we use two of the methods and show that the proposed extensions provide a more accurate transportation air pollution screening assessment at the regional and local level. © 2018 by the authors. Licensee MDPI, Basel, Switzerland.
CalEnviroScreen used	Distributed solar and environmental justice: Exploring the demographic and socio-economic trends of residential PV adoption in California	Lukanov, BR; Krieger, EM.	2019	*Energy Policy*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85070898694&doi=10.1016%2fj.enpol.2019.110935&partnerID=40&md5=5b522053884d54fb3794e328b7ae85ba	The rapid growth of distributed solar adoption in California provides an opportunity to lower electricity bills for the adopters and realize additional community benefits, including grid resilience and lower grid emissions. It is unclear, however, whether this transition is occurring equitably across the state's various demographic and socioeconomic groups and whether historically disadvantaged environmental justice (EJ) communities have been able to exploit the bill savings and other associated benefits of rooftop solar. Here we analyze the cumulative and annualized (spatial and temporal) rates of PV adoption across California and compare those with data from the state's cumulative impact EJ methodology (CalEnviroScreen). We find persistently lower levels of PV adoption in disadvantaged communities, suggesting clear distributive and equity impacts of existing PV support policies, and indicating that the benefits bypass some of the state's most vulnerable populations. The analysis reveals strong correlation of solar adoption with not only socioeconomic variables, but also with health, environmental and demographic indicators, contributing to our growing understanding of the role these factors play in household clean-energy adoption trends. The results provide a baseline from which to develop more effective policies, strategically design incentives, and track the efficacy of existing solar programs that target disadvantaged communities. © 2019 Elsevier Ltd
CalEnviroScreen used	Fine Particle Air Pollution and Physiological Reactivity to Social Stress in Adolescence: The Moderating Role of Anxiety and Depression	Miller, JG; Gillette, JS; Manczak, EM; Kircanski, K; Gotlib, IH.	2019	*Psychosomatic Medicine*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85071634722&doi=10.1097%2fPSY.0000000000000714&partnerID=40&md5=fd5ec20a552edad8be5ce1b19fdd7cdc	Objective Exposure to high levels of fine particle air pollution (PM2.5) is associated with adolescent pathophysiology. It is unclear, however, if PM2.5 is associated with physiology within psychosocial contexts, such as social stress, and whether some adolescents are particularly vulnerable to PM2.5-related adverse effects. This study examined the association between PM2.5 and autonomic reactivity to social stress in adolescents and tested whether symptoms of anxiety and depression moderated this association. Methods Adolescents from Northern California (N = 144) participated in a modified Trier Social Stress Test while providing high-frequency heart rate variability and skin conductance level data. PM2.5 data were recorded from CalEnviroScreen. Adolescents reported on their own symptoms of anxiety and depression using the Youth Self-Report, which has been used in prior studies and has good psychometric properties (Cronbach's in this sample was.86). Results Adolescents residing in neighborhoods characterized by higher concentrations of PM2.5 demonstrated greater autonomic reactivity (i.e., indexed by lower heart rate variability and higher skin conductance level) (β =.27; b =.44, p =.001, 95% CI = 0.19 to 0.68) in response to social stress; this association was not accounted for by socioeconomic factors. In addition, adolescents who reported more severe anxiety and depression symptoms showed the strongest association between PM2.5 and autonomic reactivity to social stress (β =.53; b =.86, p <.001, 95% CI = 0.48 to 1.23). Conclusions Exposure to PM2.5 may heighten adolescent physiological reactivity to social stressors. Moreover, adolescents who experience anxiety and depression may be particularly vulnerable to the adverse effects of PM2.5 on stress reactivity. © Lippincott Williams & Wilkins.

Appendix B: Literature Review for Environmental Justice Publications

Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
CalEnviroScreen used	Cumulative impact of environmental pollution and population vulnerability on pediatric asthma hospitalizations: A multilevel analysis of CalEnviroScreen	Alcala, E; Brown, P; Capitman, JA; Gonzalez, M; Cisneros R.	2019	*International Journal of Environmental Research and Public Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85070416663&doi=10.3390%2fijerph16152683&partnerID=40&md5=e2294dd8156b5c935293bb860a134310	The CalEnviroScreen created by the Office of Environmental Health Hazard Assessment, Sacramento, USA, is a place-based dataset developed to measure environmental and social indicators that are theorized to have cumulative health impacts on populations. The objective of this study was to examine the extent to which the composite scores of the CalEnviroScreen tool are associated with pediatric asthma hospitalization. This was a retrospective analysis of California hospital discharge data from 2010 to 2012. Children who were hospitalized for asthma-related conditions, were aged 0–14 years, and resided in California were included in analysis. Rates of hospitalization for asthma-related conditions among children residing in California were calculated. Poisson multilevel modeling was used to account for individual-and neighborhood-level risk factors. Every unit increase in the CalEnviroScreen Score was associated with an increase of 1.6% above the mean rate of pediatric asthma hospitalizations (rate ratio (RR) = 1.016, 95% confidence interval (CI) = 1.014–1.018). Every unit increase in racial/ethnic segregation and diesel particulate matter was associated with an increase of 1.1% and 0.2% above the mean rate of pediatric asthma, respectively (RR = 1.011, 95% CI = 1.010–1.013; RR = 1.002, 95% CI = 1.001–1.004). The CalEnviroScreen is a unique tool that combines socioecological factors and environmental indicators to identify vulnerable communities with major health disparities, including pediatric asthma hospital use. Future research should identify mediating factors that contribute to community-level health disparities. © 2019 by the authors. Licensee MDPI, Basel, Switzerland.
CalEnviroScreen used	Environmental Inequities and Water Policy During a Drought: Burdened Communities, Minority Residents, and Cutback Assignments	Wikstrom, K; Miller, T; Campbell, HE; Tschudi, M.	2019	*Review of Policy Research*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85046414257&doi=10.1111%2fropr.12301&partnerID=40&md5=d13e8384c07087b04f68933df81995f5	In 2014 the California Environmental Protection Agency (CalEPA) released CalEnviroScreen 2.0, developed to identify communities facing "multiple burdens of pollution and socioeconomic disadvantage" (CalEnviroScreen FAQs, 2016). Contemporaneously, California was suffering a severe drought. CalEPA implemented emergency water cutbacks such that community allowances ranged from approximately 70%–430% of the U.S. average for water consumption. Decades of research find that racial and ethnic minorities face greater environmental burdens than others. Did the CalEPA cutbacks disproportionately affect already burdened communities or those with higher percentages of minorities? Using geographic information systems and spatial regression analysis, we find that the water cutbacks did not, ceteris paribus, further stress already burdened communities, but communities with a more significant percentage of Hispanics are estimated to receive lower water allowances even controlling for poverty. This research broadens the areas in which we can look for environmental (in)justice beyond standard dis/amenities, and implies that even intra-organizational policy goals of reducing environmental justice burdens may not be enough. © 2018 Policy Studies Organization
Evaluated EJ Tools	Utilization of the Maryland environmental justice screening tool: A Bladensburg, Maryland case study	Driver, A; Mehdizadeh, C; Bara-Garcia, S; Bodenreider, C; Lewis, J; Wilson, S.	2019	*International Journal of Environmental Research and Public Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85060657632&doi=10.3390%2fijerph16030348&partnerID=40&md5=56bbb2b0ebda6c9a24b347b41166098a	Maryland residents' knowledge of environmental hazards and their health effects is limited, partly due to the absence of tools to map and visualize distribution of risk factors across sociodemographic groups. This study discusses the development of the Maryland EJSCREEN (MD EJSCREEN) tool by the National Center for Smart Growth in partnership with faculty at the University of Maryland School of Public Health. The tool assesses environmental justice risks similarly to the U.S. Environmental Protection Agency's (USEPA) EJSCREEN tool and California's tool, CalEnviroScreen 3.0. We discuss the architecture and functionality of the tool, indicators of importance, and how it compares to USEPA's EJSCREEN and CalEnviroScreen. We demonstrate the use of MD EJSCREEN through a case study on Bladensburg, Maryland, a town in Prince George's County (PG) with several environmental justice concerns including air pollution from traffic and a concrete plant. Comparison reveals that environmental and demographic indicators in MD EJSCREEN most closely resemble those in EPA EJSCREEN, while the scoring is most similar to CalEnviroScreen. Case study results show that Bladensburg has a Prince George's environmental justice score of 0.99, and that National Air Toxics Assessment (NATA) air toxics cancer risk is concentrated in communities of color. © 2019 by the authors. Licensee MDPI, Basel, Switzerland.
EJ Health Disparities	Racialized structural vulnerability: Neighborhood racial composition, concentrated disadvantage, and fine particulate matter in California	Liévanos, RS.	2019	*International Journal of Environmental Research and Public Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85071769936&doi=10.3390%2fijerph16173196&partnerID=40&md5=140b3e98688e8809a1e2bb8f8864b1e5	This study contributes to previous research by advancing a "racialized structural vulnerability" framework and presenting a new empirical analysis of the relationship between neighborhood Asian, Black, and Latinx composition; extrinsic and intrinsic vulnerability; and PM2.5 exposures in California with secondary data from 2004–2014. Principal component analyses revealed that tract Latinx composition was highly correlated with extrinsic vulnerability (economic disadvantage and limited English-speaking ability), and that tract Black composition was highly correlated with intrinsic vulnerability (elevated prevalence of asthma-related emergency department visits and low birth weight). Spatial lag regression models tested hypotheses regarding the association between Asian, Black, and Latinx population vulnerability factors and the 2009–2011 annual average PM2.5 percentile rankings, net of emissions and spatial covariates. Results indicated that the percent Latinx population, followed by the regional clustering of PM2.5, and the percent of non-Latinx Black and non-Latinx Asian population were the strongest positive multivariable correlates of PM2.5 percentile rankings, net of other factors. Additional analyses suggested that despite shifting demographic and spatial correlates of 2012–2014 PM2.5 exposures, the tracts' Black and Latinx composition and location in the San Joaquin Valley remain important vulnerability factors with implications for future research and policy. © 2019 by the author. Licensee MDPI, Basel, Switzerland.
EJ Health Disparities	Revisiting environmental inequity in Southern California: Does environmental risk increase in ethnically homogeneous or mixed communities?	Kim, Y; Chun, Y.	2019	*Urban Studies*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85060217908&doi=10.1177%2f0042098018803227&partnerID=40&md5=e8a589d6cb083463ca30cf4e28251f1b	This study revisits the concept of environmental inequity in Southern California using the California Environmental Protection Agency's most recent data and spatial models. Empirical studies in the late 1990s documented the existence of environmental inequity among disadvantaged populations in the area, and we still found evidence of environmental inequity. However, our findings were more nuanced and subtler than previous results. The risk of being exposed to pollutants (e.g. ozone, PM2.5 and others) increases with a corresponding increase in Hispanic or Asian populations in a census tract. The risk of living near adverse environmental conditions (e.g. hazardous facilities, ground water threats and more) was less clear according to minority status. As the percentage of Hispanics in a census tract increases, the environmental risk increases only to a point, and then decreases. This finding suggests that, at present, some Hispanic communities enjoy better environmental conditions than do ethnically mixed communities, but the risk of being exposed to pollutants still increases with an increase in the percentage of Hispanics in a census tract. If policy needs to be developed and updated accordingly to reflect changing environments, this new evidence directs urban environmental inequity research to pay attention to ethnically mixed communities as well. © Urban Studies Journal Limited 2018.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
Risk Assessment Methodology	Hybrid land use regression modeling for estimating spatio-temporal exposures to PM 2.5, BC, and metal components across a metropolitan area of complex terrain and industrial sources	Tripathy, S; Tunno, BJ; Michanowicz, DR; Kinnee, E; Shmool, JLC; Gillooly, S; Clougherty, JE.	2019	*Sci. Total Environ.* Jul 10; 673:54-63	https://pubmed.ncbi.nlm.nih.gov/30986682/	Land use regression (LUR) modeling has become a common method for predicting pollutant concentrations and assigning exposure estimates in epidemiological studies. However, few LUR models have been developed for metal constituents of fine particulate matter (PM2.5) or have incorporated source-specific dispersion covariates in locations with major point sources. We developed hybrid AERMOD LUR models for PM2.5, black carbon (BC), and steel-related PM2.5 constituents lead, manganese, iron, and zinc, using fine-scale air pollution data from 37 sites across the Pittsburgh area. These models were designed with the aim of developing exposure estimates for time periods of interest in epidemiology studies. We found that the hybrid LUR models explained greater variability in PM2.5 (R2 = 0.79) compared to BC (R2 = 0.59) and metal constituents (R2 = 0.34-0.55). Approximately 70% of variation in PM2.5 was attributable to temporal variance, compared to 36% for BC, and 17-26% for metals. An AERMOD dispersion covariate developed using PM2.5 industrial emissions data for 207 sources was significant in PM2.5 and BC models; all metals models contained a steel mill-specific PM2.5 emissions AERMOD term. Other significant covariates included industrial land use, commercial and industrial land use, percent impervious surface, and summed railroad length.
Risk Assessment Methodology	The utility of a system dynamics approach for understanding cumulative health risk from exposure to environmental hazards	Prochaska, JD; Kim, H; Buschmann, RN; Jupiter, D; Croisant, S; Linder, SH; Sexton, K.	2019	*Environ Res.* May; 172:462-469	https://pubmed.ncbi.nlm.nih.gov/30844571/	The potential of system dynamics modeling to advance our understanding of cumulative risk in the service of optimal health is discussed. The focus is on exploring system dynamics modeling as a systems science methodology that can provide a framework for examining the complexity of real-world social and environmental exposures among populations-particularly those exposed to multiple disparate sources of risk. The discussion also examines how system dynamics modeling can engage a diverse body of key stakeholders throughout the modeling process, promoting the collective assessment of assumptions and systematic gathering of critical data. Though not a panacea, system dynamics modeling provides a promising methodology to complement traditional research methods in understanding cumulative health effects from exposure to multiple environmental and social stressors.
EJ Health Disparities	Chemical exposures, health and environmental justice in communities living on the fenceline of industry	Johnston, J; Cushin, L.	2020	*Curr. Environ. Health Rep.* Mar; 7(1):48-57	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7035204/	**Purpose of review** Polluting industries are more likely to be located in low income communities of color who also experience greater social stressors that may make them more vulnerable than others to the health impacts of toxic chemical exposures. We describe recent developments in assessing pollutant exposures and health threats posed by industrial facilities using or releasing synthetic chemicals to nearby communities in the U.S. **Recent findings** More people are living near oil and gas development due to the expansion of unconventional extraction techniques as well as near industrial animal operations, both with suggestive evidence of increased exposure to hazardous pollutants and adverse health effects. Legacy contamination continues to adversely impact a new generation of residents in fenceline communities, with recent studies documenting exposures to toxic metals and poly- and perfluoroakyl substances (PFASs). Researchers are also giving consideration to acute exposures resulting from inadvertent industrial chemical releases, including those resulting from extreme weather events linked to climate change. Natural experiments of industrial closures or clean ups provide compelling evidence that exposures from industry harm the health of nearby residents. **Summary** New and legacy industries, coupled with climate change, present unique health risks to communities living near industry due to the release of toxic chemicals. Cumulative impacts from multiple stressors faced by environmental justice communities may amplify these adverse effects.
Non-governmental reports	Environmental Justice Mapping Tools: Use and Potential in Policy Making to Address Climate Change	National Wildlfe Federation	2020	White Paper	https://www.nwf.org/-/media/Documents/PDFs/Environmental-Threats/Environmental-Justice-Mapping-Tools.ashx?la=en&hash=347578719433ACCFCF5C50F1FE56C98AFFD17981	Geospatial tools can be a powerful ally in the fight for environmental and climate justice. These tools allow users to visualize and explore patterns of environmental and climate hazards, revealing what kinds of communities are (and aren't) at risk from these hazards, and the compounded pollution and climate burdens certain communities face. When they are developed with robust community input, geospatial tools can be powerful advocacy and educational instruments; when incorporated into decision-making, they can also help drive and inform government actions—ensuring spending, policies, and programs benefit everyone more equitably. The purpose of this white paper is to provide policymakers at federal and state levels with guidance on how to improve government decision-making by using these tools. We introduce these tools as crucial resources for anyone interested in furthering environmental and climate justice, discuss how they work, and include best practices for the tools themselves. We conclude with a set of recommendations on how to better integrate these tools into policymaking, drawing insights from action at the state and federal level.
US EPA EJScreen used	COVID-19 prevalence and fatality rates in association with air pollution emission concentrations and emission sources	Hendryx, M; Luom J.	2020	*Environmental Pollution*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85087018662&doi=10.1016%2fj.envpol.2020.115126&partnerID=40&md5=84c6c59c377f5da989910f70ce00cccf	The novel coronavirus disease (COVID-19) is primarily respiratory in nature, and as such, there is interest in examining whether air pollution might contribute to disease susceptibility or outcome. We merged data on COVID-19 cumulative prevalence and fatality rates as of May 31, 2020 with 2014–2019 pollution data from the US Environmental Protection Agency Environmental Justice Screen (EJSCREEN), with control for state testing rates, population density, and population covariate data from the County Health Rankings. Pollution data included three types of air emission concentrations (particulate matter<2.5 µm (PM2.5), ozone and diesel particulate matter (DPM)), and four pollution source variables (proximity to traffic, National Priority List sites, Risk Management Plan (RMP) sites, and hazardous waste treatment, storage and disposal facilities (TSDFs)). Results of mixed model linear multiple regression analyses indicated that, controlling for covariates, COVID-19 prevalence and fatality rates were significantly associated with greater DPM. Proximity to TSDFs was associated to greater fatality rates, and proximity to RMPs was associated with greater prevalence rates. Results are consistent with previous research indicating that air pollution increases susceptibility to respiratory viral pathogens. Results should be interpreted cautiously given the ecological design, the time lag between exposure and outcome, and the uncertainties in measuring COVID-19 prevalence. Areas with worse prior air quality, especially higher concentrations of diesel exhaust, may be at greater COVID-19 risk, although further studies are needed to confirm these relationships.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
CalEnviroScreen used	Risk screening methods for extreme heat: Implications for equity-oriented adaptation	Turek-Hankins, LL; Hino, M; Mach, KJ.	2020	*PLoS ONE*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85095675861&doi=10.1371%2fjournal.pone.0240841&partnerID=40&md5=18852fcf0566b7bf3c6e1dfdfcf86727	Morbidity and mortality impacts of extreme heat amplified by climate change will be unequally distributed among communities given pre-existing differences in socioeconomic, health, and environmental conditions. Many governments are interested in adaptation policies that target those especially vulnerable to the risks, but there are important questions about how to effectively identify and support communities most in need of heat adaptations. Here, we use an equity-oriented adaptation program from the state of California as a case study to evaluate the implications of the currently used environmental justice index (CalEnviroScreen 3.0) for the identification of socially vulnerable communities with climate change adaptation needs. As CalEnviroScreen is geared towards air and water pollution, we assess how community heat risks and adaptation needs would be evaluated differently under two more adaptation-relevant vulnerability indices: the Social Vulnerability Index and the Heat-Health Action Index. Our analysis considers communities at the census tract scale, as well as the patterns emerging at the regional scale. Using the current index, the state designates 25% of its census tracts as "disadvantaged" communities eligible for special adaptation funds. However, an additional 12.6% of the state's communities could be considered vulnerable if the two other indices were considered instead. Only 13.4% of communities are vulnerable across all three vulnerability indices studied. Choice of vulnerability index shapes statewide trends in extreme heat risk and is linked to a community's likelihood of receiving heat-related California Climate Investments (CCI) projects. Tracts that are vulnerable under the current pollution-focused index, but not under the heat-health specific index, received four times the number of heat-related interventions as tracts vulnerable under the reverse scenario. This study demonstrates important nuances relevant to implementing equity-oriented adaptation and explores the challenges, trade-offs, and opportunities in quantifying vulnerability. © 2020 Turek-Hankins et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.
CalEnviroScreen used	Associations between historical residential redlining and current age-adjusted rates of emergency department visits due to asthma across eight cities in California: an ecological study	Nardone, A; Casey, JA; Morello-Frosch, R; Mujahid, M; Balmes, JR; Thakur, N.	2020	*The Lancet Planetary Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85078459262&doi=10.1016%2fS2542-5196%2819%2930241-4&partnerID=40&md5=6fb4ef31d70fd5ace28e0a60e74f2675	Background: Asthma disproportionately affects communities of colour in the USA, but the underlying factors for this remain poorly understood. In this study, we assess the role of historical redlining as outlined in security maps created by the Home Owners' Loan Corporation (HOLC), the discriminatory practice of categorising neighbourhoods on the basis of perceived mortgage investment risk, on the burden of asthma in these neighbourhoods. Methods: We did an ecological study of HOLC risk grades and asthma exacerbations in California using the security maps available for the following eight cities: Fresno, Los Angeles, Oakland, Sacramento, San Diego, San Jose, San Francisco, and Stockton. Each census tract was categorised into one of four risk levels (A, B, C, or D) on the basis of the location of population-weighted centroids on security maps, with the worst risk level (D) indicating historical redlining. We obtained census tract-level rates of emergency department visits due to asthma from CalEnviroScreen 3.0. We assessed the relationship between risk grade and log-transformed asthma visit rates between 2011 and 2013 using ordinary least squares regression. We included potential confounding variables from the 2010 Census and CalEnviroScreen 3.0: diesel exhaust particle emissions, PM2·5, and percent of the population living below 2 times the federal poverty level. We also built random intercept and slope models to assess city-level variation in the relationship between redlining and asthma. Findings: In the 1431 census tracts assessed (64 [4·5%] grade A, 241 [16·8%] grade B, 719 [50·2%] grade C, and 407 [28·4%] grade D), the proportion of the population that was non-Hispanic black and Hispanic, the percentage of the population living in poverty, and diesel exhaust particle emissions all significantly increased as security map risk grade worsened (p<0·0001). The median age-adjusted rates of emergency department visits due to asthma were 2·4 times higher in census tracts that were previously redlined (median 63·5 [IQR 34·3] visits per 10 000 residents per year [2011–13]) than in tracts at the lowest risk level (26·5 [18·4]). In adjusted models, redlined census tracts were associated with a relative risk of 1·39 (95% CI 1·21–1·57) in rates of emergency department visits due to asthma compared with that of lowest-risk census tracts. Interpretation: Historically redlined census tracts have significantly higher rates of emergency department visits due to asthma, suggesting that this discriminatory practice might be contributing to racial and ethnic asthma health disparities. Funding: National Heart Lung Blood Institute. © 2020 The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY 4.0 license
Cumulative Risk Assessment	Integration of psychosocial and chemical stressors in risk assessment	Clougherty, JE; Rider, CV.	2020	*Current Opinion in Toxicology* 22:25-29	https://www.sciencedirect.com/science/article/abs/pii/S2468202020300486	Numerous papers have highlighted the need for cumulative risk assessments that evaluate the impacts of multiple chemical and nonchemical stressors on human health. Nonchemical stressors represent a diverse suite of factors (e.g., social and economic adversity) that are only beginning to be explored in risk assessment. Approaches incorporating both chemical and nonchemical stressors are critical for better understanding relative contributions of real-world stressors and developing effective intervention strategies. However, moving from traditional single chemical evaluations to cumulative risk assessments presents multiple challenges.
Key Initiatives	White House Environmental Justice Advisory Council Justice40, Climate and Economic Justice Screening Tool & Executive Order 12898 Revisions (Interim Final Recommendations)	White House Environmental Justice Advisory Council	2021	Government Document	https://www.epa.gov/sites/default/files/2021-05/documents/whejac_interim_final_recommendations_0.pdf	This report, written by the White House Environmental Justice Advisory Council (WHEJAC) provides recommendations on Justice40, Climate and Economic Justice Screening Tool, and Executive Order 12898 Revisions as per a request from The Council on Environmental Quality. In this report, WHEJAC outlines their belief that the Justice40 initiative is vital for the effectiveness of the Biden Administration's Environmental Justice Initiative, and that it must start as soon as possible. WHEJAC also outlines the transformation that is required for the just distribution of resources to the EJ communities.
Key Initiatives	Executive Order 14008 of January 27, 2021: Tackling the Climate Crisis at Home and Abroad	THE WHITE HOUSE	2021	Government Document	https://www.energy.gov/sites/default/files/2021/02/f83/eo-14008-tackling-climate-crisis-home-abroad.pdf	This is an executive order from the Biden Administration on the need to tackle the climate crisis domestically and abroad. It is divided into two parts. Part I is titled, "Putting the Climate Crisis at the Center of United States Foreign Policy and National Security." Part II is titled, "Taking a Government-Wide Approach to the Climate Crisis."
Key Initiatives	Our Commitment to Environmental Justice (April 7, 2021)	Michal Regan, EPA Administrator	2021	Government Document	https://www.epa.gov/sites/default/files/2021-04/documents/regan-messageoncommitmenttoenvironmentaljustice-april072021.pdf	Directs US EPA leadership team to work with staff in EPA offices and the Office of Environmental Justice to identify ways to ensure that the country's environmental laws—and the policies implemented under them—deliver benefits to all individuals and communities.

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Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
Key Initiatives	Using All Appropriate Injunctive Relief Tools in Civil Enforcement Settlements (April 26, 2021)	Office of Enforcement and Compliance Assurance	2021	Government Document	https://www.epa.gov/sites/production/files/2021-04/documents/usingallappropriateinjunctivereliieftoolsincivilenforcementsettlement0426.pdf	This memorandum charges enforcement staff and case teams to appropriately use the full array of policy and legal tools available to ensure that our country's environmental laws – and the policies to implement them – deliver benefits to all individuals and communities. This memorandum supersedes and replaces both the 2018 (The Appropriate Use of Compliance Tools in Civil Enforcement Settlements, Apr. 3, 2018) and 2015 (Use of Next Generation Compliance Tools in Civil Enforcement Settlements, Jan. 27, 2015) documents
Key Initiatives	Strengthening Enforcement in Communities with Environmental Justice Concerns (April 30, 2021)	Office of Enforcement and Compliance Assurance	2021	Government Document	https://www.epa.gov/sites/default/files/2021-04/documents/strengtheningenforcementincommunitieswithejconcerns.pdf	This memorandum directed all EPA offices to "strengthen enforcement of violations of cornerstone environmental statutes" in communities that are overburdened by pollution, which is consistent with Executive Order 14008. Goals outlined in this memorandum include increasing the number of facility inspections in overburdened communities, preventing further pollution, and obtaining restitution for victims of environmental crimes.
Key Initiatives	Strengthening Environmental Justice Through Criminal Enforcement	Office of Enforcement and Compliance Assurance	2021	Government Document	https://www.epa.gov/system/files/documents/2021-07/strengtheningejthroughcriminal062121.pdf	This memorandum directed all EPA offices to "strengthen enforcement of violations of cornerstone environmental statutes" in communities that are overburdened by pollution. It then sets out steps to advance these EJ goals by criminal enforcement work performed by the Office of Enforcement and Compliance Assurance. This criminal enforcement program can further environmental justice by strengthening tools to detect environmental crimes in overburdened communities.
Key Initiatives	EPA American Rescue Plan Funding	Not Named	2021	Government Document	https://www.epa.gov/system/files/documents/2021-09/arp-fact-sheet.pdf	This fact sheet summarizes how 100 million dollars appropriated to the US EPA under the Federal Rescue Plan will be allocated to support EJ initiatives. The supported activities range across several policy activities, but with half of the funds focused on enhancing community air monitoring. Also included are funds for EJSCREEN,technical assistance for communities with "air and water issues, and expanding civil and criminal enforcement .
Key Initiatives	Interim Implementation Guidance for the Justice40 Initiative	EXECUTIVE OFFICE OF THE PRESIDENT; OFFICE OF MANAGEMENT AND BUDGET	2021	Government Document	https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf	This memorandum for heads of departments and agencies gives implementation guidance for the Justice40 Initiative. The actions outlined here include identifying the benefits of covered programs, determining how these programs allocate benefits, and then how to calculate and report on achieving the 40-percent goal outlined in the Justice40 initiative.
US EPA EJScreen used	Measuring historical urban neighborhood sustainability: America's grand avenues	Greenberg, MR.	2021	*Sustainability* (Switzerland)	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85100727240&doi=10.3390%2fsu13031358&partnerID=40&md5=c3a399eeb267b9be02ec90c10d7bee68	From 1850 through approximately 1920, wealthy entrepreneurs and elected officials created "grand avenues" lined by mansions in New York City, Chicago, Detroit, and other developing US cities. This paper examines the birthplaces of grand avenues to determine whether they have remained sustainable as magnets for healthy and wealthy people. Using data from the US EPA's EJSCREEN system and the CDC's 500 cities study across 11 cities, the research finds that almost every place where a grand avenue began has healthier and wealthier people than their host cities. Ward Parkway in Kansas City and New York's Fifth Avenue have continued to be grand. Massachusetts Avenue in Washington, D.C., Richmond's Monument Avenue, St. Charles Avenue in New Orleans, and Los Angeles's Wilshire Boulevard are national and regional symbols of political power, culture and entertainment, leading to sustainable urban grand avenues, albeit several are challenged by their identification with white supremacy. Among Midwest industrial cities, Chicago's Prairie Avenue birthplace has been the most successful, whereas the grand avenues of St. Louis, Cleveland, Detroit, and Buffalo have struggled, trying to use higher education, medical care, and entertainment to try to rebirth their once pre-eminent roles in their cities. © 2021 by the author.
US EPA EJScreen used	Association of Air Pollutant Exposure and Sinonasal Histopathology Findings in Chronic Rhinosinusitis	Patel, TR; Tajudeen, BA; Brown, H; Gattuso, P; LoSavio, P; Papagiannopoulos, P; Batra, PS; Mahdavinia, M.	2021	*American Journal of Rhinology and Allergy*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85100995871&doi=10.1177%2f1945892421993655&partnerID=40&md5=0891a6f3e63bf4d64b328290c3de342e	Background: Ambient air pollution is well known to cause inflammatory change in respiratory epithelium and is associated with exacerbations of inflammatory conditions such as asthma and chronic obstructive pulmonary disease. However, limited work has been done on the impact of air pollution on pathogenesis of chronic rhinosinusitis and there are no reports in the literature of how pollutant exposure may impact sinonasal histopathology in patients with chronic rhinosinusitis. Objective: This study aims to identify associations between certain histopathologic characteristics seen in sinus tissue of patients with chronic rhinosinusitis (CRS) and levels of particulate air pollution ($PM_{2.5}$) and ground-level ozone in their place of residence. Methods: A structured histopathology report was created to characterize the tissues of CRS patients undergoing sinus surgery. An estimate for each patient's exposure to air pollutants including small particulate matter ($PM_{2.5}$) and ground-level ozone was obtained using the Environmental Protection Agency's (EPA) Environmental Justice Screening and Mapping Tool (EJSCREEN). Mean pollutant exposures for patients whose tissues exhibited varying histopathologic features were compared using logistic regression models. Results: Data from 291 CRS patients were analyzed. Higher degree of inflammation was significantly associated with increased ozone exposure ($p = 0.031$). Amongst the patients with CRSwNP (n=131), presence of eosinophilic aggregates ($p = 0.018$) and Charcot-Leyden crystals ($p = 0.036$) was associated with increased ozone exposure. Conclusion: Exposure to ambient air pollutants may contribute to pathogenesis of CRS. Increasing ozone exposure was linked to both higher tissue inflammation and presence of eosinophilic aggregates and Charcot-Leyden crystals in CRSwNP patients. © The Author(s) 2021.
US EPA EJScreen used	Ports and Environmental Justice in the United States: An Exploratory Statistical Analysis	Greenberg, MR.	2021	*Risk Analysis*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85101026109&doi=10.1111%2frisa.13697&partnerID=40&md5=88ad946a1e3bcfb57af29e67d33f19fe	A screening environmental justice analysis was conducted of 50 United States ports that manage more than 10 million tons of products. Using the U.S. EPA's EJSCREEN tool, the author examined seven demographic and 11 environmental metrics at distances of 2, 5, and 10 miles from the port centroids. The 2-mile zones were found to have higher values for 13 of the 18 environmental inequity indicators, including all three measures of air toxics, fine particles, proximity to hazardous waste sites, and facilities with risk management plans, as well as indicators of low socioeconomic status and minority populations. With ports expanding, the author discusses the need for maintaining and upgrading EPA's screening tool and considers that alternative futures for port neighborhoods depend upon the strength of their civic groups and elected officials, the role of their government port authorities, and civic values of their commercial users. © 2021 Society for Risk Analysis

Appendix B: Literature Review for Environmental Justice Publications

Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
CalEnviroScreen used	Risk factors for acute urticaria in central California	Jadhav, R; Alcala, E; Sirota, S; Capitman, J.	2021	*International Journal of Environmental Research and Public Health*	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85103504910&doi=10.3390%2fijerph18073728&partnerID=40&md5=4f2bb7e9c313dfffd1c494c6f058a757	At least 15–20% of the population in the world suffers from urticaria. Allergy triggers contribute to the development of urticaria. Not much is known about the demographic and environmental risk factors that contribute to the occurrence of acute urticaria. Methods: We utilized emergency department data on acute urticaria-related visits managed by the California Office of Statewide Planning and Operations for 201 zip codes located in southern central California (San Joaquin Valley) collected during the years 2016 and 2017. Census data from the same zip codes were considered as a population at risk. Socioeconomic and environmental parameters using CalEnviroScreen (Office of Environmental Health Hazard Assessment, Sacramento, CA, USA) database for the zip codes were evaluated as risk factors. Results: The incidence rate of acute urticaria in San Joaquin Valley during 2016–2017 was 1.56/1000 persons (n = 14,417 cases). Multivariate Poisson analysis revealed that zip codes with high population density (RR = 2.81), high percentage of farm workers (RR = 1.49), and the composite of those with high and medium percentage of poverty and those with high and medium percentage of non-white residents (RR = 1.59) increased the likelihood of the occurrence of acute urticaria. Conclusion: High population density, farm work, poverty and minority status is associated with a high risk of having acute urticaria. © 2021 by the authors. Licensee MDPI, Basel, Switzerland.
CalEnviroScreen used	Impact of 4th of July fireworks on spatiotemporal PM 2.5 Concentrations in California Based on the PurpleAir Sensor Network: Implications for Policy and Environmental Justice	Mousavi, A; Yuan, Y; Masri, S; Barta, G; Wu, J.	2021	*International Journal of Environmental Research and Public Health*	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8198140/	Fireworks are often used in celebration, causing short term, extremely high particulate matter air pollution. In recent years, the rapid development and expansion of low-cost air quality sensors by companies such as PurpleAir has enabled an understanding of air pollution at a much higher spatiotemporal resolution compared to traditional monitoring networks. In this study, real-time PM2.5 measurements from 751 PurpleAir sensors operating from June to July in 2019 and 2020 were used to examine the impact of 4th of July fireworks on hourly and daily PM2.5 concentrations at the census tract and county levels in California. American Community Survey (ACS) and **CalEnviroScreen** 3.0 data were used to identify correlations between PM2.5 measurements and socioeconomic status (SES). A two-step method was implemented to assure the quality of raw PM2.5 sensor data and sensor calibration against co-located reference instruments. The results showed that over 67% and 81% of counties experienced immediate impacts related to fireworks in 2019 and 2020, respectively. Relative to 2019, the peak PM2.5 concentrations on July 4th and 5th 2020 were, on average, over 50% higher in California, likely due to the COVID-19-related increase in the use of household-level fireworks. This increase was most pronounced in southern counties, which tend to have less strict firework-related regulations and a greater use of illegal fireworks. Los Angeles County experienced the highest July 4th daily PM2.5 levels both in 2019 (29.9 µg·m-3) and 2020 (42.6 µg·m-3). Spatial hot spot analyses generally showed these southern counties (e.g., Los Angeles County) to be regional air pollution hotspots, whereas the opposite pattern was seen in the north (e.g., San Francisco). The results also showed PM2.5 peaks that were over two-times higher among communities with lower SES, higher minority group populations, and higher asthma rates. Our findings highlight the important role that policy and enforcement can play in reducing firework-related air pollution and protecting public health, as exemplified by southern California, where policy was more relaxed and air pollution was higher (especially in 2020 when the 4th of July coincided with the COVID-19-lockdown period), and in disadvantaged communities where disparities were greatest.
EJ Analytical Framework	Intersectional environmental justice and population health inequalities: A novel approach	Alvarez, C; Evans, CR.	2021	*Soc Sci Med.* Jan; 269:113559. doi: 10.1016/j.socscimed.2020.113559. Epub 2020 Dec 2	https://pubmed.ncbi.nlm.nih.gov/33309156/#affiliation-1	Drawing on the traditions of environmental justice, intersectionality, and social determinants of health, and using data from the EPA's NATA 2014 estimates of cancer risk from air toxics, we demonstrate a novel quantitative approach to evaluate intersectional environmental health risks to communities: Eco-Intersectional Multilevel (EIM) modeling. Results from previous case studies were found to generalize to national-level patterns, with multiply marginalized tracts with a high percent of Black and Latinx residents, high percent female-headed households, lower educational attainment, and metro location experiencing the highest risk. Overall, environmental health inequalities in cancer risk from air toxics are: (1) experienced intersectionally at the community-level, (2) significant in magnitude, and (3) socially patterned across numerous intersecting axes of marginalization, including axes rarely evaluated such as gendered family structure. EIM provides an innovative approach that will enable explicit consideration of structural/institutional social processes in the social production of intersectional and geospatial inequalities.
EJ Analytical Framework	SB 673 Cumulative Impacts and Community Vulnerability Draft Regulatory Framework	California EPA	2021	Government Document	https://dtsc.ca.gov/wp-content/uploads/sites/31/2021/07/2021MAY-DRAFT-CI-Regulatory-Framework_Accessible.pdf	This report is an informal call for regulations that would enable the Department of Toxic Substances Control to 'implement, interpret, or make specific' provisions of Health and Safety Code Sections 25200.21(b) and 25200.21(c). This would allow the Department to address long-standing concerns of environmental justice that are related to the location, operation, and growth of hazardous waste facilities, the majority of which are operating near disadvantaged communities, as determined by CalEnviroScreen scores in the 75th percentile or higher. This document provides a detailed methodology to include hazardous waste facility impacts and community vulnerabilities into the Department's hazardous waste facility permitting process. This document also provides ways to determine actions to protect vulnerable communities.

Appendix B: Literature Review for Environmental Justice Publications

Topic Area	Title	Authors	Year	Source title	WebLink	Abstract
Risk Assessment Methodology	Defining and Intervening on Cumulative Environmental Neurodevelopmental Risks: Introducing a Complex Systems Approach	Payne-Sturges, DC; Cory-Slechta, DA; Puett, RC; Thomas, SB; Hammond, R; Hovmand, PS.	2021	*Environ. Health Perspect.* Mar; 129(3):35001	https://pubmed.ncbi.nlm.nih.gov/33688743/	Background: The combined effects of multiple environmental toxicants and social stressor exposures are widely recognized as important public health problems contributing to health inequities. However cumulative environmental health risks and impacts have received little attention from U.S. policy makers at state and federal levels to develop comprehensive strategies to reduce these exposures, mitigate cumulative risks, and prevent harm. An area for which the inherent limitations of current approaches to cumulative environmental health risks are well illustrated is children's neurodevelopment, which exhibits dynamic complexity of multiple interdependent and causally linked factors and intergenerational effects. Objectives: We delineate how a complex systems approach, specifically system dynamics, can address shortcomings in environmental health risk assessment regarding exposures to multiple chemical and nonchemical stressors and reshape associated public policies. Discussion: Systems modeling assists in the goal of solving problems by improving the "mental models" we use to make decisions, including regulatory and policy decisions. In the context of disparities in children's cumulative exposure to neurodevelopmental stressors, we describe potential policy insights about the structure and behavior of the system and the types of system dynamics modeling that would be appropriate, from visual depiction (i.e., informal maps) to formal quantitative simulation models. A systems dynamics framework provides not only a language but also a set of methodological tools that can more easily operationalize existing multidisciplinary scientific evidence and conceptual frameworks on cumulative risks. Thus, we can arrive at more accurate diagnostic tools for children's' environmental health inequities that take into consideration the broader social and economic environment in which children live, grow, play, and learn.
Risk Assessment Methodology	Cumulative Risks from Stressor Exposures and Personal Risk Factors in the Workplace: Examples from a Scoping Review	Fox, MA; Niemeier, RT; Hudson, N; Siegel, MR; Dotson, GS.	2021	*Int. J. Environ. Res. Public Health* May 29; 18(11):5850	https://pubmed.ncbi.nlm.nih.gov/34072475/	Protecting worker and public health involves an understanding of multiple determinants, including exposures to biological, chemical, or physical agents or stressors in combination with other determinants including type of employment, health status, and individual behaviors. This has been illustrated during the COVID-19 pandemic by increased exposure and health risks for essential workers and those with pre-existing conditions, and mask-wearing behavior. Health risk assessment practices for environmental and occupational health typically do not incorporate multiple stressors in combination with personal risk factors. While conceptual developments in cumulative risk assessment to inform a more holistic approach to these real-life conditions have progressed, gaps remain, and practical methods and applications are rare. This scoping review characterizes existing evidence of combined stressor exposures and personal factors and risk to foster methods for occupational cumulative risk assessment. The review found examples from many workplaces, such as manufacturing, offices, and health care; exposures to chemical, physical, and psychosocial stressors combined with modifiable and unmodifiable determinants of health; and outcomes including respiratory function and disease, cancers, cardio-metabolic diseases, and hearing loss, as well as increased fertility, menstrual dysfunction and worsened mental health. To protect workers, workplace exposures and modifiable and unmodifiable characteristics should be considered in risk assessment and management. Data on combination exposures can improve assessments and risk estimates and inform protective exposure limits and management strategies.
Key Initiatives	Strengthening Environmental Justice Through Cleanup Enforcement Actions (July 1, 2021)	US EPA, Lawrence E. Starfield, Acting Assistant Administrator	2021	Government Document	https://www.epa.gov/system/files/documents/2021-07/strengtheningenvirjustice-cleanupenfaction070121.pdf	This memo " sets out steps to advance these environmental justice (EJ) goals through cleanup enforcement at private and federal facility sites, primarily through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA)." Specific action that were addressed include requiring responsible parties to take early cleanup actions, ensuring prompt clean-up actions, enhancing enforcement tools/approaches, increased oversight of clean-up activities, engage in activities that build trust.

Appendix C

Summary of State Environmental Justice (EJ) Tools

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State	Tool Name	Tool Description	Environmental Indicator Only[a]	Web Link to Tool
Alabama	EJ Map	An ArcGIS and Google Earth mapping tool that identifies minority, low-income, and minority and low-income census blocks in Alabama.		http://gis.adem.alabama.gov/arcgis/rest/services/EJ_Map/MapServer
Alaska	Alaska Department of Environmental Conservation (ADEC) Web Maps	Public interactive GIS data web maps addressing Alaska's air quality, contaminated sites, and drinking water quality.	X	https://dec.alaska.gov/das/GIS/apps.htm
	Alaska Department of Commerce, Community, and Economic Development - Community Database Online	Community data on demographics, local business, schools; other information organized by school district, census area, climate region, or otherwise.		https://dcra-cdo-dcced.opendata.arcgis.com/
Arizona	Arizona uses US EPA's EJSCREEN, but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Arkansas	EnviroView	Interactive mapping tool with layers for various datasets including facilities with Arkansas Department of Environmental Quality (ADEQ) permits that regulate air emissions, water discharges, mining, fuel storage tanks, solid waste, and waste tires.	X	https://arkansasdeq.maps.arcgis.com/apps/webappviewer/index.html?id=96a9f37d695e4c48a047f11f5b541139
	AquaView	Allows users to view and access water-related data collected by ADEQ's Water Division.	X	https://arkansasdeq.maps.arcgis.com/apps/webappviewer/index.html?id=fb5a6aa70fd940cda4c9a3d7bc2fbb15
	Arkansas Brownfields Program Viewer	Provides locations and information about industrial sites that may have been contaminated by hazardous substances. It includes rehabilitated sites that now serve new purposes as well as those still in the cleanup process.	X	https://arkansasdeq.maps.arcgis.com/apps/webappviewer/index.html?id=ff40276a78994134802d88d5253dc834
California	CalEnviroScreen	Identifies communities by census tract that are disproportionately burdened by multiple sources of pollution.		https://calenviroscreen-oehha.hub.arcgis.com/
	List of California Air Resources Board (CARB)-supported research on EJ	A compilation of active and complete EJ research projects supported by CARB.		https://ww2.arb.ca.gov/research/research-environmental-justice
Colorado	Colorado Department of Public Health and Environment (CDPHE) Community Health Equity Map	An online mapping tool that provides information on a variety of social determinants of health, including income/poverty, English language proficiency, and race.		http://www.cohealthmaps.dphe.state.co.us/cdphe_community_health_equity_map/
	CDPHE Climate Equity Data View	An EJ tool that uses "population and environmental factors to calculate climate equity score[s]" for each census block group in Colorado.		https://cdphe.maps.arcgis.com/apps/webappviewer/index.html?id=25d884fc249e4208a9c37a34a0d75235
	Colorado EnviroScreen	The CDPHE is working on a new interactive mapping tool for EJ. They expect to launch the tool in summer 2022.		https://cdphe.colorado.gov/enviroscreen
Connecticut	Connecticut Department of Energy and Environmental Protection (CTDEEP) List of EJ Communities in Connecticut	List of EJ communities based on list of distressed municipalities and towns where census block groups have 30% of the population living below 200% of the federal poverty line.		https://portal.ct.gov/DEEP/Environmental-Justice/Environmental-Justice-Communities
	CTDEEP Maps and GIS Data	Identifies available maps and GIS data specific to Connecticut, including recreational maps, resource maps, and other national mapping resources.	X	https://portal.ct.gov/DEEP/GIS-and-Maps/Maps/Maps-and-GIS-Data

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Delaware	Delaware Environmental Navigator (DEN)	A database that consolidates environmental information on potential sources of contamination, violations, water quality monitoring, release locations, and wetlands.	X	http://www.nav.dnrec.delaware.gov/den3/
	Open Data from Delaware State Agencies	Provides resources for large, open collections of data from state agencies, including census data, DEN, public health statistics, labor market data, and public school GIS layers.	X	https://delaware.gov/guides/data/
Florida	Florida Department of Environmental Protection (FDEP) Geospatial Open Data	Consolidated list of available state geospatial data for administrative boundaries, atmosphere and climate, biology and ecology, business and economics, environmental monitoring, land ownership, planning and development, *etc.*	X	https://geodata.dep.state.fl.us/
Georgia	Georgia Department of Public Health (GDPH) Chemical Hazards Data	Provides environmental and public health data for Georgia, including air monitoring data, water quality information, radon exposure, and a hazardous site inventory.	X	https://dph.georgia.gov/environmental-health/chemical-hazards/environmental-data
Hawaii	Hawaii Statewide GIS Program Geospatial Data Portal	State site consolidating GIS data for a broad range of topics, including climate, infrastructure, historical, and human health risk.		https://geoportal.hawaii.gov/
Idaho	Idaho Department of Environmental Quality (IDDEQ) Interactive Mapping and GIS Data	IDDEQ list of GIS environmental data and reporting for Idaho.	X	https://www.deq.idaho.gov/public-information/assistance-and-resources/interactive-mapping-and-gis-data/
	Idaho Department of Health and Welfare (IDDHW) Idaho Health Statistics	IDDHW site providing resources from the Health Statistics Unit within the Idaho Bureau of Vital Records and Health Statistics, including vital statistics (births, deaths, teen pregnancies) and health fact sheets.	X	https://healthandwelfare.idaho.gov/about-dhw/reports-and-statistics
Illinois	EJ Mapping	Web GIS map of EJ communities in Illinois.		https://illinois-epa.maps.arcgis.com/apps/webappviewer/index.html?id=f154845da68a4a3f837cd3b880b0233c
Indiana	Indiana State Maps and GIS Applications	Consolidated GIS data from various sources, including air monitoring, water, and solid waste data.	X	https://www.in.gov/idem/resources/maps/
	Indiana State Department of Health (INDOH) Data and Reports	INDOH site that consolidates resources for various state health and demographics data, including infant mortality, suicide, cancer, and youth risk behavior.	X	https://www.in.gov/health/data-and-reports/
Iowa	Iowa Public Health Tracking Portal	State site consolidating demographics data, environmental data, and data on health conditions for Iowans.	X	https://tracking.idph.iowa.gov/
	Iowa Department of Natural Resources (IADNR) Contaminated Sites Section	IADNR site providing information on hazardous sites throughout the state.	X	https://programs.iowadnr.gov/contaminatedsites/
Kansas	Kansas Department of Health and Environment (KDHE) Environmental Interest Finder Map Tool	KDHE interactive data map that includes environmental information on air quality, toxic releases, spills, and other environmentally relevant sites.	X	https://maps.kdhe.state.ks.us/keif/
	KDHE Air Quality Data	KDHE site tracking air quality in the state.	X	https://www.kdheks.gov/bar/air-monitor/airdata.html

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State	Tool Name	Tool Description	Environmental Indicator Only[a]	Web Link to Tool
Louisiana	Louisiana Department of Health (LDH) Environmental Public Health Tracking	Provides data and information on health outcomes, the environment, population, and exposures, including data from the Centers for Disease Control and Prevention (CDC) and LDH.	X	https://ldh.la.gov/index.cfm/subhome/50
	Louisiana Department of Environmental Quality (LDEQ) Interactive Mapping Application	Interactive GIS application, including data on population, environmental features, business data, and other metrics.		http://ldeq-agsserver.deq.louisiana.gov/Html5Viewer/Index.html?configBase=http://ldeq-agsserver.deq.louisiana.gov/Geocortex/Essentials/REST/sites/LIMA_Internet/viewers/LIMA_HTML5/virtualdirectory/Resources/Config/Default
Maine	Maine CDC Division of Public Health Systems Data Index	List provided by the Maine CDC, tracking vital statistics, births, deaths, and other state demographic data.	X	https://www.maine.gov/dhhs/mecdc/public-health-systems/data-research/data/index.html
Maryland	Baltimore EJSCREEN	EJ mapping tool that functions similarly to US EPA's EJSCREEN tool but utilizes locally sourced data and is more appropriate for local concerns.		https://uofmd.maps.arcgis.com/apps/webappviewer/index.html?id=69a3b4817a2a472883dd78ceebf0f912
	Prince George County EJSCREEN	EJ mapping tool that functions similarly to US EPA's EJSCREEN tool but utilizes locally sourced data and is more appropriate for local concerns.		https://uofmd.maps.arcgis.com/apps/webappviewer/index.html?id=63dcbfb775d44aa594a17f5ffa257caa
	Maryland EJSCREEN Mapper	EJ mapping tool that function similarly to US EPA's EJSCREEN and CalEnviroScreen tools but incorporates some locally sourced data and is more appropriate for local concerns than the federal tool.		https://p1.cgis.umd.edu/EJSCREEN/
Massachusetts	Massachusetts EJ Viewer	This interactive map is maintained by the Massachusetts Department of Environmental Protection (MassDEP) and identifies EJ communities throughout the state based on 2020 US Census information.		https://mass-eoeea.maps.arcgis.com/apps/webappviewer/index.html?id=1d6f63e7762a48e5930de84ed4849212
	Massachusetts Department of Public Health (MassDPH) Environmental Justice Tool	This interactive tool is maintained by MassDPH and identifies EJ communities based on population characteristics (race, income, linguistic isolation) and health vulnerabilities (heart attack, blood lead, low birth weight, and asthma).		https://dphanalytics.hhs.mass.gov/ibmcognos/bi/?pathRef=.public_folders%2FMEPHTN%2Fcommunity%2FEJ%2BScreening%2FEJ%2BScreening%2Bv3a%2Bactive&closeWindowOnLastView=true&ui_appbar=false&ui_navbar=false
Michigan	Michigan uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Minnesota	Understanding EJ in Minnesota's Tool from the Minnesota Pollution Control Agency (MPCA)	Combines tribal areas, census tracts, and known MPCA sites to identify potential areas with EJ concerns.		https://mpca.maps.arcgis.com/apps/MapSeries/index.html?appid=f5bf57c8dac24404b7f8ef1717f57d00
	What's in my Neighborhood? Web-based Map	Searches potentially contaminated sites along with records of environmental permits and registrations so that users can learn more about environmental information in their community.	X	https://www.pca.state.mn.us/data/whats-my-neighborhood
Mississippi	Mississippi uses US EPA's EJSCREEN, but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Missouri	Missouri uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Montana	Montana uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN

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State	Tool Name	Tool Description	Environmental Indicator Only[a]	Web Link to Tool
Nebraska	Nebraska Department of Environmental Quality (NDEQ) Interactive Mapping	This interactive mapping tool allows users to view facilities/sites of interest to NDEQ and the community. The data are retrieved from NDEQ's information system. The tool does not contain any demographic information.	X	http://deq.ne.gov/NDEQProg.nsf/OnWeb/MapsData
Nevada	Nevada uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
New Hampshire	Social Vulnerability Index	A mapping tool that identifies socially vulnerable populations based on a variety of factors, including race, English language proficiency, and socioeconomic status (requires ArcGIS login).		https://nhvieww.maps.arcgis.com/sharing/oauth2/authorize?client_id=arcgisonline&response_type=token&state=%7B%22portalUrl%22%3A%22https%3A%2F%2Fnhvieww.maps.arcgis.com%22%7D&expiration=20160&redirect_uri=https%3A%2F%2Fnhvieww.maps.arcgis.com%2Fapps%2FMapS
New Jersey	NJ-GeoWeb 3.0	A mapping tool that provides access to various forms of environmental data, including air and water quality information and locations of known contaminated sites.	X	https://www.nj.gov/dep/gis/geowebsplash.htm
	New Jersey Environmental Justice Mapping Tool	This interactive mapping tool allows users to view overburdened communities in New Jersey, the criteria each census block group meets, and the municipality for which the overburdened community is designated.		https://njdep.maps.arcgis.com/apps/webappviewer/index.html?id=34e507ead25b4aa5a5051dbb85e55055
New Mexico	New Mexico EJ Mapper	Interactive map, similar to the eGIS tool, showing environmental concerns affecting New Mexico's under-represented residents and 2010 census data.		https://gis.web.env.nm.gov/oem/?map=egis
New York	New York State Department of Environmental Conservation (NYSDEC) Potential EJ Areas by County	GIS data that identifies census block groups from the 2000 US Census whose populations are at least 51.1% minority in urban areas, at least 33.8% minority in rural areas, or at least 23.59% low income.		https://www.dec.ny.gov/public/911.html
	NYSDEC Environmental Facilities Navigator	Mapping tool that identifies potential EJ areas and facilities that may pose a risk to the environment or public health.		https://www.dec.ny.gov/imsmaps/navigator/
	NYSDEC Data Clearinghouse	Provides access to wide range of data collected by NYSDEC, such as chemical spill reports, air quality information, and Clean Air Act Title V permits.	X	https://gis.ny.gov/gisdata/inventories/member.cfm?organizationID=529
North Carolina	North Carolina Department of Environmental Quality (NCDEQ) Community Mapping System	The community mapping system is used to inform department decisions, such as specific plans for local outreach and public participation. The NCDEQ Mapping Tool is only an environmental indicator tool; however, NCDEQ's EJ webpage indicates that it can be used to "inform some department decisions, such as specific plans for local outreach and public participation" (https://deq.nc.gov/outreach-education/environmental-justice).	X	https://deq.nc.gov/outreach-education/environmental-justice/deq-north-carolina-community-mapping-system
North Dakota	North Dakota uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Ohio	Ohio uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN

Appendix C: Summary of State Environmental Justice (EJ) Tools

State	Tool Name	Tool Description	Environmental Indicator Only[a]	Web Link to Tool
Oklahoma	Oklahoma uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Pennsylvania	Environmental Justice Areas Viewer	An interactive mapping tool that allows the viewer to locate EJ communities throughout Pennsylvania.		https://www.dep.pa.gov/PublicParticipation/OfficeofEnvironmentalJustice/Pages/PA-Environmental-Justice-Areas.aspx
Rhode Island	Map of EJ Areas in Rhode Island	A static map of EJ areas in Rhode Island based on the 2000 US Census Block Group Boundary layer. This is a still map rather than an interactive tool.		http://www.dem.ri.gov/envequity/graphics/ejareas.jpg
South Carolina	South Carolina uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
South Dakota	South Dakota uses US EPA's EJSCREEN, but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Tennessee	Tennessee uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Utah	Utah Environmental Interactive Map	Displays drinking water, water quality, air quality, environmental remediation/response sites, and waste management/radiation sites from Utah DEQ databases.	X	https://enviro.deq.utah.gov/
Vermont	Vermont uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Virginia	Virginia uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Washington	Washington State Department of Health Washington Tracking Network	Provides environmental and public health data as well as location-based information on vulnerability and health disparities in an information-by-location tool.		https://www.doh.wa.gov/DataandStatisticalReports/WashingtonTrackingNetworkWTN
	Washington Ecology Environmental Information Management System	Location-based search containing environmental monitoring data.	X	https://ecology.wa.gov/Research-Data/Data-resources/Environmental-Information-Management-database
West Virginia	West Virginia uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Wisconsin	Wisconsin uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN
Wyoming	Wyoming uses US EPA's EJSCREEN but has no state-specific tool	EJSCREEN is an interactive mapping tool that lets users access high-resolution environmental and demographic information for locations in the United States and compare to other locations.		https://www.epa.gov/EJSCREEN

Appendix C: Summary of State Environmental Justice (EJ) Tools

State	Tool Name	Tool Description	Environmental Indicator Only[a]	Web Link to Tool
Tools from Non-Governmental Organizations (NGOs)				
Kentucky	Mapping Environmental Justice in Kentucky	Mapping tool that displays EJ and health inequity locations throughout the state.		https://kftc.org/blog/mapping-environmental-injustice-kentucky
Minnesota	Twin Cities Environmental Justice Center for Earth, Energy, and Democracy	Displays demographic data, housing data, land use, and energy vulnerability for the Twin Cities region.		https://umn.maps.arcgis.com/apps/OnePane/basicviewer/index.html?appid=a826e71660804b97afd942c1d5001c22
Texas	Texas Environmental Justice Explorer	This mapping tool summarizes pollution, health, and socioeconomic data into a cumulative EJ risk score. This score communicates the environmental and social vulnerability of a county or census tract.		https://www.climatecabineteducation.org/texas-ej-map
Virginia	Energy Justice Map	This map, maintained by the Environmental Justice Network, identifies environmental hazards in Virginia.		http://www.energyjustice.net/map/Virginia
Academic Tools				
Michigan	Screening Tool for Environmental Justice in Michigan	This interactive map identifies EJ communities throughout the state of Michigan.		https://www.arcgis.com/apps/webappviewer/index.html?id=dc4f0647dda34959963488d3f519fd24
Texas	Houston–Galveston–Brazoria (HGB) EnviroScreen	This tool was developed by the Texas A&M University Superfund Research Center to identify and prioritize regions of heightened vulnerability within the 1,090 census tracts in he HGB region. The tool includes data in five domains: (i) social vulnerability, (ii) baseline health, (iii) environmental exposures and risks, (iv) environmental sources, and (v) flooding.		https://hgbenviroscreen.org/home
Virginia	Cumulative Impact Map	Demonstrates the disproportionate pollution burden between communities throughout Virginia.		https://mappingforej.berkeley.edu/virginia/

Notes:

GIS = Geographic Information System; US EPA = United States Environmental Protection Agency.

(a) EJ tools identified with an "X" in this column can be used to view pollution or environmental burden. These tools do not include typical sociodemographic factors such as income, race/ethnicity, or other population characteristics that

Appendix D

Comparison of US EPA's Risk-Screening Environmental Indicators (RSEI) Model and National Air Toxics Assessment (NATA)

(Note: US EPA replaced NATA with the AirToxScreen in EJSCREEN 2.0. See main report for additional explanation)

Appendix D: Comparison of US EPA's Risk-Screening Environmental Indicators (RSEI) Model and National Air Toxics Assessment (NATA)

	RSEI Model	NATA	Source
Description	A multi-media screening tool that incorporates chemical information *(i.e.*, fate, transport, and toxicity), potential human exposure (*i.e.*, route, extent, and number of people affected), and the amount of chemical released to assess potential chronic impacts of TRI chemicals to human health. According to US EPA (2020a), RSEI results "offer a screening-level, risk-related perspective for relative comparisons of certain waste management activities of TRI chemicals."	A screening tool that estimates long-term cancer risk and noncancer hazards from inhalation of outdoor "air toxics." There are four key steps: (a) compile a national emissions inventory of outdoor air toxics sources (using NEI data); (b) estimate ambient concentrations of air toxics across the United States (using CMAQ and AERMOD); (c) estimate population exposures across the United States (HAPEM); and (d) determine potential public health risks from breathing air toxics.	US EPA, 2018a; US EPA, 2020a
Most Recent Iteration[a]	Version 2.3.9 released December 2020.	Sixth version released August 22, 2018.	US EPA, 2018a; US EPA, 2020a
Media and Exposure Pathway	Air (outdoor inhalation) Surface water (drinking water ingestion and fish ingestion)	Air only (outdoor inhalation)	US EPA, 2018a; US EPA, 2020a
Emission/Release Data Sources:	Air: Facility-reported TRI emissions data Surface water: Facility-reported TRI release data Source emissions/releases include industrial and federal facilities (*i.e.*, point sources) that are required to report air emissions and direct surface water discharges under the TRI program. POTW water effluent discharge is also included in the surface water modeling. Inclusion in the TRI program is based on the facility's six-digit NAICS code.	NEI data Source emissions from the NEI database include stationary point, point airports, point rail yards, stationary nonpoint, fires, biogenics, locomotives, CMVs, on-road, and nonroad (excluding airports, locomotives and CMVs). "[E]stimates for background and secondarily formed air toxics" are also included (US EPA, 2021a). Although, releases from industrial facilities are included, not all TRI facilities are included in NATA. For more information on the emissions sources, see Table 2-1 in the Technical Support Document.	US EPA, 2018a; US EPA, 2020a; US EPA, 2021a

	RSEI Model	NATA	Source
Chemicals of Interest	TRI chemicals include "770 individually listed chemicals and 33 chemical categories," which are usually associated with waste management activities, including off-site transfers to POTW facilities (US EPA, 2021b). In the latest version of RSEI, toxicity weights are available for over 400 of these chemicals and chemical categories.	180 chemicals considered "air toxics" regulated by US EPA under the Clean Air Act and diesel particulate matter. Health-effect results are only available for 138 of these chemicals.	US EPA, 2018a; US EPA, 2020a; US EPA, 2021b
Air/Water Concentration Modeling Approach	Air: Fugitive (nonpoint) air emissions, stack (point) air emissions, off-site transfers to non-POTW (*i.e.*, incineration or thermal treatment), and off-site transfers to POTW (*i.e.*, volatilization) were all considered in the air modeling approach. Chemical concentrations for fugitive and stack air emissions are calculated for each grid cell in AERMOD using site-specific TRI emission data, NEI stack (*i.e.*, height and diameters) and exit gas velocity values, US EPA's HEM-3 modeled meteorological data, and air decay rates from SRC's AOPWIN. Surface water: Both direct surface water discharge and POTW water effluent discharge from off-site transfers to POTW were considered in the modeling approach. Chemical concentrations in the receiving flowline at a specific distance and time were estimated using the amount of chemical released, mean flow, decay coefficient, and water velocity in a simple first-order decay equation.	Uses NEI emissions data with the chemical transport model (CMAQ) and the dispersion model (AERMOD) to estimate ambient air concentrations. AERMOD is used to model concentrations from point, nonpoint, on-road, and nonroad sources. Concentrations from fires, biogenics, and secondary concentrations are modeled using CMAQ. Ambient air concentrations for 52 hazardous air pollutants (see Table 3-1 in the Technical Support Document) are modeled using a hybrid approach of AERMOD and CMAQ, which is described in Section 3.5 of the Technical Support Document.	US EPA, 2018b; US EPA, 2020a

	RSEI Model	NATA	Source
Exposure Point Concentrations	Air: The modeled chemical concentrations are combined with exposure factors (*i.e.*, inhalation rate and body weight from US EPA's EFH) to calculate the surrogate dose for each grid cell. Surface water (drinking water): The average annual chemical concentration in the flowline of interest (calculated at the upstream end of the flowline) is combined with exposure factors for drinking water ingestion rate and body weight to calculate the surrogate dose. Surface Water (fish ingestion): The chemical concentration in fish in the specified flowline is calculated using the average annual chemical concentration in the flowline of interest and the BCF for that chemical of interest. The "surrogate dose" is calculated using the average annual chemical concentration in fish tissue, fish ingestion rate for recreational or subsistence fishers (calculated using population data, family size, and fishing license data), and body weight.	Using "screening-level inhalation exposure model" HAPEM (Version 7), the ambient air concentrations are used to calculate the inhalation exposure concentrations (US EPA, 2018b).	US EPA, 2018b; US EPA, 2020a
Cohort	Results are estimated for different age and sex groups. Age groups include 0-17, 18-44, 45-64, and 65+ years old. Risk scores are also estimated for the age group 0-9 years; however, a separate exposure factor is not available, and therefore, the exposure factor for the 0-17 year age group is implemented.	Results are estimated for age groups 0-1, 2-4, 5-15, 16-17, 18-64, and 65+ years old, but are not sex-specific.	US EPA, 2018a; US EPA, 2020a
Scale	810 m grid cell, which can be summed to the census **block** level.	Varied levels of resolution, lowest of which is the census **tract** level.	US EPA, 2021a
Analysis Updates	"Full time series" that are released every year (1988 to present). Comparison between years is possible.	Single-year snapshots that are released every three years or so. Due to "changes in methods between assessments, different NATA years cannot be compared" (US EPA, 2021a).	US EPA, 2021a

	RSEI Model	NATA	Source
Toxicity Information	Toxicity weights are based on toxicity values from ATSDR, CalEPA, and US EPA organizations (including NATA). Toxicity weights are a relative value calculated based on the effect type (*i.e.*, cancer or noncancer), exposure pathway (*i.e.*, inhalation or oral), and toxicity value (*i.e.*, IUR, OSF, RfC, or RfD). The algorithms for calculating toxicity weight are presented here. Toxicity weights across chemicals range from 0.02 to 1,400,000,000. See Chapter 4: Methods for Calculating Toxicity Weights of the Technical Support Document for more information. For more information on toxicity weight selection, see Exhibit 4.4 in the Technical Support Document.	Toxicity quantified using US EPA's IRIS, ATSDR, CalEPA, and HEAST. Cancer Classification information was supplemented by IARC. NATA-specific toxicity approaches were developed for some compounds (*i.e.*, polycyclic organic matter, glycol ethers, acrolein) and some metals (*i.e.*, nickel compounds, chromium [VI] compounds, lead, manganese). Cancer dose-response assessment results were converted to a URE and multiplied by the 70-year-average exposure concentration to estimate lifetime cancer risk. Noncancer hazards (*i.e.*, RfCs) were calculated using chronic dose-response data.	US EPA, 2018a; US EPA, 2020a
Result Categories	▪ Pounds-based results ("number of pounds reported to TRI for each waste management activity") (US EPA, 2020a); ▪ Risk-related scores[b] ("exposure route-specific chemical toxicity weight" x surrogate dose[c] x population); and ▪ Hazard-based results (amount of chemical [in lbs] x toxicity weight) Cancer and noncancer effects are combined in Risk Score and Hazard-based results but can also be reported separately.	▪ Outdoor emissions data; ▪ Ambient concentrations (average annual outdoor concentrations); ▪ Population exposure estimates; and ▪ Health-effect results (cancer risks and noncancer hazard indexes). Cancer and noncancer results are reported separately and are not combined.	US EPA, 2018a; US EPA, 2020a; US EPA, 2021a
Result Interpretation	Hazard estimates and unitless risk scores "can only be interpreted as relative measures to be compared with other such values" (US EPA, 2020a). Results can "be filtered by one or more dimensions like industry, facility, chemical, year or state. Metrics are additive and comparable across any aggregations. Using the Microdata, users can link cumulative potential burden in any specific geography with the facility releases potentially causing the impact" (US EPA, 2021a).	"[R]esults can be examined by chemical and source type at various levels of aggregation from census tract to the national level" (US EPA, 2021a). However, unlike with RSEI, specific sources cannot be identified as contributing to risks.	US EPA, 2020a; US EPA, 2021a

	RSEI Model	NATA	Source
Output Types	Microsoft Excel- and Access-format files can be downloaded here. RSEI produces "Geographic Microdata," which are large datasets of grid-cell-level (810 m x 810 m) air model results (*i.e.*, RSEI score, chemical concentration, and toxicity-weighted concentration for each air release). Water Microdata are presented by stream segment. RSEI results are also accessible in EasyRSEI, Envirofacts, and CalEnviroScreen. Find more information here.	Microsoft Excel- and Access-format files can be downloaded here.	US EPA, 2020a; US EPA, 2020b
Key Exposure Assumptions	Exposure: ▪ The US EPA exposure assessment paradigm is used to evaluate exposure potential (or "surrogate dose") ▪ Standard exposure assumptions for sex- and age-specific body weight are adapted from US EPA's 2011 EFH. ▪ Potential exposure is estimated in relation to TRI chemicals included in the model. Air: ▪ Continuous exposure at place of residence is assumed. ▪ Standard exposure assumptions for sex- and age-specific inhalation rate are adapted from US EPA's 2011 EFH. Surface water (ingestion of contaminated drinking water and non-commercial contaminated fish): ▪ Flowlines up to 300 km downstream from the facility are assumed to be affected by chemical release. ▪ If outfall location coordinates are not available for a facility, the closest acceptable (*i.e.*, flow and flowline type) flowline within 4 km is used.	Exposure: ▪ It is assumed that all individuals within a census tract have the same exposure and risk. ▪ Activity patterns are assumed for each age group. Differences in susceptibility are not accounted for. ▪ Emission rates are assumed to be uniform throughout the year. Health: ▪ Cancer risk is estimated under the assumption that "the relationship between exposure and probability of cancer is linear" (US EPA, 2018a). ▪ For health effect results, continuous lifetime inhalation exposure is assumed. ▪ For multiple-pollutant cancer risks, it is assumed "that exposures to multiple carcinogens can be added together to estimate risks" (US EPA, 2018a). Likewise, the equation for multiple-pollutant noncancer hazards "assumes an additive effect from simultaneous exposures to several chemicals...for chemicals with the same target organ or organ system...for chemicals with the same target organ or organ system" (US EPA, 2018a).	US EPA, 2018a; US EPA, 2020a

	RSEI Model	NATA	Source
	▪ Facilities are assumed to release their annual discharge quantity at a constant rate throughout the year. Ingestion rate: ▪ Standard exposure assumptions for sex- and age-specific drinking water ingestion rates are adapted from the February 2019 update to Chapter 3 of US EPA's EFH. ▪ Fish ingestion rates were estimated using both US EPA's 2011 EFH and data from the 1994-1996 USDA Continuing Survey of Food Intake by Individuals. Drinking water: Despite the number of water intakes per water system, "it is assumed that the total population of the public water system is exposed to the full concentration" (US EPA, 2020a). Fish ingestion: It is assumed that 95% of the fish-eating population eat on a recreational basis and 5% are subsistence. All fishing areas within 80 km of all stream flowlines are assumed to be fish-eating populations.		

	RSEI Model	NATA	Source
Other Data Sets/Information	Surface Water: NHDPlus Version 2 (flowline location and water flow); SRC's ChemFate database (decay rate and BCFs); US EPA's NPDES permit records; USGS' PSDB[d] (drinking water intake locations and estimates of population served); state fish and wildlife licensing data used to create a "county-level dataset containing the number of fishing or hunting/fishing combination licenses" (US EPA, 2020a); US Census Bureau 1996 (family size used to estimate fish ingestion).		US EPA, 2020a
Key Advantages	Facility-specific information is retained: Scores for multiple modeled releases from a facility can be summed to provide a score for the facility, and the scores for all of the facilities located in the state can be summed to produce a state score that can be compared across states. Toxicity assessment can be performed for over 400 chemicals. See Section 2.2.1, "Strengths," in the Technical Support Document for more information.	Accounts for a more complete source of air emissions. In addition, "the contribution for each NATA source type (for example, stationary point sources, on-road gasoline vehicles, *etc.*)" can be broken out from the total risks and hazards (US EPA, 2020b). See Section 1.9.1 of the Technical Support Document for more information on strengths of the model design.	US EPA, 2020a; US EPA, 2020b
Key Limitations	Person's individual risk is not estimated. Human activity patterns are not accounted for. Does not include all of the potential factors included in a full risk assessment. Population characteristics are extrapolated from 1990-2010 data. Decay products are not modeled. See Section 2.2.2, "Limitations," in the Technical Support Document for more information.	Does not confidently capture the highest risks in a county. Person's individual risk is not estimated. Human activity patterns are not accounted for. Due to differences in emission inventories submitted by state, local, and tribal agencies, NATA risk estimates are not as easily compared between states or regions. Facility-specific information is not available. See Section 1.9.1 of the Technical Support Document for more information on limitations of the model design. See Chapter 7, "Variability and Uncertainty Associated with NATA," in the Technical Support Document for more information.	US EPA, 2020a; US EPA, 2020b

	RSEI Model	NATA	Source
Technical Support Documentation	https://www.epa.gov/sites/default/files/2020-12/documents/rsei_methodology_v2.3.9.pdf Referenced as US EPA (2020a) in this table.	https://www.epa.gov/sites/default/files/2018-09/documents/2014_nata_technical_support_document.pdf Referenced as US EPA (2018a) in this table. Supplemental data files accessed here.	US EPA, 2018a; US EPA, 2020a

Notes:

AERMOD = American Meteorological Society/Environmental Protection Agency Regulatory Model; AOPWIN = Atmospheric Oxidation Program; ATSDR = Agency for Toxic Substances and Disease Registry; BCF = Bioconcentration Factor; CalEPA = California Environmental Protection Agency; CMAQ = Community Multiscale Air Quality; CMV = Commercial Marine Vessel; CWA = Clean Water Act; EFH = Exposure Factors Handbook; HAPEM = Hazardous Air Pollutant Exposure Model; HEAST = Health Effects Assessment Summary Tables; HEM-3 = Human Exposure Model, Version 3; IARC = International Agency for Research on Cancer; IRIS = Integrated Risk Information System; IUR = Inhalation Unit Risk; km = kilometer; lbs = pounds; m = meter; NAICS = North American Industry Classification System; NEI = National Emissions Inventory; NHD = National Hydrography Dataset; NPDES = National Pollutant Discharge Elimination System; OSF = Oral Slope Factor; POTW = Publicly Owned Treatment Works; PSDB = Public Supply Database; RfC = Reference Concentration; RfD = Reference Dose; SRC = Syracuse Research Corporation; TRI = Toxics Release Inventory; URE = Upper-bound Excess Lifetime Cancer Risk; US = United States; USDA = US Department of Agriculture; US EPA = United States Environmental Protection Agency; USGS = US Geological Survey; WHO = World Health Organization.

(a) Most recent iterations for RSEI and NATA are not used in EJSCREEN.

(b) Risk-related scores include the "RSEI Score," "Cancer Score," and "Non-Cancer Score." All three scores are calculated using a surrogate dose, population data, and the chemical toxicity weight specific to the exposure pathway. The Cancer Score uses IUR in its toxicity weight, the Non-Cancer Score uses RfC in its toxicity weight, and the RSEI Score uses whichever of these two toxicity weights is higher (US EPA, 2020a).

(c) Surrogate dose is the exposure potential estimated for each chemical and exposure pathway. Exposure potential is evaluated using "models that incorporate data on pathway-specific chemical releases and transfers, physicochemical properties, and where available, site characteristics to estimate the ambient chemical concentrations in the environmental medium into which the chemical is released or transferred" (US EPA, 2020a). These ambient concentrations are then "combined with human exposure assumptions and estimates of exposed population size specific to age and sex" to calculate the surrogate dose (US EPA, 2020a).

(d) Information in PSDB is based on the Safe Drinking Water Information System (SDWIS).

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Appendix E

Summary of Public Comments Received by CalOEHHA on Draft CalEnviroScreen 4.0

Appendix E: Summary of Public Comments Received by CalOEHHA on Draft CalEnviroScreen 4.0

Comment Document Name	Supplemental Document	Type of Commenter	Entity Name	Brief Description of Public Comment
Anonymous	NONE	Resident	Anonymous	Commenter expresses concern about young professionals leaving the area.
Anonymous	NONE	Resident	Anonymous	Commenter expresses concern about refineries and asthma near the 710 and 405 freeways.
Anonymous	NONE	Resident	Anonymous	Commenter suggests that tool should examine quality of drinking water post-treatment. Data are skewed towards more contamination because they include sources that are not drinking water.
API Council	apicouncil-draftces4-5.14.21.pdf	Non-profit	Asian-Pacific Islander Council	Commenter suggests that some underserved communities are not identified in the tool. Some census tracts with high Asian/Pacific Islander populations are not classified as Disadvantaged Communities (DACs).
Associate Professor Michele La Merrill of UC Davis	measuring_inequity_methods_used_to_quantify_structural_racism.pdf	Academia	UC Davis	Commenter suggests that tool should include redlining index.
Bay Area Air Quality Management District	baaqmd_calenviroscreenv4_jpb.pdf	Government Agency	Bay Area Air Quality Management District	Commenter likes improvements in fine particulate matter ($PM_{2.5}$) methodology and diesel PM indicators. Commenter states serious concerns about use of tool to identify disadvantaged communities. Comments that the current scoring methodology identifies only a limited set of communities - misses other disadvantaged communities. Tool is being misapplied as a convenient definition of "disadvantaged" for funding. Requests addition of climate impacts and indicators of climate risk, including sea level rise, extreme weather events, urban heat islands, wildfire risk, and flood risk. Requests increase in communities categorized as disadvantaged from 25% to 30% of highest scoring. Tool does not accurately identify some fenceline communities as disadvantaged; weighting of ½ weight to environmental effects misses some communities. Tool also misses fugitive air emissions from contaminated sites because these fugitive emissions are not accounted for in facility emissions inventories.
Bill Cizmadia	NONE	Resident	Individual	Commenter expresses concern that tool conflates cause and effect: commenter does not feel like pollution caused these issues; rather, the state has purposefully altered the statistics to push funding towards certain communities.
California Environmental Justice Alliance (CEJA)	ceja_comment_letter_on_the_draft_ces_4.0_may_2021.pdf	Non-profit	California Environmental Justice Alliance (CEJA)	Commenter supports the use of the tool overall and likes the new lead risk indicator. They also provide several recommendations for improving tool, including adding a sensitivity analysis of the indicators driving each index; adding regional rankings; distinguishing lead in paint *vs.* lead in water; adding additional indicators for housing safety and quality; ranking housing stock; adding redlining and COVID-19 data; adding pesticide data from glyphosate and paraquat; adding an indicator for diesel PM burden based on truck routes; including data on proximity to ports, railyards, and airports (as a proxy for noise, vibration and risk of explosive incidents); and including small sources of hazardous waste.
California Health Collaborative	NONE	Non-profit	California Heath Collaborative	Commenter states that CalOEHHA should consider including the density of tobacco retailers as an indicator for Environmental Justice (EJ).
California Rural Legal Assistance, Inc.	calenviroscreen_4.0_crla_comments.pdf			Comments indicate difficulty of tool to identify Disadvantaged Unincorporated Communities.
Californians for Pesticide Reform	NONE	Resident	Individual	Commenter suggests addition of pollution layer for the pesticides glyphosate and paraquat.
Christine Rowe	calenviroscreen_4.0_beta_comments_christine_l_rowe_05_14_2021.pdf	Resident	Individual	Commenter uses this tool to look up information about sites nearby to commenter's home and comments on these sites. Commenter would like the following items added to tool: radon maps, and Division of Oil, Gas, and Geothermal Resources (DOGGR) well map locations. Commenter provides several pages of questions, comments, and conclusions related to specific indicators for specific areas near the commenter's residence.

Appendix E: Summary of Public Comments Received by CalOEHHA on Draft CalEnviroScreen 4.0

Comment Document Name	Supplemental Document	Type of Commenter	Entity Name	Brief Description of Public Comment
City of Los Angeles, Bureau of Sanitation	50_04_27_21_calenviroscreen_letter_final_lasanitation.pdf	Government Agency	City of Los Angeles	Commenter addresses both technical issues with tool and policy issues related to the tool application. Criticizes tool because it limits the definition of EJ to only pollution issues, when it should really be more inclusive. Commenter states that while the tool can easily identify highly impacted areas, it is not meant to be used as a precise tool with specific thresholds to support funding to improve only certain areas. Commenter disagrees with the weighting of pollution and effects of pollution more heavily than population characteristics. Tool may assign higher scores to sparsely populated areas that are heavily polluted, while assigning lower scores to larger disadvantaged communities with lower pollution scores. Commenter suggests weighting population characteristics more heavily and allowing cities to prepare corrective local lenses to use more specific data. Commenter cites technical issues with misidentification of or missing scores for certain census tracts. Commenter requests addition of indicators for climate risk indicators, freeway proximity, port and airport emissions, lead risk from airports/smelters/incinerators, and emerging contaminants such as per-and polyfluoroalkyl substances (PFAS).
City of San Diego	ces4.0commentltr_citysandiego_may2021_final.pdf	Government Agency	City of San Diego, Sustainability Department	Commenter indicates that scoring does not account for local air quality conditions in a border region and would like to see the addition of a Climate Equity Index.
City of San Diego, Lead Safety and Healthy Homes Coordinator, Chris Lee	NONE	Government Agency	City of San Diego, Lead Safety and Healthy Homes Coordinator	Commenter requests additional functionality by changing color scheme to allow colorblind users to read the maps and results.
Comite Civico del Valle: Luis Olmedo	ccv-comment_lettercalenviroscreen.pdf	Non-profit	Comite Civico del Valle: Luis Olmedo	Commenter requests that tool incorporate additional data on pollution in border regions and data on drinking water sources in certain areas.
Deborah Raphael, San Francisco Department of the Environment	calenviroscreen_signed.pdf	Government Agency	San Francisco Department of Environment	Commenter suggests changes to improve methodology: increased score weighting for social/economic factors, removal of pesticide indicator or addition of urban pesticide indicator to level the playing field between cities and agricultural areas, refine $PM_{2.5}$ data, adjust weighting for pollution indicators to account for population density, and adjust cardiovascular indicator to remove age adjustment.
Environmental Working Group	ewg_comments_oehha_enviroscreen_final.pdf	Non-profit	Environmental Working Group	Commenter suggests adding indicator for exposure to lead in water.
Fatima Malik, Del Paso Heights Growers' Alliance	NONE	Resident	Del Paso Heights Growers' Alliance	Commenter suggests adding health indicator for COVID-19 data.
Ian Dawes	NONE	Resident	Individual	Commenter question: "Does CES [CalEnviroScreen] 4.0 use 2020 Census Tract geographies or is it still using 2010?"
Janet Whittick	2021.05.14_ces_cceeb.pdf	Non-profit	California Council for Environmental and Economic Balance (CCEEB)	Commenter requests additional text in report to explain relative ranking, magnitude of risk/burden; mentions that cleanup sites score does not indicate an actual exposure. Commenter provides appendices with several example case studies using tool data.
Jason N	NONE	Resident	Individual	Commenter identifies display and usability issues; requests better display because white text on light pie chart is hard to read.
Jean-Pierre "J.P." Cativiela	dairy_cares_comment_letter.5.14.2021.f.pdf		Jean-Pierre "J.P." Cativiela	Commenter requests that specific farms not be identified by family residence or name, requests that dairy farms be excluded because it is not clear that these facilities pose a threat.
JoAnn Saccato, MA	NONE	Resident	Individual	Commenter suggests adding tobacco retailers.
Juan Gonzalez	NONE	Resident	Individual	Commenter suggests that data should be interpreted with caution given the rapid changes in socioeconomic status because of the COVID pandemic.
M.D	NONE	Resident	Individual	Commenter states that Long Beach is neglected and the air quality is very poor.
Metropolitan Transportation Commission and Bay Area Air Quality Management District	baaqmd_mtc_joint_calenviroscreen4.0.pdf	Government Agency	Metropolitan Transportation Commission and Bay Area Air Quality Management District	Commenters identify 34 census tracts in Bay Area that are not identified as disadvantaged but should have been.

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Ms. Rene Hurst	public_comment-_oehha.pdf	Resident	Ms. Rene Hurst	Commenter provides a list of personal air pollution and health complaints related to the neighborhood.
Nguyen Nguyen, City of Sacramento	NONE	Resident	Individual	Commenter requests additional functionality to allow user to select a smaller area and include and rank only those areas relative to one another.
Nonprofit Coalition for Environmental Justice	cbocoalitionletter-draftces4-5.14.21.pdf	Non-profit	Nonprofit Coalition for Environmental Justice (21 organizations)	Commenter indicates that tool is a step backwards as it fails to identify certain areas that are disadvantaged communities. Suggestions for improvement including greater weighting for diesel PM and socioeconomic factors, and weighting of pollution indicator by population to avoid inaccuracies in urban areas. Commenter states that tool should provide individual indicator scores rather than a composite index.
Parke Troutman	NONE	Resident	Individual	Commenter requests addition of indicator for tobacco retailers.
Prevention Institute	prevention_institute_comment_letter_calenviroscreen_4.0.pdf	Non-profit	Prevention Institute	Commenter requests addition of indicator for parks and green spaces and vegetation.
R Yanez - Member of the Community of East Los Angeles	NONE	Resident	Individual	Commenter states that tool is directing funds to the wrong communities based on inaccuracies in the data and that the government is not demonstrating care. Tool does not do a good job of differentiating emissions sources. Commenter questions how the water quality around the Exide Battering Plant could be good. Commenter states that soil around the Boyle area has high metals levels and wonders why those data are not included.
Shayda Azamian, LCJA	lcja_calenviroscreen_draft_4.0_comments_5_14_21.pdf	Non-profit	Group of 12 non-profits, groups, etc.	Commenter states that the tool misses data on rural communities. Tool should include more accurate data for rural communities, PM_{10} indicators, updated ozone indicator, air data from other non-California Air Resources Board (CARB) sources, pesticide data for glyphosate and paraquat, explanation of why the specific contaminants were selected, surface water flow data to understand droughts, noise data, medically underserved areas layer, health profession shortage areas, updated housing indicator to capture recent rent increases related to COVID, distance to grocery stores or schools or higher ed. Commenter is concerned that the tool only includes large hazardous waste sites that are large generators; tool should also include additional explanation for the 1,000 m cutoff for cleanup sites.
Shelby MacNab	ejscreen_report_-_elm_complete_streets.pdf	Unknown	Individual	Commenter requests additional functionality to allow for custom maps that can be edited, labeled, and printed. Commenter wants it to look similar to EJSCREEN.
Shelly Quan	NONE	Unknown	Individual	Commenter requests addition of indicators for VMT levels and proximity to transit. (Note: VMT is assumed to mean vehicle miles traveled)
Sierra Business Council - Sierra Climate Adaptation and Mitigation Partnership	sierra_camp_ces_4.0_comment_letter.docx.pdf	Non-profit	Sierra Business Council - Sierra Climate Adaptation and Mitigation Partnership	Commenter recommends alternative, more expansive definitions of "disadvantaged." Commenter cautions against setting the bar too high by requiring multiple burdens to meet disadvantaged criteria. Commenter suggests using only household income as criterion. Suggests the addition of indicator for wildfire pollution.
Sierra Institute for Community and Environment	calenviroscreen_4.0_sierra_institute_comment_letter.pdf	Non-profit	Sierra Institute for Community and Environment	Commenter criticizes that tool misses rural communities; unique socioeconomic and environmental burdens are not accounted for in current methodology. These communities are left out of the Disadvantaged Communities designation.
Southern California Association of Governments	2021_05_13_-_scag_comments_letter_-_office_of_environmental_health_hazard_assessment_-_calenviroscreen_4.pdf	Local/Regional Government Agency	Southern California Association of Governments	Commenter states that the tool fails to disaggregate multiple populations lumped together; *e.g.,* use of term 'African American' fails to appreciate the Afro-Latinx experience. All Hispanic/Latinx are in one category. Tool is relying on most prevalent race in a census tract and may miss smaller indigenous populations. Comments suggest calculation methodology changes, including increased weight for air pollution indicators and a full evaluation of the weighing structure (specifically for Exposure component being given twice as much weight as Environmental Effects component). Commenter requests addition of climate change risks.
T. Bradley	dtla_cenus_tract.pdf	Resident	T. Bradley	Notes specific census tract in Los Angeles, suggests reevaluation because commenter believes it should rank higher in CES tool.

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The Sierra Fund	tsf_enviroscreen_comments_2021.pdf	Non-profit	The Sierra Fund	Commenter states that tool is not significantly improved since last round and it misses very rural communities built on mine tailings ("legacy mine lands"); also misses subsistence fishing communities. Commenter suggests adding legacy mine lands, map of abandoned mine lands from the California Department of Conservation, the United States Environmental Protection Agency, and other agencies.
Thirdhand Smoke Resource Center, California Thirdhand Smoke Research Consortium	commentscalenviroscreen_final_0210430.pdf	Non-profit	Thirdhand Smoke Resource Center	Commenter states that tool does not include tobacco exposure/secondhand smoke exposures; requests addition of tobacco products because they contribute to pollution of environment and indoor air.
Tiarra	040816listingabirateroneacetate.pdf	Error	Tiarra	No comment provided. Document attached by commenter is not relevant.
Tom Phillips, Healthy Building Research	comments_on_cal_enviroscreen_version_4.0_submitted_online_may_14_2021.pdf	Non-profit	Healthy Building Research	Commenter requests additional indicators for climate risks, environmental burdens, and health: extreme heat, climate change vulnerability, air quality, noise, renal disease.
Tracy Ferchaw	l-draft_calenviroscreen4.0.pdf	Local/Regional Government Agency	San Diego Association of Governments (SANDAG)	Commenter states that tool is missing military and veteran populations, increase in border crossing traffic/emissions, and that tool does not account for growth in border crossings and associated traffic. Suggests the addition of updated street/roads data (currently uses 2008 traffic data for the land ports of entry from the Tijuana Municipal Planning Institute).
TreePeople	treepeople_public_comment.pdf	Non-profit	Tree People	Commenter requests additional indicator of tree canopy coverage and status of soils.
Zoey Burrows	NONE	Resident	Zoey Burrows	Commenter questions when a disadvantaged community map will be released.

Note:

The public comment submissions can be viewed using the links in the table or by visiting the California Office of Environmental Health Hazard Assessment's (CalOEHHA) draft CalEnviroScreen comment website at: https://oehha.ca.gov/calenviroscreen/comments/comment-submissions-draft-calenviroscreen-40.