Chapter 18
Community-Based Cumulative Impact Assessment: California's Approach to Integrating Nonchemical Stressors into Environmental Assessment Practices

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Abstract 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.

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18.1 Introduction

California was the first state to define environmental justice in law as "the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation and enforcement of environmental laws, regulations and policies" (Cal Gov Code §65040.12(e) 1999). This definition, coupled with the California Environmental Protection Agency's (CalEPA) leadership and commitment to promote environmental justice, led the Agency to recognize that understanding cumulative impacts (CI) in a specific area or within a community would be a critical first step. In 2005, CalEPA integrated the "working definition" from the CalEPA Interagency Working Group Report (CalEPA 2003), along with input from multiple stakeholders, and adopted a common working definition of CI as meaning "exposures, public health or environmental impacts 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 socio-economic factors, where applicable and to the extent data are available" (CDPR 2005; OEHHA 2010). Stakeholders included representatives from local and federal government, academia, environmental justice and community-based organizations, industry, and the general public.

Environmental Justice

Under California law "means the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws and policies."

California Government Code §65040.12(e)

CalEPA's Office of Environmental Health Hazard Assessment (OEHHA) was designated as the lead in developing guidance on incorporating CI into the decision-making process. The CI analysis evaluates the intersections of multiple chemicals, multiple sources, public health, and environmental effects with characteristics of the local population that could influence an adverse health outcome. In 2010, OEHHA finalized a framework documenting the scientific evidence for disproportionate CI as a first step (OEHHA 2010). This framework described factors that make up a comprehensive measure of impacts in a community and a scientific methodology that can be pursued to evaluate CI in a given community. As early as in 2004, U.S. EPA's National Environmental Justice Advisory Council (NEJAC) had recommended a similar conceptual framework known as the "Pollution Burden Matrix" for "developing a screening tool, which would rely primarily on analyses of existing or readily available sources of data, to identify the most burdened census tracts within a specified region" (U.S. EPA 2003; NEJAC 2004). NEJAC's Pollution Burden Matrix served as a guiding construct during OEHHA's cumulative impact framework development.

Cumulative Impacts

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 multimedia, routinely, accidentally, or otherwise released. Impacts will take into account sensitive populations and socioeconomic factors, where applicable and to the extent data are available.

California Environmental Protection Agency

While efforts were in progress by various institutions to evaluate and develop different approaches or methods to estimate CI in a community, the landmark California Legislation Assembly Bill 32 (AB 32) – *Global Warming Solutions Act of 2006* (Nunez, Chapter 488, Statutes of 2006) – was passed. The bill language included the term "disadvantaged communities," referred to as "communities with minority populations or low-income populations, or both," and also contained a directive to "consider the potential for direct, indirect, and cumulative emission impacts from these mechanisms, including localized impacts in communities that are already adversely impacted by air pollution" (Nunez 2006).

Although *disadvantaged community* was not defined in AB 32, subsequent legislation Senate Bill 535 (SB 535) – *Global Warming Solutions Act of 2006: Greenhouse Gas Reduction Fund* (De Leon, Chapter 830, Statutes of 2012) – provided both a clear direction and proposed factors for consideration in identifying disadvantaged communities such as those "based on geographic, socioeconomic, public health, and environmental hazard criteria, and may include, but are not limited to, either of the following:

(a) Areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation.
(b) Areas with concentrations of people that are of low income, high unemployment, low levels of homeownership, high rent burden, sensitive populations, or low levels of educational attainment." (De Leon 2012)

Thus, in California, in addition to traditional risk assessment, a community or place-based CI assessment has been developed. This approach augments the traditional concept of "risk" with the inclusion of a broader concept, "impact." Risk indicates a largely quantifiable approach to assessment, whereas impact implies a broader scope of both quantitative and semiquantitative information, including nonchemical stressors (Alexeeff et al. 2012).

This chapter focuses on place- or community-based cumulative impact assessment in the context of integrating pollution burdens and health vulnerabilities with psychosocial nonchemical stressors. For the purposes of this chapter, any discussion of *cumulative impacts* aligns with CalEPA's definition. The scope of discussion topics includes departures from traditional risk assessment, differences between risk and impact and their assessment methodologies, environmental health and/or justice-focused screening tools, community expectations for assessors, and future directions. The central focus of this chapter is to understand how the concept of community-based cumulative impacts has been successfully integrated in CalEnviroScreen. CalEnviroScreen is used to effectively characterize and combine measures of impact that are of greatest concern and contribute to cumulative impacts in communities across the state. This approach has enabled CalEPA to target multimedia enforcement action, prioritize areas for investment in emission reduction programs, and assist CalEPA and local entities with planning community engagement and outreach efforts.

18.1.1 Traditional Risk Assessment

Traditional risk assessment (TRA) is a predominantly quantitative approach that evaluates a source and/or chemical(s) on the primary steps of hazard identification, dose-response assessment, exposure assessment, and risk characterization (NAS 1983; Faustman and Omenn 2008). This approach is widely applied and has been instrumental in identifying and reducing both human and environmental health risks by (1) evaluating sources or chemicals to estimate cancer and non-cancer risk levels, (2) controlling media-specific exposures (e.g., chemicals in drinking water), and (3) creating decision-making processes that establish risk thresholds to minimize the amount of emissions or discharges of chemicals from a specific source (U.S. EPA 1991, 1992, 1996, 2005a, b). However, the TRA approach has a limited ability to account for sensitivities of subpopulations beyond those based on physiologic characteristics, such as children and the elderly (Miller et al. 2002; Alexeeff and Marty 2008). Additionally, TRA requires specific knowledge of exposures, including chemical characterization, dose levels, and routes of exposure. An understanding of these parameters is essential to establishing health guidance values or benchmarks of harm for individual chemicals (Salmon 2010).

18.1.2 Community-Based Cumulative Impact Assessment

Community characteristics, including area-specific information (e.g., water quality, pesticide use), proximity to multiple nearby pollution sources, and socioeconomic or health vulnerability, cannot be readily incorporated into the traditional paradigm. Risk assessments conducted for regulatory purposes at individual facilities or sites may include some area-specific considerations, including community notifications for site cleanups or facility permitting, but these factors are incorporated in a very limited context. TRA is a quantitative methodology that relies heavily on scientific data, including well-characterized exposure levels and dose-response relationships for environmental contaminants (NAS 1983). Even with robust data, these traditional approaches are useful in estimating the risk to individuals but are not well-suited to provide an estimate of cumulative impacts confronting a community in a specific location (ATEB 2008, 2009).

With the increasing concern for exposures to multiple pollutants from multiple sources, assessors are often tasked with evaluating highly complex scenarios with significant data gaps. An example of such an exposure scenario would be a mixture of chemicals emitted from a single site (e.g., oil refinery), combined with emissions from local factories and road traffic. Data gaps include poor characterization of the environmental contaminants, and little understanding of how these multiple contaminants interact with humans and the environment in a specific area, or the relative contributions of existing and emerging sources (ATEB 2008, 2009; Lee et al. 2011). Consideration of these factors, combined with vulnerability factors in the local community, such as source proximity to schools, hospitals, or elder care facilities, set the foundation for developing methodologies to perform assessments at the community level (Dunn and Alexeeff 2010).

Thus, the community-based concept establishes a framework for designing tools that allow assessors and decision-makers to identify communities that are disadvantaged with regard to environmental and personal health. Such communities include those areas and populations disproportionately burdened by pollution, as influenced by both intrinsic biological (e.g., age, genetic characteristics, preexisting health conditions, sex) and extrinsic socioeconomic factors (e.g., socioeconomic status, education, race/ethnicity, access to health care, housing) (Gee and Payne-Sturges 2004). Considering these nonchemical stressors in the context of environmental justice is a critical first step that enables regulatory agencies to evaluate and address community-based concerns and meet expectations to consider cumulative impacts in decision-making (Alexeeff et al. 2012). Additionally, engaging community members, including local decision-makers, to participate in and understand key elements of the assessment process may be essential to positive public health outcomes (Hallgren et al. 2014). Community outreach and education can facilitate communication, risk reduction strategy development, and chemical source identification (Dunn and Alexeeff 2010; McCloskey et al. 2011; Abara et al. 2014).

18.1.3 It's Impact, Not Risk

Often, the terms *risk* and *impact* are used synonymously, suggesting that they describe the same outcome. The term *risk* means a chance of injury or loss. Historically, in the two hemispheres of human and environmental health, risk entails a quantifiable approach to assessment that includes a wide spectrum of assumptions, modeling, uncertainties, and extrapolation to fill data gaps (NAS 1983). Such assessments are useful in estimating the risk to a population, based on theoretical exposure paradigms estimated for a "central tendency exposure" for a "maximally exposed individual," and are only feasible with contaminants or chemicals that are well-characterized with respect to exposure levels and their dose-response relationships (U.S. EPA 1989). However, the data required to adequately characterize the large number of sources of environmental contaminants in a community cannot be easily generated and may not be practical in the foreseeable future (Faust 2010). These limitations have hindered agencies at the local, regional, and state levels when initiating actions to achieve environmental justice since cumulative risk cannot be ascertained in a given community or a specific area. Hence, multiple institutions are pursuing alternate approaches to evaluate CI (OEHHA 2010). *Impact* is interpreted to mean potential effects or influences of stressors or sources that do not necessarily result in an identifiable level of injury or loss, but are known to have an influence.

Risk Versus Impact
Risk indicates a largely quantifiable approach to assessment of injury or loss, whereas impact implies a broader scope of both quantitative and semiquantitative factors that enhances the risk.

18.1.4 Cumulative Impact Assessment Tools

Community-based cumulative impact assessment approaches use scientifically justifiable, quantitative, and semiquantitative methods that permit comparisons between communities or census tracts. Current methods, including CalEnviroScreen, facilitate the relative ranking of communities with scoring systems that also allow comparisons between communities with the same score to understand the relative contributions of individual indicators representing factors that influence the cumulative impact in a community. This ability to prioritize or rank communities based on cumulative impact indicators enables assessors to more effectively represent the complex relationships between health outcomes, psychosocial stressors, and environmental exposures (Alexeeff et al. 2012).

18.1.4.1 CalEnviroScreen

The California Communities Environmental Health Screening Tool, abbreviated CalEnviroScreen, was developed by the California Environmental Protection Agency's (CalEPA) Office of Environmental Health Hazard Assessment (OEHHA) as a science-based tool for evaluating the cumulative impacts of multiple pollutants and stressors in communities (Alexeeff and Mataka 2014). The working tool reflects stakeholder input and the collaborative efforts of OEHHA and the

Cumulative Impacts and Precautionary Approaches Work Group, a collective of representatives from the private, academic, nongovernmental, and government sectors (CalEPA 2005; OEHHA 2014a).

In support of CalEPA's environmental justice mission, CalEnviroScreen assists the Agency and its departments by identifying those communities disproportionately burdened by cumulative impacts. Identifying these vulnerable communities helps the Agency and its departments to support the fair treatment of all Californians. CalEnviroScreen analyses:

- Aid decision-makers in making determinations about administering environmental justice grants.
- Inform targeted environmental law compliance and enforcement initiatives.
- Provide insight on potential implications of department activities and decisions.
- Help decision-makers prioritize site-cleanup activities and identify opportunities for sustainable economic development in heavily impacted neighborhoods (OEHHA 2014a).

Beyond its valuable uses in CalEPA, CalEnviroScreen potentially could be adapted by local and regional governments to include more precise data sets, for example, those from air and water districts or transit agencies, to facilitate community planning, engagement, and outreach efforts. CalEnviroScreen interactive maps are available on OEHHA's website. Results can be filtered by location, individual indicator, or class of indicators (i.e., pollution burden or population characteristics).

CalEPA describes CalEnviroScreen as a model that "is place-based and provides information for the entire State of California on a geographic basis." The geographic scale selected is intended to be useful for a wide range of decisions" (OEHHA 2014a). The model is comprised of two key components and four subcategories as follows: pollution burden (exposures and environmental effects) and population characteristics (sensitive populations and socioeconomic factors) (see Fig. 18.1). A suite of statewide indicators that describe pollution burden and population characteristics are assigned to each subcategory. CalEnviroScreen is a fairly simple model with a limited set of indicators. Each indicator in a given area is assigned a score that is weighted according to a scoring system. The sum of pollution indicator scores (maximum value of 10) is multiplied by the sum of population characteristic

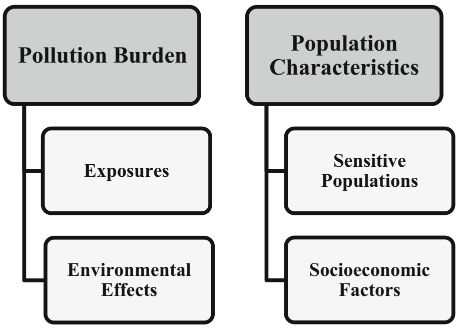

Fig. 18.1 CalEPA CalEnviroScreen tool components (OEHHA 2014a)

indicator scores (maximum value of 10) to produce a final CalEnviroScreen score with a maximum of 100. This score permits ranking of all places evaluated throughout the state relative to each other, a concept that will be discussed in more detail later in the chapter (OEHHA 2014a).

18.1.4.2 Additional Environmental Health Screening Methods

Considering cumulative impacts at the local or regional level is a practice that is gaining popularity among many decision-makers because most planning and permitting decisions take place on a local scale (Johnson Thornton et al. 2013; Corburn 2015). CI assessment leads to more informed decision-making by adding another layer of information to traditional risk assessment. Decision-makers at the statewide, regional, and community levels can utilize environmental health screening methods to guide their decision process and weigh potential impacts within a specific area or community. In the following section, we briefly describe additional approaches used to assess community-based cumulative impacts.

Environmental Justice Screening Method (EJSM) The University of Southern California Program on Environmental and Regional Equity (PERE) received a research contract from the California Air Resources Board, to develop an Environmental Justice Screening Method (EJSM) (Sadd et al. 2011). The EJSM is described as a screening approach and not as a tool because of its flexibility to include or exclude indicators or metrics, such as climate vulnerability or drinking water quality, in a given scenario (Pastor et al. 2013). EJSM incorporates data from approximately 30 metrics to generate geographic information system (GIS)-based maps of communities at the census tract scale, similar to CalEnviroScreen (Sadd et al. 2014).

The mapping approach utilizes spatial polygons that denote land use within a neighborhood such as residences, schools, health-care facilities, and playgrounds. The metrics are categorized and scored on a scale of 1 to 5 in consideration of (1) proximity to hazards, such as chrome platers and industrial emission sites; (2) air quality and estimated health risk measures, such as relative cancer risk or ambient concentration rates of ozone and particulate matter; and (3) social vulnerability measures such as poverty, race, age, home ownership rate, and birth outcomes within a community (English 2013; Sadd et al. 2011). EJSM scoring differs from CalEnviroScreen because it does not have a multiplier in the model and all indicators are weighed equally. GIS maps for the eight EJSM California regions with versions for both cumulative impact scores and select component layers are publicly available on PERE's website.

Cumulative Environment Vulnerabilities Assessment (CEVA) The University of California Davis Center for Regional Change (CRC) developed CEVA as a screening tool with the primary aim of providing a suitable framework for evaluating place-based cumulative environmental hazards that can effectively support decision-makers and environmental justice advocates in developing policy and allocating resources that assist environmentally vulnerable communities (Huang and London 2012). Similar to the EJSM, CEVA distributes pollution and population metrics into three indices or categories labeled as (1) environmental hazards that include toxic release inventory sites and refineries; (2) social vulnerability that includes locations of health-care facilities, race, and education level; and (3) health effects that include low birth weight and asthma hospitalization rates (Huang and London 2012). Each index generates a score with the higher scores indicating those communities within a census block group that are most vulnerable to adverse environmental or hazard effects. CEVA, as with the earlier versions of CalEnviroScreen, utilizes data at the ZIP code scale for some measures. Interactive Regional Opportunity Index maps are available on CRC's website to assist decision-makers in identifying regions with disproportionately disadvantaged communities.

Similar to CalEnviroScreen and EJSM, CEVA generates a spatial analysis that illustrates place-based findings that allow communities to be ranked relative to one another. CEVA's goal was to account for "both the highest concentrations of cumulative environmental hazards and the fewest social, economic and political resources to prevent, mitigate, or adapt to the conditions" (Huang and London 2012). CEVA was initially developed with a focus on Central California and Eastern Coachella Valley communities selected for their diversity in agriculture, socioeconomic status, education, language, political influence, and hazard sources (London et al. 2011, 2013).

EJSCREEN The U.S. Environmental Protection Agency created the EJSCREEN tool to assist EPA staff and managers in considering environmental justice issues. EJSCREEN uses nationwide data sets and methods to "screen for areas that may be candidates for additional consideration, analysis, or outreach as the agency develops programs, policies and activities that may affect communities" (U.S. EPA 2014). Similarly, EJSCREEN uses information at the census block group or user-defined area level and considers both demographic and environmental indicators. EJSCREEN generates an EJ index or summary of demographic information combined with a single environmental indicator (e.g., air toxics respiratory hazard). These indices generate maps, charts, and reports using a web interface. EJSCREEN contains many different environmental indicators, but only one environmental indicator is evaluated at a time in a given scenario, limiting its capacity for evaluating cumulative impacts from multiple environmental indicators. EJSCREEN is publically available, and its interactive tool can be accessed at www.epa.gov/ejscreen.

U.S. EPA continues to provide guidance for national, state, and local agencies for considering and implementing environmental justice actions in planning and decision-making. Entities such as the Federal Interagency Working Group on Environmental Justice National Environmental Policy Act (NEPA) Committee, whose members represent federal agencies subject to NEPA, aspire to design and optimize best practices for addressing environmental justice issues (U.S. EPA 2013). In addition to California, New Jersey and other states are building on U.S. EPA's example to form commissions and develop tools to facilitate the consideration and implementation of environmental justice conscious policies, such as the New Jersey Smart Growth and Environmental Justice State Planning Commission and the interactive NJ-GeoWeb environmental information tool (New Jersey 2014, 2016).

18.1.4.3 Limitations of Screening Tools

Overall, environmental health screening approaches demonstrate how the data from multiple sources can be combined and characterized to make comparisons between different geographic areas and provide helpful insights into identifying "disadvantaged communities." Evaluating information at the census tract scale, both in the context of cumulative and individual metrics, allows decision-makers to consider area- or community-specific actions that would reduce the pollution burden or decrease the vulnerability in a community. Inherent limitations to these approaches vary with the degree of accuracy, precision, and uncertainty associated with the data for each of the indicators. As tools improve and more robust data sets become available, it may be possible to reduce uncertainty by applying additional statistical analyses. This concept is similarly applied to traditional risk assessment whereby more sophisticated tools, such as benchmark dose modeling of dose-response that facilitates understanding of response levels at low doses, continue to improve and overcome current analytical limitations (U.S. EPA 2012). Other approaches to characterizing these limitations should also be explored. One current limitation is that some areas in a state or a county may have more and better quality data than others, requiring approximation or modeling to fill the data gaps. An example of this would be drinking water quality monitoring data. Densely populated areas tend to have more sophisticated drinking water systems with enhanced monitoring and quality control measures to detect contamination. More rudimentary systems or individual well sites often serve less populated areas and have very limited capabilities for monitoring drinking water contamination. Several California governmental agencies maintain databases that provide and inform decision-making tools like CalEnviroScreen.

In spite of these constraints, evidence suggests that impact assessment tools are highly beneficial in distinguishing higher-impacted from lower-impacted communities, in identifying factors that are the primary contributors to the community's cumulative impact, and in assisting regulatory agencies in allocation of resources and more effective prioritization of area-specific mitigation efforts. Evaluation of the accuracy of these tools and the value of the results is ongoing. One example of this is with EJSM and the Los Angeles Collaborative for Environmental Health and Justice (LACEHJ 2010). This cooperative of community organizations and academic researchers serves as a "frontline" team that assesses the merits and limitations of applying the Environmental Justice Screening Method in communities throughout the Greater Los Angeles Area (Sadd et al. 2011, 2014). CalEPA and OEHHA continue to hone and evaluate CalEnviroScreen, soliciting stakeholder input throughout the process. In this chapter, the focus is on CalEnviroScreen as a model screening tool because it encompasses a robust number of indicators, includes communities across the state, and is currently used by decision-makers within the California government.

18.2 CalEnviroScreen: California Communities Environmental Health Screening Tool

18.2.1 Design Factors and Considerations: Modeling Environmental Justice Concepts

CalEnviroScreen is a tool that combines multiple sets of data on pollutants and stressors in a geographic area to screen for places with the highest cumulative burdens. The tool creates one combined measure, the CalEnviroScreen score, for visualizing geographies in California that are most burdened. This combined index, as well as the underlying data sets, is made publicly available through OEHHA's website. Users of the tool can view the information as both static and interactive web maps and can download the results in various formats. The tool is not updated continuously but rather represents a snapshot of the data at the time of the release. Each version of CalEnviroScreen is the product of extensive public input and reflects the concerns of many stakeholders in California, including community-based organizations and the general public. Users, however, cannot add data to CalEnviroScreen after a version is released, but can submit feedback on additional data sets or gaps that may be addressed in the next revision. OEHHA updates CalEnviroScreen as additional relevant, statewide data sets emerge.

The early CalEnviroScreen versions (1.0 and 1.1) utilized data organized by ZIP code and included fewer indicators. The 2.0 version analysis[1], released in October 2014, contains additional indicators and now analyzes community data at the census tract scale because census tract data (approximately 8000 tracts in California) provides a finer scale of resolution for many California regions (U.S. Census Bureau 2010). Tracts are comprised of multiple block groups that contain several blocks each, with a block being the smallest geographic unit for which population data are available. In California, not all census blocks are populated. Independent of the version, CalEnviroScreen (OEHHA 2014a):

- "Produces a relative, rather than absolute, measure of impact.
- Provides a baseline assessment and methodology that can be expanded upon and updated periodically as important additional information becomes available.

[1]A subsequent version of CalEnviroscreen (3.0) with additional indicators and some modifications has been released since this chapter was authored. CalEnviroScreen 3.0 can be accessed at https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30.

- Demonstrates a practical and scientific methodology for evaluating multiple pollution sources and stressors that takes into account a community's vulnerability to pollution."

The next section expands on the CalEnviroScreen methodology, including indicator selection, indicator scoring, and the relative ranking scheme. These indicators model *stressors* or factors that contribute to the pollution burden or vulnerability within a community. Indicator selection and the data that accompany these indicators determine the total CalEnviroScreen score. The final CalEnviroScreen scores provide the basis for the ranking scheme that ultimately models the community-based cumulative impact.

18.2.2 Indicator Selection: Translating Environmental Justice Concepts into Operation

18.2.2.1 Indicator and Component Scoring

CalEnviroScreen indicators are selected based on two general considerations, (1) "information that will best represent statewide pollution burden and population characteristics" and (2) "the availability and quality of such information at the necessary geographic scale statewide" (OEHHA 2014a). These indicators are proxies for the characteristics they model. CalEnviroScreen models California communities at the census tract scale, so indicator data should be available statewide and translate to census tracts. This approach poses considerable challenges for assessors to evaluate those regions with significant data gaps for a potential indicator of interest. Hence, it is important to select data sets that are as accurate, complete, and current as possible at the state level.

The following is an overview of the indicator selection and scoring process (OEHHA 2014a):

1. "Identify potential indicators for each component.
2. Find sources of data to support indicator development.
3. Select and develop indicator, assigning a value for each geographic unit.
4. Assign a percentile for each indicator for each geographic unit, based on the rank-order of the value.
5. Generate maps to visualize data.
6. Derive scores for pollution burden and population characteristics components.
7. Derive the overall CalEnviroScreen score by combining the component scores.
8. Generate maps to visualize overall results."

CalEnviroScreen is applied to the entire state, but it is worth emphasizing that modeled data sets provide a "broad environmental snapshot of a given region" (OEHHA 2014a). A specific indicator, such as toxic cleanup sites, may be a robust marker of pollution burden, but any given region may not have any toxic cleanup sites. In such cases, this indicator is scored as zero. Alternatively, when there are not enough data to conclusively identify the presence or absence of an indicator in a specific area, such as the lack of an air monitoring station within a certain distance, it is removed from the calculation, and no score is assigned for that indicator. Next, census tract indicator raw values above zero are ordered from highest to lowest values. These ordered values are used to calculate a percentile for all areas that have a score.

Generally speaking, the percentile indicator for a select geographic area describes the percentage of California with lower values for that indicator. For example, a 75th percentile for that indicator or suite of indicators means a select geographic area is higher or more impacted compared to 75% of all other geographic areas in California. The magnitude of difference between two or more areas cannot be calculated from the difference in percentiles because of the shape of the distribution of the data. For example, the difference between the 75th and 50th percentile may not be the same as the difference between the 50th and the 25th percentile.

Pollution Burden Indicators Gathering information about direct environmental exposures poses a significant challenge as such data sets are limited and not readily available on a statewide level. Evaluating how individuals or populations come in contact with chemicals from air, water, food, or soil sources can be indirectly modeled by considering data sets relating to pollution sources, releases, and environmental concentrations. CalEnviroScreen takes this approach and includes seven *exposure indicators*: ozone concentrations in air, $PM_{2.5}$ concentrations in air (particulate matter or particles with a diameter measuring less than 2.5 microns), diesel particulate matter emissions, certain high-hazard/high-volatility pesticide use, toxic releases from facilities, traffic density, and drinking water contaminants (see Table 18.1).

When evaluating environmental effects, it is important to consider several concepts. Effects reflect a process, whether immediate or delayed, and can include environmental degradation, ecological system changes, and human lifestyle or activity changes for individuals or populations (Fan et al. 2010; Howd 2010). Communities and the environment can experience a myriad of effects when physical, biological, and chemical pollutants are released into the environment (Alexeeff et al. 2012). These effects vary by the nature, degree, and prevalence of environmental harm. Whether directly impacted through contact exposure or indirectly affected by shifts in routine practices, including restricted swimming or fishing in local waterways or changes in local traffic patterns, environmental effects can lead to elevated stress that results in adverse human health impacts (Gee and Payne-Sturges 2004). CalEnviroScreen incorporates the following five indicators to model *environmental effects*: toxic cleanup sites, groundwater threats from leaking underground storage sites and cleanups, hazardous waste facilities and generators, impaired water bodies, and solid waste sites and facilities (see Table 18.1).

Population Characteristic Indicators The process of identifying sensitive populations with increased vulnerability to the effects of pollution can be

Table 18.1 CalEPA CalEnviroScreen pollution burden indicators

	Indicator	Description
Exposures	$PM_{2.5}$ concentrations	Annual mean concentration of $PM_{2.5}$ over 3 years (2009–2011)
	Ozone concentrations	Daily maximum 8-h ozone concentration over the California 8-h standard (0.070 ppm), averaged over 3 years (2009 to 2011)
	Diesel PM emissions	Diesel PM emissions from on-road and non-road sources for a 2010 summer day in July (kg/day)
	Drinking water contaminants	Drinking water contaminant index for selected contaminants
	Pesticide use	Pounds of selected active pesticide ingredients used in production-agriculture per square mile
	Toxic releases from facilities	Toxicity-weighted concentrations of modeled chemical releases to air from facilities
	Traffic density	Vehicle-kilometers per hour divided by total road length (kilometers) within 150 meters of the census tract boundary
Environmental effects	Cleanup sites	Sum of weighted DTSC* cleanup sites
	Groundwater threats	Sum of weighted SWRCB** groundwater cleanup sites
	Hazardous waste facilities and generators	Sum of weighted permitted hazardous waste facilities and large quantity hazardous waste generators
	Impaired water bodies	Sum of number of pollutants from water bodies designated as impaired
	Solid waste sites and facilities	Sum of weighted solid waste facilities

*Data acquired from the Department of Toxic Substances Control
**Data acquired from the State Water Resources Control Board

challenging. Within a given area, factors such as health status and age can predispose individuals to adverse health outcomes and vary widely, independent of pollution (August et al. 2012; English 2013). CalEnviroScreen incorporates three indicators that may suggest increased health vulnerabilities associated with toxic chemical exposures. Robust data sets are available statewide for the following three *sensitive population indicators*: prevalence of children and elderly populations, asthma emergency department visit rates, and the rate of low-birth-weight infants (see Table 18.2).

Emerging research supports the finding that socioeconomic status, including education level and employment status, is a significant factor in gauging the vulnerability of populations to pollutants (LACEHJ 2010; English 2013). Language barriers, prevalence of individuals with less than a high school education, and disproportionate unemployment rates can reduce a community's ability to adapt to or cope with pollution (LACEHJ 2010; Ramey et al. 2015). CalEnviroScreen integrates four socioeconomic factors that link pollution with adverse health impacts. *Socioeconomic factor indicators* include educational attainment, linguistic isolation, poverty, and unemployment (see Table 18.2).

Table 18.2 CalEPA CalEnviroScreen population characteristic indicators

	Indicator	Description
Sensitive populations	Age (children and elderly)	Percentage of the population under age 10 or over age 65
	Asthma emergency department visit rate	Age-adjusted rate of emergency department visits for asthma per 10,000, spatially modeled (2007–2009)
	Low-birth-weight rates	Percentage of low-birth-weight infants under 2500 grams, spatially modeled (2006–2009)
Socioeconomic factors	Educational attainment	Percentage of the population over age 25 with less than a high school education
	Linguistic isolation	Percentage of households in which no one age 14 and over speaks English "very well" or speaks English only
	Poverty	Percentage of residents below two times the national poverty level
	Unemployment	Population over age 16 that is unemployed and eligible for the labor force

Collectively, CalEnviroScreen integrates these seven exposures and five environmental effect indicators to model relative pollution burden impacts and three sensitive population and four socioeconomic factor indicators to model relative population characteristics. The methodology and rationale for each specific indicator are described in detail in the CalEnviroScreen document *California Communities Environmental Health Screening Tool, Version 2.0 (CalEnviroScreen 2.0) Guidance and Screening Tool* (OEHHA 2014a).

18.2.2.1.1 CalEnviroScreen Score and Maps

The final CalEnviroScreen score is the product of the indicator value of the pollution burden and the indicator value of the population characteristics (see Fig. 18.2). The pollution burden component is composed of seven exposure and five environmental effect indicators. The environmental effect indicator values are multiplied by one-half (noted by an asterisk *) to weight them half as much as the exposure indicators because exposure sources generally contribute more than environmental effects to total pollution impact (OEHHA 2014a) (see Fig. 18.2 and Table 18.1). The population characteristic component is comprised of three sensitive population and four socioeconomic factor indicators with all seven indicators weighted equally (see Fig. 18.2 and Table 18.2).

The final scores for both components are calculated as follows (OEHHA 2014a):

1. Average the percentiles for all individual indicators in a group (group: exposure and environmental effects). Environmental effects are weighted half as much as exposure indicators, making the pollution burden a weighted average.

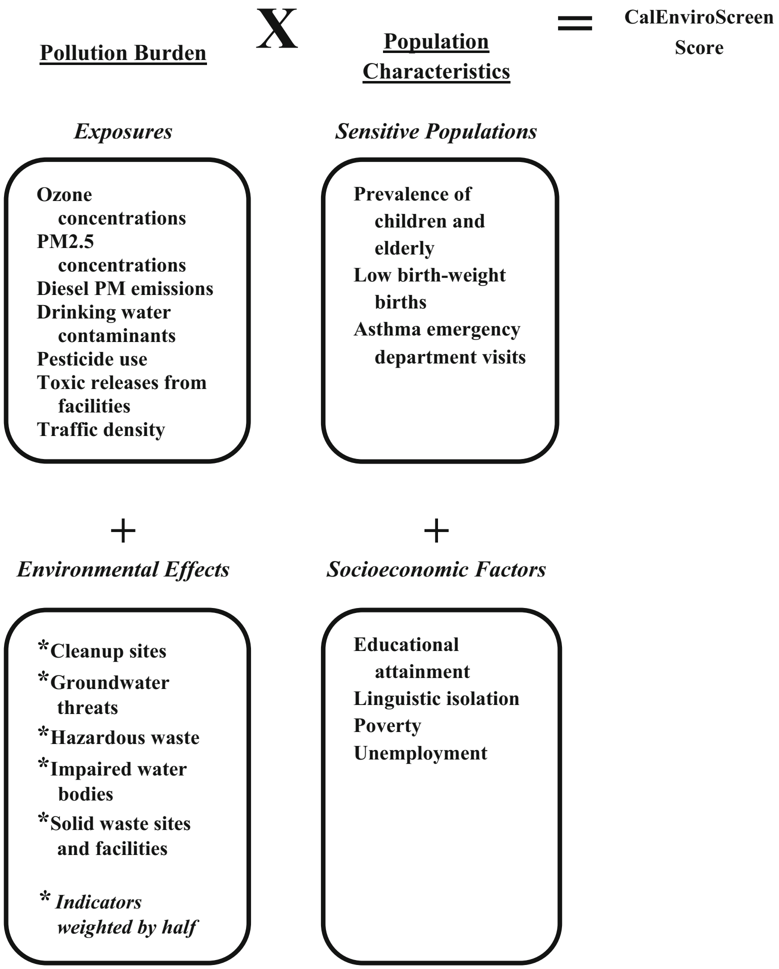

Fig. 18.2 CalEPA CalEnviroScreen model

2. Pollution burden and population characteristic percentile averages are scaled with a maximum value of 10 and a range of 0.1–10. Each average is divided by the maximum value observed in the state and multiplied by 10. Scaling ensures that the pollution and population components contribute equally to the final CalEnviroScreen score.
3. The final CalEnviroScreen score for an area is calculated as the final pollution burden score multiplied by the final population score with a possible total of 100. This final CalEnviroScreen score for each area is then used to rank all the areas from highest to lowest, based on their overall score. The percentile for the overall score is calculated. Geographic maps are generated to illustrate the percentiles for

all census tracts statewide. Highest ranking percentiles are generally brightly colored to indicate the area of greatest impact.

18.2.2.1.2 Uncertainty and Error

Even with careful data set selection, assessors must account for uncertainties. Such uncertainties can develop for any number of reasons, including database gaps or inaccuracies, changing environmental conditions over time, and the limited capacity of selected indicators to measure outcomes or exposures of interest. Despite these uncertainties, CalEnviroScreen remains a powerful tool in identifying those communities most adversely impacted due to its ranking function, particularly when modeling data sets where the highest or lowest 15–20% of communities is of great interest.

Identifying Community Profiles and Key Drivers By taking a look at the individual component and indicator scores, one can understand the similarities and differences between two communities having similar scores. Communities can have nearly equivalent overall scores but be comprised of vastly different scoring for pollution burden and population characteristic profiles. For example, a census tract in Lamont, near Bakersfield in the Central Valley, and a census tract in Long Beach in the Los Angeles region, both have overall scores of 48, placing them among the top 10 percent of the most impacted census tracts in California (see Fig. 18.3 and Tables 18.3 and 18.4).

The Lamont tract has very high scores for ozone, particulate matter, drinking water contaminants, and pesticides while scoring only moderately among the other pollution burden indicators. In contrast, the Long Beach tract has very high scores for diesel, toxic releases, traffic density, groundwater threats, and impaired water bodies while scoring only moderately for indicators for which Lamont scored highly. The Long Beach tract scores slightly higher for the overall pollution score, while the Lamont tract scores higher for the overall vulnerable population and socioeconomic score. The two components combine to yield a very similar overall score, meaning that the two tracts are viewed as equally disadvantaged in CalEnviroScreen.

A third census tract in Richmond near the San Francisco Bay Area, compared here, demonstrates that despite scoring slightly lower in the overall pollution score when compared to the other two tracts, a very high population characteristic component still yields a relatively high overall score. The Richmond tract scores highly in the diesel indicator as well as for several environmental effect indicators while scoring extremely high in the vulnerable population and socioeconomic indicators. The overall score of 45 (compared to the other two with a score of 48) places the tract among the top 15 percent of the most impacted census tracts in California (Fig. 18.3).

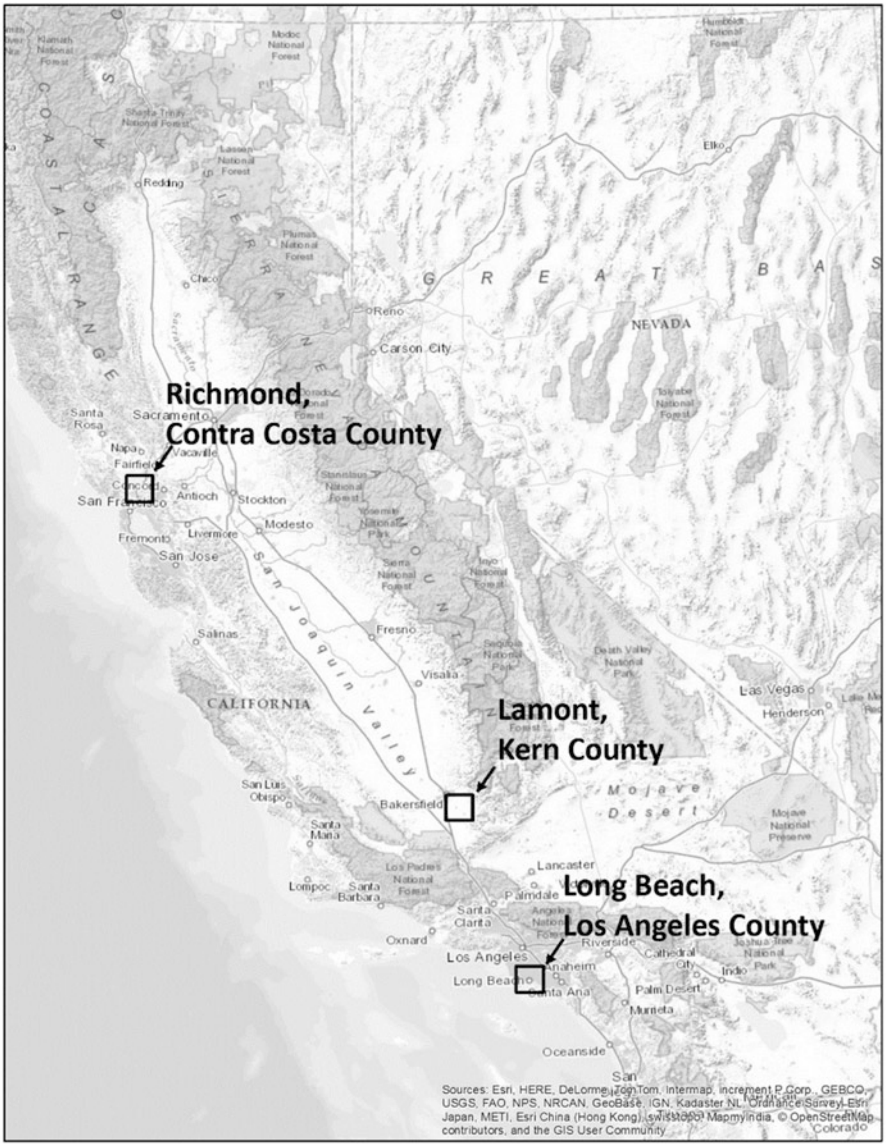

Fig. 18.3 Census tracts with similar CalEnviroScreen scores

18.2.3 Applying Community-Based Concepts to Decision-Making

CalEnviroScreen was developed through a highly public and interactive process that aligns well with the U.S. EPA's *Guidance on Considering Environmental Justice*

Table 18.3 Identifying major drivers from CalEnviroScreen scores in three census tracts

Location	Lamont, Kern County	Long Beach, Los Angeles County	Richmond, Contra Costa County
Census tract	(6029006401)	(6037572201)	(6013379000)
Population	8,320	6,197	6,117
CalEnviroScreen score	*48.14* (91–95th percentile)	*47.93* (91–95th percentile)	*45.49* (86–90th percentile)
Pollution burden	*Medium-high* (78th percentile)	*Very-high* (92nd percentile)	*Medium* (57th percentile)
Population characteristics	*Very-high* (90th percentile)	*Medium-high* (74th percentile)	*Very-high* (98th percentile)
Main drivers (≥80th percentile)	Ozone, $PM_{2.5}$, drinking water, pesticides, education, linguistic isolation, poverty	Diesel, toxic releases, traffic density, groundwater threats, impaired water, asthma, low birth weight	Diesel, cleanup sites, groundwater threats, hazardous waste, impaired water, asthma, low birth weight, education, poverty

During the Development of Regulatory Actions (Alexeeff and Mataka 2014; U.S. EPA 2015). CalEPA and OEHHA held multiple meetings with stakeholders which included community and environmental justice organizations, academia, other government agencies, and industry groups, then released interim CalEnviroScreen drafts for public comment, and conducted a dozen workshops that solicited extensive written and oral comment feedback (OEHHA 2013; OEHHA 2014b). During the conceptual phase of CalEnviroScreen's development, CalEPA and OEHHA began devising general principles that gauge and strategize efforts in the context of assessing chemical hazards from multiple sources within communities. Many studies, including individual community-based studies, served as a training ground for honing both the principles and practices of community-based cumulative impact assessment (Dunn and Alexeeff 2010).

18.2.3.1 Community-Based Studies in Decision-Making

Four general principles were derived from examining several case studies and are discussed in detail by Dunn and Alexeeff (2010). These principles can be summarized as follows: (1) consider exposure patterns and cultural practices, (2) identify populations with increased susceptibility, (3) understand the cumulative impacts, and (4) involve the community in all phases of an assessment (Dunn and Alexeeff 2010). These guiding principles were drawn from an evaluation of four diverse case studies. These included a study of traffic-related air pollution and childhood respiratory diseases around San Francisco Bay Area schools, sport fishing advisories related to chemical contamination of fish in general and in specific water bodies throughout California, a risk assessment of a chromium "hot spot" in a poor Latino

Table 18.4 Percentile ranking of individual indicators in three census tracts

LOCATION	Lamont, Kern County	Long Beach, Los Angeles County	Richmond, Contra Costa County	
Ozone	**95**	0	0	POLLUTION BURDEN
$PM_{2.5}$	**99**	67	17	
Diesel	21	**93**	**86**	
Drinking Water	**100**	24	3	
Pesticides	**95**	29	0	
Toxic Releases	25	**95**	77	
Traffic Density	9	**86**	46	
Cleanup Sites	76	56	**98**	
Groundwater Threats	16	**88**	**90**	
Hazardous Waste	0	39	**89**	
Impaired Water	0	**90**	**86**	
Solid Waste	0	73	0	
Age	66	73	73	POPULATION CHARACTERISTICS
Asthma	36	**81**	**98**	
Low Birth Weight	71	**94**	**98**	
Low Education	**98**	55	**82**	
Linguistic Isolation	**94**	44	75	
Poverty	**94**	40	**80**	
Unemployment	60	60	77	

community of San Diego known as Barrio Logan, and a study of lead exposure in Latino children throughout San Diego County.

In the sport fishing advisories case, OEHHA approached the development of advisories with an awareness of cultural practices that may increase the risks of exposure and adverse health effects that arise from eating fish contaminated with chemicals, including methylmercury and polychlorinated biphenyls (PCBs)

(OEHHA 2001). Fish consumption is much greater among some minority populations, namely, Southeast Asians, and low-income subsistence sport fishers, groups that rely on sport fishing as a major source of dietary protein (Dunn and Alexeeff 2010). These groups may also engage in practices that increase the risk for exposure, including consumption of the entire fish (OEHHA 2001). Subpopulations within these communities, including children and pregnant women, were identified as susceptible subpopulations with increased risk for adverse effects from exposure to multiple contaminants, such as methylmercury and PCBs, due to their harmful and cumulative effects on neural development (U.S. EPA 2004; Davis et al. 2012).

OEHHA evaluated the potential harmful effects from exposure to contaminants common in fish along with the health benefits of eating fish. OEHHA developed fish advisories for California sport fishers that provided guidance on fish cooking and preparation methods and recommendations for fish consumption, especially for sensitive groups such as children and pregnant women. To further enhance community outreach, OEHHA created signs and pamphlets in multiple languages to better inform communities that may not otherwise be aware of potential adverse health effects associated with eating contaminated fish. These recommendations help individuals reduce their exposure risk by modifying consumption practices based on the species, size, and number of fish consumed. The principles derived from this case study and the consideration of additional factors that influence the vulnerability within a population contributed significantly to the development of CalEnviroScreen, particularly when selecting population characteristic indicators.

18.2.3.2 CalEnviroScreen in State Regulatory Activities

Each case study highlights not only the diversity of exposure sources but also the complex factors that affect individual communities. Cultural practices and lifestyle, not just how close a population is to a pollution source, influence how and to what extent individuals within a community can be exposed (CDC 2002). Understanding the biological characteristics or types of preexisting conditions that increase the vulnerability of certain individuals to adverse pollution impacts helps to identify susceptible subpopulations within a community (de Fur et al. 2007; Medina-Ramon and Schwartz 2008; Zanobetti and Schwartz 2011). These concepts contributed to the development of CalEnviroScreen and helped focus its original purpose which was to assist CalEPA departments and the state of California in carrying out its environmental justice mission, and to continue to be a useful tool for this end.

In addition, as discussed in Alexeeff and Mataka (2014), CalEnviroScreen is a valuable resource in many additional ways. One important way CalEnviroScreen is being used is to identify disadvantaged communities for allocation of cap-and-trade funds generated under the Global Warming Solutions Act of 2006 (De Leon 2012). Of the total monies allocated from the Greenhouse Gas Reduction Fund, 25 percent "must go to projects that provide a benefit to disadvantaged communities," and a "minimum of 10 percent of the funds must be for projects located directly within disadvantaged communities" (CalEPA 2014). Another use of CalEnviroScreen is by

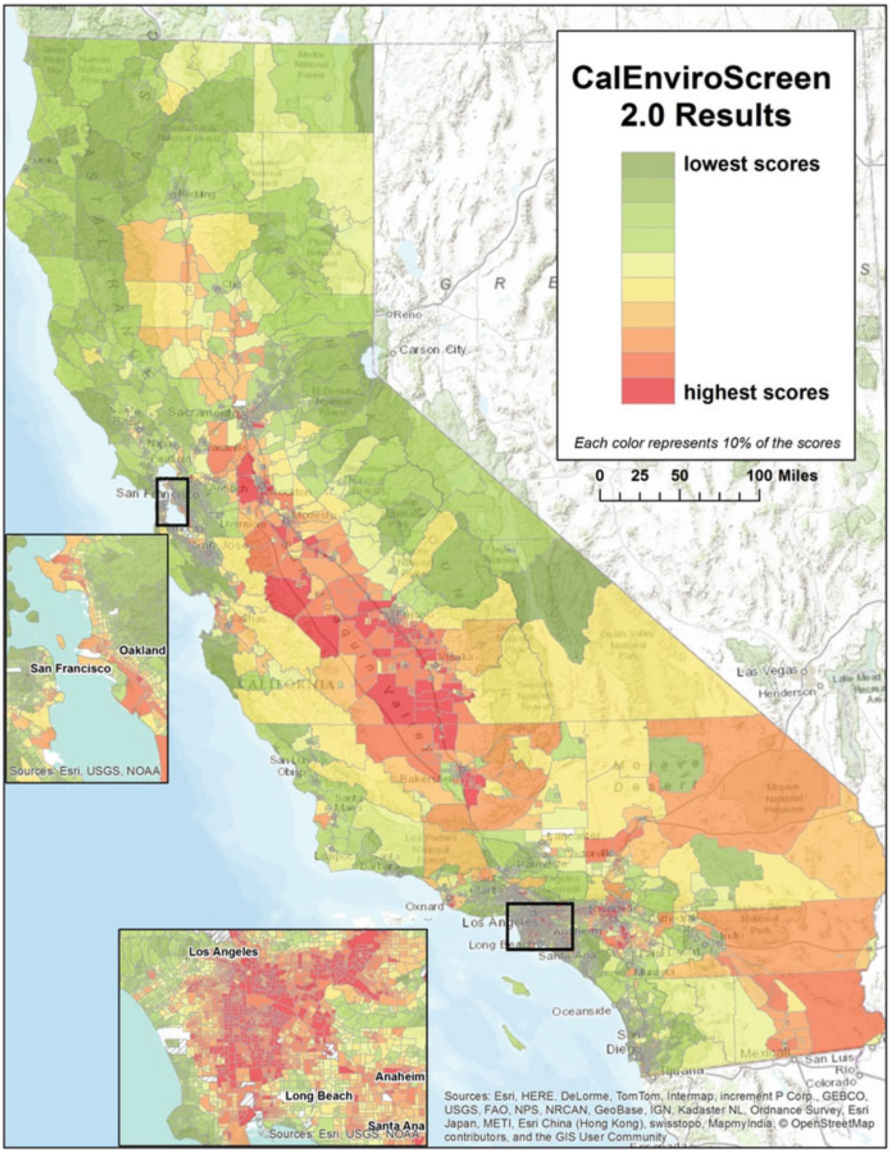

Fig. 18.4 CalEPA CalEnviroScreen statewide results

other state entities, including the Strategic Growth Council, who use CalEnviroScreen results to select communities where resources allotted under sustainable community grant funding can be most effectively distributed. An example of statewide CalEnviroScreen results is illustrated in Fig. 18.4. CalEnviroScreen facilitates collaboration between CalEPA departments, like OEHHA and the Air

Resources Board (ARB), in adapting monitoring and health benefit programs for those communities disproportionately impacted. These communities are highlighted by a specific indicator, such as air pollution hot spots (Dunn and Alexeeff 2010). Ultimately, the success of the state's application of CalEnviroScreen has led to inquiries from smaller regulatory entities about how the tool can be further scaled to provide relevant information to more effectively assist in decision-making at the city or county level. For example, decision-makers for the Greater Los Angeles Area can use CalEnviroScreen results for both population characteristics and pollution burden, such as those presented in Fig. 18.5, to identify which smaller communities may warrant a more refined scale of analysis.

18.3 Challenges and Next Steps: Future Directions in Community-Based Cumulative Impact Assessment

Risk assessment as currently practiced in environmental regulatory programs at the federal, state, and local levels is typically designed to evaluate a single contaminant or source, in one media type, and is based on the concept of risk thresholds that are considered either safe or acceptable (NAS 1983). An acceptable risk level is often set as a target and considers several factors associated with meeting the target level (ATEB 2008, 2009). These factors include evaluating the pollution control technology available in the foreseeable future, potential costs to the owners of the source, and costs subsequently passed on to the consumer. Thus, traditional quantitative risk assessment and the practices and policies that develop in response to assessment findings play a decisive role in our society. Risk assessment is evolving, particularly at the federal level. U.S. EPA, with guidance from the National Research Council Committee on Improving Risk Analysis, is broadening traditional concepts to improve both the utility and technical approaches used in risk analysis (NAS 2009). One key shift is to involve input from stakeholders early in the planning process. However, these expanded approaches still focus primarily on risk, not impact.

In contrast to the traditional assessment paradigm, people face scenarios with exposure to multiple contaminants from multiple sources. The resulting risks and impacts are also influenced by nonchemical factors and require additional approaches to integrate both chemical and nonchemical stressors. The relative ranking of communities, expressed as percentiles in CalEnviroScreen, provides a snapshot of the existing conditions, not a measure of potential risk. Increased pollution burden and poor socioeconomic status frequently go hand in hand. However, the underlying causes for this collinearity can differ significantly in different parts of state.

To design adequate and effective strategies to reduce the observed disparities, it is important to evaluate the causes that influence variability, depending on the location. Urban sprawl and zoning flaws can contribute to the formation of source clusters and resource limitations in some neighborhoods (LACEHJ 2010; Schwartz et al. 2015).

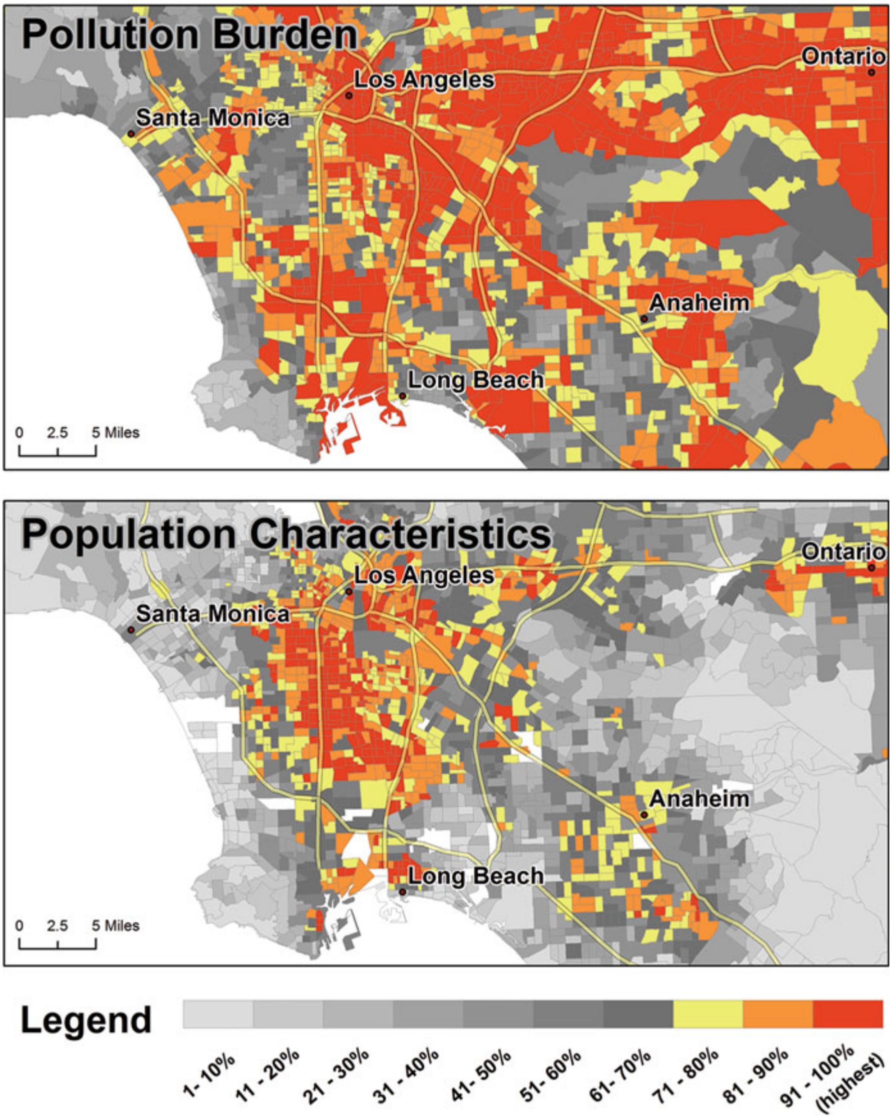

Fig. 18.5 CalEPA CalEnviroScreen results for (**a**) pollution burden and (**b**) population characteristics for the Greater Los Angeles Area

For example, past efforts to minimize expenses involved in freeway and major roadway expansion or building new roadways to meet the transportation needs of urban sprawl could have been responsible for the observed increased risk to people living near these structures. Similarly, major economic fluctuations could have led to gentrification that brings lower socioeconomic status population segments closer to sources (Pohanka and Fitzgerald 2004; Porebski et al. 2014; Shmool et al. 2015). In some multi-source clusters, individual sources may comply with the "safe" or "acceptable" set emission/discharge limit, but collectively the area or the community could be exceeding these safe or acceptable levels of risk or impacts (Batterman et al. 2014).

Although people living in such communities have demanded that cumulative impact assessments be included and considered in the context of siting, permitting, zoning, and other decision-making processes, researchers have stated that both regulatory agencies and legislative bodies have yet to take specific actions to move in that direction (Johnson Thornton et al. 2013; Corburn 2015). In addition, reluctance among some business and industry groups to support a move toward CI assessments often stems from the contention that such "redlining" could economically isolate or harm those communities (Pager and Shepherd 2008; Tso et al. 2011; Gase et al. 2014). In some instances, reconciling the realities of cumulative impacts with the potential scale of economic impacts involved to take remedial action seems to pose major challenges for any near-term legislative or regulatory action in the current political climate at the federal level. Yet, the bold step taken by the California legislature to incentivize investment in these disadvantaged communities with the allocation of cap-and-trade funds is noteworthy.

Methodological challenges that face CalEnviroScreen and other environmental health screening tools include (1) the influence of the number of indicators that are proxies for sources or media and how those are modeled, (2) capturing the strength of skewed data sets that are often associated with pollution levels and population characteristics, (3) evaluating how regional variations in cost of living may affect estimates of socioeconomic vulnerability, and (4) providing a format of quantitative information to track area-specific changes over time. Assessors confront these challenges in attempts to meet the expectations of communities throughout California. Through improved data quality, better statistical approaches, the addition of valid indicators, and constructive feedback from CalEnviroScreen users, this tool can be further modified and adapted to increase its utility.

The momentum to include cumulative impact assessment in the decision-making process is building across the country, and more methods are likely to evolve in the near future. Many are of the view that CI assessment at a local or regional level is critical since most of the growth planning, siting, and permitting decisions take place at the regional or local level (Johnson Thornton et al. 2013; Corburn 2015). A list of actions that can be considered in cumulatively impacted areas could include (1) requiring alternate buffer zone limits for new buildings from sources like refineries, landfills, oil and gas operations, agricultural lands, major roadways, and ports; (2) including permit conditions that limit the days, timing, or methods of pesticide application to reduce drift exposure; and (3) modifying area-specific risk thresholds for new and existing sources, if necessary (Prasad and Murphy 2016). Thus, CI assessment provides an additional layer of information to traditional risk assessment, leading to more informed decision-making.

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