CUMULATIVE IMPACTS: BUILDING A SCIENTIFIC FOUNDATION

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Cumulative Impacts: Building a Scientific Foundation

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DISCLAIMER:

This report was developed by the Office of Environmental Health Hazard Assessment (OEHHA) for use as a basis for further scientific evaluation and technical discussion. It is not a regulatory action and does not have the force or effect of a regulation.

This report presents the first step in developing a screening methodology to evaluate the cumulative impacts of multiple sources of pollution in specific communities or geographic areas. The scientific screening methodology is intended for eventual use by the boards, departments and office of the California Environmental Protection Agency (Cal/EPA). Cal/EPA intends shortly to initiate the development of guidelines to accompany this methodology. Until these guidelines are completed, the scientific screening methodology discussed in this report is not to be used for regulatory purposes, including the permitting of facilities or compliance with the California Environmental Quality Act. Whether and how the scientific screening methodology should be used in permitting or other regulatory processes is a topic that needs more discussion within Cal/EPA and more input from the Cumulative Impacts and Precautionary Approaches (CIPA) Work Group and other stakeholders.

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PREFACE: A NEW WAY OF LOOKING AT PEOPLE AND PLACES

The California Environmental Protection Agency (Cal/EPA or Agency) is committed to promoting environmental justice (EJ), which state law defines 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.[1] Achievement of environmental justice will require new tools and approaches to address the combined effects of various pollutants, rather than considering them one at a time.

Cal/EPA's Environmental Justice Action Plan directed the Cal/EPA Boards and Departments to develop guidance on cumulative impacts and precautionary approaches. In February 2005, the Cal/EPA Interagency Working Group on Environmental Justice (IWG)[2] adopted working definitions for the basis of Cal/EPA's cumulative impacts and precautionary approaches guidance development effort. According to the working definition, cumulative impacts means:

> "the 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 socio-economic factors, where applicable and to the extent data are available."

The precautionary approaches working definition is:

> "taking anticipatory action to protect public health or the environment if a reasonable threat of serious harm exists, even if absolute scientific evidence is not available to assess the exact risk."

Cal/EPA designated the Office of Environmental Health Hazard Assessment (OEHHA) to lead the development of guidance on cumulative impacts. This report presents a framework toward fulfilling this goal. A framework for the development of guidance for precautionary approaches will be addressed in a separate document.

This report describes a methodological approach to screen for relative cumulative impacts of pollution in different California communities in a structured and focused manner. Based on the IWG's working definition of cumulative impacts, the report explains the key components that make up cumulative impacts and provides both scientific and decision-making discussions and outlines proposed actions and next steps that Cal/EPA can pursue.

Cal/EPA's screening methodology (Chapter 4) proposes creating a fuller picture of impacts from pollutants that a population may face. This starts with an understanding of which individuals, or groups of people, may be more sensitive to additional exposures. By considering social factors such as educational level, economic factors such as income level, and other factors, Cal/EPA can develop a more complete picture of the cumulative impacts on communities.

We hope this will result in a broader and more meaningful understanding of the connections in California's various communities between multiple pollutants and the vulnerability of local residents to those pollutants.

The screening methodology discussed in this report, along with future refinement of the methodology and development of guidelines for its use, will help Cal/EPA to incorporate cumulative impacts into its work to promote environmental justice. Cal/EPA plans to continue to explore these concepts and build on these tools and methods in the years ahead. The scientific screening methodology in this report is not to be used for regulatory purposes.

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[1] California Government Code Section 65040.12.

[2] The Interagency Working Group is composed of: the Secretary for Environmental Protection; the Chairs of the State Air Resources Board and the Water Resources Control Board; the Director of Toxic Substances Control; the Director of Pesticide Regulation; the Director of Environmental Health Hazard Assessment; and the Director of the Governor's Office of Planning and Research.

Thank You to Our Partners

This report is a collaborative effort involving many entities. Cal/EPA acknowledges the following for their invaluable contributions to its development, and anticipates strengthening existing ties with these partners (and new ones):

- The Office of Environmental Health Hazard Assessment for leading the development of this report.
- The Cumulative Impacts and Precautionary Approaches Work Group (CIPA Work Group), an external stakeholder group that provided early and ongoing advice within the context of environmental justice.
- Representatives of environmental justice organizations, other non-governmental organizations and members of the public for providing comments and sharing ideas.
- Our academic partners at the University of California at Berkeley (UCB) and the University of California at Riverside (UCR) campuses for reviewing the relevant scientific literature, developing new methods and concept papers, examining case studies, and assisting OEHHA in planning and conducting meetings of the CIPA Work Group.
- The Cal/EPA Boards and Departments, for their participation and input in this project.

EXECUTIVE SUMMARY

The California Environmental Protection Agency (Cal/EPA or Agency) Environmental Justice Action Plan[3] calls for the Agency and its Boards, Departments, and Office to develop guidelines for evaluating cumulative impacts. The Agency designated the Office of Environmental Health Hazard Assessment (OEHHA) to lead the development of these guidelines. As a first step toward developing such guidelines, OEHHA prepared this report as a framework in consultation with Cal/EPA's Cumulative Impacts and Precautionary Approaches Work Group.[4] It provides scientific evidence for cumulative impacts, describes methodologies for assessing cumulative impacts, presents a new screening methodology for use by the Cal/EPA Boards and Departments, and presents next steps in the implementation of the Cal/EPA Environmental Justice Action Plan.

The report's foundation is the working definition of "cumulative impacts" adopted by Cal/EPA's Interagency Working Group on Environmental Justice (IWG):

> Cumulative impacts means 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 socio-economic factors, where applicable and to the extent data are available.

The IWG recognized that it is essential to address the combined effects of various pollutants rather than considering them one at a time. Numerous studies have shown that multiple pollution sources are disproportionately concentrated in low-income communities with high-minority populations. Also, a number of studies have reported increased sensitivity to pollution, for communities with low income levels, low education levels, and other biological and social factors. This combination of multiple pollutants and increased sensitivity in these communities can result in a higher cumulative pollution impact.

Consistent with the IWG's working definition, the report explains how the assessment of cumulative pollution impact on a community must include not only the levels of pollutants but also the public health effects found in the community from the pollution, such as asthma and cancer, and the degradation of the environment. Also consistent with the IWG's working definition, the report explains that sensitivity and socioeconomic factors of the population must also be accounted for when assessing cumulative impacts. An appendix to the report describes key scientific methods to assess cumulative impacts from an inventory.

The report lays out a new screening methodology for analyzing cumulative impacts that takes into account all the above factors. This screening methodology is not designed to serve as a quantitative assessment of community health impacts, nor is it intended to support "redlining" of communities. It can be used as a relative ranking method to distinguish higher-impacted communities from lower-impacted communities and may help identify which factors are the greatest contributors to cumulative impact.

This screening methodology is not comprehensive, is not sensitive to small changes in impact, and cannot determine the cause of health outcomes in a community. The methodology is a screening tool that, once fully developed, will help Cal/EPA programs prioritize their activities and target those communities with the greatest cumulative impacts. The scientific screening methodology presented in this document is intended for eventual use by Cal/EPA's boards, departments, and office. Until guidelines

[3] Appendix 1, California Environmental Protection Agency (Cal/EPA or Agency) Environmental Justice Action Plan.
[4] Appendix 2, Cal/EPA's Cumulative Impacts and Precautionary Approaches Work Group.

are developed, the scientific screening methodology is not to be used for regulatory purposes.

The report proposes that Cal/EPA will develop guidelines for use of this screening method. The proposed guidelines will provide a mechanism to further address scientific issues related to the application of the method. Cal/EPA Boards and Departments will need to tailor the screening method to specific programs and policies. The report also suggests the necessity for Cal/EPA to continue to develop a more refined methodology for in-depth applications, while using the screening methodology as a foundation to improve pollution and public health databases for cumulative impacts analyses and to review and modify Cal/EPA policies and procedures relevant to cumulative impacts.

INTRODUCTION

Many Californians live in close proximity to multiple sources of pollution. Past industrial activities in many areas have left a toxic legacy of Brownfields and Superfund sites where chemicals seeped into underlying soil and groundwater.

Despite regulation of major industrial facilities, these facilities still emit air pollutants and discharge water pollutants. Rail yards, freeways, ports, and other facilities bring together vehicles and equipment that produce emissions from diesel fuel and gasoline.

Today, communities by these locations are predominantly low-income, often with a large percentage of ethnic minorities and non-English speakers. Like other low-income communities, they face additional challenges that can affect the health of their residents, including limited access to health care; poor nutrition stemming in part from a shortage of grocery stores; and a lack of parks and open space.

Living next to industrial facilities, congested freeways, or fields where agricultural chemicals are applied, many residents worry about possible links between environmental quality in their communities and their health. They ask difficult questions to civic leaders, policymakers and regulators, including:

- Do these decision makers understand the cumulative impacts on our community of numerous sources of pollution that affect our air, water, and soil?
- Does anyone share our concern that our community's demographics and public health challenges are making us more vulnerable to the effects of environmental pollution?
- Are the cumulative impacts of pollution in my community greater than in other communities?

This report presents a screening methodology that, when fully developed, can be used by Cal/EPA programs and others as a first step to answer the above questions.

Cal/EPA designated its Office of Environmental Health Hazard Assessment (OEHHA), in collaboration with other Cal/EPA Boards and Departments, as lead for the development of this report. OEHHA consulted with academic partners at the University of California at Berkeley, and an external stakeholder group, the Cumulative Impacts and Precautionary Approaches Work Group (CIPA Work Group).

The CIPA Work Group Process

The CIPA Work Group represented many stakeholder interests and made significant contributions to the report. The CIPA Work Group members were selected for their expertise and their affiliation with organizations with institutional interest in cumulative impacts analysis. The names and affiliations of CIPA Work Group members are in Appendix 2.

Several areas of discussion emerged from the CIPA Work Group meetings. The themes were that decision makers should:

- Not take a long time to identify highly impacted communities via protracted analyses.
- Move beyond the analysis phase so that problems are addressed, not just assessed.
- Move beyond health risk assessment to implement a scientifically-based model that encourages more public participation and public contribution to the science considered in the analysis.
- Draw community members into meaningful public participation.
- Broadly seek opportunities to take action to develop healthy communities and reduce adverse environmental impacts.

Background

Cal/EPA is committed to promoting environmental justice—defined in California 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" (Government Code Section 65040.12).

For nearly a decade, Cal/EPA has worked to integrate environmental justice into its programs, policies, and activities. In 2001, the Cal/EPA Secretary first convened the IWG to ensure that pursuant to Public Resources Code Sections 71110-71113, Cal/EPA do the following:

1. Conduct its programs, policies, and activities that substantially affect human health or the environment in a manner that ensures the fair treatment of people of all races, cultures, and income levels, including minority populations and low-income populations of the state.
2. Promote enforcement of all health and environmental statutes within its jurisdiction in a manner that ensures the fair treatment of people of all races, cultures, and income levels, including minority populations and low-income populations in the state.
3. Ensure greater public participation in the Agency's development, adoption, and implementation of environmental regulations and policies.
4. Improve research and data collection for programs within the Agency relating to the health of, and environment of, people of all races, cultures, and income levels, including minority populations and low-income populations of the state.
5. Coordinate its efforts and share information with the United States Environmental Protection Agency (U.S. EPA).
6. Identify differential patterns of consumption of natural resources among people of different socio-economic classifications for programs within the Agency.

Working to achieve these goals, the October 2004 Cal/EPA Environmental Justice Action Plan (EJ Action Plan) committed the Agency to develop guidance for Cal/EPA BDOs to analyze, prevent and reduce cumulative impacts. Community and environ-mental-justice organizations, together with business and industry groups, urged Cal/EPA to focus on cumulative impacts during development of the EJ Action Plan. Cal/EPA agreed that guidance on cumulative impacts is critical to ensure the achievement of environmental justice in communities impacted by multiple pollution sources. Consequently, the screening method presented in this report is the first step in applying a scientific method to achieve the EJ Action Plan objectives on cumulative impacts guidance development.

The development of methods and policies involving cumulative impacts analyses will improve and enhance the Agency's overall ability to take protective actions when needed. This also will better ensure that the Agency's resources are directed where they will provide the greatest benefit.

The Need to Address Cumulative Impacts

Environmental programs are intended to protect public health and the environment from the adverse effects of toxic and hazardous contaminants and other harmful agents. Current environmental regulations generally set limits for individual pollutants in air, water, soil, food or other sources of exposure at levels that pose the lowest possible risk to human or ecological health.

While this approach has been effective in controlling media-specific exposures in the past, it does not account for exposure to multiple pollutants from multiple sources. Age, genetic characteristics, and pre-existing health conditions also may increase the risk for some populations of adverse health effects from exposure to pollutants.

Scientists have also begun to look at other human factors when assessing health risks. Income, access to health care, and other socioeconomic factors may influence the effect of environmental pollutants. These factors influence the likelihood of exposure to pollutants or proximity to sources of pollution. For example, higher pollutant levels tend to occur in low-income neighborhoods and among communities of color. Also, health disparities have been documented between groups of people of different income levels and among different racial or ethnic groups.

Environmental policies have evolved over the last 20 years to incorporate this new scientific understanding of the cumulative impacts of multiple pollutants. Risk assessments conducted for cleanups of contaminated sites were among the first to test for multiple chemicals. The U.S. Environmental Protection Agency's (U.S. EPA) 2003 *Framework for Cumulative Risk Assessment* shows the need for cumulative risk assessments that take into account multiple agents or stressors.[5]

A recent National Research Council report highlights a need to use simplified risk assessment tools that weigh nonchemical stressors, a population's vulnerability to pollution, and background risk factors. It recommends that research programs investigate interactions between chemical and nonchemical stressors, and include epidemiological studies (NAS, 2009).

Responding to this new science and to several new laws, Cal/EPA now considers more environmental and human effects when conducting a risk assessment. For example, under the Air Toxics "Hot Spots" Act, facilities now assess potential health risks from emissions of multiple chemicals into air and into other environmental media such as water, soil, and food (Salmon, 2010). When developing public health goals for drinking water contaminants, OEHHA scientists now consider potential adverse effects on sensitive subgroups, such as infants and children, the elderly, and pregnant women (Assembly Bill (AB) 2342, Chapter 678, Statutes of 2004).

These changes are steps in the right direction, but they still do not comprehensively address cumulative impact concerns across all media and all sensitive population groups.

Cumulative impact analysis provides a fuller picture by examining multiple chemicals, multiple sources, public health and environmental effects, and characteristics of the population that influence health outcomes. Approaches to assess and mitigate cumulative impacts are a logical next step in applying the best available science to environmental protection programs. As Cal/EPA further develops, adopts, and implements cumulative impact analyses, it will move closer to achieving its environmental justice and public health goals while better protecting the environment and the people of California.

Purpose

This report is a response to the vital need to provide understanding and direction in applying cumulative impacts considerations in environmental policy and programs. The report lays out the scientific evidence that some communities are likely to face greater cumulative impacts from pollutants. By providing a scientific methodology to begin assessing cumulative impacts, the report represents a major step forward and fills a gap that inhibits the achievement of environmental justice. This sets the stage for integration of cumulative impacts considerations into decision-making at Cal/EPA.

The report's foundation is the working definition for "cumulative impacts" adopted by the Cal/EPA IWG:

> Cumulative impacts means 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.

Using this definition, the report describes a common, systematic approach that Cal/EPA's Boards and Departments can use to begin to assess and respond to cumulative impacts on communities. The screening methodology described in this report is neither comprehensive nor detailed but provides a

[5] U.S. EPA, in its *Framework for Cumulative Risk Assessment*, defines cumulative risk as the combined risks from aggregate exposures to multiple agents or stressors.

foundation for development of more detailed techniques.

Overview of Report

This report is intended to assist Cal/EPA's Boards and Departments which may consider cumulative impacts in their decision-making and activities. The report includes the following information:

Chapter 1. Scientific Evidence for Disproportionate Cumulative Impacts

Description of the scientific evidence for cumulative impacts. This includes a summary of studies describing disproportionate pollution impacts, health disparities, and factors that increase sensitivity to pollutants. Much of the work focuses on concerns for minority and low-income populations.

Chapter 2. Definitions and Terms

Description of the factors that make up a comprehensive measure of cumulative impacts in a community. The chapter defines key terms in the working definition of cumulative impacts to ensure that all stakeholders are consistent in their understanding of these concepts.

Chapter 3. A Scientific Screening Methodology for Analyzing Cumulative Impacts in Communities

Presentation of the Cal/EPA methodological approach that can be used to screen for cumulative impacts according to Cal/EPA's definition of cumulative impacts. It proposes that effects of pollutants are heightened in communities with greater proportions of sensitive individuals or in communities of low socioeconomic status.

Chapter 4. Cumulative Impacts in Environmental Decision-Making

Description of how cumulative impacts analysis can be used to inform and support various types of environmental policy or decision-making.

Chapter 5. Proposed Actions and Next Steps to Address Cumulative Impacts

Recommendations for Cal/EPA action priorities in ongoing and future efforts to address cumulative impacts.

CHAPTER 1. SCIENTIFIC EVIDENCE FOR DISPROPORTIONATE CUMULATIVE IMPACTS

Scientific studies inform our knowledge about the distribution of environmental pollution and its relationship to both places and people. Part of the body of knowledge regarding cumulative impacts comes from studies that have examined differences based on demographic characteristics— particularly racial and ethnic differences (which are considered here as socioeconomic factors as discussed later in this chapter) and those based on income.

Understanding the cumulative impacts of environmental pollution fundamentally means understanding communities and people. When seeking to understand the environmental health of a community, it is important to look at its location. For example, is it near or does it contain sources of pollution such as transportation corridors, industrial sites, and hazardous waste cleanup sites?

With respect to people, learning about characteristics of the population becomes important. Is there a high prevalence of people who are intrinsically sensitive to pollutants, like children, the elderly, or those with existing health conditions? What are their characteristics as a group—for example, do they live in an impoverished community?

This chapter discusses the findings of these studies. This scientific evidence suggests a likely role for adverse effects from pollutants in people, particularly for low-income and minority populations. Differences in levels of both single and multiple pollutants are likely to contribute to differences in health outcomes and environmental conditions in places where these differences exist.

Introduction

Some pollutants are nearly ubiquitous, occurring throughout the population. These include contaminants found commonly in blood samples, such as flame retardants and dichlorodiphenyltrichloroethane (DDT, a long-banned synthetic pesticide). These pollutants and their sources tend to be concentrated in specific areas. This concentration creates concern for differences in exposures and their potential impacts among certain populations in those areas.

The following are examples of how pollutants from multiple sources can distribute, depending on their location:

- Diesel particulate matter near roadways, distribution centers, rail yards, and ports.
- Toxic air pollutants near industrial facilities.
- Pesticides and soil amendments that drift from agricultural fields.
- Metals and sulfuric acid discharged from mining operations into water bodies.
- Rock and soil containing radon and asbestos.
- Chlorinated solvents and vinyl chloride discharged from a former industrial site to groundwater.

Proximity to a source is an important factor. Proximity to source(s) alone, however, does not always predict the distribution of pollutants in the environment. Other considerations include environmental fate and transport (a pollutant's movement and dispersal throughout the environment). It is important to examine how quickly the pollutant degrades, whether it actually degrades, and how it may accumulate in different places or organisms.

Human contact with pollutants also is influenced by many factors—most importantly where, when, and how people spend time. These factors are primarily driven by where people live, work, and recreate. Understanding cumulative impacts means comprehending how this complex set of relationships, including the distribution and properties of environmental pollution, combines to create the potential for adverse health or environmental outcomes. The proposed screening method will help identify communities burdened by cumulative impacts, although it will not substitute for detailed assessments.

Types of Scientific Information Reviewed in this Chapter

Several converging lines of scientific evidence reinforce concern for people in places where multiple sources of environmental pollution exist. An important piece of scientific evidence supporting the concern for cumulative impacts comes from literature that examined low socioeconomic status (SES) and minority communities. Environmental pollution has been linked to significant impacts on the health and well-being of a population, with evidence pointing to disproportionate impacts in low-SES and minority communities, as well as other subpopulations such as children and the elderly. Studies along these lines of evidence have been assembled from a number of disciplines and organized in a report prepared for OEHHA by researchers at the University of California at Berkeley (Zuk & Morello-Frosch, 2009). The following topics form the basis of the scientific background for understanding cumulative impacts:

1. The relationship between environmental pollution and health effects.
2. Disparities in pollution exposures and environmental conditions, specifically for low-SES and minority populations.
3. Differences in intrinsic sensitivity to pollutants among certain subpopulations (*e.g.*, due to biological and physiological differences).
4. Differences in non-intrinsic sensitivity to pollutants among certain subpopulations (*e.g.*, socially-derived factors at the individual and community levels).
5. Health disparities in low-SES and minority populations and their relationship with pollutant related disease.

(1) Pollution and Public Health Effects

There is strong evidence that exposure to pollutants has caused or worsened health problems. Understanding the relationship between disease and the environment provides the foundation for consideration of cumulative impacts. This evidence largely comes from epidemiological studies of human populations with varying levels of pollutant exposure.

These studies are challenging to scientists, in large part because people are exposed to many pollutants in different circumstances and at the same time, identifying the effect from the specific agent(s) responsible for disease is difficult. Unless the disease is fairly rare and associated with a specific pollutant, such as mesothelioma and asbestos, then numerous studies are required to establish causality.

Topics that Form Scientific Background for Understanding Cumulative Impacts:

- **(1) Pollution and Public Health Effects**
- (2) Exposure Disparities and Environmental Conditions
- (3) Sensitivity Based on Intrinsic Factors
- (4) Sensitivity Based on Non-Intrinsic Factors
- (5) Health Disparities

Fully summarizing the known relationships between chemical pollutants and disease is beyond the scope of this report. However, some of the pollutants found in the environment with currently strong evidence for a relationship to disease are identified in Table 1 below.

For many other pollutants, direct correlation between exposure and disease has not been confirmed through human studies but has been revealed by toxicity testing, primarily in experimental animals. It should also be noted that many diseases have multiple causes and are not uniquely caused by environmental exposures. Other factors in the origins of disease include genetics, lifestyle and socioeconomic factors. In the following sections, we elaborate on the influence of several of these factors.

TABLE 1. SOME POLLUTANTS STRONGLY ASSOCIATED WITH DISEASE IN PEOPLE.

Pollutant	Disease
Asbestos	Lung cancer and mesothelioma (President's Cancer Panel, 2010)
Benzene	Leukemia (OEHHA, 2001)
Dibromochloro-propane	Male infertility (OEHHA, 1999)
Formaldehyde	Nasal & nasopharyngeal cancer (NTP, 2010)
Lead	Neurological effects (Bellinger, 2004)
Methyl mercury	Developmental neurotoxicity (U.S. EPA, 2001)
Occupational exposures to vapors, gases, dust, or fumes	Chronic obstructive pulmonary disease (Trupin *et al.*, 2003)
Ozone	Respiratory disease (U.S. EPA, 2006)
Particulate air pollution	Cardiovascular disease and stroke (Dockery *et al.*, 1993; Laden *et al.*, 2006) Respiratory disease (Brunekreef & Holgate, 2002; Delfino, 2002) Mortality (HEI, 2010, Brunekreef & Holgate, 2002)
Polyhalogenated biphenyls	Liver and bile duct cancer (President's Cancer Panel, 2010)
Traffic-related pollutants	Asthma (HEI, 2010)
Vinyl chloride	Liver cancer (IARC, 2008)

(2a) Exposure Disparities

As described earlier, pollutants vary in their distribution across places and among people. A number of studies have examined people and areas where different levels of exposure occur. These studies highlight disparities in exposure, where some people are exposed to more harmful pollutants than others, especially in minority and low-SES communities. Evidence also suggests that cumulative exposures from multiple sources of environmental pollution may be more harmful than single exposures (Sexton & Hattis, 2007).

This evidence is consistent with well-established toxicological principles that provide good reason to be concerned with multiple exposures (U.S. EPA, 2007).

Topics that Form Scientific Background for Understanding Cumulative Impacts:

(1) Pollution and Public Health Effects
(2) **Exposure Disparities** and Environmental Conditions
(3) Sensitivity Based on Intrinsic Factors
(4) Sensitivity Based on Non-Intrinsic Factors
(5) Health Disparities

In this section, we discuss scientific evidence relating to proximity to toxic facilities and emissions, exposure to environmental pollutants in air and other measures of expo-sure as they relate to minority and low SES populations.

FACILITY LOCATION AND TOXIC RELEASES

The federal Emergency Planning and Community Right-to-Know Act of 1986 requires U.S. EPA to maintain a database of information about toxic chemicals from industrial facilities across the country. Numerous studies have made use of this publicly available information to examine differences in the presence of hazardous chemicals in certain locations. This, along with demographic information in the study areas, has provided consistent evidence of higher chemical emissions in lower-SES and/or minority communities (reviewed by Zuk & Morello-Frosch, 2009). Some of this evidence is described below.

A study of pollution-emitting facilities in southern California applied the Toxic Release Inventory

(TRI) database to find racial disparities using simple one-variable tests (Sadd *et al.*, 1999). For example, after controlling for a variety of factors, people of color were found to be more likely to live in areas with higher toxic releases. Other statistical analyses confirm the relationship between high-TRI releases and the proportion of minorities in the population, particularly Latinos.

These findings were reinforced in a more recent analysis in southern California (Pastor *et al.*, 2004). In this study, neighborhoods near TRI facilities were found to be more than 40 percent Latino, while neighborhoods farther from such facilities were only about 25 percent Latino. Neighborhoods near TRI facilities also had higher populations of African Americans and Asian/Pacific Islanders, though the differences were not as great. Similarly, such neighborhoods also showed lower median household income and lower rates of home ownership.

OEHHA Research on Schools, Traffic, and Socioeconomic Factors

School location may be an important determinant of children's exposure to traffic-related pollutants. The populations of K-12 schools in California near major roads were characterized based on whether the traffic was high, medium, or low. Nonwhite students comprised a greater percentage of schools near high- traffic roads compared roads with little traffic. As the traffic exposure of schools increased, the percentage of both non-Hispanic black and Hispanic students attending the schools increased substantially. A substantial number of children in California attend schools close to major roads with very high traffic counts, and a disproportionate number of those students are economically disadvantaged and nonwhite.

Green et al. (2004). Environ Health Perspect, 112(1):61-6.

Studies in Minnesota investigated associations between race and poverty and proximity to TRI facility locations (McMaster *et al.*, 1997; Sheppard *et al.*, 1999). Significant relationships between poverty and race and facility location were found, with a greater association for race. Investigators also demonstrated that industrial releases in Florida were unequally distributed with respect to race (Pollock & Vittas, 1995).

With respect to income, a study in Ohio found that "[t]oxic industrial release facilities in Cuyahoga County are … more likely to be located in poorer and less affluent areas than in areas with minority concentrations" (Bowen *et al.*, 1995). Additionally, spatial associations between toxic releases and minority populations were high at the state level but not at the census tract level.

Multiple studies that considered the toxicity information for individual chemicals alongside potential health impacts from emissions have demonstrated greater emissions in low-income and disadvantaged areas (as reviewed by Szasz & Meuser, 1997). Results for a study in Allegheny County, Pennsylvania, showed exposure inequalities with respect to race, particularly for African Americans (Glickman & Hersh, 1995). Application of emission and toxicity data showed disproportionate hazard exposure among both low-income and minority populations in the U.S. (Ash & Fetter, 2004). Further, African Americans were found to live in more polluted cities than Latinos, even though both populations resided in more polluted neighborhoods within cities. The study also found a strong relationship between low-income status and higher exposure.

MONITORED AND MODELED POLLUTANTS IN AIR

Some studies have measured levels of air pollutants to establish whether inequalities with respect to race or income exist. One evaluation of the U.S. compared populations in counties that were not in attainment for several of the criteria air pollutants—ozone, carbon monoxide, particulates, sulfur dioxide, lead, or nitrogen dioxide (Wernette & Nieves, 1991). A study found Hispanic and African-American populations were more concentrated in areas out of attainment with air quality standards. Low income and unemployment status predicted exposures to particulate air pollution in a study using modeled monitoring data in Hamilton, Canada (Jerrett *et al.*, 2001). Applying an index of exposure to criteria air pollutants during pregnancy for women across the U.S. showed that Hispanic, African-American, and Asian/Pacific Islander mothers were more likely to live in polluted counties than white mothers (Woodruff *et al.*, 2003).

In a Southern California study of four specific air pollutants (benzene, butadiene, chromium particles, and diesel particles), non-white and low-income people, as well as those living in densely populated areas, were more likely to experience higher exposures (Marshall, 2008). For the four pollutants studied, mean exposures were found to be 16 to 40 percent greater for non-whites compared to whites. A separate study using air monitoring data for toxic pollutants in the Great Lakes showed that higher exposures to lead were evident for minorities compared to non-minorities (Pellizzari *et al.*, 1999).

OTHER MEASURES OF DISPROPORTIONATE EXPOSURE

Numerous studies have applied traffic data to populations that are likely to be exposed to vehicle-related air pollutants. For example, several studies in Southern California found that high traffic densities occurred more frequently in low-income and minority neighborhoods (Houston *et al.*, 2004; Ponce *et al.*, 2005; Gunier *et al.*, 2003).

Some Indicators of Exposures

- Monitored levels of criteria air pollutants
- Modeled levels of toxic air contaminants
- Estimated levels of diesel particulate matter in air
- Drinking water quality
- Age of housing (household lead level)

Other hazards, such as exposure to lead in the home from the historical use of lead-based paint, point to disparities in exposure with respect to SES. One study found low-income housing units were more likely to have lead hazards than higher-income housing (Jacobs *et al.*, 2002). Researchers also have confirmed high pesticide exposures among pregnant, inner-city African-American and Dominican women from New York City through several studies (Whyatt *et al.*, 2002; Whyatt *et al.*, 2003). Pregnant, low-income, Latina women residing in an agricultural area of California showed pesticide metabolite levels up to 2.5 times higher than a representative sample of U.S. women (Bradman *et al.*, 2005). A North Carolina study examining pesticide exposure in farm worker children also found higher pesticide metabolite levels compared to national data (Arcury *et al.*, 2006).

Some populations may also experience higher exposures due to certain cultural practices. For example, concern over herbicide application to plant materials used by Native American basket weavers led to a collaborative project by Cal/EPA's Department of Pesticide Regulation to assess exposure to herbicide residues and develop risk reduction measures (Ando *et al.* 2002).

(2b) Disparities in Environmental Conditions

Topics that Form Scientific Background for Understanding Cumulative Impacts:

(1) Pollution and Public Health Effects
(2) Exposure Disparities and **Environmental Conditions**
(3) Sensitivity Based on Intrinsic Factors
(4) Sensitivity Based on Non-Intrinsic Factors
(5) Health Disparities

Environmental conditions resulting from the presence of pollution hazards vary across different places and in their proximity to different people. There is a large body of literature examining various land uses with pollutant hazards and their relationship to nearby populations. In these cases, information on exposures or actual contact with pollutants by people is not known with certainty, as will be explained later in this chapter.[6] Many of these studies formed the foundation of concerns for environmental justice among low-income and minority populations (reviewed in Szasz & Meuser, 1997).

A 1983 study by the U.S. General Accounting Office found that hazardous waste landfills in the southern U.S. were disproportionately in low-

[6] "The presence of toxic hazards in communities can lead to general social disinvestment, bringing low property values, poor schools, stigma, blocked mobility, and intergenerational inequity. We need to develop new models of environmental impact which can explain these other phenomena in terms of a 'neighborhood quality of life.'" (Brown, 1995).

income African-American communities (United States General Accounting Office, 1983). In 1987, the United Church of Christ's Commission for Racial Justice found that race and poverty were predictors for the location of toxic waste facilities (United Church of Christ. Commission for Racial Justice, 1987). A recent update of this study reports that disparities by race and socioeconomic status continue to exist in the distribution of hazardous waste facilities across the U.S. (Bullard *et al.*, 2007). Some owners of hazardous and solid waste facilities have conducted similar analyses of their individual company footprints and determined that they did not reflect the same discriminatory pattern reported by Bullard *et al.*

The probability that a neighborhood will contain hazardous waste facilities rises in poor or minority communities even after controlling for region, urbanization, and land value (Brulle & Pellow, 2006). A 1997 study of the hazardous waste treatment, storage and disposal facilities (TSDFs) in Los Angeles County showed that race/ethnicity correlates to the location of the facilities for both African-American and Latino populations (Boer *et al.*, 1997). Latino populations showed a greater likelihood of living in closest proximity to a TSDF.

A recent broad review of studies examined the relationship between race and income and neighborhood quality, as measured independently by the presence of hazardous wastes, air and water pollution, noise, housing quality, and educational facilities (Evans & Kantrowitz, 2002). These authors concluded that "[i]t would be fair to summarize this body of work as showing that the poor, and especially the non-white poor, bear a disproportionate burden of exposure to suboptimal, unhealthy environmental conditions in the United States."

Some Indicators of Environmental Effects

- Presence of hazardous waste cleanup sites
- Presence of leaking underground
- fuel tanks
- Impaired water bodies

A study looking at race and socioeconomic position in metropolitan Detroit, Michigan, found that race was a stronger determinant of the presence of environmental hazards than income (Mohai & Bryant, 1992). Hazardous waste disposal sites on the U.S. EPA National Priorities List under the Superfund program are more likely to be in places where black and Hispanic populations live (Zimmerman, 1993).

Although some uncertainties persist regarding the extent and existence of inequities (Ringquist, 2005; Brown, 1995), a considerable body of scientific knowledge indicates there are disproportionate environmental hazards and threats for minority and low-SES populations.

(3) Sensitivity Based on Intrinsic Factors

A body of scientific evidence supports concern that some people, based on factors intrinsic to them, may be more sensitive to pollutants than others. This topic will be discussed further in Chapter 2 ("sensitive populations"). Some factors relate to age, pre-existing health conditions, gender, and genetics.

Topics that Form Scientific Background for Understanding Cumulative Impacts:

(1) Pollution and Public Health Effects
(2) Exposure Disparities and Environmental Conditions
(3) Sensitivity Based on Intrinsic Factors
(4) Sensitivity Based on Non-Intrinsic Factors
(5) Health Disparities

AGE

A recent review summarized much of the large body of evidence for associations between outdoor and indoor environmental hazards and health effects on children (Wigle *et al.*, 2007). The review observes that "[s]ome environmental toxicants, notably lead, ionizing radiation, ETS [environmental tobacco smoke], and certain ambient air toxicants, produce adverse health effects at relatively low exposure levels during fetal or child developmental time windows." The authors recommend additional research areas to fill important gaps that would improve understanding of this topic.

Possible mechanisms for the increased susceptibility of children to environmental toxicants also have been reviewed by many researchers. Some of these include biological differences in how pollutants are handled by children (that is, absorption, distribution, metabolism, and excretion), differences in behaviors that would increase exposures relative to adults (that is, food consumption, hand-to-mouth activity, greater skin contact with pollutants), and different factors related to growth and development processes, which may interact with pollutants (Faustman *et al.*, 2000; Selevan *et al.*, 2000). For example, an abundance of research on the effects of the neurotoxicant lead has highlighted the unique susceptibilities of children as described previously (Bellinger, 2004). Similarly, several studies have demonstrated effects of air pollutants on the lungs of children (Horak *et al.*, 2002; Gauderman *et al.*, 2004).

Recognizing the increased susceptibility of children, OEHHA has developed procedures to evaluate the cancer risks from early-in-life exposures of infants and children to carcinogens (OEHHA, 2009).

Some Indicators of Population Sensitivity

Presence of:

- children
- elderly
- people with pre-existing health conditions
- pregnant women

There is also evidence that the elderly may be especially sensitive to some environmental pollutants. A Netherlands-based investigation into the relationship between mortality from different causes and exposures to ozone, black smoke, sulfur dioxide, nitrogen dioxide, carbon monoxide, and particulate matter showed greater associations for people over age 65 (Fischer *et al.*, 2003). Many potential factors may influence the response to pollutants in the elderly, including a history of exposures to the same or other pollutants; increased likelihood of existing respiratory or cardiovascular disease; concurrent pharmaceutical exposures; and differences in lung function or immune responses (Sandstrom *et al.*, 2003).

PRE-EXISTING HEALTH CONDITIONS

Numerous health conditions may worsen the body's response to environmental pollutants, including respiratory and cardiovascular diseases, diabetes, and obesity (reviewed by Annesi-Maesano *et al.*, 2003).

For example, a study of men and women in Barcelona, Spain, who have chronic obstructive pulmonary disease found an association between that population's mortality and higher levels of particulate pollution (Sunyer *et al.*, 2000). Greater risks of exposure to air pollution were observed for individuals with previously diagnosed disease or previous admission to intensive care units or emergency room visits. Researchers examining hospital admissions in Chicago, Illinois, found that increased amounts of particulate air pollution increased the rate of admissions among patients with respiratory infections and certain heart conditions (Zanobetti *et al.*, 2000). A later study in Chicago showed that elderly populations diagnosed with heart attacks or diabetes had the greatest risk of mortality associated with elevated levels of particulate air pollution (Bateson & Schwartz, 2004).

A recent study in two California cities found that exposure to air pollution in children with asthma was associated with suppression of the immune system's regulatory T-cells, compared to children without the disease. Researchers also noted that the suppression of these cells was associated with an increased severity of asthma symptoms and decreased lung function (Nadeau *et al.* 2010).

For populations in Montreal, Canada exposed to certain air pollutants, associations were significant between pollutant levels and death from respiratory disease and diabetes (Goldberg *et al.*, 2001). In the same study, a similar association was found for pollutant exposure and death from cancer or coronary artery disease among those over 65. A larger investigation of 20 cities found an association between pneumonia and stroke and increased particulate pollution mortality (Zeka *et al.*, 2006). Occupational studies have surmised similar relationships between pre-existing conditions and pollutant effects. For example, among workers exposed to metal particulates, obesity was associated with a greater cardiac response (Chen *et al.*, 2007).

OEHHA Research on Temperature, Race, and Mortality

The association between ambient temperature and mortality has been established worldwide. An OEHHA study of nine California counties identified subgroups vulnerable to high ambient temperature. Applying county-specific estimates of mortality and a time-stratified case-crossover approach, each 10 degrees (Fahrenheit) increase in mean daily apparent temperature corresponded to a 2.6 percent increase for cardiovascular mortality, with the most significant risk found for ischemic heart disease. Elevated risks were found for persons at least 65 years old, infants one year or less, and the black racial/ethnic group. No differences were found by gender or educational level.

Basu and Ostro (2008). Am J Epidemiol. 168(6):632-7.

GENDER/SEX

Studies on differences in response to environmental pollutants based on gender have not been conclusive. Some studies have shown an association, while others have not (reviewed by Annesi-Maesano *et al.*, 2003). Some studies have shown higher risks among females for pollution-related respiratory symptoms from certain air pollutants. Mortality from ozone exposure has also been shown to be higher for women (Medina-Ramon & Schwartz, 2008).

(4) Sensitivity Based on Non-Intrinsic Factors

Topics that Form Scientific Background for Understanding Cumulative Impacts:

(1) Pollution and Public Health Effects
(2) Exposure Disparities and Environmental Conditions
(3) Sensitivity Based on Intrinsic Factors
(4) Sensitivity Based on Non-Intrinsic Factors
(5) Health Disparities

An emerging body of scientific work has examined the relationship between certain social factors and health outcomes from exposure to pollutants (Zuk & Morello-Frosch, 2009). An abundance of this research suggests that non-intrinsic factors such as socioeconomic status may modify the response to pollutant exposure. Health research examining the relationships between different measures of socioeconomic status, race/ethnicity and health is an emerging field. The relationship between socioeconomic status and race/ethnicity alone is complex. Understanding each of these relationships will ultimately require a consideration of the underlying pathways that lead to disparities (Braveman, 2005). Some studies examining social factors and the relationship between exposure and health suggest up to threefold increases in the response. It is difficult to sort out these relationships because socioeconomic factors and pollutant exposures influence health outcomes in different ways.

A recent review described possible ways in which the observed differences may occur (O'Neill *et al.*, 2003). These include differences in pollutant exposure among various socioeconomic groups and/or increased susceptibility to further adverse health effects from compromised health related to socioeconomic disadvantage.

The scientific literature reflects concern that socioeconomic variables may influence response to pollutants or modify the effect of exposure to pollution. In a key study on air pollution and mortality, Krewski and colleagues "identified a possible modifying effect of education on the relation between air quality and mortality in that estimated mortality effects increased in the sub-group with less than high school education." The researchers found that individuals with less than a high school education who were exposed to particulate matter exhibited a 2.7 times greater risk of dying from lung cancer than individuals with education beyond high school (HEI, 2000).

The following studies have examined the relationship between income level, another socioeconomic factor, pollution exposures and health outcomes. In a study of mortality in Ontario, Canada mortality rates varied by neighborhood of residence. "At least part of this variation is likely related to differences in biologic risk factors that were not control-led for. Two of the broader determinants of health—income and air pollution levels—were important correlates of mortality in this population" (Finkelstein *et al*., 2003). In this study, for individuals with low income and high levels of particulate matter and sulfur dioxide, the association between mortality was 2.4 to 3.4 times greater, respectively, compared to individuals with higher incomes and low pollutant exposures. Children of low-SES families (determined by income) in Vancouver, Canada, had approximately 10 percent greater asthma hospitalizations associated with exposure to nitrogen dioxide (males) and sulfur dioxide (females) (Lin *et al*., 2004). Similarly, studies in Brazil and Italy reported mortality and exposure to particulate pollution was associated with measures of socioeconomic deprivation. Martins *et al*., 2004, detected a 1.4 to 14.2 percent increase in daily deaths due to increases in daily particulate matter in Brazil and Forastiere *et al*., 2007, found an increase of 1.5 to 2 percent in mortality between low and high income or socioeconomic status groups in Italy.

In addition to socioeconomic factors, some studies have shown similar relationships between health outcomes, pollutant exposures, and race/ethnicity. Specific studies show possible health effect modification by race, meaning that race and pollution exposure may independently affect health outcomes. For example, maternal exposure to particulate pollution (PM 2.5) is associated with reduced birth weight, and this effect is greater among black mothers compared to white mothers (Bell *et al*., 2007). Similarly, ozone levels have been shown to be associated with increased mortality, with blacks showing an additional 0.53 percent increase in mortality compared to non-blacks (Medina-Ramon & Schwartz, 2008).

Some Socioeconomic Factors

- Household income
- Poverty
- Race/ethnicity
- Educational attainment
- Access to health care

Studies of other socioeconomic metrics have been linked to increased health outcomes in populations with pollution exposures. In one study, African-American mothers of low-SES exposed to traffic-related air pollution had twice the chances of delivering a preterm baby (Ponce *et al*., 2005). Similar studies in Southern California also associated exposure to traffic-related air pollutants with increased risk of preterm birth. Lower-SES neighborhoods also exhibited greater risks. In another Southern California study, researchers observed a 2.8-fold increased risk of asthma symptoms among individuals below the federal poverty line living in high traffic density areas (Meng *et al*. 2008).

Investigators looking at traffic-related pollution found an increased risk of asthma associated with childhood exposure to violence. Children exposed to violence in an environment with more air pollution had a 1.6- to-2.4-fold increase in asthma diagnosis (Clougherty *et al*., 2007). Similarly, measures of increased family stress were found to be predictive of increases in asthma symptoms from traffic-related pollution exposures in children, with an interaction between biological as well as perceived measures of stress and pollution levels (Chen *et al*., 2008).

Other research has explored the relationship between chronic stress and human health, also known as "allostasis" and "allostatic load." The allostatic load model asserts that chronic stress has physiological effects on individuals that can both cause damage to the body and leave individuals more vulnerable to different stressors. Numerous socioeconomic factors also may contribute to stress, such as residential crowding, noise, poor housing quality, exposure to violence, or the experience of racial discrimination (Evans & Marcynyszyn, 2004; Geronimus, 1996; Williams & Williams-Morris, 2000; Clark *et al.*, 1999; Kwate *et al.*, 2003; Paradies, 2006). Allostasis concepts have been advanced as a possible model for increasing understanding of the complex relationship between health outcomes, psychosocial stressors (such as those caused by socioeconomic conditions or those related to race/ethnicity), and environmental exposures (Gee & Payne-Sturges, 2004; Morello-Frosch & Shenassa, 2006; reviewed by McEwen, 1998).

(5) Health Disparities, Socio-economic factors, and their Relationship to Pollutant-Related Diseases

Topics that Form Scientific Background for Understanding Cumulative Impacts:

(1) Pollution and Public Health Effects
(2) Exposure Disparities and Environmental Conditions
(3) Sensitivity Based on Intrinsic Factors
(4) Sensitivity Based on Non-Intrinsic Factors
(5) Health Disparities

Differences in specific health outcomes have been well documented among various segments of the population in California, the United States, and worldwide. More specifically, health disparities or health inequalities have been defined as "potentially avoidable differences in health (or in health risks that policy can influence) between groups of people who are more or less socially advantaged. These differences systematically place socially disadvantaged groups at further disadvantage on health" (Braveman, 2006). Social advantage is "position in the social hierarchy determined by wealth, power, and/or prestige," which can include factors such as poverty, race, ethnicity, or discrimination (Braveman, 2006). As environmental justice in California concerns 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 (Government Code Section 65040.12), the degree to which activities at Cal/EPA may influence and reduce such health disparities is relevant.

Some Indicators of Public Health Effects

- Presence of children
- Presence of elderly
- Presence of people with pre-existing health conditions

Inequalities in health outcomes are created or perpetuated in people of different socio-economic backgrounds, races, or cultures in numerous ways. As previously discussed in this chapter, these can include exposure to environmental pollutants; adverse environmental conditions; biological or genetic differences such as early-life conditions and nutritional status; or other factors, such as housing, inadequate health care, unsafe working conditions, unhealthy behaviors (smoking, physical inactivity), social exclusion, and discrimination (Zuk & Morello-Frosch, 2009; reviewed by Adler & Rehkopf, 2008). The relative contribution of these various factors to adverse health outcomes is not well understood.

A large body of literature documents health disparities with respect to various socio-economic factors, including race/ethnicity. Disparities in health vary by cause of death, geo-graphic area, and over time, though the underlying causes and their contribution have not been firmly established (Adler & Rehkopf, 2008). In this section, we emphasize the disparities that have been observed in the literature for diseases or health outcomes that have also been associated with exposures to environmental pollutants. Interest in the described health outcomes stems from their potential relationship with exposure to environmental pollutants, illustrated earlier in this chapter.

MORTALITY DISPARITIES

Consistent relationships have been observed between higher mortality from all causes and lower socioeconomic position. A life-expectancy gap between the most- and least-deprived groups was observed when applying a broad measure of socioeconomic deprivation for U.S. populations that included indicators of poverty, income distribution, wealth, education, employment, occupation, and housing quality (Singh & Siahpush, 2006). While the trend over time is increased life expectancy among all groups, the gap between the most- and least-deprived socioeconomic groups has increased (Singh & Siahpush, 2006; Pappas *et al.*, 1993). Similarly, in the U.S., a gap in age-standardized death before age 65 or premature mortality between the highest and lowest socio-economic group, based on median family income, increased in the 1980s and 1990s (Krieger *et al.*, 2008). Age-adjusted death rates also declined significantly in the U.S. with increasing educational attainment (Kung *et al.*, 2008).

With respect to race, significantly higher death rates for African Americans than whites in California have been documented regardless of socioeconomic position, as measured by educational attainment (Lee & McConville, 2007). On the other hand, this study also found mortality among Hispanic and Asian populations in California to be slightly lower than among white populations. Greater premature mortality from heart disease contributes to the higher death rates among African Americans. Higher death rates among African Americans have also been observed in U.S. populations as a whole (Heron *et al.*, 2008). When broken down by specific causes of death, this gap in death rates is most influenced by homicide, hypertension, heart disease, diabetes, respiratory disease and some cancers (Howard *et al.*, 2000; Kung *et al.*, 2008).

INFANT MORTALITY DISPARITIES

Infant mortality rates in the U.S. declined dramatically through the 20th century (Heron *et al.*, 2009). Increases in educational attainment correlate with reductions in infant mortality across races (Braveman *et al.*, 2010). However, gaps in relative rates of infant mortality between groups of mothers based on educational attainment widened between 1986 and 2001 (Singh & Kogan, 2007). When examining infant mortality by race, the mortality rate for black infants is more than twice the rate for white and Hispanic infants, and cannot be explained even after adjusting for numerous factors (Heron *et al.*, 2009). Infant mortality from circulatory and respiratory disease and sudden infant death is greater among black mothers than among white and Latina mothers (Hessol & Fuentes-Afflick, 2005).

PERINATAL OUTCOME DISPARITIES

Differences in adverse perinatal outcomes, such as low birth weight and preterm delivery, have been observed across various socioeconomic and racial groups (Gould & LeRoy, 1988). The rate of preterm births is more than 50 percent higher among black women compared to Hispanic and non-Hispanic white women (Martin *et al.*, 2009). Similarly, rates for infants with low and very low birth weight are two to three times higher among black women than among Hispanic or non-Hispanic white women (Martin *et al.*, 2009). Although income, education, prenatal care, marital status, and substance use have been identified as contributors to different birth outcomes, these factors alone do not appear to explain the disparities (Giscombe & Lobel, 2005).

ASTHMA DISPARITIES

Data from health interview surveys have shown that low-income people have higher rates of asthma symptoms and hospitalizations. This has been shown for both California populations and the U.S. as a whole (Zuk & Morello-Frosch, 2009; CDHS, 2007; Centers for Disease Control, 2008; Gold & Wright, 2005). Furthermore, in California there is a clear relationship between lower income levels and increasing asthma hospitalizations, although differences among income levels for lifetime prevalence (the actual number of people with asthma) do not exhibit the same relationship (CDHS, 2007). Conflicting evidence was demonstrated in another study that identified an inverse relationship between some measures of asthma prevalence in Southern California and different measures of socioeconomic position (Shankardass *et al.*, 2007).

With respect to race/ethnicity, asthma is much more prevalent in California among African Americans and American Indians/Alaska Natives compared to other races (CDHS, 2007). This difference is even greater for asthma among African Americans when measured by such yardsticks as health care utilization and mortality (emergency department visits and hospitalizations). Among children of different races/ethnicities in the U.S., rates of asthma are highest in Puerto Rican children, followed by African-American, white, and Mexican-American children (Gold & Wright, 2005). African-American children are almost three times more likely to be hospitalized for asthma than children of all other races in California (CDHS, 2007).

CANCER DISPARITIES

Differences in various measures of cancer status, including incidence, survival, screening prevalence, stage at diagnosis, and mortality among different socioeconomic and racial/ethnic groups have been well documented for different types of cancer (Zuk & Morello-Frosch, 2009). Distinct cancers have different risk factors associated with them. There are many possible factors that are potentially responsible for these differences across specific groups, including tobacco smoking, alcoholic beverage consumption, diet, reproductive factors, infectious diseases (particularly sexually transmitted disease), chronic infections, occupational factors, unemployment, and environmental factors (Kogevinas *et al.*, 1997).

Among major racial groups in the U.S., cancer incidence is highest among African Americans for lung and bronchial, colon and rectal, prostate and all cancer sites combined (Altekruse *et al.*, 2010). Differences by race persist even after controlling for poverty (Ward *et al.*, 2004).

Later-stage diagnosis appears to be the primary impact on mortality disparities. White women of higher socioeconomic status have higher breast cancer incidence, though the incidence of more advanced breast cancers is higher in African-American women (Vainshtein, 2008). Additionally, breast cancer survival among African-American women is lower than that of white women and has grown since the mid-1980s (Brawley & Berger, 2008; Gorey *et al.*, 2009). With respect to the higher prostate cancer mortality in African-American men, the stage at diagnosis appears to be the primary driver of the disparity (Merrill & Lyon, 2000).

CARDIOVASCULAR DISEASE DISPARITIES

Disparities in cardiovascular disease (CVD) and risk factors such as high blood pressure, obesity, smoking and diabetes have been observed across different socioeconomic and racial groups in the U.S. Mortality from heart diseases and stroke is higher for blacks compared to whites. Populations of Hispanics, Asian/Pacific Islanders, and American Indian/Alaska Natives show comparable and sometimes lower death rates than white populations for CVD (Mensah *et al.*, 2005). Latinos born in the U.S. are more likely to be diagnosed with high blood pressure than foreign-born Latinos (Holtby *et al.*, 2008).

Evidence negating genetic differences with respect to CVD disparities comes from studies of the disease prevalence in black populations of West African origin, which suggests that the physical and social environments are important determinants in the development of disease (Cooper *et al.*, 1997).

Higher socioeconomic status, as measured by educational attainment, income, and poverty status, was found to be associated with lower prevalence of CVD and its risk factors (Pleis & Lethbridge-Cejku, 2007; Mensah *et al.*, 2005). Additionally, the gap between socioeconomic groups appears to be widening for some cardiovascular disease risk factors such as smoking and diabetes (Kanjilal *et al.*, 2006).

Conclusion

We have reviewed a large body of key scientific literature that forms some of the basis for concern for the cumulative impact of environmental pollutants, particularly in low-income and minority communities. Much of this literature has been identified in a review prepared by consultant researchers from UC Berkeley (Zuk & Morello-Frosch, 2009). This literature provides a deeper understanding of potential disparities across different populations with respect to many of the concepts that are part of the Cal/EPA working definition of cumulative impacts: exposures, environmental effects, public health effects, population sensitivity, and socioeconomic factors. These concepts will be defined and discussed in Chapter 2.

The scientific literature reviewed here points to differences in exposure to environmental pollutants, and suggests differing environmental conditions across diverse places and among diverse people. Overall, disparities in exposures and environmental conditions are prevalent among different racial and ethnic groups and across different socioeconomic strata.

Many studies have identified population-wide health variations among people of different races and ethnicities and level of socioeconomic position. Furthermore, many of the observed differences in health outcomes reflect diseases known to be influenced or caused by environmental pollutants. Scientific evidence also supports concern for populations that may be especially sensitive to environmentally mediated disease based on intrinsic characteristics, such as biological and physiological differences. Additional scientific evidence suggests that certain populations may experience more profound effects from environmental pollutants due to social factors that affect individuals and communities. These factors, such as educational attainment or race/ethnicity, can increase health disparities because they have become closely tied to pollutant exposures associated with disease.

That said, not all disparities in health outcomes can be linked to environmental pollution. Similarly, health differences measured in populations are unlikely to entirely reflect differences in exposure, particularly cumulative exposures. Therefore, considerable uncertainties remain, including multiplicity and additivity over time and cumulative impacts, as scientists strive to fully understand the relationship between pollution and its impacts on people.

Overall, a substantial, growing body of scientific evidence suggests a likely role for pollutant-mediated adverse effects in people, particularly for low-income and minority populations. It also appears that adverse effects are compounded by differences in levels of exposure to individual pollutants, as well as by the types of chemicals and the sources of the pollution burdens borne by individuals and groups.

CHAPTER 2. DEFINITIONS AND TERMS

To guide Cal/EPA's ongoing efforts to explore and develop strategies and tools for addressing environmental justice, the IWG adopted the following working definition for Cal/EPA of the term "cumulative impacts":

> Cumulative impacts means 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 socio-economic factors, where applicable, and to the extent data are available.

The purpose of this chapter is to define key terms in the definition of cumulative impacts. Arriving at a common understanding of the terms within this definition will assist Cal/EPA programs in assessing cumulative impacts systematically and consistently.

The definitions that appear below were informed by Cal/EPA's statutory authorities and program mandates, and by input from the CIPA Work Group and the public. These definitions are intended to be useful across Cal/EPA programs and to enhance consideration of cumulative impacts.

Overview of Key Definitions

The Cal/EPA working definition presents an inventory of items to be accounted for in determining cumulative impacts. These items can be grouped into three interrelated components:

I. **Burden of pollution**: Exposures, public health effects and environmental effects are manifestations of the impacts of pollution on a community.
II. **Setting**: The geographic area of interest and the presence of pollution in the area—including its sources and the emissions and discharges released by these sources—constitute the physical setting within which cumulative impacts occur.
III. **Population characteristics**: Attributes of the community—specifically the presence of sensitive populations and certain socio-economic factors—can influence the ability of the community to resist disease and other impacts of pollution.

I. Burden of Pollution: Exposures, Public Health Effects, and Environmental Effects

"Cumulative impacts means exposures, public health or environmental effects…"

Exposures, public health effects and environmental effects, which constitute the burden of pollution, represent how impacts are manifested in a community.

EXPOSURES: CONTACT WITH POLLUTION.

Exposures generally involve transport of chemicals from a source to an exposed individual or population. Transport can occur through air, water and soil. For example, facilities can release airborne chemicals that are deposited onto soil, and chemicals can leach from leaking underground storage tanks into groundwater.

Contact with chemicals in the environment can occur through inhalation, ingestion and skin absorption. Direct contact—that is, contact that does not involve transport of the chemical through an environmental medium—is also possible, as when a child ingests chemicals used as plasticizers in pacifiers or lead in paint chips.

The duration and frequency of exposures to harmful agents influence adverse outcomes. Exposure may be continuous; discontinuous but regular (*e.g.*, once daily); or intermittent (less than daily, with no standardized, quantitative definition). The magnitude of exposure or dose determines how much of a pollutant can be taken up by an individual or population.

PUBLIC HEALTH EFFECTS: DISEASE AND OTHER HEALTH CONDITIONS INFLUENCED BY EXPOSURE TO POLLUTANTS.

Disease is influenced by many factors, some relating to an individual's characteristics and behaviors (such as genetics, age, and lifestyle factors, particularly smoking and diet). The external environment, including exposures to pollution, also plays a role in public health status. Diseases and other health conditions associated with pollutant exposures can occur shortly after the exposure (an acute effect), after several exposures over a short period of time (a subchronic effect), or following recurring, long-term exposures (a chronic effect).

Because many diseases occur years after the exposure, it is often difficult to pinpoint when environmental pollutants produce disease in humans. In fact, most of our understanding of the adverse effects of exposures to chemicals comes from animal studies. Consequently, linking environmental pollution with health outcomes may require reliance on exposure assumptions, modeling techniques, and data extrapolation that lead to uncertainty in the evaluation of health effects.

On the other hand, many well-recognized studies clearly demonstrate association or causality between environmental pollutants and disease. Examples of public health effects linked to environmental or workplace-related exposures include:

- **Asthma:** Researchers have found an association between exposure to high levels of traffic-related particulate matter and increased hospital admissions for asthma.
- **Lung cancer:** Hazardous airborne asbestos fibers associated with soil and dust from mine activities is linked to increased cancer risk in mining communities.
- **Developmental effects:** Ingesting fish contaminated with mercury has been shown to produce harmful effects in the developing fetuses and children of expectant mothers. In addition, pregnant women's exposures to certain chemicals have been associated with low birth weights.
- **Neurological effects:** Children exposed to products containing lead can develop a host of health effects, including neurological effects.
- **Heat-related illness:** Exposures to heat have been associated with illnesses and deaths involving kidney failure, electrolyte imbalance, respiratory effects and other symptoms, especially among the elderly.
- **Miscarriage:** A California study found that African-American women are about three times more likely to miscarry if they lived within a half-block of a freeway or busy boulevard than if they resided near lighter traffic.

ENVIRONMENTAL EFFECTS: ADVERSE ENVIRONMENTAL CONDITIONS CAUSED BY POLLUTANTS.

This term is interpreted broadly to include various aspects of environmental degradation, ecological effects and threats to the environment and communities.

The introduction of physical, biological and chemical pollutants into the environment can have harmful effects on both living and non-living components of the ecosystem. Effects can be immediate, such as the massive fish kill that followed the 1991 spill of metam sodium into the Sacramento River from a train derailment near Dunsmuir, California. Effects can also be delayed, such as the long-term declines in bird populations due to the accumulation of the pesticide DDT in the animals' tissues over a lifetime of exposure and its resulting reproductive effects.

In addition to direct effects on ecosystem health, the environmental effects of pollution can also affect humans in at least two ways. First, these environmental changes compromise the ability of communities to make use of ecosystem resources. For example, ecosystems serve as a source of food, fresh water and wood and provide recreation. Additionally, scientific evidence suggests that living in an environmentally degraded community can lead to stress, which may affect human health.

Examples of environmental effects include:

- **Environmental degradation**, such as:
  - Beach closures due to sewage contamination
  - Smog
  - Water bodies contaminated by oil spills
  - Decreased water clarity in lakes
  - Contaminated sites
- **Ecological effects**, such as:
  - Fish and bird kills
  - Tree deaths
  - Invasive species proliferation
  - Decline in populations of threatened or endangered species
  - Climate change
- **Threats to the environment**, such as:
  - Accidental releases of hazardous air pollutants
  - Spills of toxins into waterways

  It is reasonable to assume some exposures may occur over time due to accidental releases, even if those exposures are infrequent and cannot be quantified.

II. Setting: Pollution, Sources, Emissions and Discharges, and Geographic Area

"…from the combined emissions and discharges, in a geographic area, including environmental pollution from all sources…"

The setting within which cumulative impacts occur is defined by the geographic area of interest, sources of pollution—including those outside the geographic area that are nevertheless responsible for pollution that reaches the area—and the emissions and discharges originating from these sources.

POLLUTION: HARMFUL CHEMICAL, BIOLOGICAL OR PHYSICAL AGENTS PRESENT IN THE ENVIRONMENT.

This definition recognizes the need to expand on the traditional definition of pollution to include other agents that are hazardous or potentially hazardous. Hence, the term pollution includes a wide range of potentially harmful agents.

Three broad categories of pollutants are considered:

- Chemical—such as ozone, benzene, lead, or asbestos
- Biological—such as invasive species entering the ecosystem, sewage microbes contaminating water, or toxins released by algae into water
- Physical—such as heat, trash

SOURCES: FACILITIES OR ACTIVITIES THAT RELEASE OR CAN RELEASE POLLUTANTS.

The release of pollutants to the environment can occur from a wide range of sources that directly or potentially pose hazardous exposures. Understanding potential risks to public health within a geographic area entails knowledge of the distribution of aggregate exposures to all pollutants from all sources, as well as an understanding of the interaction of chemicals over time. The following is a list of sources as examples for possible consideration.

- Facility operations as sources of pollution include:
  - Industrial facilities such as refineries or manufacturing plants
  - Commercial facilities such as dry cleaners, gas stations, or auto repair shops
- Activities as sources of pollution include:
  - Transportation, such as cars, trucks, aircraft, trains, ships at port, or construction equipment
  - Use of consumer products, such as cigarettes (second-hand smoke) or insect spray

  - Occupational exposures, such as applying or working with chemicals
  - Land use, such as mining
  - Farming activities that release dust and other particulate matter
- Natural sources or processes as sources of pollution include:
  - Rock and soil containing radon and asbestos
  - Wildfire smoke
- Accidental and unintended releases as sources of pollution include:
  - Industrial spills or mismanaged containers
  - Leaking underground tanks
  - Tire fires
- Nonpoint sources of pollution include:
  - Stormwater runoff
  - Agricultural runoff
  - Pesticide drift

EMISSIONS AND DISCHARGES: RELEASES OF CHEMICAL, BIOLOGICAL OR PHYSICAL AGENTS INTO THE ENVIRONMENT.

Emissions and discharges are generated by pollutant sources, and may be routine or accidental. They include releases of chemical agents (such as combustion products in vehicle exhaust), biological agents (such as organisms carried in sewage), or physical agents (such as sediment in stormwater runoff). Emissions and discharges can be characterized by their spatial and temporal patterns of release. These patterns determine the likelihood, frequency and duration of exposure to the agent released.

Spatially, releases can be widespread (such as airborne emissions carried over neighboring air basins), or can involve relatively small, confined spaces (for example, the off-gassing of chemicals from construction materials into indoor air). Temporally, patterns of release can be characterized as routine (such as continuous stack emissions from an industrial facility), intermittent (such as pesticide applications, use of cleaning agents or fugitive releases), or cyclic (such as highway emissions that reflect traffic patterns over the course of a day).

Geographic area: *The spatial boundaries of the population of interest.*

Spatial boundaries may be delineated by a residential area, a school site, or other geopolitical subdivision. However, when examining cumulative impacts, the margins of the population of interest may provide the best geographic boundaries.

The following are examples of geographic areas that may be considered:

- Region, city, community, or street
- Air basin
- Watershed
- Area defined by where a population works and lives (*e.g.*, farm workers)

III. Population characteristics: Sensitive populations and socioeconomic factors

> "*…Impacts will take into account sensitive populations and socio-economic factors, where applicable, and to the extent data are available.*"

Certain characteristics of the population of concern play an important role in increasing its vulnerability to disease and other impacts of pollution. These characteristics may be intrinsic biological traits or external attributes (*e.g.*, community characteristics).

SENSITIVE POPULATIONS: POPULATIONS WITH BIOLOGICAL TRAITS THAT MAY MAGNIFY THE EFFECTS OF POLLUTANT EXPOSURES.

Sensitive individuals may include those undergoing rapid rates of physiological change, such as children, pregnant women and their fetuses, and individuals with impaired physiological conditions, such as elderly persons or persons with existing diseases such as heart disease or asthma. Other sensitive individuals include those with lower levels of protective biological mechanisms due to genetic factors, and those with increased exposure rates. For instance, children breathe at higher rates than adults and have greater hand-to-mouth activity (Arcus-Arth & Blaisdell, 2007).

The following biological attributes may influence sensitivity to pollutant exposure or environmental effects:

Age:

- Infants and children have higher rates of growth, intake, and activity than adults.
- The elderly may have impaired organ function or other pre-existing health conditions.

Children are more susceptible to the health effects of air pollution because their immune systems and developing organs are still immature. For example, lead that is inhaled is more easily deposited in the fast-growing bones of children. Irritation or inflammation caused by air pollution is more likely to obstruct their narrower airways. It may also take less exposure to a pollutant to trigger an asthma attack or other breathing ailment due to the sensitivity of a child's developing respiratory system.

OEHHA (2003). Air Pollution and Children's Health.

Existing health status:

- Those with diabetes are more sensitive to health effects from exposure to air pollution (Zeka *et al.*, 2006).
- Obesity appears to act as a modifier of exposure to fine particulate matter by increasing inflammatory response and triggering cardiac events (Dubowsky *et al.*, 2006).
- Pregnant women and their fetuses are more sensitive to the toxic effects of perchlorate in drinking water (Ting *et al.*, 2006).

Genetic factors:

- Certain genes modify the impact of air pollution on respiratory symptoms, lung function and asthma (Yang *et al.*, 2009).
- Individuals with sickle cell anemia, a hereditary blood disorder, are more sensitive to the toxic effects of benzene, cadmium and lead (Hayes, 2007).

Individuals with pre-existing cardio-vascular disease are more susceptible to death during heat waves. Research indicates that significant increases in mortality will result from both increases in general temperatures and more frequent heat waves expected from global climate change.

Basu & Ostro (2008). Amer J Epidemiol 168(6): 632-637.

SOCIO-ECONOMIC FACTORS: COMMUNITY CHARACTERISTICS THAT RESULT IN INCREASED VULNERABILITY TO POLLUTANTS.

A growing body of literature provides evidence of the heightened vulnerability of people of color and lower SES to environmental pollutants. For example, maternal exposure to particulate pollution (PM 2.5) is associated with reduced birth weight; this effect is greater among African-American mothers compared to white mothers (Bell *et al.*, 2007). Social determinants of health include but are not limited to:

- Income level
- Access to healthy food
- Educational attainment
- Cultural practices
- Access to health-care services
- Race and ethnicity
- Availability of parks and open space

Other examples of socioeconomic factors are discussed in Chapter 1.

Conclusion

It is important to establish a common understanding of the concepts underlying this document so that all readers fully understand the approach. Cumulative impacts analysis addresses a wide range of factors that can influence public and environmental health. In this document, Cal/EPA attempts to capture and define as many of the factors as possible to aid decision-makers in beginning their own cumulative impacts analyses.

A comprehensive listing of all known and suspected factors that may impact environ-mental health would be beyond the scope of this report. However, the factors that are cited are some of the many examples of how a population may be impacted. Concepts discussed in this chapter provide an understanding of how we apply these terms within the definition of cumulative impacts in the chapters that follow. As such, the definitions are relevant to Cal/EPA activities.

CHAPTER 3. A SCIENTIFIC SCREENING METHOD FOR ANALYZING CUMULATIVE IMPACTS IN COMMUNITIES

In this chapter, OEHHA presents a methodology to screen for cumulative impacts that integrates Cal/EPA's working definition of cumulative impacts, key concepts and a consideration of other methods. This unique method builds on the knowledge gained from reviewing the models presented in Appendix 3. It is designed specifically as a tool to help Cal/EPA programs consider the cumulative impacts on communities of multiple chemical exposures from air, water and soil when making decisions and developing policies.

The methodology presented here is a model for how communities may be screened for cumulative impacts using a scoring system. Implementation will require the development of specific guidelines. In such guidelines, some of the details of the model may change (for example, the ranges of the scores and/or how they are combined), and the limits of its applicability will be described. These technical guidelines will be developed with a public process. In the meantime, the methodology described here will be used for purposes of further scientific evaluation and technical discussion. The scientific screening methodology is not to be used for regulatory purposes until guidelines have been completed.

OEHHA developed the methodology around the terms discussed in Chapter 2 that are contained in Cal/EPA's working definition of cumulative impacts:

> *Cumulative Impacts means 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 socio-economic factors, where applicable and to the extent data are available.*

This method uses a simple formula to screen for relative levels of cumulative impacts among communities based on the five components from Cal/EPA's working definition that describe the geographic area: exposures, public health and environmental effects, sensitive subpopulations and socioeconomic information (see Figure 1). The components are divided into two groupings: pollution burden and population characteristics.

As indicated in the working definition, cumulative impacts include the sum total of pollution in a geographic area. This total is the "pollution burden." At the same time, the working definition states that cumulative impacts need to take into account factors that relate to the people living in the geographic area. These factors are the "population characteristics." The separation of these components into two groups becomes important when we calculate cumulative impacts.

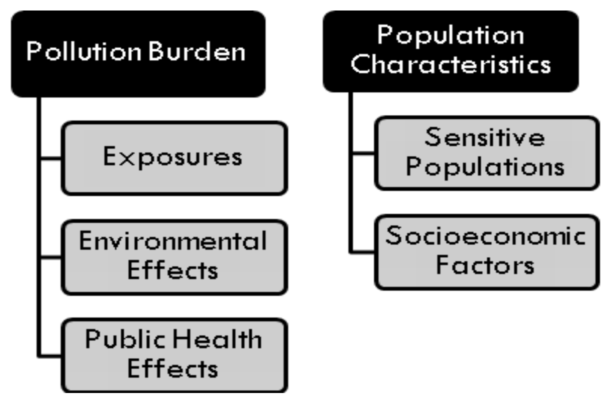

FIGURE 1. COMPONENTS OF CUMULATIVE IMPACT.

As discussed in more detail in Chapter 2, the components are:

- *Exposures, environmental effects and public health effects*. Measures of exposure can best be indicated by environmental monitoring data. While emissions by themselves do not necessarily indicate exposure, they can be used as a surrogate suggesting the potential (though not certain) contact with pollutants. Environmental effects reflect the physical conditions of the community, such as contamination by hazardous materials, and facilities where hazardous chemicals are stored, treated or disposed.[7] Public health effects include health outcomes that may be linked to chemical exposures, such as asthma, low birth weight and some cancers.

- *Sensitive populations* include the percentages of the population in the community that are children or elderly. Where appropriate, sensitive populations may also consist of individuals with certain diseases or physical conditions that render them more vulnerable to the effects of pollution, such as pregnant women.
- *Socioeconomic factors* reflect characteristics of the population that have the potential to make them more vulnerable to pollutants, such as poverty level, minority proportion, or educational attainment.

Table 2 contains further specific examples of indicators that could potentially be used in the screening methodology.

[7] The proper storage, treatment, and disposal of hazardous materials in compliance with laws and regulations should not result in an effect on the environment. However, the definition of "cumulative impacts" includes accidental releases, so the presence of the facilities is included in the methodology.

TABLE 2. POTENTIAL INDICATORS FOR DIFFERENT CUMULATIVE IMPACT COMPONENTS.

COMPONENT	CONTRIBUTION TO COMPONENT	INDICATOR	DATA SOURCE
Socioeconomic Factors	Educational attainment	% over age 24 with less than high school education	U.S. Census
	Income level	Median household income	
	Poverty	Percent residents below 2x national poverty level	
Sensitive Populations	Presence of children	Percent under age 5	U.S. Census
	Presence of elderly	Percent over age 65	
Exposures	Emission of fine particles (PM 2.5)	PM 2.5 concentrations (average of quarterly means)	California Air Resources Board: California Air Quality Data
	Criteria Air Pollutants	Ozone concentrations (average of 8-hour monthly maximum)	
	Emissions and discharges of hazardous chemicals	Toxic releases from industrial facilities	U.S. EPA: Toxic Release Inventory
	On road mobile sources	Traffic (vehicles per day)	California Environmental Health Tracking Program: Distance-Weighted Traffic Volume
	Pesticides	Pesticide use (lbs/km^2)	California Department of Pesticide Regulation
Environmental Effects	Hazardous waste sites & brownfields	Hazardous waste & clean-up sites	California Department of Toxic Substances Control: EnviroStor
	Spills, leaks	Leaking underground fuel tanks	California State Water Resources Control Board: GeoTracker
Public Health Effects	Birth outcomes	Low birth weight rate	California Department of Public Health
	Disease rates with environment component	Heart disease mortality rate	California Department of Public Health
	Cancer rates with environment component	Cancer mortality rate	
	Asthma	Asthma hospitalization rate	California Environmental Health Tracking Program

The table is not all-inclusive, and guidelines to be developed would provide more information on what component measures could be useful in estimating cumulative impacts. Data for these components can be obtained from publicly available databases and government sources.

For the screening analysis of cumulative impacts in a community, each of the five components is assigned a score based on the relative magnitude of impact (as discussed below). As illustrated in Figure 2, the five scores are added and then multiplied as indicated in the formula below to yield a final score representing the cumulative impacts of multiple pollution sources in that community.

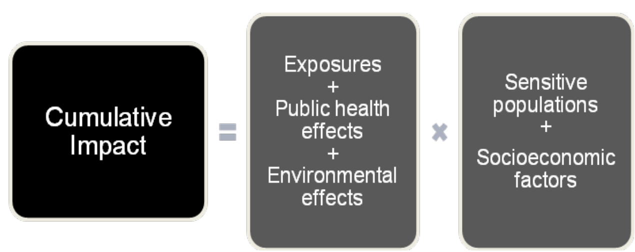

FIGURE 2. FORMULA FOR ESTIMATING RELATIVE CUMULATIVE IMPACT AMONG COMMUNITIES.

Higher scores reflect greater contributions to cumulative impact. Table 3 presents the proposed range of integer scores for each of the five components and the proposed range of total cumulative impact scores. To calculate the overall score for the community, (1) the socioeconomic factor and sensitive population scores are summed, and (2) the exposures, environmental effects, and public health effects scores are summed. These two scores are then multiplied together to produce the final cumulative impact score.

TABLE 3. RANGE OF SCORES FOR EACH COMPONENT.

Component	Range of Possible Scores
Exposures	1-10
Environmental effects	1-5
Public health effects	1-5
Sensitive populations	1-3
Socioeconomic factors	1-3
Cumulative impact	**6-120**

Why multiply together the pollution burden and population characteristics scores?

The proposal to multiply the summed scores for the pollution burden and population characteristics is based on existing risk assessment guidance regarding sensitive populations and evidence from human studies indicating multiplication is appropriate. Population characteristics modify the response to the pollution burden (see discussion in Chapter 1—Sensitivity based on intrinsic and non-intrinsic factors). It is also common in standard-setting to apply a multiplier to account for possible differences in sensitivity. Examples include the multipliers when considering population variability in non-cancer risk assessment, when considering special sensitivities of children under the Food Quality Protection Act of 1996, and when accounting for age-specific sensitivity to carcinogens in cancer potency calculations in the recent U.S. EPA and OEHHA cancer guidance documents.

We have presented some evidence that some subpopulations, including low income and minority populations, show several-fold differences relative to other populations in response to exposures to environmental pollutants. While there is still uncertainty regarding the exact relationships between health outcomes and different population characteristics, we have modeled our approach here after conventional approaches in standard risk assessment practice.

We also considered it important to separate the scoring for pollution burden and population characteristics. Because reducing pollution burden in communities is a policy goal for Cal/EPA's Boards and Departments (and changing population characteristics is not), it is useful to estimate a separate score for this set of components.

How was the proposed range of possible scores for each component established?

The range of scores for the components was selected based on several factors. The overall range of scores (6-120) had to be large enough to distinguish communities. The range of 1 to 3 for socioeconomic factors and sensitive populations scores was based on scientific evidence suggesting that several-fold differences in response to environmental pollutants exist for certain populations based on either socioeconomic factors or biological traits (see Chapter 1).

For the pollution burden-related components (exposures, public health effects and environmental effects), the maximum possible value for each component reflects the strength of the available data for that component and the Agency's ability to address these components.

For example, there is considerable information available on the types and extent of potential exposures within a community, and exposures are most closely associated with pollution impact, thus this component was assigned a maximum value of 10. In contrast, there is less certainty and less information on the other two components, public health effects and environmental effects. For this reason, these two components were assigned a maximum value of five.

How are the scores for each component calculated?

For a given community, each component is assigned a score within its range, calculated from data collected from indicators for that component. Indicators are simple measures that provide information about the condition of the community with respect to each of the different components. Examples of indicators are toxic releases from facilities in a community, leaking underground fuel tanks, median household income, and percentage of the local population under 5 years old. Table 2 presents a set of potential specific indicators that could be used to establish values for each of five components.

Indicators will typically have significance beyond that for which they provide direct information (for example, the measured ozone levels from an air monitoring station plausibly signify exposures of people in the vicinity of the station to ozone). There would be multiple possible indicators for each component.[8]

In developing indicators, we relied on information from publicly available statewide databases. This allows for rapid initial screening. The best statewide data are those that provide information at the community scale of interest, such as cities, counties, zip codes or census tracts.

We can establish scores for communities from different regions of California because of the availability of statewide information in these databases. The communities are ranked from highest to lowest for each indicator, such as ozone levels. Scores are assigned based on the community's rank within the entire data set for that indicator. For example, ozone levels are ranked from highest to lowest for the entire state. The ranking is then divided into 10 equal subgroups. Each subgroup is assigned a value of 1 to 10. If a community ranks in the lowest subgroup of all communities, it will receive a score of 1 for ozone levels. If the community ranks in the highest subgroup of all communities, it will receive a score of 10 for ozone levels.

As described above, values for each indicator are established using the ranking of the indicator across the full set of communities. These values are then averaged for each component.

How are indicators for each component selected?

The terms of the definition of cumulative impact, as detailed in Chapter 2, were used to identify potential indicators. Indicators are selected to represent major known contributions to impact and are necessarily drawn from existing publicly available statewide databases. A goal in selecting the total set of indicators is to use as few as possible to adequately explain the relative magnitude of impact in a given community.

How is "double-counting" between different indicators handled or avoided?

Indicators need to be examined on a case-by-case basis for the possibility that two or more may represent the same or similar contribution to impact. Some level of overlap between different indicators may be difficult to avoid in implementing this methodology because of limitations to available data as well as scientific uncertainty. However, it is desirable to avoid double-counting. In developing the method for specific applications, every effort will be made to acknowledge the basis of such overlaps and uncertainties, to the extent possible. Statistical correlation between indicators alone does not necessarily mean overlap exists, though it suggests the possibility should be examined.

What results would you obtain from a screening cumulative impacts analysis?

An example of a screening of 28 diverse hypothetical communities from different parts of California is presented in Table 4. The results are displayed ranking the 28 communities from the highest to lowest overall cumulative impact score.

[8] Indicator scores are assigned values from the same possible range as the component they represent. The score for the component is the rounded average of the indicator scores that make it up.

TABLE 4. TWENTY-EIGHT HYPOTHETICAL COMMUNITIES (A THROUGH BB) RANKED FROM HIGHEST IMPACT TO LOWEST IMPACT.

	Community																											
Component	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB
Exposures	7	5	8	7	6	4	7	6	8	3	6	6	5	4	6	4	7	7	4	3	3	5	4	4	5	4	5	3
Public Health Effects	5	5	5	3	4	5	3	5	3	4	3	4	3	3	1	3	3	2	3	2	2	4	3	2	2	1	1	2
Environmental Effects	3	4	3	3	3	4	4	2	1	5	2	1	5	1	5	2	1	1	3	4	2	2	3	1	1	1	2	1
Contributors to Burden	15	14	16	13	13	13	14	13	12	12	11	11	13	8	12	9	11	10	10	9	7	11	10	7	8	6	8	6
Sensitive Populations	3	3	2	3	3	3	2	2	2	2	2	3	2	3	2	3	2	2	2	2	2	2	2	2	2	2	2	1
Socioeconomic Factors	3	3	3	3	3	3	3	3	3	3	3	2	2	3	2	2	2	2	2	2	3	1	1	2	1	2	1	2
Contributors to Sensitivity	6	6	5	6	6	6	5	5	5	5	5	5	4	6	4	5	4	4	4	4	5	3	3	4	3	4	3	3
Composite Score	90	84	80	78	78	78	70	65	60	60	55	55	52	48	48	45	44	40	40	36	35	33	30	28	24	24	24	18

To illustrate what the results of the proposed screening method might look like, scores were determined based on the available data. In this case, community 'A' shows a higher score than the others, based on relatively high pollution and population characteristics that suggest increased potential vulnerability to pollutants.

What can this methodology be used for?

A screening method would:

- Distinguish higher-impacted from lower-impacted communities. Cal/EPA programs could target those communities with the highest impact scores for enforcement and incentive programs.
- Identify which of the components (exposures, public health effects, socio-economic factors, etc.) are likely to contribute the most to the community's cumulative impact and which of those components Cal/EPA programs can address.
- Identify a highly impacted area. This could be included as additional information in a risk assessment. A similar approach has been adopted in the ARB Air Toxics 'Hot Spots' guidelines for certain chemicals that affect children.
- Support intra-agency efforts to address multi-media impacts.

What can't the methodology be used for?

- A comprehensive assessment of the cumulative impacts of all pollutants within a community.
- Detecting the impact of small incremental changes within a community.
- Determining the cause of health outcomes in a community (for example, attributing impacts to a specific source or facility) or predicting human health risks.
- As a human health risk assessment.
- Supplanting existing regulatory requirements (such as those specified in CEQA).

What steps are necessary to implement the screening methodology?

- Develop guidelines to refine the weighting and scoring of each component, and to identify which indicators and databases can be used as measures of the component (exposures, public health effects, environmental effects, sensitivity and socioeconomic factors). The guidelines would explain where data can be found and how the screening method can be applied for different-sized areas such as census tracts, cities and counties. The guidelines would also explain when and how the screening method should and should not be applied. Public input will be an important element of this work moving forward.
- On a parallel track, work with other Cal/EPA Boards and Departments in the development of the guidelines and the related public process. In this way, the screening method can be tailored to meet program specific needs.

Conclusion

The methodology to screen for cumulative impacts is based on Cal/EPA's working definition of cumulative impacts and integrates key concepts from existing methodologies. It is designed specifically as a tool to help Cal/EPA programs, when making decisions and developing policies, to consider the cumulative impacts on communities of multiple chemical exposures from air, water and soil.

The method incorporates the five components of the working definition: exposures, public health effects, environmental effects, sensitive populations and socioeconomic factors. It assesses cumulative impacts by using a simple formula to combine information within the five components.

The method is a science-based tool that is simple and understandable. It incorporates information from multiple media, thus yielding a more comprehensive assessment of environmental exposures. By including socioeconomic factors (for example, income) and sensitive populations (for example, children and the elderly), this method integrates aspects of impacts that address environmental justice concerns. Finally, the proposed screening method makes use of existing statewide data, encouraging immediate use and promoting transparency.

This screening method distinguishes between communities with respect to cumulative impacts, providing Cal/EPA Boards and Departments a step towards prioritizing enforcement actions or targeting incentives toward more highly impacted communities, among other actions. The method allows decision-makers to discern between communities based on their relative levels of environmental pollution while accounting for different community-level vulnerabilities.

CHAPTER 4. CUMULATIVE IMPACTS IN ENVIRONMENTAL DECISION-MAKING

Introduction

Consideration of cumulative impacts is intended to produce a more representative picture of the burden of pollution in a community and the characteristics of its population that affect its sensitivity and vulnerability to the effects of pollutants.

Environmental regulatory decisions typically focus on a specific facility or site, pollutant or environmental medium. In contrast, weighing cumulative impacts acknowledges the multiple factors that influence human and environmental health.

Environmental programs have been taking steps to incorporate broader considerations in evaluating and addressing human and environmental impacts. For example, the Air Toxics “Hot Spots” Information and Assessment Act of 1987 requires that facilities examine potential health risks posed by emissions of multiple chemicals, as well as these chemicals’ subsequent movement across air, water, and soil. California's Global Warming Solutions Act of 2006 (AB 32, Chapter 488) requires ARB to consider the “potential for direct, indirect and cumulative emission impacts…” from any market-based compliance mechanisms before adoption into regulations.

This chapter provides an overview of Cal/EPA decision-making activities that might benefit from or that already incorporate cumulative impacts considerations. It discusses the possible value of addressing cumulative impacts in terms of meeting environmental justice mandates, focusing program resources and guiding future activities. Lastly, it highlights Cal/EPA program areas where cumulative impacts analytical approaches would better inform decision-making.

Entities with Environmental Decision-Making Authority

Cal/EPA’s Boards and Departments advise, direct and support decision-makers at all levels of government. The Boards and Departments carry out the following responsibilities:

- Air Resources Board (ARB) – ARB promotes and protects public health and ecological resources through the reduction of air pollutants. AB 32 gives ARB the authority to adopt regulations that reduce emissions of greenhouse gases without disproportionately impacting low-income communities.
- Department of Pesticide Regulation (DPR) – DPR evaluates and mitigates impacts of pesticide use on health and the environment, maintains the safety of the pesticide workplace, and encourages the development and use of reduced-risk pest management practices.
- Department of Toxic Substances Control (DTSC) – DTSC regulates hazardous waste, conducts and oversees cleanups, and develops and promotes pollution prevention to ensure public health and environmental quality that can sustain economic vitality.
- State Water Resources Control Board (SWRCB) – SWRCB preserves and enhances the quality of California's water resources, and ensures their proper allocation and efficient use for the benefit of present and future generations.
- Office of Environmental Health Hazard Assessment (OEHHA) – OEHHA protects and enhances public health and the environment by conducting objective scientific evaluation of risks posed by hazardous substances.

Cumulative Impacts and Decision-Making Activities in Cal/EPA

Cal/EPA programs already incorporate aspects of cumulative impacts analysis in their health and environmental assessments. Other activities may recognize or identify cumulative impacts but cannot draw upon precedent or analysis methods and tools to address this phenomenon. At present, consideration of cumulative impacts generally occurs at the discretion of the decision-maker, typically when these considerations are consistent with established policies and procedures. A screening of

California communities for cumulative impacts, as well as more refined analyses, would enhance the ability of Cal/EPA programs to more systemically factor cumulative impacts into their decision-making.

The following are types of activities at Cal/EPA that already incorporate elements of cumulative impacts or that could factor the results of screenings or refined analyses into their decisions:

Permitting

DTSC and the regional water quality control boards (RWQCBs) often serve as the lead authority or have oversight capacity in permitting facilities and other projects. Cal/EPA Boards and Departments also become involved in the CEQA process to the extent that they are invited to comment on projects or activities that require permits or permit renewals. For decades, CEQA has required that the potential impacts of a proposed project be assessed in combination with the impacts of other projects, that is, that cumulative impacts be assessed. Current assessment practices vary widely. Guidance for refined cumulative impact analyses may help promote consistency in CEQA assessments. Whether and how the scientific screening methodology should be considered in permitting processes is a topic that needs more discussion within Cal/EPA and more input from the CIPA Work Group and other stakeholders. In the meantime, the screening methodology discussed in this report is not to be used in the CEQA or permitting context. This issue will be discussed further during the development of Cal/EPA's guidelines.

Site Clean-Up

Cal/EPA programs have certain authorities related to site cleanup. It is common for clean-up activities to be conducted by local entities with support and oversight offered by one or more Cal/EPA Board or Department.

Opportunities exist for advancing consideration of cumulative impacts for site clean-up and related activities. This might entail assessing cumulative impacts as a basis for prioritizing clean-up projects on a statewide level. The results of screening for a community might trigger further assessment. Cal/EPA and local authorities could use such an enhanced risk assessment to target clean-up funds based on the relative level of pollution burden a community bears.

Enforcement

The goals of California's environmental laws cannot be achieved without compliance. Enforcement is an important tool in achieving compliance. Enforcement activities include actions such as inspections; notices of violation; notices to comply; and administrative, civil and criminal enforcement actions.

Cal/EPA programs have used their discretion to target enforcement activities in areas of the state already known to have higher pollution burdens. An example is ARB's Diesel Emissions Enforcement Program, which targets enforcement in communities most affected by diesel pollution sources. For three years, DTSC, through its Environmental Justice Enforcement Initiative, has partnered successfully with EJ organizations and communities who have concerns regarding multiple pollution sources. The ongoing Environmental Justice Task Forces in the communities provide opportunities for residents to help monitor and report what is going on in their areas and learn about environmental law and enforcement procedures. Cal/EPA could use the screening methodology outlined in Chapter 3 to target enforcement efforts based on the relative ranking of pollution within a particular community.

Environmental Monitoring

Monitoring for pollution levels in the environment is an essential element of verifying compliance with environmental laws and standards, ranging from permitting requirements for individual facilities to regional compliance with ambient air quality standards. The screening methodology could assist Cal/EPA programs in identifying priority areas for environmental monitoring.

Risk Assessment and Standard-Setting

Standard-setting at environmental agencies involves the development of health-protective pollutant levels for specific environmental media. Standards for toxic contaminants in air, drinking water and soils generally address statewide environmental conditions rather than community-level pollution problems. Standards can also involve setting guidelines for site remediations and for use of products such as pesticides and consumer goods. They can also require use of equipment to control facility pollutant emissions, such as use of "best available control technology." These standards are at least partly based on the results of scientific assessments of the health and environmental risks posed by environmental contaminants.

In the development of some public health standards (*e.g.*, Public Health Goals, Child-Specific Reference Doses, site-specific risk assessments, and risk characterization documents), Cal/EPA scientists now consider sensitive populations, such as children, pregnant women and the elderly. These groups experience greater health effects from exposure to many pollutants than the general population. Cal/EPA increasingly considers vulnerable populations when formulating safe pollutant levels for environmental media.

For certain programs, Cal/EPA scientists consider multiple contaminant sources in establishing media-specific standards. For example, when developing total maximum daily loads (TMDLs) for a water body, SWRCB requires that loads from all pollution sources within an impaired watershed be allocated. TMDLs also generally require that diverse programs and agencies work together to achieve the desired level of pollution control.

A screening of cumulative impacts could help define geographic areas or sites where further health risk assessment is needed. Special analyses may be needed to identify and more fully consider specific components of risk assessments, such as vulnerable populations.

FOCUSED REGULATORY ENFORCEMENT EFFORTS

Information about cumulative impacts can provide valuable input into regulatory decision-making and priority-setting activities. For example, Cal/EPA agencies could develop targeted enforcement programs designed to reduce violations of existing laws and regulations and deter future violations in highly impacted communities. Other activities that could benefit from information concerning cumulative impacts include programs that develop prevention and mitigations strategies for certain pollutants or sources of pollution. These efforts would be most effective if they were coordinated statewide, region-wide, cross –agency or that otherwise leverage state, regional and local regulatory programs.

A screening analysis based on the approach outlined in this report would assist the existing regulatory programs within Cal/EPA to identify the state's most highly impacted areas or communities. Cal/EPA could then use this information to inform priority setting and resource allocation to help reduce those negative impacts. However, this scientific screening methodology is not to be used for regulatory purposes until guidelines have been completed.

Financial Assistance

Cal/EPA Boards and Departments provide loans and grants to state and local entities and others to promote activities that protect public health and the environment. These grants and loans draw on local community knowledge and expand available resources. Loans and grants provide unique opportunities to better characterize and mitigate pollutant impacts in California communities.

Cal/EPA has begun to consider cumulative impacts with existing loan and grant programs. For example, DTSC's Environmental Justice Enforcement Initiative facilitates state efforts to work with disproportionately affected communities in addressing local environmental and public health issues. By screening for highly impacted communities, outreach efforts could prioritize those most in need of financial assistance. This assistance could be used to increase public participation opportunities and other capacity-building efforts.

Education and Outreach

An important component of many Cal/EPA programs is educating the public about environmental and public health concerns such as hazards and risks associated with exposure to pollutants; ways they can reduce exposures; promoting green activities; and obtaining information about Cal/EPA programs. Education and outreach also can provide capacity-building for communities, enabling them to participate in efforts to address cumulative impacts.

Cal/EPA's FRONTERA Project provides training to local agencies and community groups at the California/Mexico border on the recognition of environmental health threats. It also offers technical advice on how to minimize such threats. The project serves low-income Spanish-speaking communities heavily impacted by environmental pollution. This population is considered especially vulnerable due to socio-economic conditions.

Conclusion

The case for considering cumulative impacts in priority-setting and other environmental decision-making is compelling. Further, the responsibilities of Cal/EPA's Boards and Departments accommodate providing relief to communities from the cumulative impacts of pollutants. Consequently, environmental programs have begun to take steps to incorporate broader considerations (*e.g.*, multiple sources of pollutants in multiple media and sensitive populations) in their decision-making activities.

Screenings can support activities like site clean-up, enforcement, environmental monitoring, and provision of financial assistance and education and outreach resources.

The use of cumulative impacts analysis, such as a screening methodology can better inform decision-making efforts. These efforts will move Cal/EPA forward in meeting its environmental justice mandates, addressing cumulative impacts in the most highly impacted communities, and guiding future research.

CHAPTER 5. PROPOSED ACTIONS AND NEXT STEPS TO ADDRESS CUMULATIVE IMPACTS

This report presents a screening methodology for characterizing cumulative impacts. Cal/EPA will have a tool that can be used to gain a better understanding of the populations served and the impacts of its programs on communities. It will allow population characteristics, such as socioeconomic status, to be quantitatively factored into impact analysis in support of various processes at Cal/EPA.

While significant scientific and policy challenges persist, Cal/EPA will begin to integrate considerations of cumulative impacts into program activities. To accomplish this goal, Cal/EPA proposes the following actions:

(1) **CUMULATIVE IMPACTS GUIDELINES**: Build on this report by developing and adopting cumulative impacts guidelines, including guidelines for conducting screening cumulative impact analyses.
(2) **METHODOLOGY FOR MORE COMPREHENSIVE ANALYSIS**: Build methodology for conducting more comprehensive cumulative impacts analyses.
(3) **DATA**: Gather new data and get the most out of current data relevant to cumulative impacts, while making it more accessible to communities and the public.

These actions are briefly described below.

1. CUMULATIVE IMPACTS GUIDELINES

Cal/EPA and its Boards, Departments, and OEHHA will develop Cumulative Impacts Guidelines. These guidelines will address program (policy) and screening methodology (scientific) issues.

Cal/EPA is directing OEHHA to prepare more-detailed scientific guidelines for the screening methodology analysis of cumulative impacts. The guidelines will describe the type of data available for cumulative impacts analysis and how they can be incorporated. These guidelines will be designed and developed to assist specific Cal/EPA programs and to establish criteria to help identify the analytical and data needs for those situations where cumulative impacts may be an issue. Topics that guidelines may address include: how to incorporate socioeconomic data into the analysis, how to evaluate the data to assign the proper weighting factor, how to collect data; how to analyze certain types of data; and how to conduct specific steps in using the formula described in Chapter 3.

2. METHODOLOGY FOR MORE COMPREHENSIVE ANALYSIS

OEHHA will, as the state of science, the availability of data, and resources allow, continue to work to improve the scientific tool to assess cumulative impacts.

3. DATA

Analysis of cumulative impacts requires the use of multiple data sets. In using the screening methodology, Cal/EPA will need to draw on data sets for pollution sources, population exposures, environmental effects, public health effects, and socioeconomic factors.

While some of this data will need to be collected, much already exists within different databases maintained by Cal/EPA and other state, federal, or local entities. However, compiling this data in a usable fashion in many cases requires considerable time and labor. Making these data more accessible and usable will greatly facilitate cumulative impacts analyses.

For example, some off-line databases are maintained by different authorities that do not inform each other or the public of their availability. Cal/EPA encourages its Boards and Departments to take steps to improve accessibility of these databases and consolidate such databases where feasible.

In some cases, important information may not be immediately available. An important element of Cal/EPA's commitment to address cumulative impacts will involve identifying needed data that is not currently available and taking steps to accelerate the production of such data.

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APPENDIX 1. CAL/EPA'S OCTOBER 2004 ENVIRONMENTAL JUSTICE ACTION PLAN

https://calepa.ca.gov/wp-content/uploads/sites/6/2016/10/EnvJustice-ActionPlan-Documents-October2004-ActionPlan.pdf

APPENDIX 2. CUMULATIVE IMPACTS AND PRECAUTIONARY APPROACHES WORK GROUP MEMBERS

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APPENDIX 3. OVERVIEW OF KEY METHODS FOR ANALYZING CUMULATIVE IMPACTS

There is no single established methodological approach to the analysis of cumulative impacts. Further, no established method currently directly addresses the needs of cumulative impact analysis as envisioned in Cal/EPA's working definition. The screening and other methodologies described in this Appendix will provide decision-makers with information regarding important current approaches to cumulative impacts analyses.

This Appendix describes:

- The major types of methodological approaches to assessment.
- Examples of methods that have been developed for other purposes.

Chapter 4 of this report describes the screening methodology developed by OEHHA to screen for impacted communities in a manner consistent with Cal/EPA's working definition of cumulative impacts.

Major Types of Methodological Approaches to Assessment

The working definition of cumulative impacts is broad and does not suggest a specific decision-making process. With that in mind, the following methodological approaches were identified (Kyle, 2010):

I. **Screening for Communities of Concern.**
II. **Community-Specific Assessments.**
III. **Cumulative Impacts in Land Use and Planning.**
IV. **Methods to Assess Inequalities.**

I. Screening for Communities of Concern

Screening methods are tools used to make relative comparisons of cumulative impacts across multiple communities. Screening methods generally use data on environmental pollution, health and population demographics to estimate cumulative impacts of multiple pollutants on a community. Screening methods can be applied in various ways to inform policy decisions.

Following are some examples of screening-based methods developed by a variety of government agencies and researchers.

ENVIRONMENTAL JUSTICE STRATEGIC ENFORCEMENT ASSESSMENT TOOL (EJSEAT) (U.S. EPA)

EJSEAT is a proposed screening method developed by the U.S. EPA Office of Enforcement and Compliance Assurance to identify areas with disproportionately high adverse environmental and public health burdens (U.S. EPA, 2009). Through the use of a consistent screening assessment, this tool may enhance enforcement and compliance activities in the identified areas. U.S. EPA is currently revising this tool.

To identify areas of potential environmental justice concern, four categories of data from 18 federally managed databases were used in a simple equation. The four data categories were: 1) Environmental indicators (for example, cancer risk from the National Air Toxics Assessment and toxic chemical emissions); 2) Social demographic indicators (for example, percentage of poverty or minority population), 3) Compliance indicators (for example, violations at facilities), and 4) Human health indicators (for example, percentage of low birth

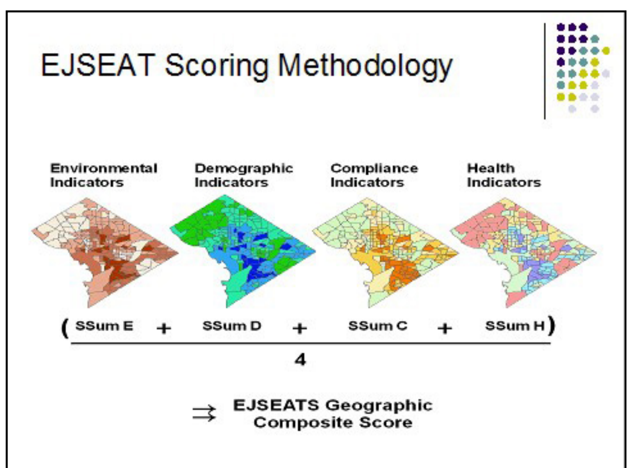

FIGURE 3. U.S. EPA'S ENVIRONMENTAL JUSTICE STRATEGIC ENFORCEMENT ASSESSMENT TOOL.

weight births) (see Figure 3). These were averaged for an EJSEAT Geographic Composite Score at the census tract level.

CUMULATIVE IMPACT SCREENING TOOL (PASTOR, MORELLO-FROSCH, AND SADD)

In a project funded by the California Air Resources Board (ARB), researchers Manuel Pastor, Rachel Morello-Frosch, and James Sadd developed a geographically based cumulative impacts screening method using publicly available data for several southern California counties. This tool provides a screening method that combines indicators of air pollution risk with social and health vulnerability. In addition to integrating information on exposure and socioeconomic indicators, it also includes a method to characterize proximity of sensitive land uses to potential emission sources.

In quantifying cumulative impacts, this method applies three categories of data: 1) Proximity to hazards and sensitive land uses; 2) Health risk and exposure measures for air toxics; and 3) Social and health vulnerabilities. The researchers use census tracts for geographic scale. Cumulative impact scores for all southern California census tracts were obtained by combining data from the three categories using the methodology described in the following:

1. Proximity to sources and sensitive land uses

Residential and sensitive land use areas as defined by ARB, such as schools and parks, were combined with census block groups to carve out areas known as cumulative impact polygons (Morello-Frosch, 2009). Three buffers were drawn around each polygon to account for proximity to pollution sources (sources are termed “hazards” in this proposed methodology; see Figure 4).

Sources in this analysis included air-pollutant point sources such as refineries or other facilities and land-use sources such as ports and rail yards. Sources closer to the polygon receive a higher score than those farther away.

The population-weighted sum of a polygon is determined by estimating the population in each polygon and its distance-weighted source count. All

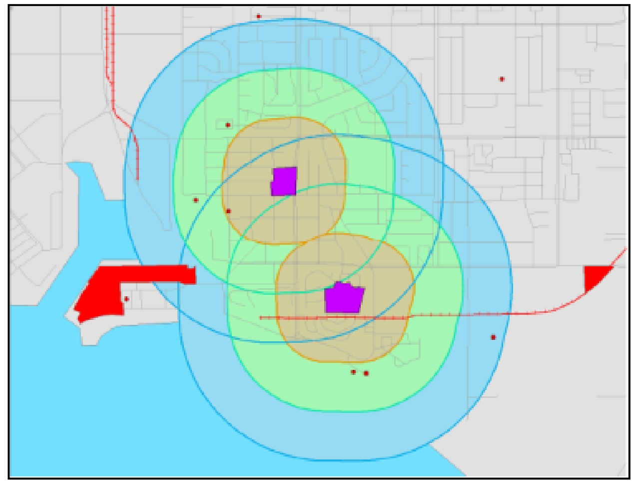

FIGURE 4. BUFFERS FROM POLYGON.

census tracts were ranked, then placed into quintiles (fifths) in order to assign a source proximity and sensitive land use score of 1 to 5.

2. Health risk and exposures

Health risk and exposure indicators included the U.S. EPA’s Risk Screening Environ-mental Indictors (RSEI), the National Air Toxics Assessment (NATA), ARB’s estimated fine particulate matter (PM) 2.5 and ozone concentrations, and ARB inhalable cancer risk to estimate exposure to hazardous substances in each census tract. Each tract was ranked from 1 to 5 for each indicator based on a quintile distribution of the data. These were then added and normalized into quintiles and again ranked to five.

3. Social and health vulnerability

Ten metrics were used to describe social and health vulnerabilities in the census tracts. These included percentage of non-white residents, educational attainment, age, and birth outcomes. For each metric, tracts were assigned a score of 1 to 5, based on a quintile distribution of the data. The 10 scores were added and normalized to obtain a score of 1 to 5 for each census tract.

The overall cumulative impact score for a census tract is calculated by adding the 3 category scores, which range from 3 to 15, with 15 being the most impacted. A depiction of cumulative impact scores for the south Los Angeles area is provided in Figure 5.

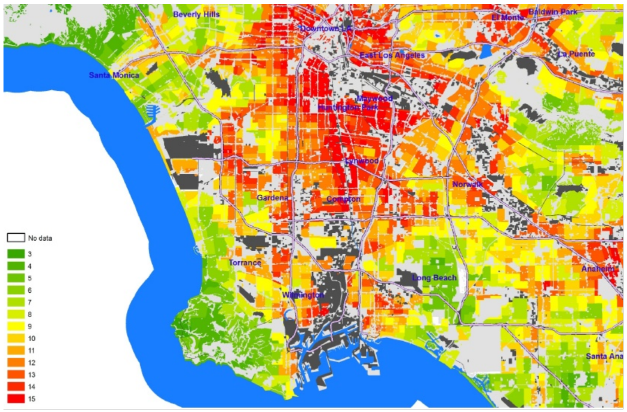

FIGURE 5. CUMULATIVE IMPACT SCORES FOR THE LOS ANGELES AREA (MORELLO-FROSCH, 2009).

AIR RESOURCES BOARD (ARB) DEVELOPMENT OF SCREENING METHODS

For certain regulations such as the cap-and-trade program being developed under California's Global Warming Solutions Act (AB 32), ARB assessments must, to the extent feasible, do the following: (1) consider the potential for cumulative emissions impacts, including localized impacts in communities already adversely impacted by air pollution; and (2) ensure that activities to comply with the regulation do not disproportionately impact low-income communities.

To begin the process of assessing the potential for cumulative impacts for the cap-and trade rule, ARB compiled air quality data statewide in a GIS format in order to map communities with the highest air pollution exposures. This provides part of the context for assessing any emissions impacts of the rule. ARB staff also compiled statewide information on two indicators related to low-income status: percent of a census tract's population below twice the federal poverty level and median household income. This data can be used in a variety of analyses related to cumulative impacts and low-income status. The broader issue of identification of disadvantaged communities relative to other AB 32 requirements remains to be addressed. The April 2010 ARB staff proposal of a screening method that combined these indicators of exposures to air pollution with indicators of low-income status, was just one step in the process of developing screening methods for various program purposes. More work is underway.

TABLE 5. STATEWIDE INDICATORS COMPLIED FOR SCREENING PURPOSES (ARB, 2010)

Category	Health Risk and Exposure Indicators
Ozone and particulate matter air pollution exposures	Monitored concentrations of ozone PM2.5
	Annual number of days exceeding the 8-hr federal ozone standard
Toxic air contaminant exposures	Modeled cancer risk from diesel PM (ARB)
	Cancer risk and non-chronic cancer hazard index (U.S. EPA National Air Toxics Assessment)
	Risk Screening Environmental Indicators for cancer and non-cancer (U.S. EPA)

Another tool available to ARB is the screening tool developed through an ARB research contract by Manuel Pastor, Rachel Morello-Frosch, and James Sadd (See above).

A PRELIMINARY SCREENING METHOD TO ESTIMATE CUMULATIVE ENVIRONMENTAL IMPACTS (NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION)

New Jersey's Department of Environmental Protection (NJDEP), developed a preliminary cumulative impacts screening tool for identifying "communities of concern," based on recommendations of its Environmental Justice Advisory Council (NJDEP, 2009). The NJDEP chose nine indicators of environmental exposures to assess cumulative impact, based on criteria such as statewide availability and consistent format.

The NJDEP used 100-meter grid cells covering the state of New Jersey as the geographic scale to approximate census block groups, which are uneven in size. Data for each indicator were normalized by calculating z-scores for each grid cell (Z-scores quantify how far a value is from the mean of the distribution of all grids; higher z-scores reflect greater deviation from the mean). Z-scores were capped at 3, leading to possible scores of 0 to 3.

Indicator	Data Source	Original Geographic Scale	Original Units
NATA cancer risk (1999)	EPA data	Census tract	Risk per million
NATA diesel (1999)	EPA data	Census tract	μg/m³
NJDEP Benzene estimate	DEP emission inventory	100 meter grid	μg/m³
Traffic All	Congestion Management System	1000 foot buffer	Traffic Counts all vehicles
Traffic trucks	Congestion Management System	1000 foot buffer	Traffic Counts heavy trucks
Density of Major Regulated sites	DEP NJEMS data	100 meter grid	Sites per acre
Density of Known Contaminated Sites	DEP SRP data	100 meter grid	Sites per acre
Density of Dry Cleaners	DEP GIS data	100 meter grid	Sites per acre
Density of Junkyards	DEP NJEMS data	100 meter grid	Sites per acre

TABLE 6. SUMMARY OF NJDEP INDICATORS (NJDEP, 2009).

For the overall grid score, the NJDEP explored two methods of combining indicators. The first method added up the score for each of the nine indicators, with a maximum score of 27 ($9 \times 3 = 27$). In the second method, the number of indicators with a z-score above one was counted, producing a maximum score of 9 if all indicators had z-scores above one. Both methods are proposed as ways to calculate total cumulative impact for the grid cell.

One advantage of a grid-level analysis is the ability to "scale up" and examine impacts at larger geographic scales, such as census block groups or tracts. The NJDEP used this method to evaluate how their results related to socioeconomic factors, because they only accounted for environmental indicators in their methodology. The results across census block groups showed that the percentages of both minority population and poverty increased as the cumulative impact score rose, as measured by the summation method (NJDEP, 2009).

II. Community-Initiated Assessments

Community-initiated methods differ from screening methods in that they do not compare communities, but aim to understand and characterize the cumulative impacts within their community and recognize ways to reduce them.

CUMULATIVE IMPACTS REPORT OF EAST OAKLAND (COMMUNITIES FOR A BETTER ENVIRONMENT)

In a community-based study conducted by the non-profit organization Communities for a Better Environment (CBE), East Oakland, California residents mapped and evaluated stationary and mobile air-pollution sources in an industrial East Oakland neighborhood (CBE, 2008). The project sought to conduct a community-level inventory of sources of air pollution to determine whether any of the sources were listed in inventories maintained by ARB and the Bay Area Air Quality Management District.

In their analysis, CBE detected 216 stationary and mobile sources of air pollution, and found 49 places with susceptible populations or "sensitive receptors"— only some of which were included in ARB's inventories. Gaps in current inventory methods were indentified, with major concern surrounding diesel truck idling, which is not appraised by ARB. The study illustrates the high concentration of polluting sources in close proximity to sensitive receptors and demonstrates that, in certain communities, air pollution inventories may underestimate the cumulative burden of air pollution.

III. Cumulative Impacts in Land Use and Planning

PROPOSED GUIDANCE REGARDING THRESHOLDS OF SIGNIFICANCE AND CUMULATIVELY IMPACTED COMMUNITIES (BAY AREA AIR QUALITY MANAGEMENT DISTRICT)

The Bay Area Air Quality Management District ("Air District" or "BAAQMD") developed new thresholds of significance that address cumulative impacts when placing a new source or receptor of air pollution within the Bay Area (BAAQMD, 2010). Under the California Environmental Quality Act (CEQA), thresholds of significance are used to determine whether the project under consideration may cause significant environmental impacts. A finding of significant impacts triggers a cascade of additional requirements under CEQA.

For assessing impacts of local community risks and hazards, sources are defined as new facilities or new land-use developments that release fine particulate matter or toxic air emissions, such as roadways or gas stations. Receptors are new land-use developments, including residential developments, schools and hospitals, whose occupants may be particularly sensitive to pollutants. The Air District thresholds include thresholds for single source impacts and *cumulative thresholds* (multiple-source impacts) for both sources and receptors of pollution to assess and mitigate project level impacts.

Adopted CEQA Thresholds for Risks and Hazards

The CEQA thresholds of significance adopted by the Air District in June 2010 for both new sources and new receptors apply to all areas of the Bay Area (see Table 7).

Community Risk Reduction Plans and Impacted Communities

As part of its efforts to address the local impacts of emerging and increased air quality burden, the Air District's Community Air Risk Evaluation (CARE) program identified six Bay Area communities that are disproportionately affected by local air pollution (Figure 6; BAAQMD, 2009). Areas with the highest cancer risk from diesel particulate matter were combined with vulnerable and susceptible populations. Applying these methods, BAAQMD identified six Bay Area communities as impacted: Concord, Richmond/San Pablo, Western Alameda County, San Jose, Redwood City/East Palo Alto and Eastern San Francisco (see Figure 6).

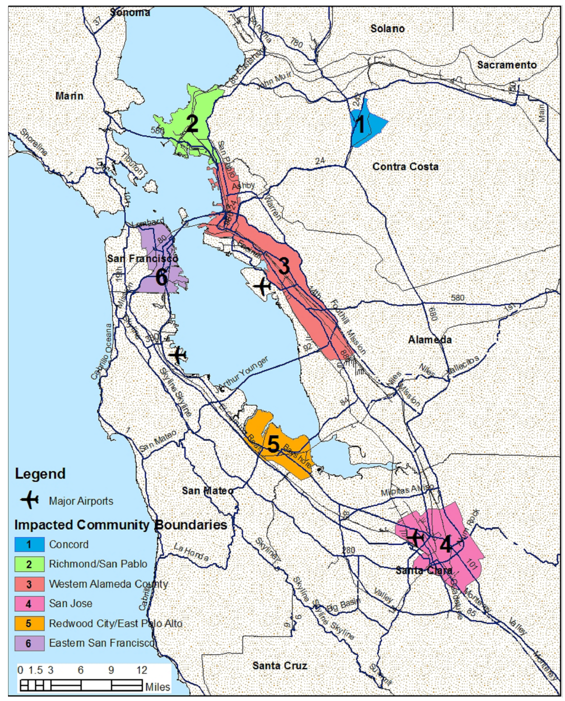

FIGURE 6. AREAS DISPROPORTIONATELY IMPACTED BY AIR POLLUTION (BAAQMD, 2009).

For impacted communities in particular, the Air District CEQA guidance recommends the development of a Community Risk Reduction Plan (CRRP) as a plan-level option for a community to demonstrate compliance with CEQA thresholds (see Table 7) (BAAQMD, 2010). The CRRPs would be developed by the local communities with assistance from the Air District to bring toxic air pollutants and fine particulate matter to acceptable levels. The advantage of the CRRP is that it provides communities a proactive alternative to analyzing development proposals on a project-by-project basis, encouraging instead a community-level planning effort (general plan or specific plan). This is particularly important in communities that have been identified as being impacted.

Pollutant	Construction-Related	Operational-Related
Risks and Hazards for New Sources and Receptors (Individual Project)	Same as Operational Thresholds	Compliance with Qualified CRRP OR Increased cancer risk of >10.0 in a million Increased non-cancer risk of >1.0 Hazard Index (Chronic or Acute) Ambient PM2.5 increase: >0.3 μg/m^3 **Zone of influence**: 1,000-foot radius from property line of source or receptor
Risks and Hazards for New Sources and Receptors (Cumulative Threshold)	Same as Operational Thresholds	Compliance with Qualified CRRP OR Increased cancer risk of >100.0 in a million (from all local sources) Increased non-cancer risk of >10.0 Hazard Index (from all local sources (Chronic) Ambient PM2.5 increase: >0.8 μg/m^3 (from all local sources) **Zone of influence**: 1,000-foot radius from property line of source or receptor

TABLE 7. BAAQMD'S ADOPTED AIR QUALITY CEQA THRESHOLDS OF SIGNIFICANCE FOR LOCAL RISKS AND HAZARDS (BAAQMD, 2010).

In developing the CEQA guidelines the BAAQMD developed, and presented as an option for the Air District Board to consider, an option that included tiered thresholds for local risks and hazards from air pollution sources. Under this proposal, the thresholds would have recommended stricter standards for new sources in impacted communities. Staff did not recommend this option in large part because the thresholds already consider sources within a zone of influence of the project site; in areas with multiple sources nearby, the thresholds are more difficult to meet, minimizing the justification for a tiered threshold. Also, while the Air District recognizes the six Bay Area communities identified as impacted through grant and incentive programs—to reduce air pollution more or sooner—and through focused enforcement efforts, it also recognizes many areas within the areas identified as impacted share the same level of air quality as the rest of the Bay Area.

HEALTHY DEVELOPMENT MEASUREMENT TOOL (SAN FRANCISCO DEPARTMENT OF PUBLIC HEALTH)

The Healthy Development Measurement Tool of Public Health is a comprehensive metric and checklist used to address community health needs in new development plans and projects. It is intended to support health-based planning. The HDMT stems from a history of infrastructure, displacement, safety and environmental impacts from land-use decisions made in San Francisco (Farhang *et al.*, 2008). The three components of the HDMT, used independently or together, present a systematic way to evaluate the health impacts of a plan or project.

The first component is the *community health indicator system*, which consists of 100 health indicators representing social, environmental, and economic conditions. The indicators are classified into community health objectives, which are categorized under six elements. Indicators were chosen through a multi-stakeholder, community-based process that identified attributes of a healthy city. The goal of the indicators is to provide criteria to evaluate development plans and projects.

The second component of the HDMT is a checklist of *development targets* used to assess whether community health objectives are achieved, based on best practice research. They are explicit benchmarks and minimum goals for each indicator that can be used in development plans and projects to achieve objectives.

Third are *policy and design strategies*, which list potential actions decision-makers can take to ensure the objectives are being met. In applying the HDMT to a plan or project, the three components can be used to answer the following questions:

- On the basis of community health indicators and other data on existing conditions, what are the health needs of a neighborhood or place?
- Does a plan or project meet the health needs of the neighborhood, as reflected in the HDMT development targets or objectives?
- What recommendations for planning policies, implementing actions, or project design would advance community health objectives? (Farhang *et al.*, 2008).

An analyst applying the HDMT for a plan or project would take four preliminary steps. First, the analyst would identify the project or plan. Second, the analyst would review relevant documents and perform a site visit or assessment. Third, the analyst would identify the geographic area surrounding the plan or project. Finally, the analyst would review the HDMT and select community health objectives of interest for analysis.

In applying the tool, the San Francisco Department of Public Health (SFDPH) analyzed a 3,000-unit residential development project called Executive Park. The SFDPH applied the HDMT to address community concerns regarding the project's impact on surrounding neighborhoods and its ability to provide residents with adequate services. The SFDPH evaluated the project against 84 indicators and 87 development targets to answer the questions described above. For example, under the community health objective, "Assure access to daily goods and service needs," they used the *indicator* "Proportion of population within a half mile from full-service grocery store/supermarket" to quantitatively analyze the baseline conditions of the neighborhood. At the same time, they applied the *development target*, "For residential uses, is the project within a half mile of a full-service grocery store/supermarket?" Using the HDMT, the SFDPH made a policy recommendation that the Executive Park project provide financial support for a grocery store. There had been no grocery within a half mile of the project and the current plan had no policies for one.

IV. Methods to Assess Inequalities

Inequality is a concern of any cumulative impact analysis, as exposure and environmental factors tend to be concentrated more in some areas than in others. Development of transparent and scientifically sound methodologies with ability to identify disparate impacts between and within geographic regions may be useful in achieving policy goals and ensuring that policies do not exacerbate inequalities between communities. Because analyzing inequalities may require robust data to address inequalities over time or in response to regulatory actions, caution should be taken in interpreting results.

INDEX FOR ASSESSING DEMOGRAPHIC INEQUALITIES IN CUMULATIVE ENVIRONMENTAL HAZARDS WITH APPLICATION TO LOS ANGELES, CALIFORNIA (SU AND OTHERS, UC BERKELEY)

UC Berkeley researchers and consultants developed an "inequality index" capable of summarizing socioeconomic inequalities in exposure to environmental hazards. Data from Los Angeles County were used as a pilot (Su *et al.*, 2009). This index integrates both environmental hazards and demographic factors to give a measure of inequality for the population and area under study.

Inequality here is calculated using the ranked cumulative percentage of a demo-graphic variable (such as income or percentage of minority population) against the cumulative percentage of the outcome variable (in this case, toxic air hazards), thus creating a “concentration index” (Kakwani *et al.*, 1997; O'Donnell *et al.*, 2008). The “concentration index” was originally developed in the areas of social science and health planning and has been adapted in this assessment to environmental hazards. The concentration curve is derived by reference to the 45° equality line, which would describe environmental equality for the demographic measures for all population groups. If the curve falls above the equality line, the most disadvantaged groups experience higher cumulative environmental hazards. The numerical measure of inequality is defined as twice the area between the curve and the equality line. It can range from 0 to 1, with 1 being the highest level of inequality (see Figure 7). The method calculates a cumulative environmental hazard inequality index (CEHII) using the distribution of a demographic metric, race/ethnicity or poverty, against the cumulative share of environmental hazard. To estimate cumulative environmental hazards, analysts may consider ambient air concentrations of particulate matter, nitrogen oxides, and cancer risk associated with diesel emissions. In their application to Los Angeles County, census tracts were the geographic level of analysis.

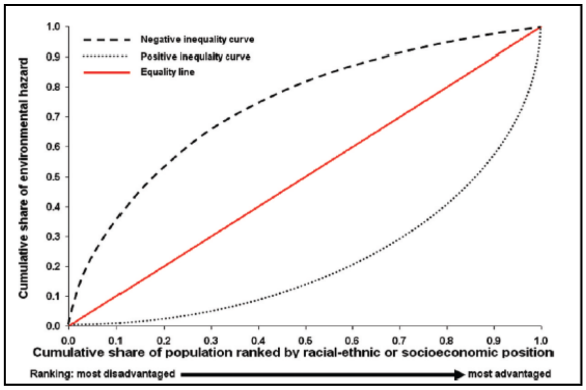

FIGURE 7. CONCENTRATION INDEX.

For the Los Angeles County analysis, the cumulative proportion of the population was ranked by a demographic metric for each census tract and arranged on the x-axis from the most disadvantaged to the least. Analyses were performed for the percentage of non-white population and percentage below 200 percent of the federal poverty line.

On the y-axis, the environmental hazard was plotted with its corresponding census tract. Separate analyses were performed individually for environmental hazards, which included concentrations of particulate matter, nitrogen oxides and cancer risk from diesel emissions; and aggregated using various weighting functions. The final index, or CEHII, is based on the use of aggregated environmental hazards.

Environmental inequality indices were calculated for both percentage of non-white population and poverty for the following measures: (1) inequality indices for individual environmental hazards and (2) CEHII for multiplicative and additive methods of combining environmental hazards.

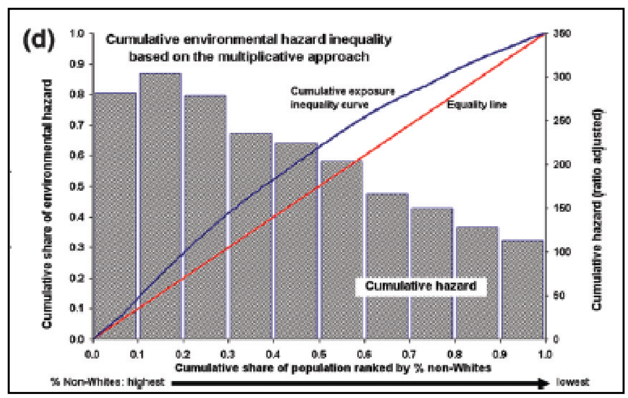

FIGURE 8. CUMULATIVE ENVIRONMENTAL HAZARD INEQUALITY (MULTIPLICATIVE APPROACH).

In the Los Angeles County analysis, the highest level of inequality occurred using a multiplicative model to estimate CEHII for the percentage of non-white population (see Figure 8). In this instance, the curve was higher than the equality line, indicating that the most disadvantaged census tracts experience higher cumulative environmental hazards. For example, where the cumulative proportion of the non-white population is 50 percent, those census tracts bear 60 percent of the cumulative proportion of environmental hazard. The multiplicative CEHII resulted in significantly larger inequality than individual environmental inequality curves. However, all curves were above the equality line, which suggests inequalities exist for all poorer and non-white Los Angeles populations.

Conclusion

Each of these methods drawn from the inventory of studies represents an important contribution to the evaluation of cumulative impacts. They have been developed by government agencies, researchers, and others for specific purposes or programs. Several of these methods integrate different important aspects of cumulative impacts, such as pollutant exposures, demographic data, and human health information. Other methods focus on socioeconomic inequalities in exposure to environmental hazards. Features of these methods were useful to consider in the development of the screening methodology presented in this report.