Technical Guidance for Assessing Environmental Justice in Regulatory Analysis

DRAFT 2023

Table of Contents

Contributors and Acknowledgements

The U.S. Environmental Protection Agency (U.S. EPA), Office of Policy staff that coordinated and contributed to this revision are Ann Wolverton, Peiley Lau, Chris Dockins, Wes Austin, and Jennifer Bowen.

A draft of the revised technical guidance was carefully reviewed internally by staff and management in the U.S. EPA Program Offices, who provided thoughtful comments on how to improve the document. In addition, Industrial Economics provided technical and editing support on the revision. We extend our appreciation to Cynthia Manson and Stephanie Penn for their diligent work in managing this process. The U.S. EPA also acknowledges the public, Tribes, and the EPA' Science Advisory Board reviewers for their constructive comments.

What's New

This document is a revision of the 2016 *Technical Guidance for Assessing Environmental Justice in Regulatory Analysis*. Updates to the original guidance reflect advancements in the state of the science; new peer-reviewed Agency guidance; and new priorities, policy, and direction related to the conduct of environmental justice analysis, including Executive Order 14096.

Improvements relative to the original version include expanded or new discussions of:

- How meaningful involvement can inform regulatory analysis,
- Terminology and definitions,
- Vulnerability as a function of intrinsic and extrinsic factors,
- Compliance and enforcement,
- Vulnerability to climate change,
- Considering the role of multiple stressors and cumulative effects,
- Hot spots as a function of existing conditions,
- Investigating underlying heterogeneity, and
- Presentation of results, among others.

Note that the EPA is also in the process of updating several other relevant documents, which will be cited in the final version of this guidance document. For instance, the EPA is in the process of updating its Cumulative Risk Assessment Guidelines for Planning and Problem Formulation, which were released for public comment in the summer of 2023. The EPA is also updating its Public Participation Policy, which is being released for public comment in the fall of 2023.

Acronyms and Abbreviations

ACS	–	American Community Survey
CCR	–	Coal Combustion Residuals
CDC	–	Centers for Disease Control and Prevention
CEQ	–	Council on Environmental Quality
CPI-U	–	Consumer Price Index for all Urban Consumers
CIA	–	Cumulative Impact Assessment
CRA	–	Cumulative Risk Assessment
DQO	–	Data Quality Objectives
ECHO	–	Enforcement and Compliance History Online
EJ	–	Environmental Justice
E.O.	–	Executive Order
EPA	–	Environmental Protection Agency
GIS	–	Geographic Information System
HFC	–	Hydrofluorocarbon
HHRA	–	Human Health Risk Assessment
HIA	–	Health Impact Assessment
IQ	–	Intelligence Quotient
IQG	–	Information Quality Guidelines
NAAQS	–	National Ambient Air Quality Standards
NHANES	–	National Health and Nutrition Examination Survey
NOX	–	Nitrogen Oxide
NRC	–	National Research Council
NYCHANES	–	New York City Health and Nutrition Examination Survey
OMB	–	Office of Management and Budget
ORD	–	Office of Research and Development
PFAS	–	Per- and Polyfluoroalkyl Substances
PM	–	Particulate Matter
RSEI	–	Risk Screening Environmental Indicators
SAB	–	Science Advisory Board
SHOW	–	Survey of the Health of Wisconsin
TRI	–	Toxics Release Inventory

Disclaimer: *This document identifies internal Agency policies and recommended procedures for EPA employees. This document is not a rule or regulation, and it may not apply to a particular situation based upon the circumstances. This guidance does not change or substitute for any law, regulation, or any other legally binding requirement and is not legally enforceable. As indicated by the use of non-mandatory language such as "guidance," "recommend," "may," "should," and "can," it identifies policies and provides recommendations and does not impose any legally binding requirements.*

Chapter 1: Introduction

Executive Order 14096 defines environmental justice (EJ) as "the just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, Tribal affiliation, or disability, in agency decision-making and other Federal activities that affect human health and the environment so that people are fully protected from disproportionate and adverse human health and environmental effects (including risks) and hazards, including those related to climate change, the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic barriers; and have equitable access to a healthy, sustainable, and resilient environment in which to live, play, work, learn, grow, worship, and engage in cultural and subsistence practices." In implementing its EJ-related efforts, the U.S. Environmental Protection Agency (EPA) not only considers the distribution of burdens across all populations, but also the distribution of reductions in risk from EPA actions. At the same time, the Agency encourages staff to examine the distribution of positive environmental and health outcomes resulting from regulatory actions (U.S. EPA, 2015a).

EPA Administrator Michael Regan emphasized Agency responsibility "to protect the health and environment of all Americans, including those historically marginalized, overburdened, underserved, and living with the legacy of structural racism." To accomplish this task, he called on Agency staff to "infuse equity and environmental justice principles and priorities into all EPA practices, policies, and programs." In the context of rulemakings, he identified two ways in which this can occur, by (1) "assessing impacts to pollution-burdened, underserved, and Tribal communities in regulatory development processes and considering regulatory options to maximize benefits to these communities;" and (2) "taking immediate and affirmative steps to improve early and more frequent engagement with pollution-burdened and underserved communities affected by agency rulemakings, permitting and enforcement decisions, and policies."[1]

The purpose of this document, the *Technical Guidance for Assessing Environmental Justice in Regulatory Analysis* (*EJ Technical Guidance*), is to outline analytic expectations and particular technical approaches and methods that can be used by Agency analysts (including economists, risk assessors, and others) to evaluate EJ concerns for regulatory actions.[2] Senior EPA managers will also find this document useful for understanding what role analysis can play in ensuring that EJ concerns are appropriately considered and addressed in the development of regulatory actions. It is particularly important to integrate EJ into the rulemaking process at its earliest stages. This helps ensure that EJ concerns are given due consideration, including informing how to avoid, minimize, or mitigate disproportionate and adverse human health and environmental effects through regulatory design and the proposed options, information provision, opportunities for retrospective analysis, the leveraging of statutory authorities, and monitoring, compliance, and enforcement, among others. The Executive

[1] The complete memo from the EPA Administrator is available at: https://www.epa.gov/sites/default/files/2021-04/documents/regan-messageoncommitmenttoenvironmentaljustice-april072021.pdf.

[2] E.O. 12866 (1993) defines a regulatory action as "any substantive action by an agency (normally published in the Federal Register) that promulgates or is expected to lead to the promulgation of a final rule or regulation, including notices of inquiry, advance notices of proposed rulemaking, and notices of proposed rulemaking."

Orders (E.O.s) that underpin EPA's efforts to incorporate EJ analyses into rulemakings are summarized in Table 1.1.[3]

Table 1.1: Executive Orders with Implications for EJ Analysis of Federal Rulemakings

Executive Order	Year	Main Directives Pertaining to EJ Analysis for Rulemakings
12898	1994	"To the greatest extent practicable and permitted by law, make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the U.S."[4]
14008	2021	Develop "programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities, as well as the accompanying economic challenges of such impacts."
14094	2023	"Regulatory analysis, as practicable and appropriate, shall recognize distributive impacts and equity, to the extent permitted by law."
14096	2023	Identify, analyze, and address: (1) "disproportionate and adverse human health and environmental effects…, including those related to climate change and cumulative impacts of environmental and other burdens on communities with environmental justice concerns;" (2) "historical inequities, systemic barriers, or actions related to any Federal regulation, policy, or practice that impair the ability of communities with environmental justice concerns to achieve or maintain a healthy and sustainable environment;" and (3) "barriers related to Federal activities that impair the ability of communities with environmental justice concerns to receive equitable access to human health or environmental benefits..."

Note: This is not an exhaustive list of the directives contained within these E.O.s that pertain to rulemakings or to Federal activities more generally.

The guidance recommends that early in the rulemaking process analysts identify the extent to which a regulatory action may raise EJ concerns that need further evaluation, including the level of analysis that is feasible and appropriate (see Section 3.2). Factors that can be used in determining the level and type of analysis include information on proximity of population groups or communities of concern to sources, literature documenting existing exposure or health disparities relevant to the regulatory context, unique exposure pathways, and a history of EJ concerns associated with the pollutant being regulated (see Sections 4.1 and 6.1 for more detail). Based on this initial evaluation, this guidance discusses a suite of methods that can be applied depending on the data and resources available, time needed to conduct the analysis, and other technical challenges that vary by media and regulatory context.

[3] For more details, see E.O. 12898: http://www.archives.gov/federal-register/executive-orders/pdf/12898.pdf; E.O 14008: https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad; E.O. 14094: https://www.federalregister.gov/documents/2023/04/11/2023-07760/modernizing-regulatory-review and E.O. 14096: https://www.federalregister.gov/documents/2023/04/26/2023-08955/revitalizing-our-nations-commitment-to-environmental-justice-for-all

[4] The term "effects" is typically interpreted by the EPA as a reference to risks, exposures, and outcomes and is sometimes used interchangeably with the term impacts.

This document is intended for use alongside other Agency guidance, including guidance on human health risk assessment (HHRA) and economic analysis (see Appendix A).[5] It will evolve with advances in the state of the science, data, and analytic methods available to Agency analysts. Regarding risk assessment, this technical guidance currently is limited to a discussion of how to integrate EJ into the planning of an HHRA. The EPA has developed and continues to refine methods and guidance on a variety of topics relevant to conducting analyses of EJ concerns in the context of a regulatory action. Such references are noted in throughout the document, and future updates to the *EJ Technical Guidance* may include more detail on these topics.

1.1 How Is This Guidance Document Organized?

The first four chapters of this guidance establish the objectives, definitions, main analytic considerations, and context for an assessment of EJ concerns in support of EPA regulatory actions:

- This chapter **(Chapter 1: Introduction)** provides background and outlines the main objectives of the *EJ Technical Guidance*.
- **Chapter 2: Key Definitions** reviews key EJ concepts from E.O.s 12898 and 14096 that are expected to influence analytic considerations. In particular, the chapter discusses how to define the concepts of an EJ concern; disproportionate and adverse effects; race, ethnicity, national origin, low-income, and disability; Tribal affiliated and Indigenous Peoples; subsistence practices; and meaningful involvement.

Text Box 1.1: Overarching Recommendations to Analysts

1. While analysts should use best professional judgement to decide on the type of analysis that is feasible and appropriate, when risks, exposures, outcomes, or benefits are quantified, some level of quantitative EJ analysis is recommended.
2. Analysts should integrate EJ into the planning of a risk assessment conducted for the regulatory action.
3. Analysts should strive to characterize the distribution of risks, exposures, or outcomes within each population group, not just average effects.
4. Analysts should follow best practices appropriate to the analytic questions at hand.
5. As relevant, analysts should consider any economic challenges that may be exacerbated by the regulatory action for relevant population groups of concern.

- **Chapter 3: Key Analytic Considerations** discusses three questions analysts should strive to answer when evaluating EJ concerns, provides a basic framework to guide the analysis, and presents overarching recommendations (Text Box 1.1) and best practices to guide assessments

[5] See also E*PA Legal Tools to Advance Environmental Justice* (U.S. EPA, 2022a) and *EPA Legal Tools to Advance Environmental Justice: Cumulative Impacts Addendum* (U.S. EPA, 2023a) available at: https://www.epa.gov/ogc/epa-legal-tools-advance-environmental-justice.

of EJ concerns for EPA regulatory actions. Appendix A provides links to additional guidance that may be helpful when assessing EJ concerns.

- **Chapter 4: Contributors to Environmental Justice Concerns** identifies factors that contribute to EJ concerns and highlights reasons why environmental health risks are unevenly distributed across population groups.

The main technical chapters of this document provide guidance for considering EJ in two specific contexts:

- **Chapter 5: Considering Environmental Justice when Planning a Human Health Risk Assessment** provides guidance on incorporating EJ concerns into the planning of an HHRA, including descriptions of available methodologies and tools. Appendix B provides examples of approaches for incorporating EJ concerns into the planning of exposure and dose-response assessments.

- **Chapter 6: Conducting Regulatory Analyses to Assess Environmental Justice Concerns** discusses how to identify and evaluate the feasibility and appropriateness of different analytic approaches and tools for assessing EJ concerns; the types of information that should be included in the assessment; other analytic considerations that could affect results; and how to consider costs and non-health effects in the assessment.

This guidance assumes that an analyst may consult only one of the technical chapters to address a specific context. Therefore, by design, Chapters 5 and 6 present some overlapping information about key concepts and methods.

The final chapter describes identified near-term research needs related to the analysis of EJ concerns:

- **Chapter 7: Research Priorities to Fill Key Data and Methodological Gaps** provides information on research goals to improve assessment of EJ at the EPA.

Chapter 2: Key Definitions

This chapter briefly defines and discusses key terms and concepts, including from E.O.s 12898 and 14096, that are important for the analyst to understand before conducting an analysis of EJ concerns. These key terms and concepts include EJ concern; disproportionate and adverse; race, ethnicity, national origin, low-income, and disability; Tribal affiliated and Indigenous Peoples; subsistence practices; and meaningful involvement.[6]

2.1 EJ Concern and Disproportionate and Adverse

An *EJ concern* is the actual or potential lack of just treatment or meaningful involvement on the basis of income, race, color, national origin, Tribal affiliation, or disability status in the development, implementation and enforcement of environmental laws, regulations and policies.[7] For analytic purposes, this concept refers specifically to disproportionate and adverse health and environmental effects that may exist prior to or be created by the proposed regulatory action.

For this technical guidance, the terms *disproportionate and adverse* are used to refer to unfavorable differences in effects or risks that are extensive enough that they may merit Agency action and should include cumulative impacts or risks where appropriate (U.S. EPA, 2022a).[8] In general, the determination of whether there is a disproportionate and adverse effect is ultimately a policy judgment which, while informed by analysis, is the responsibility of the decision-maker.[9] The terms *difference* or *differential* indicate an analytically discernible distinction in effects or risks across population groups. It is the role of the analyst to assess and present differences in anticipated effects across population groups of concern for both the baseline and proposed regulatory scenarios, using the best available information (both quantitative and qualitative) to inform the decision-maker and the public. See Text Box 2.1 for examples of the ways in which differences in effects have been characterized for a regulatory action.

2.2 Population Groups of Concern Highlighted in E.O.s 12898 and 14096

E.O.s 12898 and 14096 identify several population groups of concern due to the potential for disproportionate and adverse human health and environmental effects (and risks) based on race,

---

[6] E.O. 14008 uses the term "disadvantaged communities" to describe those that are "historically marginalized and overburdened." While the Justice40 Initiative uses the term "disadvantaged," it is not widely used at EPA for purposes of identifying and/or evaluating populations or communities with EJ concerns in the context of rulemaking. For information on the Justice40 Initiative, see Interim Implementation Guidance for the Justice40 Initiative: https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf.

[7] The term EJ concern was first defined in U.S. EPA (2015a) and used in the 2016 version of this technical guidance. While consistent with those earlier definitions, it has been revised slightly here to reflect E.O. 14096.

[8] The definition of disproportionate is consistent with U.S. EPA (2022a) and builds on what was used in the 2016 version of this technical guidance. For consistency with E.O. 14096, we use the term "disproportionate and adverse" here, but it is consistent with the prior definition.

[9] A finding of disproportionate and adverse effects is neither necessary nor sufficient for the EPA to address them. In particular, the Agency's statutory and regulatory authorities provide a broad basis for protecting human health and the environment and do not require a demonstration of disproportionate effects to protect the health or environment of any population.

ethnicity, national origin, low-income, and disability status when considering the EJ implications of a regulatory action. Tribal affiliated and Indigenous Peoples, and those engaged in cultural or subsistence practices are also explicitly mentioned.[10] This section provides information for analysts on how to define many of these population groups of concern for purposes of analysis. Beyond the population groups identified in E.O.s 12898 and 14096, analysts may also want to consider other economic or social factors associated with increased vulnerability to environmental exposure such as linguistic isolation, occupation, and employment status, among others.

Text Box 2.1: Characterizing Differences in Effects for a Regulation

Recent regulatory actions have used different phrases to describe differences in the size, type, or distribution of environmental and health effects among populations, both in the baseline and due to regulatory changes. Terminology varies with specific context. For instance, the final rule for the Phasedown of Hydrofluorocarbons (HFC) (U.S. EPA, 2021b) states:

> "EPA finds evidence of environmental justice concerns near HFC production facilities from cumulative exposure to existing environmental hazards in these communities. However, given uncertainties about where and in what quantities HFC substitutes will be produced, EPA cannot determine the extent to which this rule will exacerbate or reduce existing disproportionate adverse effects on communities of color and low-income people."

The final rule for the National Emission Standards for Hazardous Air Pollutants: Iron and Steel Foundries Major Source Residual Risk and Technology Review (U.S. EPA, 2020a) describes its demographic analysis as follows:

> "The results of the major source Iron and Steel Foundries source category demographic analysis indicate that emissions from the source category expose approximately 144,000 people to a cancer risk at or above 1-in-1 million and zero people to a chronic noncancer hazard index greater than or equal to 1. The African American population exposed to a cancer risk at or above 1-in-1 million due to iron and steel foundries emissions is 4 percent above the national average. Likewise, populations living 'Below Poverty Level' and 'Over 25 and without High School Diploma' are exposed to cancer risk above 1-in-1 million, 6 and 4 percent above the national average, respectively. The percentages of the at-risk population in other demographic groups are similar to or lower than their respective nationwide percentages."

The final Steam Electric Reconsideration rule (U.S. EPA, 2020b) states:

> "Overall, the various analyses show that estimated environmental changes under the regulatory options analyzed, including the final rule, may affect minority and/or low-income populations to different degrees across environmental media, exposure pathways, and over time, but the estimated effects (positive or negative) of the changes will be small."

It may be useful in some contexts to analyze these population categories in combination or to evaluate additional aspects of diversity within the population groups of concern (e.g., by life stage, gender), particularly when some individuals within specific population groups may be at greater risk for

[10] The term, *population groups of concern,* is used instead of *subpopulations* to include "population groups that form a relatively fixed portion of the population (e.g., based on ethnicity)." See the EPA's Early Life Stages website: http://www.epa.gov/children/early-life-stages.

experiencing disproportionate and adverse effects due to greater exposure or vulnerability, including via unique exposure pathways (see Chapter 4).

In addition to the information below, analysts should rely on the OMB or other federal statistical agencies (e.g., U.S. Census Bureau), when available, to define relevant population groups of concern (or combinations thereof) for a specific regulatory action. Note that analysis of additional population groups is not a substitute for examining the population groups explicitly mentioned in the Executive Orders.

2.2.1 Race, Ethnicity, Tribal Affiliated and Indigenous Peoples, and National Origin

The OMB provides minimum reporting standards for "maintaining, collecting, and presenting data on race and ethnicity for all federal reporting purposes. The standards have been developed to provide a common language for uniformity and comparability in the collection and use of data on race and ethnicity by federal agencies…The racial and ethnic categories set forth in the standards should not be interpreted as being primarily biological or genetic in reference. Race and ethnicity may be thought of in terms of social and cultural characteristics as well as ancestry" (OMB, 1997).

The OMB defines six racial and ethnic categories:

- American Indian or Alaska Native;
- Asian;
- Black or African American;
- Native Hawaiian or Other Pacific Islander;
- White; and
- Hispanic or Latino.

Note that these categories are not necessarily mutually exclusive and cannot simply be added to estimate a total population. For example, Hispanic or Latino is an ethnic category and, as such, an individual may identify as both Hispanic or Latino and as one or more races. [11]

While the OMB does not use the terms *Tribal affiliated* or *Indigenous*, it defines someone who identifies as an American Indian or Alaska Native as a person "having origins in any of the original peoples of North and South America (including Central America) and who maintains [T]ribal affiliation or community attachment" (OMB, 1997). The EPA provides a more detailed definition of Tribal-affiliated in the *EPA Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples* (U.S. EPA, 2014a) to include state-recognized Tribes; Indigenous and Tribal community-based organizations; individual members of federally recognized Tribes, including those living on a different

[11] EJScreen defines people of color as "the number or percent of individuals in a block group who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino. That is, all people other than non-Hispanic white-alone individuals The word 'alone' … indicates that the person is of a single race, since multiracial individuals are tabulated in another category" (U.S. EPA, 2021c).

reservation or living outside Indian country; individual members of state-recognized Tribes; Native Hawaiians; Native Pacific Islanders; and individual Native Americans.[12]

National origin refers to where a person or their family is from originally and may encompass his or her birthplace, ethnicity, ancestry, culture, and language. In addition, national origin may refer to a specific country or to a part of the world. While potentially inclusive of national origin, the race and ethnicity categories in the U.S. Census do not distinguish individuals based on national origin (U.S. Census Bureau, 2023).

The U.S. Census asks about an individual's ancestry, which is defined as "a person's ethnic origin or descent, 'roots,' or heritage, or the place of birth of the person or the person's parents or ancestors before their arrival in the United States." In addition, it may encompass identities that originate in geographic areas outside the United States or from within the United States (U.S. Census Bureau, 2023). Up to two ancestries are tabulated per respondent. Note that some ancestries may not be reported to protect confidentiality.

In addition, the U.S. Census Bureau collects data on foreign-born individuals living in the United States, which includes anyone who is not a U.S. citizen at birth (U.S. Census Bureau, 2023).

2.2.2 Low-Income Populations

The OMB has designated the U.S. Census Bureau's annual poverty measure, produced since 1964, as the official metric for program planning and analysis by all Executive branch federal agencies in *Statistical Policy Directive No. 14*, though it does not preclude the use of other measures (OMB, 1978). The Council on Environmental Quality (CEQ) also suggests analysts use "annual statistical poverty thresholds from the Census Bureau's Current Population Reports, Series P-60 on Income and Poverty" to define low-income populations (CEQ, 1997).

The U.S. Census Bureau's annual official poverty measure uses a set of income thresholds that vary by family size and composition to determine the households that live in poverty. If a family's total income falls below the threshold, then that family and every individual in it is defined as being in poverty. This measure of poverty has remained essentially unchanged since its inception.[13] It does not vary geographically, though it is updated for inflation using the Consumer Price Index for All Urban Consumers (CPI-U). It also does not account for capital gains or non-cash benefits such as public housing, Medicaid, and food stamps (U.S. Census Bureau, 2022).

The ability of the official poverty measure to adequately capture regional and other differences in economic well-being has been the subject of ongoing debate. In particular, the National Research Council (NRC) recommended that the official measure be revised because "it no longer provides an accurate picture of the differences in the extent of economic poverty among population groups or

[12] Tribal affiliation includes "any American Indian or Alaska Native Tribe, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges as a federally recognized Tribe pursuant to the Federally Recognized Indian Tribe List Act of 1944, 25 U.S.C.5130 5131" (E.O. 14096).

[13] The U.S. Census Bureau produces single-year estimates of median household income and poverty by state and county, and poverty by school district in its *Small Area Income and Poverty Estimates*. It also provides estimates of health insurance coverage by state and county in its *Small Area Health Insurance Estimates*. These data are broken down by race at the state level and by income categories at the county level.

geographic areas of the country, nor an accurate picture of trends over time" (Citro and Michael, 1995). In response, the OMB convened an interagency group in 2009 to define a supplemental poverty measure based on the NRC recommendations. The U.S. Census Bureau has produced a Supplemental Poverty Measure annually since 2011 (Fox and Burns, 2021). Unlike the official poverty measure, it accounts for "co-resident unrelated children" (such as foster children), any cohabiters, and their children, and uses a broader resource measure to account for out-of-pocket medical expenses and in-kind benefits. It also improves on the traditional measure of poverty by adjusting for differences in housing prices and family size by metropolitan statistical area.[14] However, since the Supplemental Poverty Measure is based on survey data and available only at a relatively aggregate geographic spatial scale, it should not supplant the use of official poverty measures in the analysis of EJ concerns.[15]

Unlike its treatment of poverty, the U.S. Census Bureau does not provide an official definition of *low income*. For screening purposes, EJScreen defines low income as the "number or percent of a block group's population in households where the household income is less than or equal to twice the federal poverty level" (U.S. EPA, 2021c). However, an analyst may characterize low-income populations more broadly than just those that fall a certain amount below the poverty threshold (e.g., include families with income above the poverty threshold but still below the average U.S. household income). Additional socioeconomic characteristics typically collected by U.S. statistical agencies, such as educational attainment, baseline health status, and health insurance coverage, may also be useful for characterizing low-income populations. Measures that capture the dynamics of poverty such as the percent of people who are chronically poor versus those who experience poverty on a more episodic basis are also available in other U.S. Census Bureau data products (Iceland, 2003).[16]

Finally, the U.S. Census Bureau makes available several cross-tabulations between poverty measures and other socioeconomic characteristics of interest such as race, ethnicity, age, sex, education, and work experience; these can be useful in developing more specific population descriptions.

2.2.3 Disability Status

The Federal government defines an individual with a disability as someone who has a physical or mental impairment that substantially limits one or more major life activities, has a record of such an impairment, or is regarded as having such an impairment (The Rehabilitation Act of 1973, as amended (29 U.S.C. 701)).

[14] The NRC recognizes that income-based measures such as the official or supplemental poverty thresholds are not necessarily the best measure of relative poverty since they do not account for differences in accumulated assets across households. The Supplemental Poverty Measure tries to capture inflows of income and outflows of expenses, which are likely correlated with short-term poverty since many assets are not easily convertible to cash in the short run (Short, 2012).

[15] See CRS (2022) for more information on the Supplemental Poverty Measure, including limitations and outstanding issues.

[16] This type of measure is reported in the U.S. Census Bureau's *Survey of Income and Program Participation.* For more information, see https://www.census.gov/programs-surveys/sipp.html.

Beginning in 2008, the U.S. Census Bureau asked respondents of the American Community Survey (ACS) about six types of disability:[17]

- Hearing difficulty: deaf or having serious difficulty hearing.
- Vision difficulty: blind or having serious difficulty seeing, even when wearing glasses.
- Cognitive difficulty: having difficulty remembering, concentrating, or making decisions because of a physical, mental, or emotional problem.
- Ambulatory difficulty: Having serious difficulty walking or climbing stairs.
- Self-care difficulty: Having difficulty bathing or dressing.
- Independent living difficulty: having difficulty doing errands alone such as visiting a doctor's office or shopping because of a physical, mental, or emotional problem.

Several other agencies also collect statistical information on disability status based on the same six disability categories listed above. For instance, the Bureau of Labor Statistics collects information on the employment status of persons with disabilities as part of the Current Population Survey. The Centers for Disease Control and Prevention includes disability status in several population surveys about a wide range of demographic and health indicators.[18]

2.2.4 Populations that Rely on Cultural and Subsistence Practices

E.O. 12898 identifies the need to analyze the human health risks of "populations with differential patterns of subsistence consumption of fish and wildlife … whenever practical and appropriate." E.O. 14096 also highlights the importance of analyzing differences in consumption patterns related to the cultural and subsistence practices of Tribal and Indigenous populations. For example, Tribes and Indigenous populations often rely on traditional diets of indigenous fish, vegetation and/or wildlife. These subsistence lifestyles are integral to Tribal cultural practices and help define them as a people. (U.S. EPA, 2019a).

The CEQ (1997) describes the two main components of subsistence practices: differential patterns and subsistence consumption. *Differential patterns* are "differences in rates and/or patterns of subsistence consumption … as compared to rates and patterns of consumption of the general population." The term *subsistence consumption* is defined as dependence "on indigenous fish, vegetation and/or wildlife, as the principal portion of their diet." See Section 4.1.2 for a discussion of unique exposure pathways.[19]

---

[17] In 2013, the U.S. Census Bureau produced the first set of 5-year estimates on disability status for all geographies including tracts and block groups. See https://www.census.gov/topics/health/disability/guidance/data-collection-acs.html for more information. Note that these data exclude people in institutions such as nursing or retirement homes, correctional facilities, and inpatient hospice care.

[18] For more information, see https://www.cdc.gov/ncbddd/disabilityandhealth/datasets.html.

[19] For example, over 40% of non-Hispanic Asian populations in the United States eat seafood at least twice per week compared to a national average of 20% between 2013 and 2016 (Terry et al., 2018). This can result in elevated mercury levels that can affect neurodevelopment in children and the risk of cardiovascular disease in adults (e.g., Buchanan et al., 2015).

Note that this category identifies populations based on specific pathways of exposure and may overlap with those defined based on income, race/ethnicity, and national origin.[20]

While federal statistical agencies do not specifically track the cultural and subsistence practices of individuals and population groups, the EPA has conducted consumption surveys and exposure assessments in specific geographic areas to inform policy formulation (see U.S. EPA (2011b) for examples). If indigenous fish, vegetation, and wildlife consumption is a substantial concern for a specific regulatory action, analysts should refer to existing EPA guidance when collecting and using these data for analysis (e.g., U.S. EPA, 2011b; 2016a; 2019a).

Analysts may also investigate whether survey data are available from other federal agencies, or from state, Tribal, or local governments. However, per EPA guidance, they should verify that any survey data used in an EJ analysis accords with appropriate parameters and methodology for that specific analysis (U.S. EPA, 2016a). Note, it is important to gain permission from a Tribe to gather and use information on cultural practices (e.g., Indigenous Knowledge, also referred to as Traditional Ecological Knowledge) and that there may be privacy and confidentiality concerns that limit its use.[21]

2.3 Meaningful Involvement

The EPA meaningful involves or engages "persons or communities with EJ concerns that are potentially affected by Federal activities by:

- providing timely opportunities for members of the public to share information and concerns and participate in decision-making processes,
- fully considering public input provided as part of decision-making processes,
- seeking out and encouraging the involvement of persons and communities affected by Federal activities; … [and][22]
- providing technical assistance, tools, and resources to assist in facilitating meaningful and informed public participation, whenever practical and appropriate" (E.O. 14096).

The EPA is committed to proactively engaging the public as it develops and implements Agency regulatory actions but also recognizes that special attention is often needed to ensure meaningful involvement by communities with EJ concerns.

[20] The overlap between populations that principally subsist on indigenous fish, vegetation, and wildlife and other population groups based on race, ethnicity, income, or other factors is an important consideration when evaluating EJ concerns in a risk assessment. As part of a risk assessment, analysts are encouraged to evaluate as appropriate all consumption/contact patterns and rates that are relevant from an EJ perspective, including those associated with populations that subsist on indigenous fish, vegetation, and wildlife.

[21] See the EPA's Policy on Environmental Justice for Working with Federally-Recognized Tribes and Indigenous Peoples (https://www.epa.gov/environmentaljustice/epa-policy-environmental-justice-working-federally-recognized-tribes-and).

[22] Federal agencies can seek out and encourage public involvement by offering or providing information in a way "that provides meaningful access to individuals with limited English proficiency and is accessible to individuals with disabilities; providing notice of and engaging in outreach to communities or groups of people who are potentially affects and who are not regular participants in Federal decision-making; and addressing, the extent practicable and appropriate, other barriers to participation" (E.O. 14096).

Rule-writing teams will likely need to go beyond the minimum requirements of standard notice and comment procedures to engage these populations early in the process. Community engagement works best when affected individuals and communities are consulted early and often. The OMB (2023) recommends that agencies engage communities through trust-based, long-term, and two-way relationships.[23] By doing so, they will produce more responsive, effective, durable, and equitable regulations. Communities with EJ concerns have unique knowledge of their goals, needs, and vulnerabilities. Through early involvement, the EPA can obtain information and improve understanding of issues affecting these populations in the context of the regulatory action. [24] Text Box 2.2 lists the basic steps to plan for effective community engagement.[25]

Text Box 2.2. Planning for Effective Community Engagement

1. Organize for Participation
2. Identify and Get to Know Affected Groups and Individuals
3. Pick an Appropriate Level of Public Participation
4. Integrate Public Participation in the Decision Process
5. Match Public Participation Tools to Objectives Throughout the Process

For more information, see the EPA's Public Participation Guide at: https://www.epa.gov/international-cooperation/public-participation-guide-process-planning.

E.O. 14096 calls for the removal of barriers to meaningful involvement that affect communities with EJ concerns, including those related to disability, language access, and lack of resources. It also reiterates the importance of continuing to respect Tribal sovereignty and support self-governance by ensuring that Tribal Nations are consulted on Federal policies that have Tribal implications.[26]

Meaningful involvement intersects with analytic considerations in several important respects. First, if the analysis of EJ concerns is explained in plain language with consideration given to improving accessibility for a wide variety of educational backgrounds, then key assumptions, methods, and results

[23] EPA staff should also hold early, transparent discussions about Freedom of Information Act with public participants prior to seeking public input, exchanging information, obtaining recommendations, entering into collaborations or agreements, conducting community-based participatory research, and working together. Sharing the EPA's limitations with participants allows communities the ability to assess how they intend to share information or knowledge with the Agency prior to engagement as well as facilitates trust and relationship building.

[24] Note that the Paperwork Reduction Act requires that an Information Collection Request be submitted for collecting information (e.g., focus groups, interviews, surveys) from more than nine people (44 U.S.C. 3501).

[25] The EPA's National Environmental Justice Advisory Council (NEJAC) issued updated recommendations on public participation in 2013, *Model Guidelines for Public Participation*, available at https://www.epa.gov/environmentaljustice/model-guidelines-public-participation. See also U.S. EPA (2015b). The EPA is also in the process of updating its Public Participation Policy, the final version of which will be reflected in this guidance once it is released.

[26] It is important to note the difference between meaningful involvement of Tribes and Indigenous Peoples in the EJ context versus formal consultation with Tribes. The federal trust responsibility is a doctrine defining the United States' unique relationship with federally recognized Tribes and arises from treaties, statutes, executive orders and the ongoing historical relations between the United States and Tribes. The EPA acts consistently with the federal trust responsibility when it consults with and considers the interests of Tribes when taking actions that may affect them. Tribal consultation is the subject of E.O. 13175 and the Agency's Tribal Consultation Policy (https://www.epa.gov/sites/production/files/2015-02/documents/ej-indigenous-policy.pdf).

will be more transparent and easier to understand.[27] This can further a clear understanding of the EJ implications of a regulatory action and allow for more substantive engagement by community members and other interested parties during public comment periods. Second, analysts play a role in ensuring meaningful involvement by evaluating possible differences in opportunities for ongoing public input and feedback across the regulatory options under consideration, the ability to identify and resolve compliance issues and ways implementation may be improved once a regulation is in place. Third, it may be possible for analysts to request information early in the process regarding unique exposure pathways or end points of concern, as well as data sources that could improve the analysis of potential EJ concerns. Text Box 2.3 highlights several examples of activities taken to ensure meaningful involvement on EJ issues for regulatory actions. Section 5.3.1.2 also discusses meaningful involvement in the context of a human health risk assessment.

[27] The Plain Writing Act of 2010 (Public Law 111-274) defines plain language as "writing that is clear, concise, well-organized, and follows other best practices appropriate to the subject or field and intended audience." For Federal plain language guidelines, see https://www.plainlanguage.gov/guidelines/.

Text Box 2.3: Examples of Meaningful Involvement for EPA Regulatory Actions

EPA regulatory actions have included steps to encourage meaningful involvement when evaluating EJ concerns. The EPA has responded to this feedback by refining its EJ analyses or by changing aspects of the regulatory program, when possible, as illustrated in the following examples:

To consider EJ for the Phasedown of Hydrofluorocarbons rulemaking, the EPA stated that it seeks:

> "data or analysis to identify whether it is reasonable to expect net increases in emissions [at specific locations]; and if so how we might isolate the impacts of this program (i.e., effects resulting from the phasedown itself, the trading of production allowances, or some other factor) that would enable the Agency to conduct a more nuanced analysis of changes in releases associated with chemical feedstocks and byproducts for HFC substitutes, given the inherent uncertainty regarding where, and in what quantities, substitutes will be produced. EPA is also seeking comment on whether there are other regulatory tools better suited than adjustments to the HFC program design to address potential increases in emissions in non-HFC feedstocks and byproducts observed at facilities [and]… what mechanisms the Agency could consider to prevent or mitigate any increase in exposure to air toxics emissions from facilities located near high risk communities, including from the proposed provisions relating to transfer of allowances" (U.S. EPA, 2021a).

In response to public comments, the EPA considered additional buffer distances of five and 10 miles around HFC production facilities due to concerns that releases may travel longer distances. In addition, in response to public comments highlighting the benefits of providing facility-level chemical specific production data to communities, the EPA stated that it "intends to release this information to the public…[to] allow neighboring communities to see how emissions from a particular facility compare to changes in HFC production levels." (U.S. EPA, 2021b).

For the Petroleum Refineries Risk and Technology Review, the EPA conducted EJ-relevant outreach activities with communities living near refineries in the two years prior to proposing the rule. It was in the context of this outreach that the possibility of fenceline monitoring was first raised as a regulatory option. In response to public comments asking for more data on refinery emissions that may affect nearby communities, the EPA changed several aspects of its proposed electronic reporting requirements: it required data collection no later than 2 years from the effective date of the final rule instead of the originally proposed 3 years and required submission of fenceline monitoring data on a quarterly instead of semiannual basis.

In addition, the EPA stated that it "will continue to work with communities to better understand their unique concerns and needs. We will seek opportunities to enhance education and engagement around our rules, including the best way to make the monitored data required by this rule accessible and digestible by those who need to understand what the data means." (U.S. EPA, 2015c). Subsequent public outreach and solicitation of input specifically asked for feedback from the public:

- "What information needs to be included on the web page to understand the data?
- Within context of the rule, what information and data on benzene do you want to see on the web page?
- Do you have ideas for other ways to share the information besides a web page?
- What other information would be helpful for you? Other EPA information about air toxics? Links to EPA environmental justice tools?
- Is there other training or support that might be helpful?" (U.S. EPA, 2016b).

Chapter 3: Key Analytic Considerations

This chapter provides an overview of the questions analysts should aim to evaluate when conducting an analysis of EJ concerns, provides a framework for structuring the analysis, and offers four broad recommendations to enhance consistency across assessments.

3.1 Analyzing EJ Concerns

The analysis of EJ concerns for regulatory actions should address three questions: [28]

- **Baseline**: Are there existing (baseline) EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern?[29]
- **Regulatory options**: Are there potential EJ concerns associated with environmental stressors that are affected by the regulatory action for population groups of concern for the regulatory option(s) under consideration?
- **Mitigation or exacerbation of impacts**: For the regulatory option(s) under consideration, are EJ concerns exacerbated, mitigated, or unchanged compared to the baseline?

The term *environmental stressors* encompasses the range of chemical, physical, or biological agents, contaminants, or pollutants that may be subject to a regulatory action. *Baseline* is defined as "the best assessment of the way the world would look absent the proposed action" (OMB, 2003). Section 6.2 of this document provides more information on characterizing the baseline for a regulatory action. Note that characterizing the baseline might include consideration of other relevant chemical, physical, or social stressors that increase a community or population group's vulnerability, including cumulative effects and those related to climate change. See Chapter 4 for a discussion of vulnerability.

To answer each of the three questions, an analyst should characterize effects for population groups of concern relative to a comparison population group. Comparison population groups are discussed in greater detail in Section 6.5.2.

The extent to which an analysis can address all three questions will vary due to data limitations, time and resource constraints, and other technical challenges that vary by media and regulatory context. Offices may also develop program-specific approaches to evaluating EJ concerns for regulatory actions to reflect their specific methodological, regulatory, and resource constraints. The EPA encourages analysts to document key reasons why a particular question cannot be

[28] Differences in effects or risks may include differential exposures, differential health and environmental outcomes, or other relevant effects. The subsequent analytic questions are intended to prompt assessment of differences in anticipated effects across population groups of concern for the baseline and proposed regulatory options, and to prompt presentation of these results to decision-makers to support their determinations regarding potentially actionable disproportionate and adverse effects.

addressed to help identify future priorities for filling key data and research gaps. In addition, due to the inherent limitations and uncertainties associated with analyses of EJ concerns, sensitivity analysis around key assumptions is particularly important for clearly communicating results to the public (see Chapter 6).

3.2 Identifying Objectives, Data, and Other Information

The purpose of a regulatory analysis is to "anticipate and evaluate the likely consequences" of a regulatory action in a way that informs the public and decision-makers (OMB, 2003).[30] Before conducting a detailed analysis of EJ concerns, it may be helpful for analysts to first identify what level of assessment is feasible and appropriate to support the regulatory action. Feasibility is based on a technical evaluation of the data and methods available (e.g., the availability of data at a disaggregated level, data quality, availability of methods to analyze such data, and availability of evidence from the peer-reviewed literature, community input, and other information).[31] Appropriateness is informed by relevant policy, budgetary, and statutory considerations (see Chapter 6).

In addition, a preliminary analysis can help identify the extent to which a regulatory action may raise EJ concerns that need further evaluation as part of the regulatory action development process. While there is no single recommended approach for conducting a preliminary analysis, Section 6.1 discusses the types of factors and tools an analyst could consider as part of a preliminary analysis, including EJScreen.

To help inform the decision of what level of analysis of EJ concerns is feasible and appropriate, analysts should also identify data to support a quantitative analysis. In some circumstances, available data may not be sufficient to perform a quantitative evaluation, but it may be possible to develop a meaningful qualitative analysis (see Sections 6.1 and 6.3 for more information). Documentation of the process of identifying what level of analysis is feasible is encouraged and ensures transparency when communicating with the public. It is also recommended that analysts coordinate with the Office of Policy when determining the level of analysis of EJ concerns undertaken for a specific regulatory action.

In cases where a preliminary analysis identifies the potential for EJ concerns that therefore need further evaluation, the analysis should aim to accomplish the following early in the process:

[30] E.O. 12866 (1993) expects agencies to consider "distributive impacts" and "equity" when choosing among alternative regulatory approaches, unless prohibited by statute. The OMB's Circular A-4 also states that "regulatory analysis should provide a separate description of distributional effects (i.e., how both benefits and costs are distributed among sub-populations of particular concern) so that decision-makers can properly consider them along with the effects of economic efficiency … Where distributive effects are thought to be important, the effects of various regulatory alternatives should be described quantitatively to the extent possible, including the magnitude, likelihood, and severity of impacts on particular groups" (OMB, 2003).

[31] In general, the EPA relies on peer-reviewed literature to support decision-making for regulatory actions. Addressing environmental justice is no exception.

- ***Identify EJ objectives:*** Analysts should communicate with decision-makers regarding how the relevant Executive Orders and other applicable EPA policies or statutes interact with the evaluation of EJ concerns for a regulatory action.
- ***Understand factors that contribute to EJ concerns:*** Recognizing underlying contributors within a specific regulatory context is important for properly assessing EJ concerns and can aid in the design of regulatory options. This may include evidence of already overburdened communities, including cumulative effects of exposure to multiple stressors (see Chapter 4).
- ***Identify and characterize population groups of concern:*** When possible, it is recommended that analysts identify the population groups of concern of greatest relevance within the context of a specific regulatory action to inform data collection and analysis. It is also useful to identify possible comparison population groups early in the process.
- ***Identify data, methods, and analytical needs:*** Analysts should evaluate quantitative and qualitative data and methodological needs for an analysis of EJ concerns early to ensure that they are duly considered and reasonably accommodated. Data and methods availability influence the scope and complexity of an assessment and may inform the extent to which EJ concerns are considered in the decision-making process.
- ***Identify the potential for hot spots:*** In some cases, extensive differences in effects among population groups of concern may occur in only a few geographic locations. Referred to as *hot spots*, these locations are typically exposed to localized concentrations of emissions from one or more sources along with other stressors. In these cases, it may be appropriate to tailor the analysis to evaluate effects in a few specific areas. Identifying the potential for hot spots early helps analysts develop appropriate sources of data and analytic techniques, which may differ from those used for a broader analysis.

3.3 Recommendations for Analyses of EJ Concerns

This technical guidance makes five overarching recommendations to ensure high quality analysis that is feasible and appropriate (see Section 3.2), while also recognizing the need for flexibility to reflect policy considerations and technical challenges within a particular regulatory context. The recommendations are intended to bring greater consistency in quality across EJ analyses but are not prescriptive and do not mandate the use of a specific approach.

While these recommendations and best practices are intended as a starting point, they should not be interpreted as limiting the scope of the EJ analysis. It is recommended that analysts thoughtfully tailor their analysis to the rule context and incorporate new data and methods as they become available. Ultimately, the EPA strives to innovate and improve upon EJ analyses as the state of science continues to evolve.

The five overarching recommendations are:

1. While analysts should use best professional judgement to decide on the type of analysis that is feasible and appropriate, when risks, exposures, outcomes, or benefits of the regulatory action are quantified, some level of quantitative EJ analysis is recommended (see Chapter 6).

- When achievable, analysts should present information on estimated health and environmental risks, exposures, outcomes, benefits, or other relevant effects disaggregated by race, ethnicity, income, and other demographic categories.

- When such data are not available, it may still be possible to evaluate potential risk or exposure using other metrics (e.g., proximity to affected facilities, cancer or asthma prevalence, or evidence of unique consumption patterns by race, ethnicity or income) in a scientifically defensible way.

- When health and environmental outcomes or benefits are not quantified or disaggregated by race, ethnicity or income, analysts should present available quantitative and/or qualitative information that sheds light on EJ concerns that may arise.

2. Analysts should integrate EJ into the planning of a risk assessment conducted for the regulatory action (see Chapter 5).

3. Analysts should strive to characterize the distribution of risks, exposures, or outcomes within each population group, not just average effects.

   - In particular, analysts should pay attention to whether populations in the upper tail of the distribution face the highest risks, exposures, or adverse health outcomes.

4. Analysts should follow best practices appropriate to the analytic questions at hand.

   - Text Box 3.1 outlines best practices for evaluating EJ concerns. If it is not feasible for analysts to follow these best practices, analysts are encouraged to explain their use of different approaches.

5. As relevant, analysts should consider any economic challenges that may be exacerbated by the regulatory action for relevant population groups of concern.

   - For instance, per E.O. 14008, it may be appropriate to consider how low-income populations are affected by price increases or to consider the distribution of economic costs (i.e., private and social costs) more broadly from an EJ perspective (see Section 6.7.1).[32]

[32] See the EPA's Guidelines for Preparing Economic Analyses, hereafter referred to as the *Economic Guidelines* (U.S. EPA, 2010a), for information on defining costs.

Text Box 3.1: Current Best Practices for Evaluating EJ Concerns

- Use the best available science while relying on current, generally accepted Agency procedures for conducting risk assessment and economic analysis.
- Use existing frameworks and data from other parts of the regulatory analysis, supplemented as appropriate.
- Be consistent with the basic assumptions underlying other parts of the regulatory analysis, such as using the same baseline and regulatory option scenarios.
- Use the highest quality and most recent data available. Discuss the overall quality and main limitations of the data (e.g., completeness, accuracy, validation).
- Discuss available evidence of factors that may make population groups of concern more vulnerable to adverse effects (e.g., unique pathways; cumulative exposure from multiple stressors; and behavioral, biological, or environmental factors that increase susceptibility).
- Identify unique considerations for subsistence populations when relevant.
- Carefully select and justify the choice of a comparison population group (discussed in Section 6.5.2).
- Carefully select and justify the choice of the geographic unit of analysis and discuss any particular challenges or aggregation issues related to the choice of spatial scale.
- Analyze and compare effects in baseline and across policy scenarios to show differences in effects.
- Present summary metrics for relevant population groups of concern as well as the comparison population group.
- When data allow, characterize the distribution of risks, exposures, or outcomes within each population group, instead of presenting only average effects.
- Disaggregate data to reveal important spatial differences (e.g., demographic information for each facility/place) when feasible and appropriate.
- Discuss the severity and nature of the health consequences for which differences between population groups have been analyzed.
- Clearly describe data sources, assumptions, analytic techniques, and results.
- Discuss key sources of uncertainty or potential biases in the data (e.g., sample size, using proximity as a surrogate for exposure) and how they may influence results.
- When possible, conduct sensitivity analysis for key assumptions or parameters that may affect findings.
- Make elements of EJ assessments as straightforward and easy for the public to understand as possible.

Chapter 4: Contributors to Environmental Justice Concerns

The U.S. EPA uses the term "overburdened" to describe population groups or communities that experience disproportionate and adverse environmental harms and risks due to greater vulnerability and/or susceptibility to environmental hazards, lack of opportunity for public participation, or other factors (U.S. EPA, 2022c). Increased vulnerability or susceptibility may be attributable to differences in intrinsic – meaning, biologic – factors (e.g., age, gender, genetic conditions) or extrinsic – meaning, acquired – factors over a person's lifetime (e.g., socioeconomic status, stress, nutrition, lifestyle, workplace, geography, previous or ongoing exposure to multiple chemicals).[33, 34, 35]

Together, these factors interact in complex ways that can result in differential patterns of exposure to environmental hazards for some population groups, and/or result in a greater response of some individuals to a given level of exposure to an environmental hazard (i.e., higher susceptibility). These factors can ultimately result in higher incidence of adverse health effects for these population groups and communities (McHale et al., 2018; U.S. EPA, 2019a; World Health Organization, 2023).[36, 37]

4.1 Contributors to Higher Exposure to Environmental Hazards

Important extrinsic factors that contribute to higher exposure among population groups of concern include:

- Proximity to emissions and discharges from nearby sources (U.S. EPA, 2022c; Morello-Frosch et al., 2011);
- Unique exposure pathways (Burger and Gochfeld 2011; Solar and Irwin, 2010);

---

[33] It is important to note that race/ethnicity is a social construct that captures the complex interplay of social vulnerability factors that drive environmental health risk. Belonging to a race/ethnic or low-income group does not on its own influence how a stressor causes adverse health effects. Rather, they are upstream factors in a causal chain for which there may be little or no data (Morello-Frosch et al., 2011).

[34] Extrinsic factors may relate to current and historical mechanisms that operate through the labor market, real estate market, educational system, political institutions, and cultural and societal values to reinforce social hierarchies based on race, ethnicity, income, occupation, age, or other characteristics (NASEM, 2016; Solar and Irwin, 2010).

[35] Differences in outcomes due to intrinsic and extrinsic factors related to economic, demographic, social, cultural, psychological, and physical factors ore sometimes also referred to as non-chemical stressors (NASEM, 2023).

[36] For instance, Knapp et al. (2023); Ding et al. (2023); Tessum et al. (2021); Bekkar et al. (2020); Colmer et al. (2020); Deere and Ferdinand (2020); Manuck (2017); Akinbami et al. (2016), and Wilson et al. (2015).

[37] The World Health Organization (2006) defines vulnerability as "a matrix of physical, chemical, biological, social, and cultural factors that result in certain communities and subpopulations being more susceptible to environmental factors because of greater exposure to such factors or a compromised ability to cope with and/or recover from such exposure."

- Physical infrastructure (e.g., housing conditions, water infrastructure) (Solar and Irwin, 2010);
- Exposure to multiple stressors/cumulative exposures (U.S. EPA, 2022e; Morello-Frosch et al., 2011; Brender et al., 2011);
- Differential monitoring, compliance, and regulatory enforcement (Banzhaf et al., 2019); and
- Community capacity to meaningfully participate in decision-making (U.S. EPA, 2011c).

4.1.1 Proximity to Emissions and Discharges from Nearby Sources

It is well documented that sources of environmental hazards are often concentrated in communities with higher proportions of people of color, low-income populations, Indigenous Peoples, or persons with disabilities (Mohai et al., 2009; Chakraborty et al., 2020; Chakraborty et al., 2016).[38] Researchers have pointed to a variety of explanations for these spatial patterns, including the legacy of historically discriminatory land use siting decisions (e.g., redlining, other zoning practices) and other systemic barriers (Shkembi et al., 2022; Grove et al., 2017; Mohai and Saha 2015).

Not surprisingly, given greater proximity to sources of environmental hazards, these populations often experience higher levels of exposure.[39] Note, however, that proximity to an emission source does not account for what or how much is being emitted or discharged from a source, how and where the pollutant travels as it moves through the environment (i.e., fate and transport), the time-activity patterns of individuals, and other key determinants of exposure (Banzhaf et al., 2019; NRC, 1991). See Section 6.4.1 for further discussion of proximity-based analysis.

4.1.2 Unique Exposure Pathways

Exposure pathways describe the means by which exposure to a given stressor occurs. Environmental hazards and risks are not uniformly distributed throughout a population; biological and social factors intersect to create unique exposure pathways that put some individuals at higher exposure risk (Burger and Gochfeld, 2011). At the community level, groups of individuals may be exposed to certain stressors through shared cultural or social practices, learned traditions, values, and life experiences. For example, subsistence fishing is more prevalent in some communities, leading to potential exposure through handling and ingesting fish with high levels of mercury or other chemicals (U.S. EPA, 2021f). Occupation-related pathways are also relevant to consider, such as potential exposures from “take home” chemical residues on clothing or from pesticide drift (Kalweit et al., 2020; Hyland and Laribi, 2017).

---

[38] Other studies documenting environmental hazards in communities with higher proportions of non-White populations include Bullard et al. (2008), Faber and Krieg (2005, 2002), Wilson et al. (2002), and Maantay (2001).

[39] For instance, Morello-Frosch and Obasogie (2023); Di Fonzo et al. (2022); Jbaily et al. (2022); Pace et al. (2022); Grineski and Collins (2018); and Ash and Boyce (2018).

Exposure pathways are also related to life stages (U.S. EPA, 2011b). For example, object-to-mouth behavior and crawling are behaviors associated with infants and toddlers that could increase exposure to contaminants that accumulate on floors or carpets such as lead dust (U.S. EPA, 2013a).

4.1.3 Physical Infrastructure

For some environmental stressors, physical infrastructure may contribute to increased exposure. For instance, housing in the United States built before1978 is more likely to contain lead-based paint, exposure to which can impair cognitive function in children and lead to lower Intelligence Quotient (IQ) (U.S. EPA, 2020b). Likewise, older homes may have leaded pipes and result in exposure via drinking water (Triantafyllidou et al., 2021). Sub-standard structural and building conditions such as dampness, poor ventilation, dust collection, and pest infestation can also trigger asthma or other negative health effects (U.S. EPA, 2021f; Stephens, 2016).

4.1.4 Exposure to Multiple Stressors and Cumulative Exposures

People of color and low-income populations are often impacted by exposure to environmental hazards from multiple sources, such as contaminants from industrial facilities, landfills, leaking underground tanks; transportation-related air pollution; and consumer products (e.g., Banzhaf et al., 2019; California Environmental Protection Agency, 2015). The uneven distribution of the impacts of climate change, such as increased risk of wildfires, droughts, flooding, and other extreme weather events can further compound these exposures (Nolte et al., 2018; Lall et al., 2018). An analysis that considers risk from only one source can inaccurately characterize the potential health risks faced by a population group of concern if they are also exposed to stressors from other sources. The presence of non-chemical stressors, such as discrimination or stressful life events, may also exacerbate the effects of some chemical exposures for vulnerable communities (e.g., increased likelihood of adverse health outcomes due to increased presence of stress hormones from psychological factors and the legacy of structural racism (Padula et al., 2020; Swope et al., 2022).

4.1.5 Monitoring, Compliance, and Enforcement

The monitoring activities, compliance efforts, and enforcement of existing environmental regulations can also contribute to differences in exposure. The difficulty and cost of siting and maintaining monitoring equipment often limits the amount of environmental sampling performed. This can lead to an underestimate of the emissions generated by regulated sources (Hoyt and Raun, 2015). Given that industrial activity tends to be clustered in communities with EJ concerns, inadequate monitoring can further mask the magnitude of potential exposure faced by these communities.

Differential compliance across sources can also exacerbate pre-existing disparities (e.g., Balazs et al., 2012; Allaire et al., 2018; Fedinick et al., 2019). For instance, drinking water systems that serve low-income, Indigenous, and rural communities, and communities of color have been found to have higher levels of drinking water violations and poorer water quality (McDonald and Jones, 2018; Mueller and Gasteyer, 2021; Martinez-Morata et al., 2022). The way environmental policies are enforced may also differ across local jurisdictions or between Tribal and nontribal lands (Switzer, 2019; Teodoro et al., 2018).[40]

4.1.6 Community Capacity to Meaningfully Participate in Decision-Making

The capacity to meaningfully participate in decision-making varies widely across communities and depends on a variety of factors such as leadership, skills, resources, community power, and social and organizational networks (Freudenberg et al., 2011). E.O. 14096 highlights removing barriers related to disability, language access, and lack of resources as particularly important for facilitating meaningful involvement in decision-making. For example, community planning meetings that make facility siting and permitting decisions without translating key materials and discussion limit the ability of a non-English speaking community to participate. When communities are unable to participate effectively in decision-making due to these types of barriers, they may be more likely to experience negative environmental consequences.

Though meaningful involvement is related to a community's capacity to participate in the decision-making process, these topics are not discussed in depth in this guidance document. Additional information about meaningful involvement to inform EJ analysis can be found in Sections 2.3 and 5.3.1.2.

4.2 Contributors to Higher Susceptibility

A person's susceptibility to an environmental stressor is an important determinant of both the occurrence and severity of an adverse health effect. Potentially relevant current and historical intrinsic and extrinsic factors that may influence susceptibility include:

- Pre-existing diseases and health conditions (e.g., asthma, disability) (Varshavsky et al., 2023);
- Material circumstances (e.g., neighborhood quality and housing conditions, green space, walkability, access to fresh foods and high-quality schools) (Jimenez et al., 2021);
- Behavioral and biological factors (e.g., nutrition, smoking, genetic factors) (Varshavsky et al., 2023);
- Access to health care (e.g., interaction with health care providers and resources; lack of preventative care and deferred treatment) (Varshavsky et al., 2023);

[40] In the context of enforcing federal environmental regulations, enforcement is a shared responsibility of federal and state governments. This requires cooperative, periodic, and early joint planning and regular communication between the EPA and states on the sharing of enforcement responsibilities. That said, the EPA is ultimately "responsible for fair and effective enforcement of federal requirements. If a state partner is not taking timely or appropriate action to address threats to public health and the environment, [the] EPA has the authority and responsibility to take direct action" (U.S. EPA, 2023b).

- Psychosocial circumstances (e.g., stressful living conditions and relationships, low socioeconomic status, discrimination, lack of coping and support mechanisms) (Padula et al., 2020; McEwen and Tucker, 2011; Couch and Coles, 2011);

- Limited capacity to adapt to the impacts of climate change and other natural disasters (U.S. EPA, 2023c; World Health Organization, 2023); and

- Co-exposure to similarly acting toxics or chemicals, and cumulative burden of disease resulting from exposure to all stressors throughout the course of life (McPartland et al., 2022; Schwartz et al., 2011a, b).[41]

Also known as risk- or effect-modifiers, these factors may influence the health-related outcome of exposure through biological interactions at the individual level. Socioeconomic status, which does not by itself elicit a biological interaction, has a complex and robust association with many health states (Mani et al, 2013), and may influence factors such as diet, nutrition, and access to health care and consequently health status (Christensen et al., 2022; Munoz-Pizza et al., 2020; Clougherty et al., 2014).[42]

Some individuals within population groups of concern may have higher susceptibility to the effects of some stressors due to their stage of physiological and behavioral growth and development, referred to as *life stage* (U.S. EPA, 2011b). Susceptible individuals based on life stage can include children, the elderly, and pregnant women. Workers in certain occupations may also have higher susceptibility depending on the health outcome and stressor. These groups may also have unique exposure pathways or may be exposed to multiple exposure sources (e.g., workers that are both exposed occupationally and also reside in neighborhoods with high ambient concentrations of air pollution) that, when combined with higher susceptibility, can further increase the risk for adverse health effects.

The concepts of susceptibility and vulnerability can be used to identify population groups of concern. For example, profiles can be constructed that combine available data on baseline health and demographic information to identify susceptible or vulnerable population groups and then use combinations of demographic, education, poverty, and environmental data to describe them (Fann et al., 2011). Further discussion about considering susceptibility and exposure factors in risk assessments are found in Section 5.3 and Appendix B. Text Box 4.1 provides an overview of the literature on increased vulnerability to the impacts of climate change.

[41] Several conceptual frameworks explicitly integrate social context into the exposure-disease paradigm to highlight how these factors may interact with environmental exposures to yield health differences (Gee and Payne-Sturges, 2004; Morello-Frosch and Jesdale, 2006).

[42] See Schwartz, et al. (2011a, b) for several examples of how these risk- or effect-modifiers may increase risk.

Text Box 4.1 Increased Vulnerability to the Impacts of Climate Change

Changes in global temperatures due to climate change are expected to result in higher changes in average annual temperatures in the U.S. in the future. For instance, a global warming of 2°C by 2100 is projected to result in average annual temperature increases of between 3°C and 4°C for large portions of the country (U.S. EPA, 2021g). These changes in temperature and other changes to our natural systems are expected to affect human health in myriad ways over the coming decades. These effects are due to changes in the frequency, duration, timing, and location of extreme events such as heat waves, floods, and droughts. These extreme events can also affect human health through their impacts on vector-, food-, and waterborne infectious diseases, through changes in temperature-related mortality, climate-driven air pollution exposure, flooding-related property damage, and effects on labor productivity, to name a few. These impacts are not expected to be evenly distributed across the U.S. population (U.S. EPA, 2021g; USGCRP, 2018).

Low-income and predominantly non-White communities are especially vulnerable to these and other impacts of climate change because of their limited adaptive capacity; dependence on climate-sensitive resources, such as local water and food supplies; and inadequate access to information (USGCRP, 2018; IPCC 2018; NASEM, 2017; USGCRP, 2016; IPCC, 2014; NRC, 2011b). For example, low-income households typically have limited access to healthcare and often do not have adequate insurance. Workers in outdoor occupations such as agriculture or construction may not be able to avoid working on high-temperature days without significant loss of income. Non-English speaking and disabled individuals may have more difficulty accessing flood or fire-hazard alerts, evacuating safely, or accessing aid after natural disasters (U.S. EPA, 2021g).

In addition, health conditions such as cardiovascular or respiratory illnesses that occur at higher rates in many socially and economically vulnerable communities may also be exacerbated by the impacts of climate change. Outdoor workers, who frequently are comprised of already at-risk groups, are also more likely to be exposed to poor air quality and extreme temperatures (U.S. EPA, 2021g). Low-income households may also face increased food insecurity as climate change reduces food availability and increases prices (USGCRP, 2018; USGCRP, 2016).

Chapter 5: Considering Environmental Justice when Planning Human Health Risk Assessment

This chapter provides guidance to Agency analysts on integrating EJ concerns into the planning of a human health risk assessment (HHRA) conducted to support a regulatory action. As noted in the EPA's *Framework for Human Health Risk Assessment to Inform Decision- Making* (referred as the *HHRA Framework*) (U.S. EPA, 2014b), EJ concerns are a key consideration in the early stages of HHRA, including planning and scoping and problem formulation.

5.1 Introduction

Human health risk assessment is a complex, iterative, and multidisciplinary process intended to inform decision-makers about the effects of environmental stressors on human health and to support the formulation of policy actions that impact these stressors. The following questions, outlined in Section 3.1 (and repeated here), are important to consider during HHRA planning to help ensure that it provides relevant information about differential risks for population groups of concern that can then be used as inputs into the EJ analysis for a regulatory action (see Chapter 6):

- **Baseline**: Are there existing (baseline) EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern?
- **Regulatory options**: Are there potential EJ concerns associated with environmental stressors that are affected by the regulatory action for population groups of concern for the regulatory option(s) under consideration?
- **Mitigation or exacerbation of impacts**: For the regulatory option(s) under consideration, are EJ concerns exacerbated, mitigated, or unchanged compared to the baseline?

Even when methods and data relevant to these questions are not available, their consideration can highlight where additional data or research are needed. HHRA and the science and practices that support it continue to evolve. As new tools and information become available, incorporating EJ considerations into HHRA should also evolve to reflect improved risk assessment methodologies and guidance.

5.2 Modeling and Data Needs for Evaluating EJ Concerns

HHRA seeks to characterize the nature, probability, and magnitude of current or future risks of adverse human health effects related to exposure to environmental stressors (e.g., chemical, physical, or biological agents). This can include both quantitative and qualitative characterizations of risk (NRC, 1983; U.S. EPA, 2014b) and may incorporate different approaches, methods, and metrics, depending on the nature of the decision that the assessment is intended to inform. The EPA has published guidance on all steps of the HHRA process, as well as a *Framework for HHRA for Decision-Making* (U.S. EPA, 2014b).

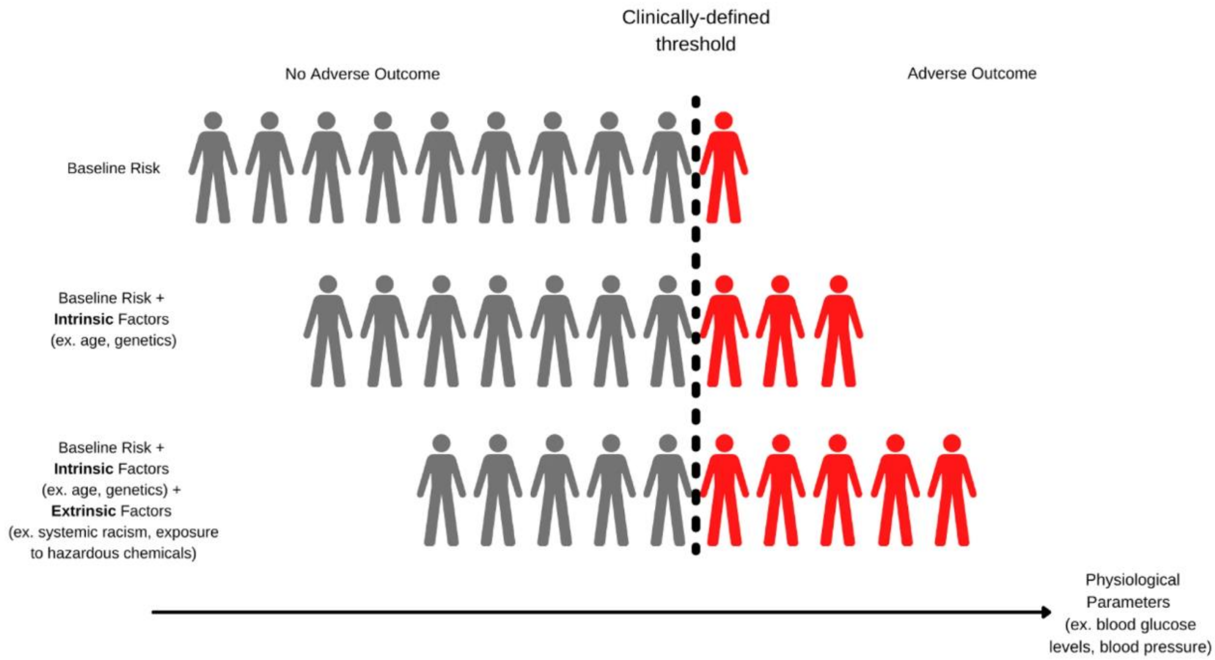
Analyzing EJ concerns as part of HHRA requires spatially and temporally resolved data, including environmental exposures, health data, and demographic information. However, information on EJ concerns is often qualitative and place specific, which results in several challenges when considering EJ in HHRA.

5.2.1 HHRA requires sufficient data and modeling capabilities to incorporate EJ considerations

As noted by the NRC "the goal [of HHRA] of achieving accurate, highly quantitative estimates of risk…is hampered by limitations in scientific understanding and the availability of relevant data…" (NRC, 2009). These data requirements may be even greater when it comes to risk estimates to inform EJ considerations due to complexities of exposure and the existence of additional stressors. For example, modeling how non-chemical stressors such as nutritional deficits and stress interact with chemical stressors to exacerbate or mitigate health outcomes is important to consider in a comprehensive quantitative analysis of EJ concerns but is still at a nascent stage of development.

Figure 5.1 illustrates how considering intrinsic and extrinsic factors, including both chemical and non-chemical stressors, can impact risk. The first row, baseline risk, depicts how exposure above a clinically defined threshold leads to adverse health outcomes in the general population. As we also consider intrinsic factors such as age and genetics, a greater proportion of the population experiences an adverse health outcome. Adding extrinsic factors, such as systemic racism and exposure to hazardous chemicals results in a more accurate estimation of the population with an adverse health outcome.

Figure 5.1. How intrinsic and extrinsic factors influence adverse health outcomes in a population



(Source: Varshavsky et al., 2023)

Data needed for HHRA to more fully consider EJ may be difficult to find, particularly given the importance of considering it within a holistic framework. For example, robust national studies of health outcomes and their variability are often limited because specific measurements of non-chemical stressors vary locally. Many studies target populations whose socioeconomic status is higher than the national average (e.g., white, male adults) and who reside in urban areas that are well monitored and therefore may not be generalizable to populations with EJ concerns (Payne-Sturges, 2011; Pelacho et al., 2021).[43] That said, a growing literature is focused on vulnerable population groups, including Medicare populations (Di et al., 2017), Hispanics/Latinos (Letellier et al., 2022), Native Americans, Asians, and those who experience low income (Liu and Eichen-Miller, 2021; Jbaily et al., 2022).

[43] In the absence of scientific data to fully characterize the range of responses to chemical exposures, the EPA employs default assumptions, such as uncertainty factors used in non-cancer risk assessments, to account for human variability. As noted by the Science Advisory Board (SAB, 2015), however, "…the use of uncertainty factors in developing dose-response assessments for an individual level chemical might address the general population as a whole but does not specifically address differential or disproportionate vulnerability."

The limited utility of national data for informing health disparities and the limitations of extrapolating community-level data from national surveys has also been noted (Dosemagen and Williams, 2022; Nweke et al., 2011). See Chapter 7 for a discussion of identified research priorities for improving EPA analysis of EJ concerns, which elaborates upon these modeling and data gaps.[44]

5.2.2 It can be difficult to incorporate cumulative effects of multiple, dissimilar stressors into HHRA

Communities with EJ concerns are often exposed to many environmental and economic stressors through multiple pathways. HHRA is most often conducted on a chemical-by-chemical basis using single exposure-to-effect pathways.[45] Broadening the scope of HHRA to incorporate non-chemical stressors requires addressing challenging scientific and technical questions (e.g., what effect does exposure to pesticides have on rural, Indigenous Peoples? Or how does living near an existing environmental hazard affect susceptibility to other environmental concerns?). While there is a dearth of quantitative data available for non-chemical stressors, how they interact with chemicals is a growing area of research (Payne-Sturges et al., 2018; Aker et al., 2020).

In addition, adoption and use of a framework for cumulative risk assessment is rare among practitioners (Clougherty and Rider, 2020). Cumulative risk assessment that incorporates both chemical and nonchemical stressors requires more comprehensive data than traditional HHRA (e.g., information on background exposure or health status among specific populations). While the Scientific Advisory Board (SAB, 2015) continues to recommend use of HHRA, it encourages the EPA to develop further guidance for quantitative and/or qualitative evaluation of cumulative effects. See Section 5.4 for additional discussion.

5.2.3 HHRA is highly technical and defines risk in specific ways

HHRA has been criticized for often having limited consideration of public perceptions of risk and, more broadly, for limiting public input into the process; both factors are critical to the assessment of EJ concerns (Sexton and Linder, 2010).[46] The technical complexity of HHRA can also lead to a lack of transparency and accountability (SAB, 2015).

Effective communication about HHRA is therefore necessary for meaningful public involvement, and public involvement is essential for decision-making. Payne-Sturges (2011) notes that "when

---

[44] Varshavsky et al. (2023) notes that emerging tools and data "that better account for human variability and susceptibility include probabilistic methods, genetically diverse in vivo and in vitro models, and the use of human data to capture underlying risk and/or assess combined effects from chemical and non-chemical stressors."

[45] Some assessments have also evaluated the risk associated with exposure to multiple chemicals that act by similar mechanisms (Backhaus and Faust, 2012; Cattaneo et al., 2023).

[46] HHRA is framed in terms of the risk of an adverse outcome from a specific stressor or stressors, but EJ advocates and analysts are often interested in broader concepts of health (Barzyk et al., 2015). For example, HHRA as traditionally practiced does not quantify factors such as fairness, voluntariness, responsibility, control, trust, reversibility, and identifiable victims (Corburn, 2002; Sexton and Linder, 2010), though these factors may be identified and characterized as part of risk management discussions. HHRA methods also do not typically consider public attitudes toward risk or incorporate community insights and priorities around sources of risk (Sandman, 1989).

affected citizens actively participate in the process to better understand science and inform policy responses, better decisions emerge as a result." Risk communication can increase community involvement in decision-making processes and better informs risk assessors regarding community perceptions of risk and provides opportunity to create dialogue around the limits and opportunities of policy making efforts at the federal and local levels (Barzyk et al., 2015). See Section 2.3 for further discussion of meaningful involvement and Section 5.3.1.2 for further discussion of risk communication in the context of EJ.

5.3 Considering EJ Concerns when Planning a HHRA

When considering EJ concerns, it is important that analyses conducted in support of regulatory actions explicitly consider both baseline health risks and whether changes in risk due to policy actions may disproportionately accrue within population groups of concern. Specific demographic attributes can be correlated with increased vulnerability and susceptibility to environmental stressors. Also, the burden of health problems and potentially disproportionate and adverse environmental exposures associated with race, ethnicity, income, or other relevant demographic characteristics may overlap with other factors that influence susceptibility such as life stage, genetic predisposition, or pre-existing health conditions (Shao et al., 2022). See Chapter 4 and Section 6.2 for further discussion.

5.3.1 Overview of the HHRA process

The EPA's *HHRA Framework* provides an overview of the risk assessment process (Figure 5.2). The HHRA process is not strictly sequential; steps are often performed together in an integrative fashion, and EJ can be considered at multiple points in the HHRA process. Ultimately, the final step, risk characterization, synthesizes information from the other steps and provides the basis for communicating the results to decision-makers and the public.

The Planning and Scoping, and Problem Formulation phases are key initial elements of the *HHRA Framework*. At the Planning and Scoping stage, analysts define the process for conducting the risk assessment and establish its analytic scope. The Problem Formulation phase informs the HHRA technical approach. Important outcomes of this step are a conceptual model that describes the relationship between stressors, exposure pathways, exposed life stages, populations, and health endpoints that will be addressed in the risk assessment as well as an analysis plan for conducting the assessment (U.S. EPA, 2014b). The consideration of EJ throughout the risk assessment Planning and Scoping and Problem Formulations phases is important to ensuring an effective assessment.

Figure 5.2 also illustrates two key elements to consider throughout the risk assessment process, from initiation to informing decisions: Fit-for-Purpose, and Public and Community Involvement.

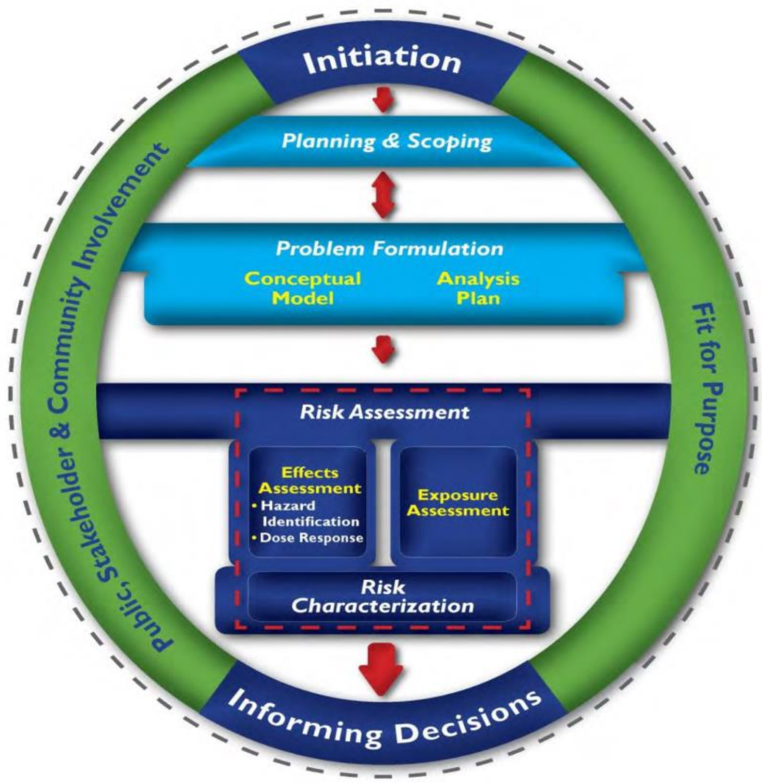


Figure 5.2: Framework for Human Health Risk Assessment to Inform Decision-Making

Adapted from: U.S. EPA (2014b)

5.3.1.1 Fit-for-Purpose

Fit-for-Purpose refers to the concept that risk assessments and associated products should be suitable and useful for their intended purpose(s), particularly for informing choices among risk management options (U.S. EPA, 2014b). Accordingly, throughout the process of planning and performing HHRAs, it is important to evaluate whether the assessment is effectively addressing the information needs of decision-makers. This is primarily accomplished through transparent dialogue between risk assessors and risk managers early in the assessment process.

While the nature and scope of an HHRA may vary by statute and the type of problem being addressed, and will be limited by available data, methods, and resources, a robust fit-for-purpose process will maximize the usefulness of the assessment for considering EJ concerns.

Risk assessment can be used to help characterize differential risks to better evaluate EJ concerns for risk-based decision-making. Because fit-for-purpose will be continually evaluated throughout the risk assessment process, it is important to raise key questions early and even revisit questions that bear on whether the resulting risk characterization will be able to inform EJ concerns. These questions include:

1. What types of individuals or population groups face higher risks in the baseline relative to the average or comparable individuals in the general population?
2. What types of individuals or population groups could experience higher risks relative to the average or comparable individuals in the general population as a result of a regulatory option?
3. What are the reasons why an identified population group (or life stage within a population group) may potentially experience higher risk than the average person?
4. What tools and data are available to estimate and characterize the potential for differences in risk for affected groups? (This is especially relevant when developing the HHRA analysis plan.)
5. How can information about differences in risk for affected groups, or the potential for these differences, be effectively communicated in the risk characterization?

5.3.1.2 Public and Community Involvement

Public and community involvement is integral to both the HHRA process and the broader consideration of EJ concerns. For example, engaging Tribes early in the process, as relevant, may lend new insights into how Tribes and indigenous groups define human health (U.S. EPA, 2017) and allow for consideration of Indigenous Knowledge (also referred to as Traditional Ecological Knowledge).[47]

To enable communities to meaningfully participate, it is important to recognize and address conditions that could reduce or hinder their ability to participate in the HHRA and regulatory action development process. These could include time and resource constraints; barriers due to limited English proficiency or disability; lack of trust; lack of information; and difficulty in accessing and understanding complex scientific, technical, and legal resources. Public participation may also be hindered by socio-political dynamics that serve to weaken democratic processes, which raises the importance of finding approaches that function in contexts of social distrust and creating positive participatory experiences (Webler and Tuler, 2018). For instance, some forms of public participation can give those with political power a larger platform and do not necessarily lead to more equitable outcomes. It is therefore paramount that the EPA is intentional about creating opportunities for meaningful public involvement so that risk-based decisions do not lead to unsatisfactory community outcomes (Sexton, 2013).

See Chapter 3 of the *HHRA Framework* (U.S. EPA, 2014b) on how to involve the public and the broader community in the risk assessment process. Text Box 5.1 also highlights the potential

---

[47] Indigenous Knowledge is defined as, "the body of observations, oral and written knowledge, innovations, practices, and beliefs developed by Tribes and Indigenous Peoples through direct contact and experience with the environment." While Indigenous Knowledge is used here, a variety of terms, including Traditional Ecological Knowledge, Traditional Knowledge, Indigenous Traditional Knowledge, Native Science and related terms are used and preferred by different Tribes and Indigenous Peoples. For more information, see https://www.whitehouse.gov/wp-content/uploads/2022/12/OSTP-CEQ-IK-Guidance.pdf.

Text Box 5.1: Participatory Science

Participatory science engages the public in advancing scientific knowledge by formulating research questions, collecting data, and interpreting results. This includes a broad and inclusive range of activities, from those originating in academic and government institutions that enlist the public in data collection to create knowledge, to community-led projects intended to identify potential EJ issues and community concerns.

For HHRA planning and scoping, participatory science may be able to fill information gaps and provide useful data that informs analysis. For example, projects may collect monitoring data in overburdened communities. For data generated by the public to have a meaningful impact, quality assurance during data gathering is critical, and the EPA has developed a handbook to help guide data collection efforts See https://www.epa.gov/participatory-science/quality-assurance-handbook-and-toolkit-participatory-science-projects.

Participatory science may also facilitate meaningful community involvement in the HHRA process. As described in the EPA's Vision for Participatory Science (U.S. EPA 2022f), it can create a stronger, more inclusive, and collaborative network of individuals dedicated to environmental problem solving. It can also contribute to effective risk communication by improving public understanding of environmental issues and actions to address them.

Note: Other terms sometimes used to refer to participatory science include citizen science, community science, volunteer monitoring, or public participation in scientific research.

role of participatory science in further enhancing data available for HHRA. See Section 2.3 for more discussion of meaningful involvement in the context of analysis.

Risk Communication

Risk communication is intended to provide the public with the information it needs to make informed, independent judgments about risks to health, safety, and the environment. The EPA has extensive resources on effective risk communication, including frameworks, tools, and case studies.[48]

To identify potentially affected members of the public, the Presidential/Congressional Commission on Risk Assessment and Risk Management suggests using the following questions:[49]

- Who might be affected by the risk management decision?
- Who has information and expertise that might be helpful?
- Who has been involved in similar risk situations before?

[48] See the EPA's Risk Communication page at https://www.epa.gov/risk-communication.

[49] See the EPA's Presidential Commission on Risk Assessment and Risk Management website: http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=55006&CFID=55036505&CFTOKEN=43224210.

- Who has expressed interest in being involved in similar decisions before?
- Who might reasonably feel they should be included?

Analysts and risk managers can consult the *Framework for Implementing EPA's Public Involvement Policy* (U.S. EPA, 2003a) for general guidance for scoping a public involvement process. To ensure that the public can participate meaningfully in the HHRA process, the approach for soliciting information should be specific, involve interactive dialogue that is designed to elicit specific responses, and include accommodations for population groups facing additional barriers to participation, such as those in rural areas, with limited English proficiency, or a disability. Elements of such a dialogue could include specific questions about the types of data or models that are needed to adequately reflect EJ concerns.[50]

5.3.2 Planning and Scoping

Planning and Scoping is the stage in which the risk assessor defines the process for conducting the risk assessment and identifies its general scope. This activity contributes to the development of a sound risk assessment that will eventually accomplish its intended purpose. It also assists those interested in the risk assessment process in understanding the broader context and how the anticipated results will satisfy the intended purpose. A broad range of technical experts (e.g., toxicologists, epidemiologists, statisticians, economists, and other social scientists) working as a team may be involved in this stage.

The Framework for HHRA identifies several aspects of planning and scoping. Of note for EJ considerations are the context, purpose, and scope of the risk assessment; and planning scientific peer (and other) review.

5.3.2.1 Defining the Context, Purpose, and Scope of the Risk Assessment

EPA human health risk assessments conducted for rulemaking are intended to inform and support risk management decisions and the development of regulatory actions, focusing on the changes in health risk that are anticipated. When planning a risk assessment for any purpose, the analyst should clearly identify the decision(s) that will be supported by the analysis, specify the boundaries for the assessment (i.e., the scope), and detail what will not be addressed in the risk assessment.

Context of the risk assessment

A key first step in an HHRA is documenting the context for the analysis. This includes the regulatory and statutory context (the policy context) as well as the physical and cultural context for the investigation. To provide regulatory and statutory context that considers EJ issues, an

[50] When EPA actions or decisions may affect Tribes, the EPA has instituted a Tribal consultation policy that provides clear guidance for when, how, and on what issues consultations with Tribal governments should occur (U.S. EPA, 2011d).

analyst should identify any complementary requirements between the triggering statutory authority and E.O.s 12898 and 14096 that focus on identifying and addressing potentially disproportionate and adverse health effects and risks. For example, a new regulation of coal combustion residuals (CCR) and how they are managed will have an impact on the community surrounding the waste site, as well as along the roadways traveled by large vehicles moving CCR waste.

In addition to the specific policy context, other contexts may also be relevant to consider. For example, background exposure to chemicals from multiple sources that might affect responses, or an enhanced background risk for a relevant adverse health outcome due to other factors that may complicate measurements, are important for assessing differential risk. In addition, communities with EJ concerns also may experience differential risks due to higher susceptibility (e.g., due to life stage or pre-existing health conditions) or other factors influencing exposures (e.g., behavioral patterns or proximity to sources of exposure).[51] Together, these existing conditions help frame and clarify the context of the HHRA.

Purpose of the risk assessment

Clearly articulating the overall purpose of an assessment is an iterative process and may involve extensive interaction between the assessment team and the range of affected members of the public to establish a common understanding and ensure that relevant community priorities are considered. In addition, in this step, analysts may conduct a review of data needs and limitations to ensure that the results will adequately inform decision-makers and community members (NRC, 2009).

The assessment's purpose and scale (e.g., regional or national) will have significant implications for the assessment's scope, level of detail, and approach. Key considerations at this stage include:

- What specific policy or regulatory decision is to be informed by the risk assessment? When is the decision anticipated? What are the risk management options being considered?
- What legal or statutory requirements affect risk management options and the level or type of analysis? (U.S. EPA, 2014b)

[51] As an example, primary National Ambient Air Quality Standards (NAAQS) are required to protect public health, including the health of sensitive or at-risk population groups, with an adequate margin of safety. The Integrated Science Assessment (ISA) and ISA supplement cite extensive evidence indicating that ''both the general population as well as specific populations and life stages are at risk for $PM_{2.5}$-related health effects'' (U.S. EPA, 2019b; U.S. EPA, 2022d). Factors that may contribute to increased risk of $PM_{2.5}$-related health effects include life stage (children and older adults), pre-existing diseases (cardiovascular disease and respiratory disease), race/ethnicity, and socioeconomic status.

Text Box 5.2: Considering EJ Concerns for the 2014 Coal Combustion Residuals Generated by Electric Utilities Final Rule (U.S. EPA, 2014) - Examples of Risk Management and Analytic Objectives

Regulatory Context: The Resource Conservation and Recovery Act gives the EPA authority to regulate non-hazardous wastes. These regulations ban open dumping of waste and set minimum federal criteria for the operation of industrial waste landfills and impoundments. The 2014 CCR Final Rule established requirements for CCR landfills and surface impoundments, including structural integrity requirements to reduce catastrophic failure risk, groundwater monitoring and corrective action, location restrictions, liner design and operating criteria, closure and post-closure requirements, and record keeping and notification, including public websites documenting monitoring and corrective action planning. These regulations reduce releases of arsenic and other contaminants to water and air, help ensure actions taken by power plants to comply with the rule are transparent, and that the communities impacted by the disposal of CCRs have the information they need to understand risks.

Risk Management Objective: Evaluate the effect of the 2014 CCR rule on the potential for increased risk to human health and the environment.

Example Questions:

- What hazards from corrective action, operations and closure and post-closure requirements, including accidental releases of CCR, could pose hazards resulting in differential risks to population groups and communities of concern?
- How does the rule affect the likelihood of such hazards compared to pre-2014 regulations?
- Are there potential CCR handling hotspots of concern?

Analytical Objectives: (1) Evaluate whether baseline demographic characteristics of populations potentially affected by the rule differ from the broader population; (2) Evaluate whether other factors that affect the potential for differential risk are present under the rule; and (3) Evaluate whether the potential for exposure to communities of concern is exacerbated or mitigated by the 2014 CCR rule.

Example Questions:

- Do communities near facilities subject to the rule have higher percentages of population groups of concern relative to national, state, or regional populations?
- Are the communities potentially affected by the 2014 CCR rule also affected by other sources of pollution (e.g., industrial facilities, landfills, leaking underground storage tanks)?
- Do other factors contribute to higher susceptibility (e.g., life stages, nursing mothers) among population groups of concern?
- Does the 2014 CCR rule reduce or improve the ability for potentially impacted communities to participate in the decision-making process?
- Does the regulation reduce existing (baseline) disparities in risk?

To ensure that an HHRA generates useful information, risk managers and analysts should develop concise statements of risk management and analytical objectives that incorporate EJ concerns. See Text Box 5.2 for an example. As risk managers and analysts develop these objectives, it is important to frame them such that the data generated by the HHRA can be used to respond to the main EJ analytic questions from Section 3.1. Analytical objectives for incorporating EJ concerns should concisely identify the evidence to be collected; the direction and structure of the planned consideration of EJ concerns; the analytical methods to be employed (e.g., between socioeconomic group comparisons); the type of data required; and the scope of the analysis (e.g., national versus local scale).

Scope of the risk assessment

Scoping establishes the boundaries of the HHRA (e.g., what population groups, health effects, chemicals, and exposure pathways will be included in the assessment). These boundaries should align with and support the stated purpose of the risk assessment.

At this step, most EPA assessments focus on identifying and considering information available in areas such as the sources of contaminants, stressors, and associated effects; exposure routes and pathways; and susceptible populations or life stages. Incorporation of public concerns is also important at this stage (and should be built upon throughout the assessment process).

Depending on the nature of the assessment, it can be helpful to consult with affected communities when identifying exposure routes, duration, pathways, and other information for constructing exposure scenarios (U.S. EPA, 2014b). The EPA has developed extensive guidance on community and public involvement for this purpose and continues to update its guidance specifically for EJ-related contexts (U.S. EPA, 2003a; 2013b; 2015b).[52] See Section 2.3 for a general discussion of meaningful involvement.

In the scoping stage of an HHRA that supports a regulatory action, analysts should consider several questions that can aid in identifying EJ concerns:

- **Which population groups, as characterized by geographic location, ethnicity or race, gender, occupation, age, baseline health status or other factors, should be part of the assessment?** In some instances, the presence of risk- or effect-modifiers may mean that some types of individuals or communities are at greater risk for experiencing adverse effects. In identifying target population groups for the assessment of differential risks, an analyst should consider the extent to which risk- or effect-modifiers may explain differences that vary by demographics. If an analyst decides to assess population groups defined by risk- or effect modifiers, the rationale for this decision and the associated methods should be transparently documented.

- **What health endpoints are to be addressed by the assessment?** Defining health endpoints clearly in the planning and scoping phase focuses the risk assessment and increases the transparency of the process. When selecting health endpoints, an analyst

---

[52] For EPA tools and resources for public participation and outreach, also see https://www.epa.gov/international-cooperation/public-participation-guide-introduction-guide.

should consider whether specific health endpoints may be significant in population groups of concern. In making this selection, it is important to evaluate whether baseline health endpoints for a given exposure differ across population groups and to consider what intrinsic and extrinsic factors might contribute to variation. This type of information is most often found in epidemiology and toxicology studies, such as those focused on the modifying effects of social context on environmental risk. It may not be possible to identify all relevant health endpoints at the beginning of the HHRA. Some information found in toxicity assessments may only define the potential for an adverse health outcome for specific stressors. Information from sources such as EJScreen as well as community insights may also identify areas of further research as the HHRA progresses.

- **What exposure routes and pathways are relevant, do specific exposure pathways potentially lead to specific effects, and what exposure scenarios should be modeled?** An analyst should evaluate whether population groups of concern may have different exposure routes, pathways, or contact scenarios from the general population. Scoping for an exposure assessment should include timing and duration of exposure, both historical and current. Unique exposure pathways based on life stages, cultural practices, and other relevant categories may also be considered. Different pathways of exposure (e.g., inhalation, dermal, ingestion) may produce different effects with varying levels of severity. See Appendix B.

At the completion of the scoping step, analysts will have a well-defined context for the analysis, a set of key analytic priorities to evaluate key policy questions, and a set of boundaries for the HHRA that reflect how the analysis will address its analytic priorities. All of these elements can be incorporated into problem formulation to produce a detailed plan for the assessment.

5.3.2.2 Scientific Peer Review or Other Reviews

During the planning and scoping phase of a HHRA, analysts should also consider the need for and timing of peer review. Peer review is a documented process conducted to ensure that activities are technically supportable, competently performed, properly documented, and consistent with established quality criteria (U.S. EPA, 2014b).[53] When an HHRA that incorporates EJ concerns is subject to scientific peer review, the key expertise needed may include community representatives with technical expertise and public health scientists with community and EJ experience. Peer review usually involves a one-time or limited number of interactions by the independent peer reviewers with the authors of the work product.

An assessment also may benefit from other types of input, such as peer involvement and public comment. Planning and scoping for the assessment includes discussion of whether and what types of reviews will be included in light of the context and constraints for the assessment, including schedule and resources (U.S. EPA, 2014b). In addition, risk assessors may rely on

---

[53] Guidelines for the peer review process are available in the EPA's *Peer Review Handbook*: http://www.epa.gov/osa/peer-review-handbook-4th-edition-2015.

existing peer-reviewed literature to consider topics such as cumulative risk or differential effects across communities.

5.3.3 Problem Formulation

Problem formulation builds on the planning and scoping phase to identify major factors to consider in the risk assessment and informs its technical approach. Two important products from problem formulation are:

- A conceptual model to describe the linkages between stressors and adverse human health effects, including the stressor(s), exposure pathway(s), exposed life stage(s) and population(s), and health endpoint(s) that will be addressed in the risk assessment.
- An analysis plan based on the conceptual model to describe the approach for conducting the risk assessment, including its design, methods, key inputs, intended outputs, and assessments of uncertainty and variability that might specifically affect communities with EJ concerns.

Like the planning and scoping phase, problem formulation is often an interactive, nonlinear process, and substantial re-evaluation is anticipated in the development of resulting products.

In considering EJ, problem formulation focuses on identifying whether population groups of concern experience elevated risks relative to the broader population or other appropriate comparison population group (see Section 6.5.2), both in the baseline and in response to policy changes. Specifically, this involves: (1) clarifying the relevant source and characteristics of the stressors; (2) identifying factors that may influence exposures that contribute to those risks; and (3) characterizing susceptibilities or vulnerabilities of the population groups of concern that may exacerbate exposure or risk.

Text Box 5.3 provides examples of EJ-related questions that may be raised during problem formulation. For additional sample problem formulation questions, see U.S. EPA (2014b).

Text Box 5.3: Examples of EJ-Related Questions to Consider During Problem Formulation

Characteristics Related to Proximity to a Stressor or Source

- What are the sources of the stressor?
- Is the source located in geographic areas with greater proportions of population groups of concern?
- Are other sources of the stressor more prevalent in these geographic areas?
- Are there historical releases or uses of the stressor in such areas?
- Is the concentration of the stressor in the relevant ambient media higher in these geographic areas?
- Does each stressor have multiple sources that should be evaluated?

Differential Exposures to a Stressor

- Do population groups of concern have higher body burdens of the contaminant?
- Are these population groups more likely to experience current or historically higher exposures to the stressor from sources other than the one under consideration?
- Are there particular life stages within these population groups that may be more at risk to higher exposure to the stressor?
- Are there products/consumer goods that contain the stressor?
- Are these products/consumer goods used at noticeably higher rates among population groups of concern?
- Are there cultural practices or other activities that are unique to these population groups?
- What is the frequency and duration of occurrence of the unique cultural practice or atypical activity?
- Is proximity to the emitting source an important factor in assessing differential exposure?
- What geographic scale is important to highlight different exposures between population groups for the pollutant in question?

Population Characteristics

- What are the rates of the adverse health outcome among population groups of concern?
- Are the rates of the adverse health outcome higher among these population groups?
- What factors or conditions are known to modify the effect of the contaminant?
- How are these modifying factors or conditions distributed across population groups?
- Do population groups of concern have a higher prevalence of modifying effects or conditions?
- Are members of these population groups employed in specific professions known to have higher risks of the adverse health outcome?

5.3.3.1 EJ Considerations when Developing the Conceptual Model

Conceptual models consist of (1) a set of risk hypotheses that describe predicted relationships among stressor(s), exposure(s), and health endpoints and/or responses, along with the rationale for their selection; and (2) a diagram that illustrates the relationships presented in the risk hypotheses.[54]

Generally, the conceptual model addresses the following with respect to EJ concerns:

- How and to what degree identified risk factors contribute to differences in exposure and/or risk;
- The strength and direction of relationships between these risk factors and exposure and/or risk;
- Identification of data needs by characterizing these relationships as low, medium, and high uncertainty; and
- Scope of the assessment as to EJ concerns given current scientific understanding.

Characterizing the Stressor and its Sources

The properties and sources of the stressor(s), and how these may drive differential risks, are important to consider in the context of EJ. This includes the source(s) of regulatory concern – e.g., what is the likelihood that the sources of the stressor(s) are located in areas where population groups of concern live or experience exposure? But it can also include, where relevant and appropriate, identifying the distribution of additional sources of the stressor(s) that are not the focus of the regulatory action because they may contribute to differential risks. For example, a stressor may be present in environmental media due to background concentrations (e.g., resulting from historical or past industrial activity, or natural occurrence) in areas with population groups of concern.

Identifying Exposure Pathways

It is important to clearly articulate how population groups of concern may be exposed to a stressor(s). That is, it is key to describe the exposure pathways experienced by population groups of concern and to identify unique exposure pathways relevant to assessing EJ concerns.[55] Burger and Gochfeld (2011) discuss the types of unique exposure pathways that may occur in population groups of concern, and suggest that the first step in improving the risk methodology is to recognize and account for unique exposure sources (e.g., hand-to-mouth behavior of small children; use of personal care or cleaning products that contain harmful chemicals; fish consumption for subsistence or cultural reasons) and the corresponding

---

[54] The *HHRA Framework* (U.S. EPA, 2014b) provides descriptions of, resources on, and examples of conceptual models.

[55] Examples of such pathways include exposure to heavy metals from the use of non-traditional medicines, to mercury from high fish consumption, to pesticides tracked into homes from places of work, and to inorganic mercury in cosmetic products.

exposure pathways. Examples of questions helpful for extracting information about unique exposure pathways are presented in Text Box 5.3.[56]

New pathways can be identified during or after planning as new data become available. For example, biomonitoring data acquired during the assessment may provide evidence of unexpected health differences, resulting in additional analyses of exposure pathways that may cause these differences. It also may be useful to seek new information about certain exposure pathways to ensure a comprehensive evaluation of the range of exposures in the population groups of concern.

In more data limited settings, it may be helpful to use national databases and screening tools to identify the potential for differential exposure for specific population groups of concern. Screening-level assessments can also be used to exclude exposure pathways of minor importance from further consideration or to determine where additional data and information is needed to evaluate key pathways (U.S. EPA, 2019a). See Appendix B for additional discussion.

Identifying Differences in Exposures that May Lead to Differential Risks

Differential exposures can be an important indicator of differential risks across population groups of concern. For example, if the regulated sources are co-located with other sources of the same stressor, this may contribute to significant differences in patterns of exposure to the stressor.

Patterns of exposure evaluated can be location-specific or population group-specific, depending on the scale of the assessment and the types of data available. Differences in cultural practices, use of specific consumer products, and behaviors can lead to differences in exposures. Considering other characteristics, such as life stage, gender, or income, can further clarify which population groups may face higher exposures. For example, children living in older housing, lower incomes households, and identifying as Non-Hispanic Black have higher blood lead levels in the United States (U.S. EPA, 2023d). In addition, due to exposure via personal care products marketed to Black women, they are more highly exposed to endocrine disrupting chemicals than White women (Helm et al., 2018).

Identifying Population Characteristics that May Lead to Differential Risks

Population characteristics refer to those attributes shared by individuals within a population group that influence not only the likelihood of exposure to a stressor but may also affect the risk of adverse health outcomes from this exposure. These characteristics range from those with direct health effects, such as pre-existing disease conditions, chronic disease, age, medication status, and immune status, to those with more indirect influences, such as a lack of access to resources (e.g., health care, transportation), age of housing, occupation, income, and educational status. Group differences in body burdens of the contaminant (e.g., blood

---

[56] The *Exposure Factors Handbook* (U.S. EPA, 2011b) also has exposure factors data stratified by race and ethnicity.

concentrations) and co-exposures to multiple stressors that may affect the body's ability to detoxify a particular contaminant (e.g., metabolism) can be factors to consider.

Characterizing the distribution of relevant demographic characteristics across population groups of interest helps identify factors that may affect a community's ability to withstand or recover from exposure to a stressor. Appendix B provides examples of integrating these characteristics into a dose-response assessment.

5.3.3.2 Analysis Plan

The analysis plan provides details on technical aspects of the risk assessment and how the hypotheses about the relationships described in the conceptual model will be assessed. While the conceptual model may identify a larger set of pathways and relationships, the analysis plan focuses on the pathways and relationships that will be pursued in the risk assessment analysis. The plan includes the rationale for selecting or omitting pathways, the relationships between stressors and outcomes, and acknowledgements of data gaps and uncertainties.

The analysis plan also may consider how the level of confidence (or precision) needed for the management decision compares with that expected from available analytical approaches. This informs how data are used, the preferred analytic approach, and the extent to which new data are needed and may be obtained.

The analysis plan may be divided into specific components: (a) the assessment design and rationale for selecting specific pathways to include in the risk assessment; (b) a description of the data, information, methods, and models to be used in the analyses (including uncertainty analyses), as well as intended outputs (e.g., risk metrics); (c) quality assurance and quality control measures; and (d) the associated data gaps and limitations. The analysis plan may also describe scientific review and specify actions for community involvement (U.S. EPA, 2014b).

A central challenge for HHRA planning is identifying the data, tools, and models needed to inform EJ considerations. Data selection should be based on the context, risk management and analytic objectives, and scope of the analysis. (Appendix B provides sample questions to help identify data and model needs when planning for exposure assessment and dose-response assessment.)

Identifying Data

A key planning element for identifying data relevant to EJ concerns is consultation with the public, including communities that may have access to data useful for improving the characterization of exposure and risk. Relevant data can be location-specific or population group-specific, or, ideally, both. It may also include ambient concentration data (e.g., from air monitoring stations and water quality measures) or public health data such as disease incidence.

Exposure data may include information on consumption or contact rates, routes, and duration of exposure, behavior data for estimating contact rates, concurrent exposures to other stressors that are of toxicological relevance, biomonitoring, or emissions. There are many sources of exposure data. Some exposures can be evaluated using bio-monitoring data on chemical hazards such as the National Health and Nutrition Examination Survey (NHANES), although NHANES provides exposure data for limited geographic areas, so it may not be useful if broader geographic coverage is an important aspect of the HHRA. [57]

Health risk data could include toxicological data, such as that found in the EPA's Integrated Risk Information System database,[58] as well as incidence data specific to population groups with EJ concerns, and historical population-specific disease or illness rates.[59] States, Tribes, and local governments may also have relevant monitoring data for use in HHRA. Appendix B provides more detailed information on using bio-monitoring data and an example of estimating exposure using ambient concentration data.

Identifying Models and Tools

Risk assessment employs a range of models and tools to estimate ambient concentrations of stressors, exposure, amounts of stressors likely to reach the target organ(s) (e.g., effective dose), risks for a specific health endpoint(s), locational vulnerability to health effects, and other key factors.

A challenge for developing an HHRA that can inform EJ concerns is ensuring that input parameters for models are representative of population groups of concern. Traditional defaults used as inputs for HHRAs may not adequately reflect the demographic characteristics of these population groups.

Identifying Data Quality Limitations and Data Gaps

Consideration of EJ concerns may be aided by rapidly developing data and tools; thus, it is important that the HHRA planning process include a clear discussion of data available to characterize key uncertainties, data quality, and lack of data that may affect methodology development and/or results.

In some cases, lack of data may prompt a decision to limit the scope of planned analysis within an HHRA. It is recommended that such decisions be clearly documented, and where possible affected communities be consulted because they can often provide input into how to proceed when there is a lack of data. In some instances, clear documentation of lack of data may lead to

[57] Some limitations of data available through NHANES can be addressed by location-specific surveys such as the New York City Health and Nutrition Examination Survey (NYCHANES) and other site- and population-specific surveys that may be conducted for reasons other than EJ considerations. Some limitations to the availability of primary site- and population-specific surveys are cost and the amount of time required to conduct these surveys.

[58] See https://www.epa.gov/iris.

[59] Analysts should assess historical population-specific disease or illness rates to understand whether these data are built on potentially flawed assumptions or population selection that could exacerbate or negatively affect the accuracy of the HHRA results. For example, some population groups are less likely to seek medical care due to lack of health insurance or access to care.

changes in the design of the regulatory action to facilitate better monitoring in more vulnerable communities.[60]

To further promote the quality of data used in planning risk assessments, analysts should review the EPA's Information Quality Guidelines (IQG) and Data Quality Objectives (DQO) (U.S. EPA, 2012a). IQGs and DQOs help increase the integrity, objectivity, and quality of data when evaluating EJ concerns.[61]

5.4 Multiple Exposures and Cumulative Effects

The science supporting assessments of cumulative effects is evolving, and the data and analytical tools needed to develop richer and more informative analyses may become available as research continues. Given the importance of the cumulative effects of multiple exposures in the context of environmental justice, we briefly summarize cumulative risk and cumulative impact assessment approaches below. In the meantime, even when utilization of a more formal approach to assessment is not feasible, this guidance recommends that analysts consider the potential implications of exposure to multiple stressors, both chemical and non-chemical, when planning and scoping for a HHRA.

Cumulative Risk Assessment

HHRAs often focus on characterizing risk from a single stressor or contaminant. Recognizing the potential harm associated with multiple stressors from one or more pollution sources or exposure pathways, the EPA has described a framework for assessing the cumulative risk of adverse effects associated with multiple stressors (U.S. EPA, 2003b). Cumulative risk assessment (CRA) evaluates the combined risks from aggregate exposure to multiple agents or stressors (both chemical and non-chemical), though the specific elements and implementation of CRA may differ according to programmatic needs. Because of data and methodology limitations, applications of CRA at EPA have mainly focused on chemical mixtures and/or single chemicals from multiple sources.[62,63] See Appendix A for links to other U.S. EPA guidances on the conduct of CRA.

[60] For example, public comments during the nitrogen oxide (NOx) NAAQS rulemaking process resulted in siting additional monitors in vulnerable communities (U.S. EPA, 2010b). Likewise, outreach to communities living near refineries during a risk and technology review resulted in fenceline monitoring of benzene emissions to provide access to data on what is being released into nearby communities (U.S. EPA, 2015c).

[61] For information on IQGs and DQOs , visit the EPA's Information Quality Guidelines website (http://www.epa.gov/quality/epa-information-quality-guidelines) and the EPA's *Guidance on Systematic Planning Using the Data Quality Objectives Process* (http://www.epa.gov/sites/production/files/documents/guidance_systematic_planning_dqo_process.pdf).

[62] Definitions of CRA vary somewhat but the concept is consistent. For example, NRC (2009) defines CRA as "evaluating an array of stressors (chemical and non-chemical) to characterize – quantitatively to the extent possible – human health and ecologic effects, taking into account factors such as vulnerability and background exposures."

[63] While this broader definition of cumulative risk considers multiple agents or stressors (both chemical and non-chemical), it is important to acknowledge that the Food Quality Protection Act also requires the EPA to evaluate aggregate risks of one chemical from multiple sources and/or cumulative exposures to multiple chemicals with similar mechanisms of toxicity (U.S. EPA, 2002a).

In planning an HHRA, attention may be given to epidemiology studies that can indicate multiple chemical exposures and other factors that may modify or increase the risk of an adverse outcome from the target contaminant. It may be useful to use epidemiological data to focus on diseases or health conditions with a higher prevalence within or across population groups of concern. Studies that employ stratification can provide insight into how co-exposure to additional chemical, physical, environmental, social, or biological stressors may affect the risk of an adverse health outcome for a given population of concern.

Cumulative Impact Assessment

Cumulative impact assessment (CIA) is the process of accounting for cumulative impacts in the context of problem identification and decision-making. The term, cumulative impacts, refers to "the totality of exposures to combinations of chemical and nonchemical stressors and their effects on health, well-being, and quality of life outcome" (U.S. EPA, 2022e).

There are linkages between CRA and CIA, but these analyses are not the same and may use different outcome measures. For example, total burden in CIA encompasses direct health effects but also considers a wide set of outcomes that fall outside the purview of CRA, some of which may not be conducive to quantification (NRC, 2009). CIA may be able to "use information supported by relationships among stressors, exposures, effects, and/or health, well-being, and quality of life outcomes for which cause-and-effect linkages may not be well understood" (U.S. EPA, 2022e). Note that the EPA does not currently have guidance on the use of CIA in the context of rulemaking, though it has used a community-engaged approach to assessing cumulative impacts called Health Impact Assessment (HIA) in other decision contexts (See Text Box 5.4).

Text Box 5.4 Health Impact Assessment

Health impact assessment (HIA) is “a systematic process that uses an array of data sources and analytic methods and considers input from [affected individuals, communities, and other members of the public] to determine the potential effects of a proposed policy, plan, program, or project on the health of a population and the distribution of those effects within the population” (NRC, 2011a). Given the broad purview of this approach, HIAs may consider a wider spectrum of health determinants than a typical HHRA, such as housing quality, access to services, and social cohesion, as well as exposure to contaminants or the impacts of climate change.

The HIA process typically emphasizes meaningful public engagement that focuses on empowering vulnerable and affected populations to participate in decisions that have the potential to affect their daily lives. Effective input from the public can provide local knowledge of health and existing conditions; identify areas of concern and issues of interest that not readily apparent to those outside the community; offer contextual/cultural perceptions and experiences; and assist in identifying and refining the HIA scope and recommendations.

HIA is most often applied in the context of a specific local community. However, while the EPA has not used HIA in support of national regulatory actions, it could serve as a complement to HHRA in the national context, for instance to evaluate cumulative effects and EJ concerns related to hot spots. The figure below illustrates how an HIA can be tailored to available time and resources.

DESKTOP	RAPID	INTERMEDIATE	COMPREHENSIVE
2-6 weeks for one person full time.	6 to 12 weeks for one person full time.	12 weeks to 6 months for one person full time.	6 to 12 months for one person full time.
Involves an ‘off the shelf’ exercise analyzing existing, accessible data.	Involves collecting and analyzing existing data with limited input from stakeholders.	Involves collecting and analyzing existing and new data, including input from stakeholders	Involves collecting and analyzing existing and new data, including input from stakeholders
Provides a broad overview of potential health impacts.	Provides a more detailed overview of potential health impacts.	Provides a more thorough assessment of potential health impacts, and more detail on specific predicted impacts.	Provides a comprehensive and detailed assessment of potential health impacts.
Applied when time and resources are limited.	Applied when time and resources are limited.	Requires moderate time and resources.	Requires significant time and resources.
LESS IMPACTS →			MORE IMPACTS

Case studies to explore how HIA can be used to engage the public and incorporate EJ concerns and public health considerations into local environmental decision-making are available at: https://www.epa.gov/healthresearch/epa-health-impact-assessment-case-studies. The EPA also has compiled an inventory of HIA resources at: https://www.epa.gov/healthresearch/health-impact-assessment-hia-resource-and-tool-compilation and synthesized the state of practice at: https://www.epa.gov/healthresearch/hia-review-synthesis-report.

Chapter 6: Conducting Regulatory Analyses to Assess Environmental Justice Concerns

This chapter discusses how to assess whether a regulatory action has EJ concerns using information generated from human health risk, exposure, or other assessments, and how to incorporate the information into regulatory analyses.[64] In particular, it discusses methods that may be useful for answering the three analytic questions from Section 3.1 of this document, which are repeated here:

- **Baseline:** Are there existing (baseline) EJ concerns associated with environmental stressors affected by the regulatory action for population groups of concern?
- **Regulatory options**: Are there potential EJ concerns associated with environmental stressors that are affected by the regulatory action for population groups of concern for the regulatory option(s) under consideration?
- **Mitigation or exacerbation of impacts**: For the regulatory option(s) under consideration, are EJ concerns exacerbated, mitigated, or unchanged compared to the baseline?

These questions provide the framework for analyzing the effects of a regulatory action on population groups of concern. The extent to which an analysis can address all three questions will vary due to data limitations, time and resource constraints, and other technical challenges that vary by media and regulatory context. Regardless of the approach taken, the highest quality and most relevant data should be applied in a manner consistent with the EPA's data quality guidelines (U.S. EPA, 2012a) and *Peer Review Handbook* (U.S. EPA, 2015d).

In determining whether EJ concerns may arise in the context of a specific regulatory action, some level of analysis is needed, be it qualitative, quantitative, or some combination of both. For many regulatory actions, including actions that strengthen environmental protection, it is not possible to rule out EJ concerns without some level of assessment.

Generally, the EPA prefers quantitative assessments that complement other types of quantitative regulatory analyses (e.g., benefit-cost analysis, risk assessment) conducted for regulatory actions. Section 3.3 recommends some level of quantitative analysis, when feasible, to address the questions above for regulatory actions where impacts or benefits will also be quantified. When information on exposures, health and environmental outcomes, and other

[64] While the focus in this chapter is on population groups mentioned in E.O.s 12898 and 14096, the methods discussed may be applied to any population group of concern.

relevant effects by population groups is available, an analyst may be able to quantify exposure in the baseline and likely changes in exposure for each policy option. In cases where such data are unavailable, it may still be possible to evaluate risk or exposure using other quantitative metrics (e.g., density of regulated facilities as a function of race, ethnicity, or income).

When environmental and health effects or benefits cannot be quantified or disaggregated by race, ethnicity, income, or other relevant demographic factors, analysts should present available quantitative and/or qualitative information that sheds light on EJ concerns. Qualitative assessment is particularly appropriate when high quality and relevant quantitative data are not available.

This chapter is organized as follows: Section 6.1 discusses how a preliminary analysis can be used to evaluate the feasibility of an in-depth analysis of EJ concerns. Section 6.2 discusses the conceptual approach to evaluating the baseline, regulatory options, and incremental changes in an analysis of EJ concerns. Section 6.3 reviews the data and information needed to assess EJ concerns. Section 6.4 summarizes methods for assessing the three analytic questions for population groups of concern. Section 6.5 discusses analytic issues, including comparison population groups and geographic issues when the source of emissions is identifiable and health effects are fairly localized and spatially distinguishable. Sections 6.6 discusses characterizing and communicating results. Section 6.7 discusses the evaluation of costs and non-health effects.

6.1 Preliminary Analysis of EJ Concerns

As discussed in Section 3.2, a preliminary analysis early in the rulemaking process may help identify the extent to which there are EJ concerns in the baseline and offer initial insights into whether a regulatory action is anticipated to raise EJ concerns.

While there is no single prescribed method for conducting a preliminary analysis, the analysis should review the quality and availability of data, the availability of defensible methods to analyze the data, and the peer-reviewed literature and public input that might be used to evaluate EJ concerns. Such information may include:

- Proximity of regulated sources near population groups of concern;
- Number and types of sources that may be impacting these populations;
- Types of stressor(s) that may be affecting these populations in the baseline, including from sources other than those being regulated;
- Any unique exposure pathways associated with the stressor(s) being regulated;
- Evidence of differential current or historical exposure to or risk from the stressor(s) being regulated for population groups of concern;
- Evidence of the prevalence of factors or conditions that may modify the effect of the regulated stressor(s) for population groups of concern;

- Public or community concern(s) about the effects of the potential regulatory action on specific population groups or communities of concern; and
- History of EJ concerns associated with the stressor(s) or sources(s) being regulated.

A variety of tools and methods are available to the analyst to support a preliminary analysis.[65] For instance, EJScreen allows analysts to quickly examine several demographic variables and environmental indicators at the block group resolution for the United States (including Puerto Rico).[66] Demographic information is taken from the most recent American Community Survey five-year summary file.

While EJScreen provides a way to identify areas in the United States where population groups or communities of concern or environmental indicators are currently at or above a specific relative percentile, analysts are advised to summarize the demographic characteristics and relevant environmental indicators for all communities near sources likely subject to the rule (not just for those above a specific threshold).[67] In addition, it is recommended that analysts avoid using indices that combine information across multiple variables or indicators that are hard to interpret, instead presenting the results for each relevant variable separately. Finally, analysts should present information on the demographic characteristics of nearby communities and the environmental exposure they face in levels (e.g., percent of the population that is low-income, $PM_{2.5}$ concentrations), not just in relative percentile terms. It is also important to keep in mind that, while EJScreen and other screening tools can shed light on pre-existing disparities for the included environmental indicators, they typically only provide a snapshot and may not include important sources of exposure relevant to the regulatory action.

More generally, when evaluating whether a screening tool is sufficient or appropriate for conducting a preliminary analysis of EJ concerns in the federal rulemaking context, the analyst should consider the purpose for which the tool was originally designed. Certain tools are designed to evaluate environmental conditions within a certain region or state and, as such, may not contain nationally representative data. Other tools may be designed to help prioritize funding, permitting, or compliance and enforcement actions and therefore may define population groups or other key variables in specific ways, or they may incorporate policy decisions directly into the tool by weighting certain indicators or characteristics over others.

A preliminary analysis can also act as an input into determining whether it is feasible to conduct an in-depth assessment. Feasibility is informed by a technical evaluation of available data and methods, including:[68]

---

[65] Envirofacts contains information on the location, reported emissions, and compliance history of sources regulated by the U.S. EPA under various statutes (https://enviro.epa.gov/}. EasyRSEI allows analysts to examine the types and amounts of toxic chemicals reported annually by facilities to the Toxic Releases Inventory (https://edap.epa.gov/public/extensions/EasyRSEI/EasyRSEI.html).

[66] See the EPA's EJScreen website: www.epa.gov/ejscreen.

[67] See Appendix H in the EJScreen Technical Documentation for more information (U.S. EPA, 2021).

[68] Recall that appropriateness is informed by relevant policy, budgetary, and statutory considerations (see Section 3.2).

- Scientific literature that discusses the effects of the stressor(s) being regulated on population groups of concern;
- Information received via public comments, technical reports, press releases, or other documentation discussing the environmental and health effects of the stressor(s) being regulated for population groups of concern, including information on other chemical, physical, or social stressors;
- Availability of spatially disaggregated data for population groups that may live, work, or play in close proximity to the stressor(s) being regulated, or may otherwise be affected by the stressor(s); or
- Availability of methods for conducting in-depth analysis (e.g., proximity-based approaches, risk- or exposure-assessment, and mixed methods, as discussed below).

If the preliminary analysis reveals that the scientific literature and data are unavailable or of insufficient quality to pursue an in-depth analysis that characterizes how exposure, risk, or health outcomes are distributed across population groups of concern, the analyst is encouraged to characterize the issues that cannot be quantified, including a discussion of any evidence, key limitations, and sources of uncertainty highlighted in the published literature (U.S. EPA, 2010a).

6.2 Defining Baseline, Regulatory Options, and Incremental Changes

The first step in any regulatory analysis is to characterize baseline conditions. The OMB (2003) defines the *baseline* as "the best assessment of the way the world would look absent the proposed action." It includes the characteristics of current populations and how they are affected by pollutant(s) prior to the regulatory action under consideration. As the OMB definition implies, however, the baseline is not a static concept. In particular, the OMB notes that an analyst may need to consider the evolution of the market, compliance with other regulations, and the future effect of current government programs and policies, as well as other relevant external factors to project future baseline conditions. Anticipated changes in baseline demographic composition may also be relevant in an EJ context.

Because other chemical and non-chemical stressors can increase susceptibility to negative health effects from exposure, it is also important to understand how other risks that are already present may interact with the pollutant being regulated. While explicit modeling of these interactions is often not feasible, analysts can evaluate the extent to which there are multiple polluting facilities or elevated risks for other key environmental stressors within affected communities.[69] Prevalence of pre-existing health conditions, such as asthma, among specific populations may also be indicative of increased susceptibility.

[69] Possible data sources include EJScreen and many that can be accessed through Envirofacts, such as the Toxics Release Inventory (TRI) and the National Emissions Inventory. Information on past enforcement and compliance with environmental statutes is available in Enforcement and Compliance History Online (ECHO).

Per the recommendations in Section 3.3, the definition of the baseline for the analysis of EJ concerns, including the geographic scope, year of analysis, and health and other effects should be consistent with other parts of the regulatory analysis. See Chapter 5 of the EPA's *Economic Guidelines* (U.S. EPA, 2010a) for a more detailed discussion of baseline issues.

The second step in an EJ analysis is to examine the distribution of effects for each regulatory option – different configurations of the regulatory action being considered. This analysis is based on a prediction of how the world will look once the regulation is in place, including how effects are related to the characteristics of the affected populations. For the analysis of EJ concerns, the analyst should examine how the exposure, health or environmental effects, or other outcomes of the regulatory action are distributed across population groups of concern for the regulatory options being considered, where practicable.[70]

For the third step, the differences between the environmental and health effects in the baseline and under the regulatory options under consideration are compared to evaluate the incremental changes associated with each of the regulatory options. Incremental changes reflect the improvement or decrement in effects of stressor(s) on specific populations that can be attributed to the regulatory options. In addition to identifying whether the regulatory action is expected to exacerbate, mitigate, or leave baseline EJ concerns unchanged, the analysis should shed light on the extent and distribution of any changes.

With these three sets of information –effects in the baseline, effects under the regulatory options, and the incremental changes associated with the regulatory options – the analyst can characterize the distribution of environmental and health effects associated with a regulatory action, thus answering all three analytic questions from Section 3.1. Specifically,

- An assessment of the baseline can inform whether pre-existing differences in environmental and health effects are associated with the stressor(s) under consideration.

This analysis depicts how the stressor(s) and its effect(s) are distributed across population groups prior to any regulatory action. For instance, if emissions or effects are more concentrated in one population group (e.g., Black or low-income households), the decision-maker may want to take this into consideration when making decisions about the regulatory action; mechanisms or choices associated with implementation, for example, may allow the EPA to address pre-existing differences.

- An assessment of the regulatory options being considered can inform how the stressor(s) and its environmental and health effects are distributed.

[70] The regulatory options in the EJ analysis should be the same as in the other parts of the regulatory analyses (e.g., benefit-cost analysis) to facilitate comparisons and ensure consistency. Typically, multiple scenarios or options are considered in a regulatory analysis. The OMB recommends "… you generally should analyze at least three options: the preferred option; a more stringent option that achieves additional benefits (and presumably costs more beyond those realized by the preferred option; and a less stringent option that costs less (and presumably generates fewer benefits) that the preferred option" (OMB, 2003).

It is important to note that analysis of the regulatory options is based on predictions, which may not always be sufficiently disaggregated across population groups to enable a rigorous EJ analysis. Ideally, the analyst is able to provide an indication of how the stressor is distributed across population groups of concern for the options being considered, either quantitatively or qualitatively. There may be some options for which the distribution of the stressor and its effects across population groups of concern is more equitable than others.

- An assessment of the incremental changes associated with the regulatory options can help inform to what extent the regulatory action will address identified EJ concerns.

It is helpful for the analyst to provide information how the incremental change compares to the baseline for each of the options in order to show the extent to which each option improves or degrades environmental quality across population groups of concern.

Note that the distribution of effects from a regulatory option is different than the distribution of the incremental change. It may be ideal if there is no difference in the distribution of effects across population groups for the regulatory options being considered. This indicates that everyone is experiencing the same environmental quality post-regulation. However, one might instead evaluate the distribution of the incremental change and find that there is an even change, which indicates that the regulatory option results in a constant reduction in environmental risk or exposure across population groups. The concern with using this measure is that if there are pre-existing disparities, then an even reduction after the regulatory action is implemented still would not mitigate the EJ concern.[71] While characterizing both types of distributions is useful, knowing the distribution of the effects is likely more informative.

6.3 Data and Information to Assess EJ Concerns

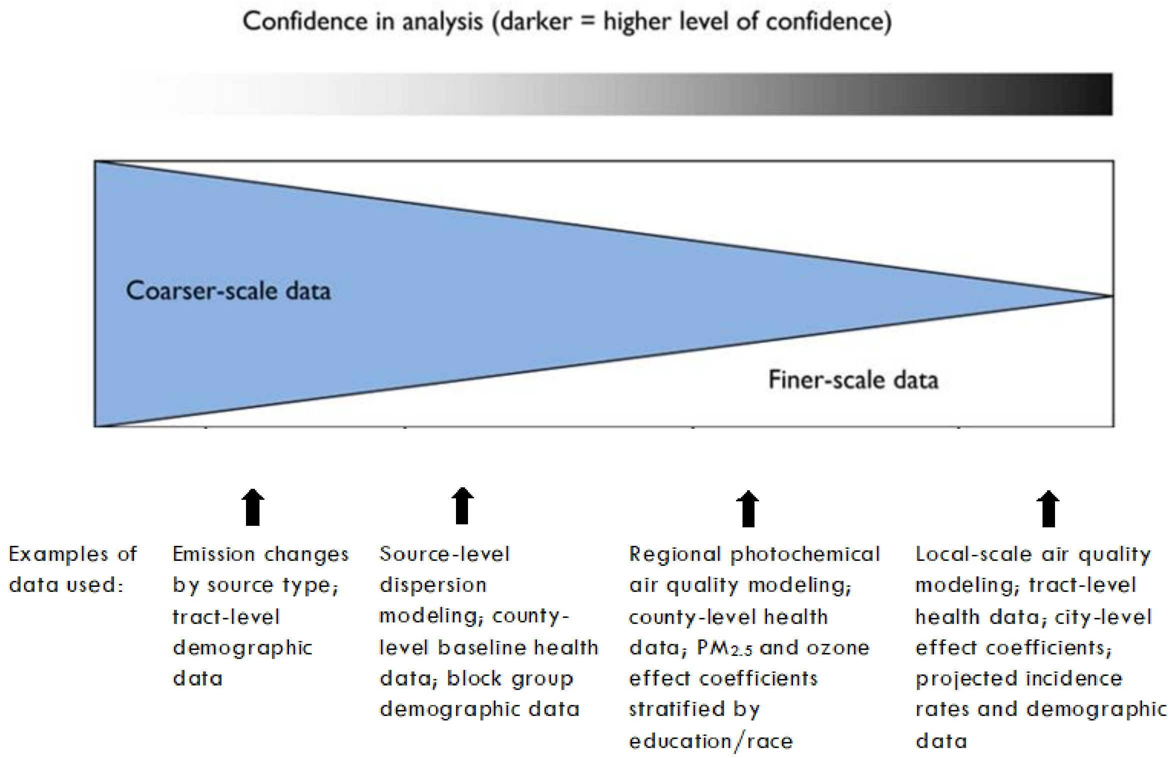
This section describes the types of data needed to assess EJ concerns. In general, the type of analysis that can be conducted depends upon the availability and quality of data. In some cases, spatially resolved, individual-level data may be most appropriate and relevant for an analysis of EJ concerns. In other cases, distance from a regulated source may be the best available metric. At times, the best available information will be qualitative. In all cases, analysts should use the highest quality and most relevant data and information, as discussed below. See Text Box 6.1 for an example of how data quality may affect the level of analysis in an air quality context.

Recognizing the importance of data quality, data needed to conduct an EJ analysis may include:

- Demographic characteristics (e.g., race, ethnicity, income);
- Health data (e.g., hospital and emergency admissions, race/ethnicity-stratified mortality rates, race and ethnicity-stratified asthma or other morbidity rates);

[71] See Maguire and Sheriff (2011) for more information.

Text Box 6.1: Data Quality and Spatial Resolution in the Context of Air Regulations



An analyst's ability to address how a regulatory action changes the distribution of risk across population groups of concern depends on the quality and spatial resolution of the data available. Finer-scale air quality, health, and demographic data allow one to assess the distribution of effects across population groups of concern and to have greater confidence in the conclusions drawn from these data. When air quality data are lacking or only available at a coarse level, the ability to assess change in risk across populations and other conclusions is more limited.

An example in limited data environments: Using race-stratified county-level mortality and morbidity data, an analyst can calculate population-weighted mortality rates by county. The analyst can then use a highly aggregated baseline air quality modeling projection (e.g., 12 or 36 km) to identify population groups most exposed to air pollution. Using geographic information system (GIS) tools, it is possible to combine the two sources of data. The coarse geographic scale of air quality information may inhibit the analyst's ability to detect meaningful differences in effects among and between groups. When risk coefficients are unavailable, it is not possible to estimate health effects separately for each population group.

An example in data-rich environments: Using finely resolved air quality data, an analyst can identify at a highly disaggregated level (e.g., 1 km) population groups of concern that experience the highest exposure to air pollution. An analyst can also identify population groups who exhibit the highest baseline incidence or prevalence rates for air pollution health effects. Using GIS modeling tools, an analyst can join the two data sources. Using race-specific or standard risk coefficients the analyst can then estimate health effects for each population group.

- Other triggers or co-stressors that may be confounders (e.g., indoor air concentrations; vulnerability to impacts of climate change);

- Prevalence of specific exposure pathways that may increase risk for some population groups;

- Risk coefficients stratified by population groups of concern (e.g., race, ethnicity, income);

- Location of pollution sources (e.g., latitude/longitude coordinates, zip code, county);

- Historical, current and projected emissions or concentrations of stressor(s) relevant to the regulatory action; and/or

- Distribution of economic costs, when relevant (see Section 6.7.1).

The U.S. Census Bureau is the recommended source for demographic data used in an EJ analysis for rulemaking. It produces several products that report demographic characteristics at relatively fine spatial scales (e.g., census tract and block group): for instance, the decennial Census, the American Community Survey, and the American Housing Survey. The decennial Census has an advantage over the ACS in that most individuals are sampled, and therefore margins of error are minimal. Yet, after 2010, the decennial Census has had a limited set of questions on age, sex, race, and owner/renter status. The ACS gathers more demographic characteristics such as income, education, employment, and form of transportation. Further, the ACS relies on annual population sampling, and so it will often reflect more timely information, especially for rapidly changing areas. Note that the five-year ACS is generally preferable to the one-year ACS because it contains information on all areas and has estimates of population statistics with lower margins of error. These more reliable estimates may be especially important when investigating areas with low population, such as rural regions, or when investigating a limited number of locations. Estimates from areas with low population are likely to be based on smaller samples and have larger margins of error and reduced accuracy. Strategies to improve estimates in areas with low population include combining data across geographic units or consolidating data into population subgroups. The U.S. Census Bureau suppresses estimates with unacceptable levels of statistical reliability, but analysts should still consider data quality carefully, especially within rural regions.[72]

Data quality can be evaluated in a variety of ways. Both the EPA and the OMB have Information Quality Guidelines that should be followed when evaluating whether data are of sufficient quality for use in analyses of EJ concerns (see U.S. EPA, 2002b; OMB, 2019). These guidelines establish internal mechanisms for ensuring that quality procedures are followed (e.g., data quality managers and plans) and establish that data should have objectivity, integrity, and utility when used in decision-making. Objectivity means the information is accurate, clear, and unbiased. Integrity means the information is protected from unauthorized changes. Public input

[72] For more information on compensating for low population in rural areas, see Section 2 of *Understanding and Using American Community Survey Data: What Users of Data for Rural Areas Need to Know* (U.S. Census Bureau, 2020a) at: www.census.gov/programs-surveys/acs/library/handbooks/rural.html.

and comment periods, peer review, and other input from experts help ensure data are of sufficient quality and adhere to the principles outlined above.

Regardless of the analytic methods used to analyze the data, information used to assess EJ concerns should be presented in a transparent way, and should include the following:

- Information about the specific population groups and individuals affected by the regulatory action;
- Main exposure pathways and expected health and environmental outcomes;
- Evidence for why risk, exposure, or outcomes may vary by population group;
- Relevant geographic scale;
- Descriptions of the main methods of analysis used;
- Summary statistics for the baseline and each regulatory option (both the mean and distribution) by population group;
- An easy-to-understand description of what the summary statistics show;
- Conclusions based on the information available;
- Robustness of results across options presented; and
- Data quality and limitations that affect conclusions regarding potential differential impacts.

6.4 Analytic Methods

A variety of scientifically defensible methods can be used to assess EJ concerns associated with regulatory actions. The choice of analytic method is most often driven by data availability. In some cases, the analyst will have data at the individual level for the pollutant(s) being regulated, allowing for a detailed, rigorous analysis. In other cases, the distribution of ambient environmental quality indicators (e.g., pollutant concentrations) or stressors from regulated sources (e.g., waste sites or permitted facilities) may be useful proxies for individual level effects. In some cases, information may be limited to the proximity of the affected population to the regulated source. Analysts may also rely on a combination of these methods when analyzing a regulatory action. The conclusions that can be drawn from the analysis will vary depending on the method used.

Considerable uncertainty may exist about key relationships and endpoints, such as how a reduction in emissions or other types of releases from a given source translates into ambient environmental quality and how it, in turn, translates into the human health effects of interest. This is particularly problematic if uncertainties differ across population groups. For instance, if an overexposed population group is more susceptible (i.e., it experiences greater health effects per unit of exposure), then using exposure as a proxy will underestimate the health risk posed by a stressor to that group. On the other hand, if proximity to a pollutant source does not correlate with exposure, it could overstate potential differences in health risk. The analyst should select the method that is most appropriate for the available data, recognizing time and resource constraints. The sections below discuss three methods that are often used for assessing EJ concerns: proximity-based analysis, use of exposure and risk modeling tools, and qualitative approaches. Note that these are not the only possible methods that can be used to assess EJ concerns. For each of the three approaches discussed, we highlight key advantages and limitations.

Regardless of the analytic approach, analysts should follow best practices appropriate to the questions under consideration. Best practices that may be helpful for evaluating EJ concerns are outlined in Text Box 3.1. If it is not feasible to follow a particular best practice, the analyst should explain why this is the case.

6.4.1 Proximity-Based Analysis

Proximity to a polluting source is commonly used when a direct measure of risk or exposure is not available and the activities or emissions associated with the stressor of concern are likely localized (Baden and Coursey, 2002; Wolverton, 2009; Cameron et al., 2012; Banzhaf et al., 2019; Maantay et al., 2022).[73] Generally speaking, a proximity-based approach compares the demographic characteristics of population groups affected by the polluting sources to the demographic characteristics of population groups unaffected by these sources. Note that it cannot differentiate between sources based on the magnitude of emissions, concentrations, exposure, or risk of health effects.

It is important to note that proximity-based approaches are not recommended when risk of exposure to a specific stressor is not correlated with the location of its source. For example, exposure to pollutants found in drinking water systems can be more dependent on distribution system characteristics than proximity to a pollutant source or the treatment plant. Likewise, exposure to specific chemicals may occur at home or in the workplace, such as through use of cleaning or personal care products or because of lack of access to personal protective equipment, rather than proximity to where the chemicals are manufactured.

For practical reasons, the boundary of an affected area is usually based on a Census-defined geographic area (e.g., census tract or block group) or a distance-based buffer (e.g., a specified radius around a site). It is critical to use accurate spatial information when mapping the location of polluting sources. Analysts must also decide what distance from the facility most accurately reflects the community's exposure to a stressor; no single distance is appropriate for all analyses. The buffer distance around polluting sources can be chosen to approximate actual risk and exposure, although distance should be the same around each source. It is also possible to use more continuous measures of distance such as distance to the nearest polluting site or, when additional information is available, an emission-weighted distance measure. In some cases, it may be possible to use dispersion models to select a buffer that approximates

[73] Even when risk or exposure modeling is available, proximity analysis with a relatively small distance buffer (e.g., 1 or 3 miles) may offer insights into who is impacted by potential harms from changes in economic activity (e.g., noise, odors, traffic, leaks).

the effect of atmospheric conditions (for instance, wind direction and weather patterns) on exposure; these types of models are more data intensive.[74]

Applying proximity-based analysis to evaluate the implications of a regulatory action to improve surface water quality deserves special mention, as proximity is along a river network or water feature affected by the regulation. In these cases, the analyst should select a distance upstream or downstream that is likely related to the stressor(s). Pollutant transport and dilution models can also provide insight on the relevant distance. Some pollutants may degrade after a relatively short distance, while others (e.g., bromide) maintain their physical properties for hundreds of kilometers. For this type of proximity analysis, it is appropriate to incorporate a buffer around the water segment to define the affected population. Depending on the regulation's effects, the buffer could be relatively narrow (e.g., 1, 3, or 5 miles) or wide (e.g., up to 25 miles). Multiple buffers around affected water segments may also be appropriate to reflect uncertainty as well as distinct exposure pathways, such as via drinking water or subsistence fishing.

Regardless of how the size or extent of the affected area is selected, proximity-based approaches typically assume that the effects of the stressor(s) occur only within the designated boundary (i.e., people located outside the boundary do not suffer ill effects) and that all individuals residing within the boundary are equally exposed.[75] As such, a proximity-based analysis is not able to determine which populations within the boundary may face higher risks or adverse health effects. The results of proximity-based analyses may also vary with the geographic unit of analysis (e.g., Ringquist, 2005; Mohai and Saha, 2007; Mascarenhas et al., 2021). For this reason, an analyst should explore alternative geographic units or distances when defining proximity to a source and describe the choices and assumptions that are used in selecting specific buffers. When conducting a proximity analysis, the results can also vary with the method used for assigning populations from Census-designated geographic units (e.g., a tract or block group) to a specific distance buffer (see Text Box 6.4).

The two groups – individuals located near and far from the source, as determined by the selected buffer – can be compared based on simple statistical or regression estimation techniques. Statistical tests on summary data can be used to identify whether, on average, statistically discernible differences exist in the characteristics of the two groups. Regression techniques, such as a binary logit, can formalize this comparison, where the dependent variable takes on the value of 1 for areas where one or more sources are located, and 0 indicates areas with no sources of the stressor. The independent variable would be a demographic variable, such as share of the population that is low-income in that area. A statistically significant coefficient on the independent variable indicates a measurable difference in the demographic

[74] For an overview of proximity analysis, including a discussion of various spatial analysis techniques used in the literature, see Chakraborty and Maantay (2011) and Mohai and Saha (2007).

[75] Chakraborty and Maantay (2011) address how to account for areas with more than one pollutant source, which are typically treated the same as those with only one source. Each pollutant source is treated as identical with regard to its effect on the nearby community. In reality, sources may vary widely in size, age, and production techniques resulting in differing amounts of emissions.

variable across geographic areas with and without stressor sources. See Section 6.6.3 for a discussion of statistical significance.

Advantages of Proximity-Based Analysis

- Provides a quantitative analysis of the characteristics of communities in nearby locations;
- Can be a statistically rigorous approach if supported by data;
- Accounts for where individuals reside, providing a proxy for exposure when other more detailed information is unavailable; and
- Can be used to identify potential hot spots.

Disadvantages of Proximity-Based Analysis

- Requires accurate information on locations of sources;
- Not useful when risk of exposure to the stressor is not correlated with the location of its source;
- Cannot distinguish between sources based on the level of exposure, risk, or health effects for the population within the boundary; and
- Exposure is often defined as a binary indicator instead of a continuous measure.

6.4.2 Exposure and Risk Modeling

When data are available, analysts may choose to combine either a direct measure of or proxy for exposure with fate and transport modeling to examine distributional effects at a disaggregated level. For instance, the EPA's Air Toxics Screening Assessment tool uses fate and transport modeling to estimate hazardous air pollutants concentrations and respiratory and cancer risks from point, non-point, and mobile sources at the census tract level. The Risk-Screening Environmental Indicators (RSEI) model combines a fate and transport model and information on chemical toxicity to estimate the dispersion of toxic chemicals reported by specific facilities to the Toxics Reporting Inventory (TRI). Information from these types of modeling exercises can be combined with demographic data to generate baseline and regulatory distributions of pollutants by population groups of concern. (See Appendix B for examples.)

Likewise, direct measures of surface water quality or modeled water quality data can be combined with hydrological modeling to estimate pollutant concentrations in waterways. This allows the analyst to consider exposure to pollutants such as lead and mercury via fish consumption. Drinking water quality sampling results or violations of the Safe Drinking Water Act can also be used in tandem with water system service area boundaries to estimate exposure to pollutants through drinking water and assess distributional effects across population groups.[76] In cases where disaggregated information is available on the types of activities that result in differences in exposure across population groups, it may be possible to characterize differences in health effects due to the regulatory action. In some cases, it also may be possible to combine exposure data with information on differences in risk across population groups.

Advantages of Exposure and Risk Modeling Methods

- Represent the most detailed and rigorous type of analysis; and
- Provide the most direct source of information on exposures or other outcomes.

Disadvantages of Exposure and Risk Modeling Methods

- Require detailed data at a fine geographic scale;
- Are more complex to implement; and
- Provide results in a form that may be more challenging to communicate to the public.

6.4.3 Qualitative Approaches

While the EPA prefers using quantitative data and analysis to support the regulatory process, it is not always feasible to do so.[77] Often the available data are not sufficiently disaggregated to allow for quantifying the distribution of effects in the baseline and across regulatory options. Other times, only partial information may be available. In either case, the use of qualitative information or methods may be an appropriate supplement. Qualitative methods may be particularly useful for offering insight into people's values, behaviors, motivations, or cultures, or when providing context for cumulative effects, which are often omitted from quantitative assessment. Qualitative approaches may also be useful at the preliminary stages of analysis.

Qualitative approaches can range from a survey of existing literature to more formal analysis with one or more of the following characteristics:

- Employ a variety of empirical materials, such as case study, personal experience, introspection, life story, interview, observational, historical, interactive, and visual text;
- Gather empirical materials using some form of observation or interviewing method;
- May be iterative, with initial results informing later choices; and
- May rely on primary or secondary data sources, or a combination of the two.

[76] When evaluating exposure to specific drinking water pollutants, it is important to know who is served by a specific water system. However, drinking water service areas rarely correspond to Census or other standardized geographic designations.

[77] U.S. EPA (2010a) discusses how to consider qualitative information in the context of benefit-cost analysis (Chapters 7 and 11).

Most, if not all, regulatory actions include some level of qualitative discussion to add important details to the description of differences in effects across population groups. Text Box 6.2 highlights several examples of qualitative analyses from recent regulatory actions.

Analysts should use their best judgment when evaluating the appropriate use of quantitative and qualitative information for analysis of EJ concerns.[78] Note that approaches that directly engage local communities can be long, time-intensive processes and are subject to Paperwork Reduction Act requirements and Tribal outreach protocols. Special thought should also be given to addressing barriers to meaningful involvement when using qualitative analytic approaches, including those related to disability, language access, and lack of resources per E.O. 14096. (See Section 2.3.)

Advantages of Qualitative Approaches

- Useful when data are unavailable for conducting a quantitative analysis; and

Allow analysts to incorporate hard-to-quantify information, such as cultural factors, vulnerabilities, public narratives, and community lived experiences.

Disadvantages of Qualitative Approaches

- Can be difficult to summarize results succinctly;
- Results can be uncertain, and the degree of uncertainty can be difficult to characterize; and
- Can be difficult to compare to quantitative information, e.g., from a benefit-cost analysis or risk assessment.

6.5 Analytical Considerations

Regardless of the analytic approach taken, an analyst makes a number of key decisions that can have a substantial effect on the results of the analysis, including: the geographic and temporal scope of the analysis; how to specify the comparison population group; how to spatially identify and aggregate effects across affected and unaffected populations; how to evaluate underlying heterogeneity, including the potential for hotspots; and whether to conduct analysis from a community and/or facility perspective.

An important general strategy in analyzing EJ concerns is the use of sensitivity analysis. Due to the uncertainties associated with the analytic decisions discussed below, sensitivity analysis around key assumptions is often critical for clearly communicating results to the public.

[78] See Tesch (2013) for a discussion of different types of qualitative analyses. Mohai and Saha (2015) also provide a literature review of mixed method and qualitative studies in the EJ context.

Text Box 6.2: Examples of Qualitative Discussion of EJ Concerns

Revised 2023 and Later Model Year Light Duty Vehicle Greenhouse Emissions Standards (U.S. EPA, 2021h):

> Individuals living in socially and economically disadvantaged communities, such as those living at or below the poverty line or who are experiencing homelessness or social isolation, are at greater risk of health effects from climate change. This is also true with respect to people at vulnerable life stages, specifically women who are pre- and perinatal, or are nursing; in utero fetuses; children at all stages of development; and the elderly… Many health conditions such as cardiopulmonary or respiratory illness and other health impacts are associated with and exacerbated by an increase in greenhouse gases and climate change outcomes, which is problematic as these diseases occur at higher rates within vulnerable communities…
>
> Individuals face differential exposure to criteria pollutants, in part due to the proximities of highways, trains, factories, and other major sources of pollutant-emitting sources to less-affluent residential areas. Outdoor workers, such as construction or utility crews and agricultural laborers, who frequently are comprised of already at-risk groups, are exposed to poor air quality and extreme temperatures without relief. Furthermore, individuals within EJ populations of concern face greater housing, clean water, and food insecurity and bear disproportionate economic impacts and health burdens associated with climate change effects. They have less or limited access to healthcare and affordable, adequate health or homeowner insurance. Finally, resiliency and adaptation are more difficult for economically disadvantaged communities: They have less liquidity, individually and collectively, to move or to make the types of infrastructure or policy changes to limit or reduce the hazards they face. They frequently are less able to self-advocate for resources that would otherwise aid in building resilience and hazard reduction and mitigation…

Agricultural Worker Protection Standard Revisions (U.S. EPA, 2015e)

> The analysis of potential EJ concerns and overall benefit analysis include qualitative discussions of factors that may cause farm workers to be more susceptible to pesticide exposure and to have a larger risk of harm from exposure. These reasons include higher acute and chronic exposures than that of the general public, poor nutrition due to food insecurity, lack of access to healthcare, language barriers, low educational attainment, and low-income status.

6.5.1 Geographic and Temporal Scope

The geographic scope of analysis for an EPA regulatory action is often the entire United States since requirements typically apply nationwide. However, in some cases the effects of a regulatory action are expected to be concentrated in specific regions or states. In such cases, it may make sense for an analyst to analyze and present differences in health and environmental outcomes across population groups of concern at both a national and a sub-national level. The scope of the analysis should match the scope used in other parts of the regulatory analysis (e.g., benefit-cost analysis). Because the geographic scope can affect the results of the analysis (see Baden et al., 2007), the analyst should make certain that the scope is relevant for the regulatory action under consideration.

It may be important to evaluate regulatory action effects on both shorter and longer time horizons. For instance, while a regulatory action may result in near-term reductions in emissions, changes in health and other risks may occur on a much longer timeframe. In some cases, effects may even be felt intergenerationally (e.g., climate change). In general, the period of time over which the analysis is conducted should also be consistent with other parts of the regulatory analysis.

However, in some situations, using a different time horizon or spatial scale may be appropriate when considering EJ. For example, phasing in of regulatory requirements or relocation of polluting activities in response to the regulatory action could result in EJ concerns due to effects that occur on a time horizon or spatial scale that differs from other effects considered in the regulatory analysis. If such situations arise, the analyst should clearly articulate the reasons for considering an alternative time horizon.

6.5.2 Comparison Population Group

To evaluate differential effects on population groups of concern, information needs to be presented in relation to another group, typically referred to as a comparison population group. The way in which the comparison population group is selected can have important implications for evaluating differences in health, risk, or exposure effects across population groups of concern. It is possible to define the comparison population group as individuals with similar socioeconomic characteristics in areas of the state, region, or nation unaffected by the regulatory action (i.e., within-group comparison) or as individuals with different socioeconomic characteristics within the affected areas (i.e., across-group comparison).

Ideally, the comparison population group for an across-group comparison is as similar as possible to the population group of concern, but without the socioeconomic characteristics defining the group of concern. For example, the analyst could compare the proportion of low-income households within areas affected by the regulatory action to the proportion of non-low-income households within the same affected areas. If the analyst has information on emissions, he or she can compare the average concentrations faced by low-income households within the affected areas to those faced by non-low-income households living in the same areas. Thus, the results from an across-group comparison indicate how the likelihood of risk or exposure within the affected areas varies with demographic characteristics.

A within-group comparison compares the likelihood of risk or exposure for a specific demographic group in affected areas to the likelihood of risk or exposure for that same demographic group elsewhere. For example, the analyst can compare the proportion of low-income households within areas affected by the regulatory action to the proportion of low-income households in unaffected areas. Similarly, if an analyst has information on emissions, they can compare the average concentrations faced by low-income households within the affected areas to those faced by low-income households living in areas unaffected by the regulatory action.

If a regulatory action is expected to differentially affect populations within a given area (e.g., communities living near regulated facilities or in a specific region), then a combination of within- and across-group comparisons can demonstrate whether there are differences between specific population groups of concern and the general population. Across-group comparisons are also informative in instances where it is difficult to identify a comparison population group because a large share of the U.S. population will be affected by the regulatory action. In these instances, using a comparison population group inclusive of the population of concern (such as the U.S. average) can dilute differences.

It is unlikely that the same comparison population group will be appropriate in every instance. It is important to articulate clearly how the comparison population group is defined in the EJ analysis. Analysts should carefully document the criteria used to select the comparison population group for a particular regulatory action.

In some contexts, it may make sense to define the comparison population group at a sub-national level to reflect differences in socioeconomic composition across geographic regions (see Text Box 6.3). For instance, because larger populations are concentrated in urban areas, the results of the analysis are often dominated by effects in these areas. If a regulatory action primarily affects rural areas, inclusion of urban areas in the comparison population group may obscure underlying differences. Using a sub-national comparison population group may also be more defensible when there is a great deal of heterogeneity in industrial development and economic growth and/or inherent differences in demographic composition across geographic regions (e.g., relatively more Hispanics reside in the Southwest) (e.g., Bowen, 2001). Note, however, that placing restrictions on comparison population groups may "reduce the power of statistical tests by reducing sample sizes" (Rinquist, 2005) or bias results against finding differences in adverse human health and environmental effects because such restrictions reduce variation in demographic variables of concern.

In selecting a comparison population group, an analyst should therefore evaluate how different comparison population groups affect the way information is conveyed. When appropriate and practicable, an analyst may wish to conduct sensitivity analysis using alternate definitions of the comparison population group to provide a more complete depiction of potential effects.

6.5.3 Spatial Identification and Aggregating Effects

The spatial distribution of health and welfare outcomes is a relevant consideration for some regulatory actions, such as those that reduce emissions from point sources that have fairly localized effects or when there is a differential distribution of associated health or environmental effects. In other cases, the regulatory action's effects may be more widespread, and spatial distribution is less relevant. For instance, the effects of a national regulatory action on a chemical product do not depend on the spatial distribution of production facilities, but on variation in the purchase, use, transport, and disposal of the product.

Text Box 6.3: Choosing a Comparison Population Group – Recent Examples

For the final Phasedown of Hydrofluorocarbons rule (U.S. EPA, 2021a), analysts examined the socioeconomic characteristics of communities living within a specific distance of a production facility subject to the rule both in aggregate and for each individual facility. The comparison population group for the facility-by-facility analysis was selected to reflect whether a facility is located in a rural or urban area (i.e., overall or rural average) and presented at both the state and national levels.

For the final Control of Air Pollution from Heavy Duty Engine and Vehicle rule (U.S. EPA, 2022g), analysts used a proximity-based approach to examine the proportion of the population living within different distances of major truck freight routes by race, ethnicity, and income. The analysis then compared the demographic composition of those living within 1,000 meters to those living beyond 1,000 meters. Results were further delineated based on USDA rural-urban continuum designations and by region.

For the final Mercury and Air Toxics Standards rule (U.S. EPA, 2011e), analysts examined mortality risk associated with fine particulate matter (PM) by race, income, and poverty level for people living in high-risk counties (i.e., in the counties identified as experiencing the top five percent of risks from exposure). The comparison population group was defined as people living in counties not facing a high mortality risk.

When exposures, risks, or human health outcomes are spatially distributed, analysts need to determine how to spatially identify and aggregate affected and unaffected populations. The nature of the stressor(s) should guide an analyst's choice of the geographic area of analysis. Some air pollutants, for example, may be emitted out of tall stacks and travel long distances, affecting individuals hundreds of miles away from the source(s) and thereby making it appropriate to choose a relatively large geographic area. In contrast, water pollutants or waste facilities may have more localized effects, making it appropriate to select relatively small areas for analysis. Likewise, an assessment of local effects from point sources - including possible traffic, odors, and noise implications from changes in production - may call for more spatially resolved air quality, demographic, and health data than those that affect regional air quality.

Complications can arise when the spatial resolution of the analysis is either too refined or too coarse. For example, small geographic areas of analysis (e.g., less than one mile from the source location) may not be sufficiently outside of an emitting source's fenceline to capture potential effects on nearby populations. A geographic unit of analysis that is too large may begin to resemble state or national averages and can be more difficult to interpret due to the influences of many, multiple sources of risk and exposure.

The quality and type of data available also affect the spatial resolution of the analysis. For instance, in rural areas Census-based geographies can be large, introducing a higher level of uncertainty regarding where specific populations groups live within that boundary. Thus, more than one geographic area of analysis to examine the robustness of results may be useful since effects are unlikely to be neatly contained within geographic boundaries and results may be sensitive to the choice of the geographic area of analysis (Mohai and Bryant, 1992; Baden et al., 2007).

Census-based geographic delineations and definitions often align with topographical or infrastructure features such as rivers, highways, and railroads. As a result, they may exclude a portion of the affected population that experiences the same adverse effects from a stressor, even if they are on the other side of the physical feature. While Census-based definitions are easily accessible and offer many options with regard to geographic scale, use of GIS techniques allows for a potentially more flexible approach. GIS-based methods enable analysts to define spatial buffers around an emissions source that are more uniform in size and easier to customize to reflect the appropriate scale and characteristics of the emissions being analyzed (e.g., fate and transport).

Buffers can be created and combined with Census data in many ways, including selecting the Census units (e.g., tracts or block groups) that intersect the buffer circle, selecting tracts with centroids within the buffer circle, spatially intersecting the buffer circle with the tract polygon, and transferring the attributes from tracts to the buffer area using area- or population-weighting (see Text Box 6.4). Mohai and Saha (2006, 2007) show that using distance from a facility instead of a buffer-based approach may provide a more complete comparison of effects (see also Mohai and Saha, 2015; Mascarenhas et al., 2021).

Analysts should be aware of the potential for the “modifiable areal unit problem” when aggregating geospatial data. The modifiable areal unit problem refers to the fact that results can be sensitive to the level of aggregation used in the analysis (see Mohai and Bryant, 1992; Baden et al., 2007; Shadbegian and Wolverton, 2015). When selecting a unit of analysis, it is also important to weigh any potential tradeoffs between completeness - fully capturing the populations at risk - and heterogeneity in risk – for instance, possibly masking information about those most at risk by including populations that are much less affected. Analysts are encouraged to discuss the approach used to create buffers and aggregate geospatial data, as what is most appropriate will vary with the stressor(s) affected and data used in the analysis, and to provide a transparent justification of their choice.

6.5.4 Facility vs Community-Based Perspectives

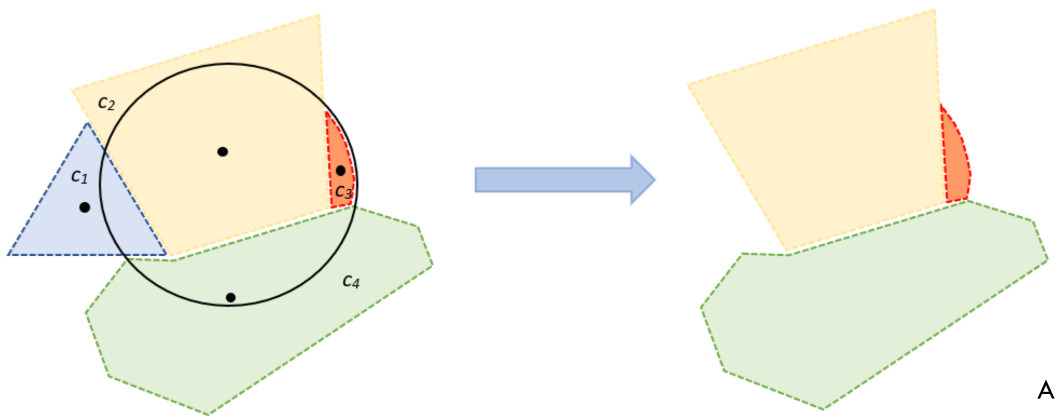
Exposure to physical, social, and other chemical stressors can increase the susceptibility of individuals or population groups to negative health effects from exposure to a specific environmental hazard. While explicit modeling of these interactions is often not feasible, analysts can shed light on this issue by evaluating and presenting results using not only a facility- but also a community-based perspective.

An analysis with a facility-based perspective primarily considers who may be exposed to sources regulated by the specific action under consideration. For example, such an analysis would examine proximity, emissions, concentrations, or risk associated with each regulated source in conjunction with the demographic characteristics of those most likely to be exposed.

Text Box 6.4: Centroid-Based vs. Areal Apportionment Methods

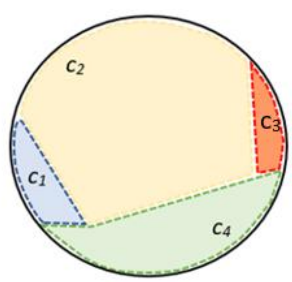
Demographic data are typically available at an aggregate level within the boundaries of a Census geographic unit (e.g., tract or block group). Analysts must then decide how to map the available data to circular buffers around an emissions source. There are two main approaches.

The centroid-based method assigns the population from a Census geographic unit to the circular buffer when the centroid of the unit lies within it. In the figure below, the centroid method excludes the population in Census unit c_1 because its centroid lies outside the circular buffer but includes the entire populations of Census units c_2, c_3, and c_4, resulting in the area depicted in A.



A

An alternative method is areal apportionment, which assigns populations to a circular buffer based on the extent to which a Census geographic unit overlaps with that buffer. In the example from above, this approach includes only the portions of $c_1 – c_4$ that overlap with the circular buffer, depicted in B. It apportions the population living within $c_1 – c_4$ to the circular buffer by assuming they are uniformly distributed within each Census geographic unit.



B

For a given spatial resolution, areal apportionment can yield more accurate estimates than the centroid-based approach. When the centroid-based approach is applied to Census geographic units with large spatial extents (e.g., rural areas), analysts may find that the centroids of some units are not located within the circular buffer. This leads to the exclusion of geographic areas from the analysis and can skew results. Note, however, that the centroid-based method is less computationally intensive and therefore may have the advantage when Census geographic units are small.

However, communities may be affected by multiple sources of pollution relevant to characterizing risk for a specific regulatory action. An analysis that takes a community-based perspective considers proximity, emissions, concentrations, or risk to a given community from multiple nearby sources of pollution to which individuals are exposed, accounting for the possibility that certain communities face increased vulnerability due to a greater number of nearby pollution sources.

Examples of analyses that take a community-based approach include:

- The total number of polluting facilities within a specific distance from the regulated source.[79]
- Measures of other sources of exposure to the same environmental stressor being regulated (e.g., age of home and proximity to a major highway are positively associated with the likelihood of homes having lead in paint, service lines, and soil).
- Measures of exposure or risk to a broader array of contaminants in communities near the regulated source (e.g., cancer risks from exposure to air toxics). [80]
- Explicitly accounting for non-regulated or other routes of exposure when modeling risk faced by the affected communities.[81]

6.5.5 Evaluating Underlying Heterogeneity and Identifying Potential Hot Spots

In addition to presenting aggregate results for population groups of concern affected by the regulatory action, it is important to understand the extent to which there are heterogeneous effects, both within specific population groups as well as across communities, given that sources often vary widely in the risks they pose. When data allow, analysts should characterize the distribution of risks, exposures, or outcomes within each population group of concern, not just average effects, with particular attention paid to the characteristics of populations at higher risk of exposure. When relying on proximity analysis, differentiating results by key facility characteristics that may be correlated with risk (e.g., plant age, capacity, production levels, accident history) can be useful.

It is also important to evaluate the potential for hot spots, with particular attention paid to the communities in the tail of the distribution. Hot spots refer to higher levels of localized concentrations of emissions from one or more sources along with exposure to other stressors. Hot spots may result from baseline conditions, such as exposure to other pre-existing stressors within the community. For example, the siting of polluting facilities near populations of concern

---

[79] For examples that use counts of TRI facilities, see EJ analyses for the Phase Down of Hydrofluorocarbons (U.S. EPA, 2022h) and TSCA Section 6 Proposed Rule for Asbestos Risk Management, Part 1 rules (U.S. EPA, 2022i).

[80] For cancer risks associated with air toxics, see the Air Toxics Screening Assessment Tool at: https://www.epa.gov/AirToxScreen

[81] See the EJ analysis in the proposed New Source Performance Standards for the Synthetic Organic Chemical Manufacturing Industry and National Emission Standards for Hazardous Air Pollutants for the Synthetic Organic Chemical Manufacturing Industry and Group I & II Polymers and Resins Industry (U.S. EPA, 2022j), in which cancer risk is modeled using hazardous air pollutant concentrations from both regulated and non-regulated sources within a specific distance of regulated sources.

may be reflective of historic discriminatory policy and practices, such as redlining (Gonzalez et al., 2023). Studies have demonstrated that population groups of concern experience higher concentrations of air toxics due to proximity to nearby industrial facilities (Pastor et al., 2003; Ash et al., 2013; Bouvier, 2014; Zwickl et al., 2014). Extractive industries are also associated with localized environmental concerns such as contamination of groundwater in rural areas and Tribal land from abandoned uranium mines, resulting in high incidences of kidney cancer and other adverse health effects (Corlin et al., 2016; Lewis et al., 2017; Ingram et al., 2020). See Text Box 6.5 for a specific example.

It is also possible that hot spots may be created, exacerbated, or mitigated following a regulatory action. Relevant issues to consider may include proximity to multiple sources of pollution, specific exposure pathways, and drivers of differential susceptibility.

A preliminary analysis early in the analytic process may help identify the potential for hot spots. In addition, information received via public comments can yield insights into the potential for a regulation to create or exacerbate hot spots.[82] More sophisticated modeling or econometric approaches may also facilitate systematic identification of potential hotspots (e.g., fate and transport modeling, hydrologic modeling, hedonic analysis). If a relatively small number of potential hot spots are identified, case studies or in-depth qualitative analysis may be useful.[83]

6.6 Characterizing Analytic Results

Once an EJ analysis has been conducted, analysts face choices about how to communicate the results. This section discusses the way in which information from the analysis can be summarized and presented, including the choice of summary metrics, ways of displaying the results in tables, maps or other visual displays, and the distinction between statistical and policy significance when interpreting results.

6.6.1 Choice of Summary Metrics

A variety of simple summary measures can be used to characterize the distribution of health and environmental effects in the baseline and for regulatory options relative to appropriate comparison population groups. Metrics commonly used to summarize information on effects across population groups of concern relative to a comparison population group include:

- Levels, stratified by demographic characteristic (e.g., average $PM_{2.5}$ concentrations for Black residents within three miles of regulated sources compared to average $PM_{2.5}$ concentrations nationally)

---

[82]For instance, the public has expressed concern that cap-and-trade policies designed to reduce carbon dioxide emissions may lead to increases in criteria air pollutants in already overburdened neighborhoods, further exacerbating existing health issues. In the context of the California trading program, research has not reached consensus on the degree to which the policy has exacerbated existing emissions in communities of color or low-income communities (e.g., Fowlie et al., 2012; Grainger and Ruangmas, 2017; Mansur and Sheriff, 2019; Hernandez-Cortez and Meng, 2020; Cushing et al., 2018).

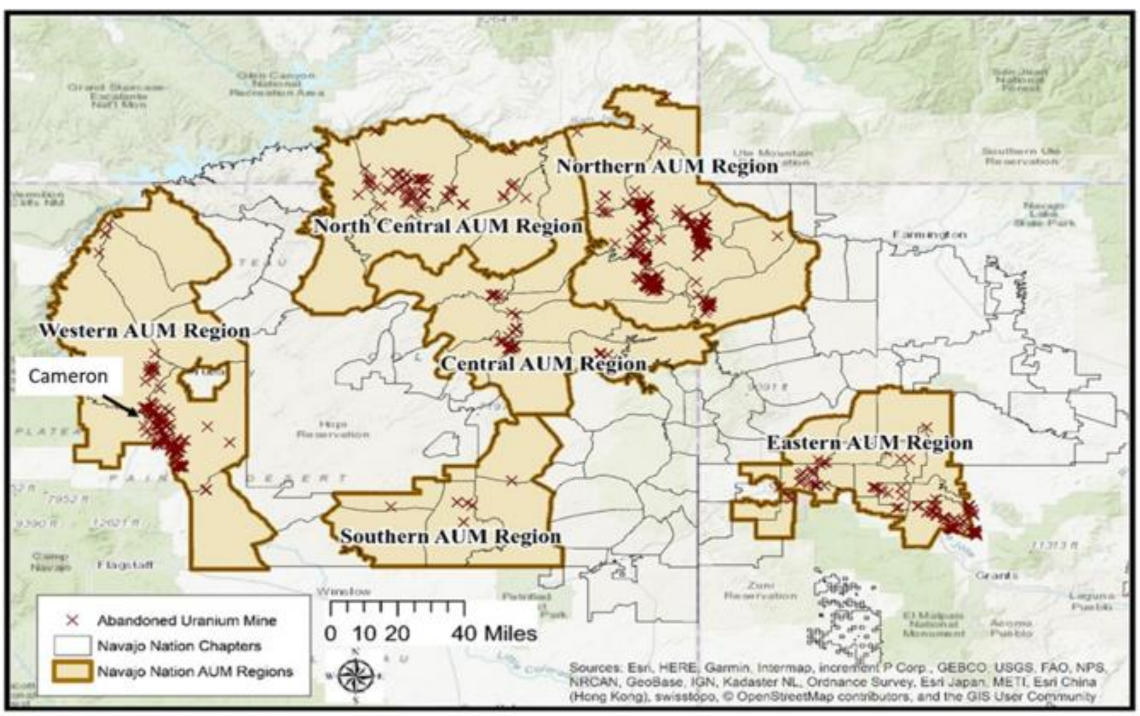
[83] See Grineski (2009), Mohai and Saha (2015), Schwartz et al. (2015), Rocha et al. (2017), and Arcury et al. (2021) for examples of qualitative discussions of hot spots.

Text Box 6.5: Hot Spots Example: Abandoned Uranium Mines on Navajo Nation Land

In the western United States, many abandoned hardrock mines are located near or on Tribal land. Over 600,000 Native Americans live within 10 kilometers of an abandoned mine (Lewis et al., 2017). Of particular concern are the over 4,000 abandoned uranium mines, 75% of which are within 80 kilometers of an Indian reservation.

A total of 520 abandoned uranium mines and over 1,100 waste sites are located near the Navajo Nation in the Four Corners region alone. These mines' legacy contamination of Tribal lands and ongoing groundwater contamination poses a drinking water concern to residents. Drinking water issues are further compounded by limited public water infrastructure in the region, with many households relying on private wells. Studies testing drinking water in the Navajo Nation have detected uranium above the national regulatory limit (Corlin et al., 2016; Ingram et al., 2020).

Documented adverse health outcomes for Navajo Nation community members exposed to uranium mine waste during the mining era (1940s-1980s) include congenital anomalies at birth and later life kidney disease. One report found that Navajo residents were more than seven times more likely to die from gallbladder cancer, more than four times more likely to die from stomach cancer, more than two times more likely to die from kidney cancer, and almost two times more likely to die from liver cancer compared to non-Hispanic White people (Navajo Cancer Workgroup, 2018).



Map of the Navajo Nation with abandoned mine sites represented by "X"s and the Navajo Agencies and Chapters outlined within the map (OpenStreetMap on Garmin May 13, 2019). Retrieved from:
https://wiki.openstreetmap.org/w/index.php?title=OSM_Map_On_Garmin&oldid=1851574

- Percents, stratified by demographic characteristic (e.g., percent low-income within three miles of regulated sources compared to percent low-income nationally).
- Differences in means (e.g., the difference in mean cancer risk for low-income vs. for non-low-income residents affected by the regulatory action).
- Percentile rankings (e.g., how affected areas rank, in percentile terms, relative to the national, regional, or state average).
- Relative ratios (e.g., the ratio of average risk or exposure for a given demographic group to the average risk or exposure for another group within the same geographic area).[84]

Analysts should consider characterizing results of the EJ analysis using more than one type of summary metric to provide a richer picture of potential effects. For instance, relative ratios can facilitate comparisons across groups or locations because all ratios are in common units. However, without presenting information on the absolute levels of risk or exposure, it is not possible to determine if either group is at risk of experiencing a potential health effect.

Counts of the number of sources or geographic areas where the percent of a specific population group living nearby exceeds a particular threshold (e.g., the state/national average or a specific percentile) are not recommended. Counts are hard to interpret because they do not account for differences in population size or density across geographic areas. It is more informative to display metrics that characterize the full population or risk distribution in order to understand the extent to which affected communities differ from the comparison group.

To the extent that the underlying data allow, analysts should disaggregate the summary information so that the public can discern how risk, exposure, and/or health effects vary for different types of individuals within a population group. For instance, exposure or health outcomes can be presented for income quantiles, in addition to presenting this information for those above or below a particular income threshold. Likewise, an analyst might characterize the average demographic characteristics of workers differentiated by the affected industry and/or geographic areas relative to a comparable but unaffected population of workers.

In many cases, the distribution of environmental exposure or risk across individuals or communities follows a non-normal distribution with a long right tail. In other words, while many individuals may be exposed to low or moderate levels of pollutants or stressors, a handful of them may face differentially high risk. In these cases, demonstrating that the average of the affected group is similar to the national average is not very informative. Rather, it would be useful to characterize the full distribution as well as the exposure or risk for individuals or communities that are in the high-end of exposure, such as those in the 95th or 99th percentile (Gochfeld and Burger, 2011). Information on risk, exposure, and/or health effects can be presented for the average-exposed individual as well as a maximally exposed individual in each

[84] A relative ratio of one means that the specific group has the same risk or exposure as the comparison group. The higher the ratio is above one, the higher the difference relative to the comparison group. If the ratio falls below one, this indicates that the specific group has a lower risk or exposure than the comparison group.

population group. If specific communities are substantially affected, an analyst can present summary statistics for those specific communities in addition to presenting aggregate summary statistics for all communities affected by the regulatory action. (Also see Section 6.5.5.)

6.6.2 Displaying Results Visually

Tables, maps, and other types of visuals help communicate a large amount of information in an organized way to facilitate comparisons and support discussion. Careful thought should go into how information is presented, particularly when there are:

- Multiple comparison groups (e.g., state, U.S., rural),
- Different types of effects (e.g., pollutants affected, health endpoints, or other environmental metrics),
- Multiple categories of regulated facilities or types of sources,
- Many individual sources,
- Clustering of sources in specific geographic areas,
- Multiple scenarios (e.g., baseline, multiple regulatory options), or
- Sensitivity analysis around key analytic assumptions (e.g., buffer distance).

Analysts should clearly explain how to interpret the information presented in tables, maps, or figures to properly contextualize the results and guard against erroneous conclusions (e.g., a large percentage change from a small baseline risk value may not represent a large change in absolute risk).

Often more than one table is needed to present results. In addition, bolding or shading specific cells can ease navigation of a dense table of results. Table 6.1 illustrates how results for multiple types of sources and several distance buffers can be presented within a single table. This example also uses shading to indicate values above the national average.

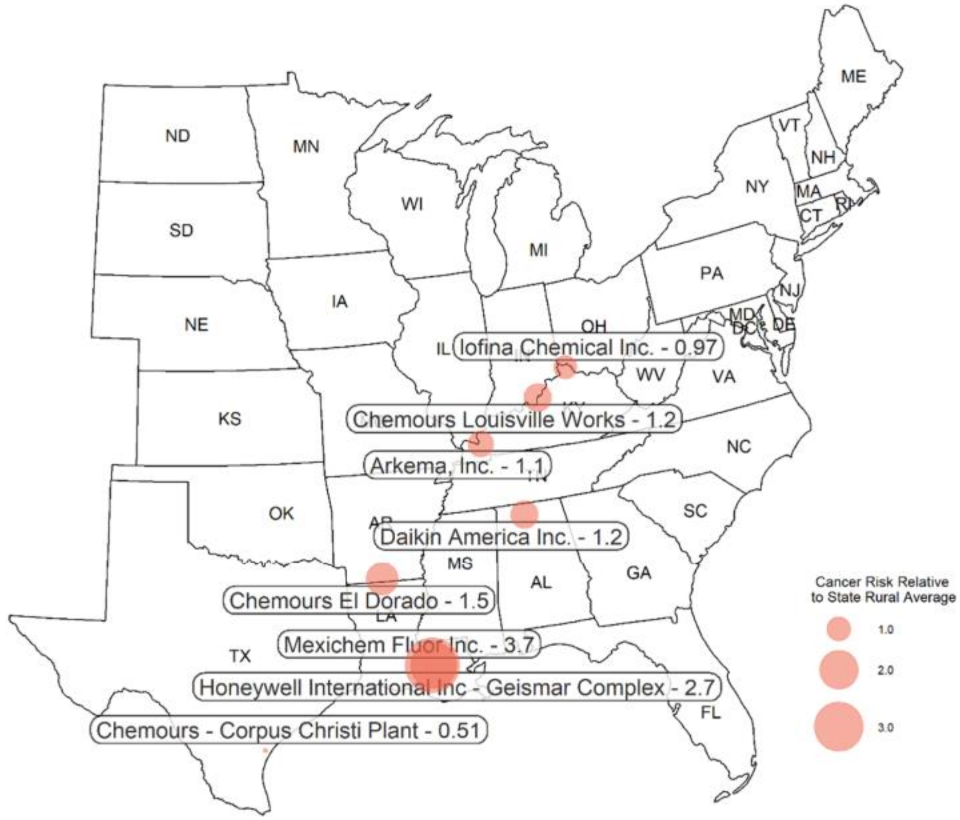
Table 6.1. Example Summary Table for Proximity Analysis Results

Estimated Proportions of Key Demographics Near Legacy and Management Unit Sites and the Total U.S. Population					
Demographic Category	**Population within 1 Mile of Sites with Legacy CCR Surface Impoundments**	**Population within 3 Miles of Sites with Legacy CCR Surface Impoundments**	**Population within 1 Mile of Sites with CCR Management Units**	**Population within 3 Miles of Sites with CCR Management Units**	**U.S. Population**
Race					
Asian	2.67%	2.95%	2.77%	2.55%	5.59%
Black or African American	15.41%	19.15%	15.83%	14.88%	12.61%
Hawaiian/Pacific Islander	0.08%	0.07%	0.01%	0.07%	0.19%
Native American	0.87%	1.29%	0.48%	0.58%	0.82%
Other	15.86%	16.77%	10.07%	9.19%	10.49%
Ethnicity					
Hispanic (any race)	31.15%	25.9%	14.87%	15.27%	18.97%
Minority					
Minority	52.42%	51.56%	37.74%	36.15%	40.49%
Poverty Level					
Households below the poverty level	17.39%	17.79%	15.21%	14.45%	12.83%
Other Demographics					
Linguistically isolated households	7.44%	6.16%	1.77%	2.86%	4.87%
Less than a High School Education	19.85%	17.01%	11.99%	12.61%	11.59%

Source: Table ES.13 of the Regulatory Impact Analysis for the CCR Legacy Proposed Rule (U.S. EPA, 2023e)

Visually displaying information in maps or figures can also help demonstrate how sources, risks, and exposures are geographically distributed in relation to population groups of concern, including baseline conditions and spatial clustering of sources (see Figure 6.1). Note that it can be difficult to visually discern differences between baseline and regulatory options in maps or figures unless differences are large. It is important to keep in mind that differences not discernible on a map may still be important. For this reason, visual displays are only suggestive of potential effects and should be accompanied by tables or other graphics that allow the reader to access the underlying statistical information.

Figure 6.1. Example Map of Relative Cancer Risks from Air Toxics within 1 Mile of Regulated Sources



Source: Regulatory Impact Analysis for Phase Down of Hydrofluorocarbons Final Rule (U.S. EPA, 2022h).

6.6.3 Statistical Significance and Other Considerations

Analysts should bear in mind that a statistical difference does not necessarily indicate that the difference is meaningful from a policy perspective. For instance, an analyst may find that low-income households are more likely to be located near a pollution source than wealthier households, and that this effect is statistically significant (i.e., the effect is statistically distinguishable from zero and not due to sampling error).[85] However, the difference in likelihood between these types of households could still be quite small. Analysts need to examine what the difference implies (e.g., how different poverty is across geographic areas), and summarize those differences in a manner appropriate for policy relevance.

When using multi-variate regression analysis, analysts should be aware that many of the demographic characteristics that are typically included are highly correlated with each other,

[85] When using U.S. Census Bureau ACS data, analysts can use the Census' Statistical Testing Tool to conduct statistical analyses. See https://www.census.gov/programs-surveys/acs/guidance/statistical-testing-tool.html for more information and to download the tool. Also see Chapter 7 in U.S. Census Bureau (2020b).

making it difficult to interpret the meaning of a coefficient on any given variable. Finally, analysts should consider other factors aside from demographic characteristics that may have influenced the location of sources (e.g., past discriminatory land use policies such as redlining).[86] Regression techniques are able to partially control for these factors; the use of statistical tests on summary data cannot. See Gilbert and Chakraborty (2011) and Kim and Chun (2018) for examples of how researchers have approached these issues.

It is also important for analysts to be aware of and discuss the biases and limitations introduced when proximity or distance is used instead of risk and exposure modeling (see Chakraborty and Maantay, 2011; Mohai and Saha, 2015). Given the analytic challenges associated with proximity-based analysis, it may only be possible to draw limited conclusions regarding differences across populations groups.

Finally, it is important to address and characterize uncertainty. When statistical analysis is used, information such as confidence intervals and variance should be presented. In cases where statistical analysis is not used, uncertainty can be discussed by highlighting limitations in the literature, caveats associated with results, or gaps in the data.

6.7 Assessing the Distribution of Costs and Other Effects

This section addresses when it may be appropriate to evaluate the distribution of costs across population groups of concern, how compliance and enforcement may vary across policy options under consideration, and the evaluation of non-health effects. We specifically refer to costs as defined in U.S. EPA (2010a).[87]

6.7.1 Distribution of Economic Costs

This *EJ Technical Guidance* mainly focuses on approaches to assess the potential for differential exposure, risk, or health effects associated with regulatory actions on population groups of concern. However, certain directives (e.g., E.O. 13175, E.O. 14008, and OMB Circular A-4) identify the distribution of economic costs or challenges as an important consideration in developing policy alternatives and for regulatory analysis. The economics literature also typically considers both costs and benefits when evaluating distributional consequences of an environmental policy to understand its net effects. Fullerton (2011) discusses six possible types of distributional effects that may result from an environmental policy: higher product prices; changes in the relative returns to capital and labor; the distribution of scarcity rents (i.e., excess benefits due to restricted nature of a good, such as pollution permits); the distribution of environmental benefits; transitional effects of the policy (e.g., changes in employment); and the capitalization of environmental improvements into asset

[86] For example, digitized maps showing Home Owners' Loan Corporation (HOLC) neighborhood quality grades for mortgage lending purposes are available for over 200 U.S. cities. Neighborhoods that received a grade of D or hazardous are commonly referred to as redlined. See https://dsl.richmond.edu/panorama/redlining/ for more information and to download these data.

[87] Private costs are the costs that the purchaser of a good or service pays the seller. Social cost represents the total burden a regulation will impose on the economy. The bearers of social costs can be either specific individuals or society at large.

prices (e.g., land or housing values). That said, the consideration of economic costs in an EJ context may be challenging, given a lack of data and methods in many instances.

In the context of EJ, the distribution of health or environment effects alone might convey an incomplete – and potentially biased – picture of the overall burden faced by population groups of concern. For instance, if costs are unevenly distributed such that low-income households bear a larger relative share, it is possible that they may experience net costs even after accounting for environmental improvements.

Whether to undertake an analysis of economic costs as it pertains to EJ is a case-by-case determination. It will depend on the relevance of the information for the regulatory decision at hand, the likelihood that economic costs of the regulatory action will be concentrated among particular types of households, and the availability of data and methods to conduct the analysis.[88] Analysts should coordinate with economists from the Office of Policy when evaluating the potential relevance of economic costs for EJ and the degree to which they can be discussed or analyzed.

In many cases, analysis of economic costs from an EJ perspective will not substantially alter the assessment of distributional effects for population groups of concern. For instance, often the costs of regulatory action are passed onto consumers as higher prices or changes in wages that are spread fairly evenly across many households. When these price increases are small, the effect on an individual household also will likely be relatively small. In this case, further analysis is unlikely to yield additional insights.

However, in some circumstances further exploration of the distribution of economic costs may offer substantial insight because costs are expected to differentially burden population groups of concern. For example, further analysis may be warranted when costs to comply with the regulatory action represent a noticeably higher proportion of income for population groups of concern; when some population groups are less able to adapt to or substitute away from goods or services with now higher prices; when costs are concentrated on some types of households (e.g., renters) more than others; when there are identifiable plant closures in or relocation of facilities away from or into neighborhoods in which population groups of concern reside and may work; or when behavioral changes in response to the costs of the regulatory action leave population groups of concern less protected than other groups.

While the Agency continues to investigate ways to improve incorporation of economic costs into an analysis of EJ concerns, it recognizes that, even in cases where the information is relevant, data or methods may not exist for full examination of the distributional implications of costs. For example, the EPA may expect pollution control costs to be passed on to electricity consumers in the form of higher prices that differentially affect budget-constrained households in particular regions more than others. To evaluate the effects of the regulatory action properly, analysts

[88] Note that there may be other effects of a regulatory action (e.g., employment effects) beyond direct compliance and (indirect) social costs but understanding how all effects vary across population groups of concern may not be feasible. For example, data on the distribution of changes in employment across low-income households may be difficult to assess.

need to understand how costs are passed through as rate increases (which differ by state); how these increases are broken down between residential and commercial customers; what assistance is available for low-income consumers; how consumption patterns differ by race, ethnicity, and income; and how these consumption patterns may change in response to electricity price changes. Likewise, if environmental improvements associated with the regulatory action are unevenly distributed, demand for housing in some neighborhoods may affect rental prices for housing. This, in turn, may result in households moving to other locations that have a different risk and exposure profile.

While a static analysis may be possible in some cases, it is challenging to anticipate and model the dynamic effects of a regulatory action on migratory patterns and other types of behavioral change. For example, the literature uses spatial sorting models to examine responses to regulation, but typically with a focus on a specific city or region (e.g., Kuminoff et al., 2015; Redding and Rossi-Hansberg, 2017).[89] In addition to methodological limitations, incomplete data may limit the ability of the analyst to fully characterize the distribution of costs across population groups of concern. Specifically, available data may only shed light on baseline distributions, without anticipating the distribution of costs in cases where the regulatory action is expected to result in indirect behavioral changes through changes in price.[90] Due to method and data limitations, it might not be possible to predict the total effect of a regulatory action on different population groups. In these instances, the issue can be qualitatively discussed and the limitations and assumptions associated with characterizing costs explained.

When analyzing the distribution of costs, other considerations include the time frame and use of partial versus general equilibrium approaches for the analysis. For instance, it is possible that most consumers face similar price changes due to a regulatory action, but in the short run budget-constrained households face more difficulties accommodating higher prices. In contrast, higher automobile prices due to a regulatory action will initially affect higher income households who purchase new cars more frequently; over a longer period of time, however, these higher prices will also affect lower-income households due to higher prices for used cars. More extensive analysis could consider the use of dynamic general equilibrium analysis to examine first and second-order costs and their implications for changes in wages and prices across households over time. However, such analyses are typically resource- and time-intensive, usually only utilized in cases where sectors are expected to experience significant effects as the result of a regulatory action, and generally focused on medium- to long-run effects (U.S. EPA, 2010a).

[89] Likewise, while hedonic price methods may be useful for demonstrating how changes in environmental quality factor into housing prices, predicting the effect of such price changes on household migration by race or income may be infeasible.

[90] Data for exploring differential consumption patterns in the baseline may be available from the Consumer Expenditure Survey, which provides information on the purchase of goods and services across households. The baseline distribution of electricity and energy prices by household type is also available from the Energy Information Administration. In addition, industry-specific data on baseline household consumption patterns may be available for specific products or services related to the policy action. When such disaggregated data are available, they are less likely to differentiate by race and ethnicity; by income class is more likely.

6.7.2 Considering Compliance and Enforcement

Evidence suggests that compliance with environmental regulations can vary widely across sources in ways that exacerbate other pre-existing disparities (e.g., Balazs et al., 2012; Allaire et al., 2018; McDonald and Jones, 2018; Fedinick et al., 2019). Analysts may want to consider whether regulated sources have a history of significant non-compliance or enforcement actions taken against them under various statutes. Past compliance issues may indicate pre-existing EJ concerns that warrant further investigation. There is also a literature that explores whether the intensity of enforcement activities (Shadbegian and Gray, 2012; Konisky et al., 2021) for environmental regulations varies with demographics such as race and income.

It is recommended that analysts consider incentives for compliance and ease of enforcement across policy options as part of the EJ analysis. When there are pre-existing disparities in risk or exposure to environmental contaminants, policy options that facilitate easier monitoring or encourage better compliance can reduce exposure in communities with EJ concerns (e.g., enhanced reporting requirements in areas near population groups of concern). Likewise, collecting, processing, and making publicly available real-time monitoring data may be effective for enhancing public awareness and participation (U.S. EPA, 2021i).[91]

6.7.3 Other Effects and Considerations

While this technical guidance mainly focuses on tools that analysts may use to evaluate differences in health effects across population groups of concern, the distribution of non-health effects associated with environmental stressors affected by the regulatory action may also be important to consider. For instance, certain population groups may place a higher value on a cultural resource (e.g., spiritual or sacred sites). If a regulatory option affects those resources, then the groups with a higher value will experience a different effect than groups that do not place a value on the cultural resource. Likewise, some regulatory options may differentially affect access to specific recreational activities for some population groups.

Quantifying changes in non-health outcomes may be challenging. Often, data on the distribution of baseline conditions for non-health endpoints are not easily available or are difficult to quantify, and/or are not suitable for analyzing the effects of a regulatory action. For instance, data on some ecosystem services (e.g., cultural uses of specific ecosystems) in the United States are quite limited in availability compared to baseline health data, such as mortality incidence. Likewise, data and models to assess how various regulatory options affect non-health endpoints may not be available.

---

[91] For example, the proposed oil and gas rule (U.S. EPA, 2021d) allows for certified third parties to report methane leaks from oil and gas sources using remote sensing technology, which the EPA will make publicly available online immediately. Likewise, the 2015 Petroleum Refinery Sector Risk and Technology Review and New Source Performance Standards created a dashboard for benzene concentrations collected from refinery fenceline monitoring. See Textbox 2.3 and: https://awsedap.epa.gov/public/extensions/Fenceline_Monitoring/Fenceline_Monitoring.html?sheet=MonitoringDashboard

When the distribution of non-health effects is difficult to quantify, a case study approach may more easily accommodates qualitative sources of information such as Indigenous Knowledge (also referred to as Traditional Ecological Knowledge), or allows for enhanced meaningful involvement to gain better understanding of how these endpoints may be affected by the regulatory action (see Section 5.3.1.2). For example, analysts may note any non-health endpoints associated with specific cultural practices for population groups of concern, discuss how they are distributed across population groups in the baseline, and describe how they may be affected by the regulatory action under consideration when feasible.

Chapter 7: Research Priorities to Fill Key Data and Methodological Gaps

High quality, scientific peer-reviewed data, methods, tools, and findings are necessary to support the conclusions drawn from prospective analyses of EJ concerns, including information about demographics, environmental exposures and contaminants, routes of exposure, health outcomes, and current and past experiences and concerns within communities. Keeping up with current data and state-of-the-art methodologies to inform analyses of EJ concerns is of critical importance to the EPA.

For the purposes of identifying research priorities related to the intersection of EJ and regulatory actions, *data gaps* include situations where data are missing all together or limited in scope (including environmental and demographic data). For example, the spatial or temporal resolution of the data may be insufficient, data may be unavailable or inaccessible due to privacy issues, or no data have been collected to date. M*ethodological gaps* are areas where the current peer-reviewed literature does not point to an established method, or existing published methods are insufficient to evaluate a specific question. EPA's program offices conducting EJ analyses have an interest in addressing data and methodological gaps to improve their analyses and advance equitable outcomes. The intensity of effort and amount of time needed to address important research gaps depend upon such factors as the complexity of the issue being studied and the extent to which conventional or new research techniques are required. Note that the specific nature of some data and method gaps will also vary across programs and regulatory contexts.

Developing research plans and strategies to address the breadth of EJ issues is an iterative process requiring multiple levels of public engagement. This section provides a summary of data and methodological gaps identified through brainstorming sessions (focus groups) with EPA program office management and staff who write or inform the development of regulatory actions (See Text Box 7.1). The EPA also intends to solicit input from the Science Advisory Board (SAB) and the public on research needs and priorities relevant to the analysis of EJ concerns for regulatory actions. This document will be updated before it is finalized to reflect that input. Together, recommendations from these groups will provide the impetus for understanding and identifying research priorities related to data, methods, tools, and information for assessing EJ concerns in regulatory analysis.

Text Box 7.1. Main Categories of Identified Data and Methodological Needs

1) Building consistency in terminology and definitions

2) Enhancing consideration of EJ in human health risk assessments

3) Cross-cutting analytic issues

4) Meaningful involvement and risk communication

5) Incorporating EJ into regulatory analysis

7.1 Building Consistency in Terminology and Definitions

While the EPA has operationalized consistent, agency-wide definitions for many key EJ-related terms, focus group participants expressed a need for guidance on how to interpret terminology when research areas or peer-reviewed studies use differing definitions, such as for cumulative impacts, people of color, communities with EJ concerns, historically marginalized, and overburdened communities.[92] Participants also identified common terminology and definitions for risk communication as an important need. Precise terminology and definitions underpin the EPA's risk analyses and provides an important basis for ensuring that clear and consistent terminology is used in incorporating EJ concerns into regulatory analysis.

7.2 Enhancing Consideration of EJ in Human Health Risk Assessment

The following sections describe the research priorities relevant to HHRA identified by EPA program offices.

7.2.1 Planning and Scoping and Problem Formulation

Problem formulation is a process for generating and evaluating preliminary hypotheses about why health effects may be associated with specific stressors. Because the planning and scoping and problem formulation stages of a risk assessment rely on defining the regulatory question, the language and terminology need to be clear and concise to lay a strong foundation for the analysis. To that end, focus group participants emphasized a need for clear definition of terms such as chemical versus non-chemical stressors in the context of cumulative or aggregate risk assessments. More specifically, analysts highlighted a need for research to evaluate the impact of adopting various assumptions and definitions for considering EJ in the risk assessment. For example, this research would inform how different income level thresholds that are used to define populations who experience low income could introduce large variability in establishing reference populations for the risk assessment.

[92] The EPA's online EJ glossary (U.S. EPA, 2020c) defines some of these terms. See https://www.epa.gov/environmentaljustice/ej-2020-glossary.

7.2.2 Effects Assessment

Effects assessment includes both hazard identification and dose-response assessment. *Hazard identification* is the process of identifying the type of hazard to human health (e.g., cancer, birth defects) posed by the exposure of interest. In an EJ context, one can ask, "What health problems may be caused by the pollutant(s) and how might populations vary in their response?" *Dose-response assessment* addresses the relationship between the exposure or dose of a contaminant and the occurrence of specific health effects or outcomes. In an EJ context, analysts can ask, "What health problems exist at different exposures, and do these health effects vary by type or incidence in populations of concern?"

Identified data and methodological needs for effects assessment focus on better understanding the links between demographic characteristics and the responses to environmental stressors that are associated with adverse health outcomes. Focus group participants also identified the need to develop tools to integrate community characteristics, social conditions, and cultural influences into risk assessments. For example, current data indicate that communities with EJ concerns may be exposed to a greater number and amount of environmental pollutant(s) based on proximity to waste sites, landfills, congested roadways, and manufacturing facilities. Such communities may experience co-exposure to multiple chemical and nonchemical agents that may contribute to variability in individual responses.

Focus group participants indicated a need to better understand the variability in human responses across different populations and of existing factors that might drive differences in population-level responses. More specifically, they identified a need to incorporate life stages and pre-existing conditions, including allostatic load (cumulative stress effects), into risk assessment.

Risk assessment uses a variety of dose-response models and tools to estimate the dose or concentration relationships for adverse health effects. Focus group participants highlighted the need to ensure that dose-response modeling accounts for differences in susceptibility associated with population groups of concern. An important first step would be to produce a comprehensive review of each relevant dose-response function that includes an analysis of baseline risk variation across different population groups. This information would enable risk analysts to consider the range of population-specific risk distributions along the dose-response curve.

7.2.3 Exposure Assessment

Focus group participants noted a need for research to better understand actual exposures rather than relying on standard models of fixed behavior. A critical area for research is the continued development of cumulative risk assessment and cumulative impact assessment methods for evaluating multiple chemicals and non-chemical stressors. Analysts also identified the need to delineate more clearly between measures of cumulative impacts, measures of exposure, and/or indicators of risk to communities experiencing multiple and layered stressors. In addition, it is important to continue to develop ways in which input by a community regarding its values and traditions can be used to inform a cumulative assessment.

7.2.4 Risk Characterization

The final step in the risk assessment paradigm is the characterization of risk. Risk characterization strives to provide a clear and integrated discussion of the overall findings, key areas of uncertainty, overall data quality, and data deficiencies that may affect methodology development and the overall conclusion. Identified data and methodological needs in this area include:

- Identifying non-residential exposures and variation in baseline risk by demographic group and life stage. Focus group participants identified as a need better understanding of the kinds of experiences and exposures people have when they are outside the home (e.g., the workplace, commuting, schools, recreational activities, or senior centers) via activity diary datasets or household surveys. How activity patterns change over time as individuals age or move was also identified as important for future-year projections for exposure and risk. Research is also needed to understand and include data on toxicokinetic and toxicodynamic differences across life stages, especially for infants and children to understand the adequacy (or not) of default assumptions to account for unique differences among different populations.

- Identifying demographics of workers and business owners. Related to non-residential exposures, focus group participants identified as a need data on the demographics of workers in specific locations, as well as for small business owners and owners of regulated facilities.

7.3 Cross-Cutting Analytical Needs

Beyond characterizing the risk paradigm, focus group participants identified several other cross-cutting analytical needs that have bearing on EJ-related analyses. They emphasized the importance of filling data gaps on topics including land use and environmental exposure data (including legacy exposure), biomonitoring data, drinking water service boundaries, private well data, and fish and game consumption data. Analysts also need more spatially resolved human health, environmental sampling (e.g., water and soil), and emissions monitoring data.

The following are cross-cutting considerations that have bearing on filling data gaps, especially for more spatially resolved data:

- While race, ethnicity, and income are often used to characterize communities of concern, analysts asked for research into ways to characterize vulnerable communities more broadly, both in the context of potential impacts from climate change and from other environmental stressors, at a spatially disaggregated scale.

- Thoughtfully standardized approaches to data collection and analytic methods for more spatially resolved data may require coordination across the EPA's program offices and with other federal agencies and external researchers and practitioners to limit duplication and ensure that the data serve the needs of as many users as possible.

- There may also be benefits to clear and consistent definitions of key spatial features and their representation in the spatial datasets used to assess EJ concerns. For example, differences arise when representing ports as points (i.e., a location on a map represented as a zero-dimensional point) vs. polygons (i.e., an area on a map represented as a two-dimensional shape, such as a site footprint).
- Another identified data need for conducting risk evaluations and EJ analyses is improved understanding of how population demographics are expected to change over time. This includes both geographical shifts of the U.S. population and population demographics and/or exposure dynamics over time due to aging and migration (i.e., predicting movement of groups over time).
- Focus group participants raised the question of how to balance the need for improved spatial resolution to adequately consider heterogeneity in exposure and health effects (e.g., biomarker data) with maintaining anonymity and protecting individuals from accidental disclosure of personally identifiable information.
- Generating more spatially resolved estimates requires running models with higher-resolution data, which can result in computational challenges (e.g., requires significant computer memory, data storage, expertise, or computation time) that are sometimes costly to address.

7.4 Meaningful Involvement and Risk Communication

As emphasized in Chapters 2 and 5, meaningful involvement and community outreach throughout the policy process are integral to the consideration of EJ concerns. Focus group participants pointed to the need for research on appropriate ways to collect and use community-generated information in the EPA's regulatory analyses, including data collected by community groups, Indigenous Knowledge, also referred to as traditional ecological knowledge, and lived experiences of communities. These data are typically community-generated and more qualitative in nature.

Focus group participants also identified a need for more detailed guidance on public engagement and communicating about EJ concerns throughout a rulemaking (e.g., how to best communicate about individual actions as part of a larger and more dynamic set of policy goals and how to measure the effectiveness of communication approaches on a continuous basis).

7.5 Incorporating EJ into Regulatory Analysis

Data and methodological needs for incorporating EJ into regulatory analysis are discussed in this section.

7.5.1 Evaluating the Feasibility of an Assessment of EJ Concerns

Often, data most relevant to EJ analysis are not sufficiently disaggregated by race, ethnicity, income, or other demographic characteristics of interest, which is necessary to better understand the distributional effects of a particular regulatory action. Focus group participants identified several specific data gaps:

- Finer resolution air quality data and alternative ways to collect them;
- Spatially granular household information on access to income-based government programs that may offset some distributional effects (e.g., Supplemental Nutrition Assistance Program assistance, utilities assistance);
- Delineation of water and other utility service areas that may affect the type or amount of assistance received (e.g., healthy homes inspections and modifications, such as radon remediation);
- How product use varies with demographic characteristics;
- Characteristics of workers affected by exposures, including access to personal protective equipment;
- Drinking water quality across communities (e.g., rural private wells are sampled inconsistently);
- Data on subsistence fishers, where they live and their fish consumption behavior; and
- Information on non- or under-monitored areas.

Collaboration with other federal agencies to facilitate the sharing and access to data sources was also identified as a need. Currently, access to data collected by other federal agencies, Tribes, states, or local governments, universities, and non-government organizations varies.

7.5.2 Evaluating Baseline and Incremental Changes

Agency analysts indicated a need to continue to improve characterization of relevant pre-existing conditions into the baseline for EJ analysis. Focus group participants also pointed to a lack of methodological tools to account for behavioral responses to proposed regulatory actions when analyzing their distributional effects. This research gap is likely broader than just analyses of EJ concerns but can be particularly important for understanding who is ultimately affected by the regulatory action. For example, focus group participants identified the need to better understand the adaptive behavior of lower-income households (e.g., purchase of air filters or bottled water), and improved approaches for evaluating affected worker and employment effects. Focus group participants also identified improved modeling of the incidence of price changes faced by households that vary with respect to key demographic characteristics as a need for evaluating the incremental changes of a regulatory action.

To better evaluate incremental changes associated with a regulatory action, EPA program offices expressed a need for dose-response curves that vary by demographic characteristics; information on how to consider exposures during critical life stages, such as childhood; and the link between genetic factors or behaviors that could give rise to greater susceptibility. Another frequently noted methodological gap was how to incorporate non-chemical stressors into the analysis and consideration of cumulative effects.

7.5.3 Methods to Assess EJ Concerns

Focus group participants noted a need for research into methods to capture EJ concerns in specific regulatory contexts. For example, it is not always clear how to analyze EJ concerns for global pollutants, mobile sources, or ubiquitous chemicals where it is difficult to characterize exposures due to the wide commercial use, persistence, and accumulation of the chemicals over time. In addition, focus group participants identified improved approaches for analyzing the EJ implications of regulations that indirectly affect health by affecting which chemicals are used in manufacturing and production or how information is provided as a research need.

Agency program offices also identified as a methodological gap how to leverage qualitative analysis in assessing environmental justice in regulatory analysis. Mixed methods approaches and qualitative case studies can be time- and resource-intensive and often focus on narrow applications in a specific setting or place. Additional research is needed to understand how these methods may be leveraged for regional and national scale applications.

7.5.4 Other Analytical Considerations

Focus group participants expressed a need for more spatially granular Census data to better align with the spatial resolution of certain environmental sampling data. Given the aggregate nature of the publicly available Census demographic data (e.g., the ACS), analyses do not report information on within-area demographic heterogeneity (e.g., within a block group).

Finally, focus group participants identified the need to investigate downstream chemical effects relevant to evaluating EJ concerns and potential risk mitigation options. Chemical environmental fate and its effects on exposure are important considerations. Participants identified the example of mapping changes in emissions from utility and transportation sectors over time to specific geographic areas with population groups of concern with higher or lower exposures. Focus group participants also noted the importance of sensitivity testing of low probability but high consequence events (e.g., accidental releases) and setting the scope or system boundary for transport modeling.

7.6 Other General Needs

Focus group participants identified the need for enhanced cross-agency coordination and information sharing. Specifically, participants expressed interest in sharing best practices across EPA offices through a methods or resource library to address common EJ analytical questions, such as:

- stratification of effects by demographics;
- best practices for proximity and other types of quantitative analysis;
- expanded use of additional surrogate or proxy variables for identifying populations of interest (e.g., health disparities, critical service gaps); and
- understanding population-level risk; and
- measuring and modeling cumulative impacts/exposure/risk to communities.

Focus group participants also expressed a need for in-house technical support and/or training for addressing specific EJ methodological gaps in their work.

7.7 Next Steps

The EPA is a science-based agency. As such, it is committed to the pursuit of research related to EJ and regulatory action to better meet the needs of Agency analysts, decision-makers, and the public in support of scientifically sound regulatory decisions that protect the health of all communities.

The EPA's Office of Environmental Justice and External Civil Rights was launched in October 2022 to:

- Support communities by providing grants and technical assistance;
- Ensure equity, EJ, and civil rights are incorporated into EPA's policies and programs;
- Ensure compliance and enforcement of federal civil rights laws; and
- Provide conflict prevention and resolution on environmental issues.

In addition, each program office engages in research to address specific needs and concerns. The EPA's Office of Research and Development (ORD) actively pursues and supports research to improve EJ consideration in the regulatory process. It developed an EJ Research Roadmap to highlight the role of ORD science in addressing EJ concerns (U.S. EPA, 2016c). It also provides an inventory and analysis of the EPA's EJ-related research activities and serves as a useful resource for EPA programs and the public.

Building on this roadmap, the ORD also developed a series of actionable recommendations for cumulative impacts research, including: establishing the decision context for cumulative impact assessment with meaningful public engagement, addressing scientific considerations for meeting community needs with holistic and fit-for-purpose approaches with the support of decision tools (e.g., EJScreen), empowering local decisions and actions through participatory science, supporting science translation and delivery to meet community needs, and providing research management and support (e.g., coordinating with other EPA offices and external partners such as decision-making authorities and non-governmental organizations) (U.S. EPA, 2022e). The document also includes definitions for cumulative impacts and cumulative impacts assessment, a summary of current research areas, and an overview of research gaps and barriers identified by ORD (many of which are consistent with the topic areas described in this chapter).

Glossary

Agency action: includes rules, policy statements, risk assessments, guidance documents, and models that may be used in future regulatory actions, and strategies that are related to assuring compliance with applicable laws and regulations.

Background exposures: potential exposures to stressors due to background levels of both naturally occurring and anthropogenic sources.

Baseline: describes an initial, status quo scenario that is used for comparison with one or more alternative scenarios. In typical regulatory analyses, the baseline is defined as the best assessment of the world absent the proposed regulatory or policy action.

Bioaccumulation: the uptake of organic compounds by biota from either water or food. Many toxic organic chemicals attain concentrations in biota several orders of magnitude greater than their aqueous concentrations, and therefore, bioaccumulation poses a serious threat to both the biota of surface waters and the humans that feed on these surface-water species. Sometimes used interchangeably with "bioconcentration."

Comparison population group: The effects of a regulatory action on population groups of concern need to be presented in relation to another group, which can be defined as individuals with similar socioeconomic characteristics in areas unaffected by the regulatory action or as individuals with different socioeconomic characteristics within the affected areas.

Contaminant: Any physical, chemical, biological, or radiological substance found in air, water, soil, or biological matter that can have a harmful effect on people, animals, or plants. Also, see "stressor."

Cumulative impact assessment: the process of accounting for cumulative impacts in the context of problem identification and decision-making.

Cumulative impacts: the totality of exposures to combinations of chemical and nonchemical stressors and their effects on health, well-being, and quality of life outcome.

Cumulative risk assessment: an analysis, characterization, and possible quantification of the combined risks to human health or the environment from multiple agents or stressors (both chemical and non-chemical).

Disproportionate and adverse effects: in this document, refers to differences in effects or risks that are extensive enough that they may merit Agency action.

Dose: the amount of a substance that enters a target in a specified period of time after crossing an exposure surface.

Dose-response assessment: a determination of the relationship between the magnitude of an administered, applied, or internal dose and a specific biological response. Response can be expressed as measured or observed incidence, percent response in groups of subjects (or populations), or as the probability of occurrence within a population.

Effects: refers to changes in actual or potential risks, exposures, and outcomes caused by a chemical, activity, or process as it comes into contact with humans or the environment and is sometimes used interchangeably with “impacts.”

Effect-modifier: factors that may alter an individual’s reaction to exposure (i.e., influence susceptibility), such as genetics, diet, nutritional status, pre-existing disease, life stage, psychological stress, co-exposure to similarly-acting toxics, and cumulative burden of disease resulting from exposure to all stressors throughout the course of life.

Environmental justice: the just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, Tribal affiliation, or disability, in agency decision-making and other Federal activities that affect human health and the environment so that people are fully protected from disproportionate and adverse human health and environmental effects (including risks) and hazards, including those related to climate change, the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic barriers; and have equitable access to a healthy, sustainable, and resilient environment in which to live, play, work, learn, grow, worship, and engage in cultural and subsistence practices.

Environmental justice concern: the actual or potential lack of just treatment or meaningful involvement of all people on the basis of income, race, color, national origin, Tribal affiliation, or disability status in the development, implementation, and enforcement of environmental laws, regulations, and policies.

Exposure: human contact with environmental contaminants in media including air, water, soil, and food through inhalation, ingestion, or direct contact with the skin or eye.

Exposure assessment: the process of estimating or measuring the magnitude, frequency and duration of exposure to an agent and the size and characteristics of the population exposed.

Exposure pathway: the course a chemical or contaminant takes from its source to the person being contacted.

Extrinsic factors: Factors or conditions acquired over a person’s lifetime (e.g., socioeconomic status, disease status, stress, nutrition, lifestyle, workplace, geography, previous or ongoing exposure to multiple chemicals) that may contribute to increased vulnerability.

Fit-for-purpose: the concept that risk assessments and associated products should be suitable and useful for their intended purpose(s), particularly for informing choices among risk management options.

Hazard: inherent property of an agent, contaminant, or situation having the potential to cause adverse effects when an organism, system, or population is exposed to that stressor.

Hazard identification: the process of determining whether a stressor has the potential to cause harm to humans and/or ecological systems, and if so, under what circumstances.

Health impact assessment: a systematic process that uses an array of data sources and analytic methods and considers input from affected individuals, communities, and other members of the public to identify the potential effects of a proposed regulatory action, policy, or project on the health of a population and the distribution of those effects within the population.

Hot spot: a geographic area where exposure to high levels of environmental stressors may result in elevated risks of adverse health effects for individuals and population groups living nearby compared to those living in other geographic areas.

Human health risk assessment (HHRA): the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals or other stressors in contaminated environmental media, now or in the future.

Indigenous Knowledge/Traditional Ecological Knowledge: a body of observations, oral and written knowledge, innovations, practices, and beliefs developed by Tribes and Indigenous Peoples through direct contact and experience with the environment.

Indigenous Peoples: includes state-recognized Tribes; Indigenous and Tribal community-based organizations; individual members of federally recognized Tribes, including those living on a different reservation or living outside Indian country; individual members of state-recognized Tribes; Native Hawaiians; Native Pacific Islanders; and individual Native Americans. A reference to populations characterized by Native American or other pre-European North American ethnicity or cultural traits.

Intrinsic factors: Biologic conditions or factors that cannot be altered (e.g., age, gender, genetic conditions) that contribute to increased vulnerability.

Life stage: a distinguishable time frame in an individual's life characterized by unique and relatively stable behavioral and/or physiological characteristics that are associated with development and growth.

Low-income: a reference to populations characterized by limited economic resources. The OMB has designated the U.S. Census Bureau's annual poverty measure as the official metric for program planning and analysis, although other definitions exist.

Meaningful involvement: indicates actions that agencies take to engage persons or communities with EJ concerns that are potentially affected by Federal activities by: providing timely opportunities for members of the public to share information and concerns and participate in decision-making processes; fully considering public input provided as part of decision-making processes; seeking out and encouraging the involvement of persons and communities affected by Federal activities; and providing technical assistance, tools, and resources to assist in facilitating meaningful and informed public participation, whenever practical and appropriate.

Non-chemical stressor: a stressor that is not based on chemical exposure. This could include biological or physical factors and activities that directly or indirectly adversely affect health or increase vulnerability to chemical stressors. The term is often used to refer to psychological or social stressors that might also act as an exposure-response modifier to other stressors.

Overburdened: a term used to describe population groups or communities that potentially experience disproportionate environmental harms and risks due to greater vulnerability to environmental hazards, lack of opportunity for public participation, or other factors.

Peer review: a documented process conducted to ensure that activities are technically supportable, competently performed, properly documented, and consistent with established quality criteria.

People of color: populations of individuals who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino. That is, all people other than non-Hispanic white-alone individuals. People of color has been used as a synonym for minority populations.

Pollutant: Any substance introduced into the environment that may adversely affect the usefulness of a resource or the health of humans, animals, or ecosystems. For most environmental media, this term is commonly understood to refer to substances introduced by human activities. Also, see "stressor."

Population groups of concern: in this document, population groups of interest for EJ analysis based on race, ethnicity, national origin, low-income, and disability status in the United States and its territories and possessions.

Proximity analysis: analytical approach using spatial data that uses proximity to or distance from the source(s) of an environmental stressor to indicate a population group's likelihood of risk or exposure when direct measurement is unavailable.

Quantitative methods: explaining phenomena by collecting numerical data that are analyzed using mathematically-based methods (in particular, statistics).

Qualitative methods: encompasses a wide range of methods, such as interviews, case studies, discourse analysis, and ethnographic research. A key distinction from quantitative methods is that qualitative methods do not necessarily collect numerical data, and therefore frequently cannot provide numerical results.

Regulatory action: a subset of Agency actions conducted in direct support of a rulemaking; means any substantive action by an agency (normally published in the Federal Register) that promulgates or is expected to lead to the promulgation of a final rule or regulation, including notices of inquiry, advance notices of proposed rulemaking, and notices of proposed rulemaking. Also, see "Agency actions."

Regulatory analysis: a tool used to anticipate and evaluate the likely consequences of regulatory actions. It compares the baseline scenario to one or more regulatory or policy scenarios. Economic and other effects of policies or regulations are then measured as the differences between these two scenarios.

Regulatory options: the expected state of the world with the proposed policy or regulation in effect.

Risk: the probability of an adverse effect in an organism, system, or population caused under specified circumstances by exposure to a contaminant or stressor.

Risk analyst/assessor: one who plans and conducts a risk assessment. In particular, the risk analyst provides a transparent description of all aspects of the risk assessment (e.g., default assumptions, data selected and policy choices) to make clear the range of plausible risk associated with each risk management option.

Risk characterization: the integration of information on hazard, exposure, and dose-response to provide an estimate of the likelihood that any identified adverse effects will occur in exposed people.

Risk management: in the context of human health, a decision-making process that accounts for political, social, economic, and engineering implications together with risk-related information in order to develop, analyze, and compare management options and select the appropriate managerial response to a potential chronic health hazard.

Social context: refers to all social and political mechanisms that generate, configure, and maintain social hierarchies. These mechanisms can include the labor market, the educational system, political institutions, and cultural and societal values.

Source: the origin of potential contaminants or environmental stressors; frequently a facility or site.

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

Subsistence populations: Populations, including people of color, low-income populations, and Indigenous Peoples, that fish, forage vegetation and/or hunt wildlife to furnish a portion of their diet.

Susceptibility: increased likelihood of an adverse effect, often discussed in terms of relationship to a factor that can be used to describe a population group (e.g., life stage, demographic feature, or genetic characteristic). In this document, the term refers to an individual's responsiveness to exposure.

Summary statistics: descriptive statistics which provide an overview of available data and may include the mean, median, mode, interquartile mean, range, and/or standard deviation, etc.

Underserved: refers to populations sharing a particular characteristic, as well as geographic communities, that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life, such as Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders, and other persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality.

Variability: refers to inherent differences in risks of engaging in the same activity among a population. For example, among a population that drinks water from the same source and with the same contaminant concentration, the risks from consuming the water may vary due to differences in exposure as well as differences in response.

Vulnerability: Differences in intrinsic and extrinsic factors over one's lifetime that increase the likelihood and/or consequences of being exposed to environmental stressor(s).

References

Arcury, T., H. Chen, T. Arnold, S. Quandt, K. Anderson, R. Scott, J. Talton, and S. Daniel. 2021. Pesticide exposure among Latinx child farmworkers in North Carolina. *Am J Ind Med*. 64: 602– 619.

Aker A., R. McConnell, R. Loch-Caruso, S. Park, B. Mukherjee, and others. 2020. Interactions between chemicals and non-chemical stressors: The modifying effect of life events on the association between triclocarban, phenols and parabens with gestational length in a Puerto Rican cohort. *Sci Total Environ* 708: 134719.

Akinbami, L., A.E. Simon, and L.M. Rossen. 2016. Changing trends in asthma prevalence among children. *Pediatrics* 137(1): 1-7.

Allaire, M., H. Wu, and U. Lall. 2018. National trends in drinking water quality violations. *Proceedings of the National Academy of Sciences* 115(9): 2078-2083.

Ash, M., Boyce, J. K., Chang, G., & Scharber, H. (2013). Is Environmental Justice Good for White Folks? Industrial Air Toxics Exposure in Urban America. Social Science Quarterly, 94(3), 616-636.

Ash, M., and J.K. Boyce. 2018. Racial disparities in pollution exposure and employment at US industrial facilities. *PNAS* 115(42): 10636-10641

Backhaus T., and M. Faust. 2012. Predictive environmental risk assessment of chemical mixtures: A conceptual framework. *Environmental Science & Technol*ogy 46: 2564-2573.

Baden, B.M., and D. Coursey. 2002. The Locality of Waste Sites within the City of Chicago: A Demographic, Social, and Economic Analysis. *Resource and Energy Economics,* 24, 53-93.

Baden, B.M., D.S. Noonan, and R.M. Turaga. 2007. Scales of justice: Is there a geographic bias in environmental equity analysis? *Journal of Environmental Planning and Management,* 50(2), 163-85.

Balazs, C. L., R. Morello-Frosch, A.E Hubbard and I. Ray. 2012. Environmental justice implications of arsenic contamination in California’s San Joaquin Valley: a cross-sectional, cluster-design examining exposure and compliance in community drinking water systems. *Environmental Health* 11(1): 1-12.

Banzhaf, S., L. Ma, and C. Timmins. 2019. Environmental justice: The economics of race, place, and pollution. *Journal of Economic Perspectives* 33(1): 185-208.

Barzyk, T., S. Wilson, and A. Wilson. 2015. Community, State, and Federal Approaches to Cumulative Risk Assessment: Challenges and Opportunities for Integration. *Int J Environ Res Public Health* 12(5): 4546–4571.

Bekkar, B., S. Pacheco, R. Basu, and N. DeNicola. 2020. Association of Air Pollution and Heat Exposure with Preterm Birth, Low Birth Weight, and Stillbirth in the US: A Systematic Review. *JAMA Network Open* 3(6): e208243.

Bouvier, R. (2014). Distribution of income and toxic emissions in Maine, United States: Inequality in two dimensions. Ecological Economics, 102, 39-47.

Bowen, W. 2001. *Environmental Justice through Research-Based Decision-Making*. New York: Garland.

Brender, J.D., J.A. Maantay, and J. Chakraborty. 2011. Residential Proximity to Environmental Hazards and Adverse Health Outcomes. *American Journal of Public Health,* 101(S1), S37–S52.

Buchanan, S., L. Targos, K. Nagy, K. Kearney, and M. Turyk. 2015. Fish Consumption and Hair Mercury Among Asians in Chicago. *Journal of Occupational and Environmental Medicine* 57(12): 1325-30.

Bullard, R.D., P. Mohai, R. Saha, and B. Wright. 2008. *Toxic Wastes and Race at Twenty: 1987-2007 Grassroots Struggles to Dismantle Environmental Racism in the United States*. Cleveland, OH: United Church of Christ Justice and Witness Ministries.

Burger, J., and M. Gochfeld. 2011. Conceptual Environmental Justice Model for Evaluating Chemical Pathways of Exposure in Low-income, Minority, Native American, and Other Unique Exposure Populations. *American Journal of Public Health,* 101(S1), S64-73.

California Environmental Protection Agency. 2015. *Air Toxics Hot Spots Program – Risk Assessment Guidelines*, Sacramento, CA: California Environmental Protection Agency, Office of Environmental Health Hazard Assessment. Retrieved from http://oehha.ca.gov/air/hot_spots/hotspots2015.html.

Cameron, T., G. Crawford, and I. McConnaha. 2012. Superfund Taint and Neighborhood Change: Ethnicity, Age Distributions, and Household Structure. In Banzhaf, S. (Ed.), *The Political Economy of Environmental Justice*. Stanford University Press, pp. 137 – 169.

Centers for Disease Control and Prevention (CDC). 2022. *National Report on Human Exposure to Environmental Chemicals*. Updated. Atlanta, GA: Centers for Disease Control and Prevention, U.S. Department of Health and Human Services. Retrieved from: https://www.cdc.gov/exposurereport/

Chakraborty, J. 2020. Unequal Proximity to Environmental Pollution: An Intersectional Analysis of People with Disabilities in Harris County, Texas. *Professional Geographer* 72(4): 521-534.

Chakraborty J., T.W. Collins, and S.E. Grineski. 2016. Environmental justice research: Contemporary issues and emerging topics. *International Journal of Environmental Res Public Health*. 13(11):1072.

Chakraborty, J., and J. Maantay. 2011. Proximity Analysis for Exposure Assessment in Environmental Health Justice Research. In J. Maantay and S. McLafferty (Eds.), *Geospatial Analysis of Environmental Health*, volume in series "Geotechnologies and the Environment" Springer-Verlag, pp. 111-138.

Chakraborty, J., J. A. Maantay, and J. Brender. 2011. Disproportionate Proximity to Environmental Health Hazards: Methods, Models, and Measurement. *American Journal of Public Health,* 101(S1), S27-36.

Cattaneo, I., A. Kalian, M. Di Nicola, B. Dujardin, S. Levorato, and others. 2023. Risk Assessment of Combined Exposure to Multiple Chemicals at the European Food Safety Authority: Principles, Guidance Documents, Applications and Future Challenges. *Toxins* 15(1): 40.

Christensen, G., Z. Li, J. Pearce, M. Marcus, J. Lah, L.. Waller, S. Ebelt, and A. Huls. 2022. The complex relationship of air pollution and neighborhood socioeconomic status and their association with cognitive decline. *Environment International* 167: 107416.

Citro, C.F., and R.T. Michael (Eds.). 1995. *Measuring Poverty: A New Approach*. Washington, DC: National Academy Press. Retrieved from http://www.nap.edu/catalog/4759/measuring-poverty-a-new-approach.

Clougherty, J., J. Shmool, and L.. Kubzansky. 2014. The Role of Non-Chemical Stressors in Mediating Socioeconomic Susceptibility to Environmental Chemicals. *Curr Envir Health Rpt* 1: 302–313.

Clougherty J. and C. Rider. 2020. Integration of psychosocial and chemical stressors in risk assessment. *Current Opinion in Toxicology* 22: 25-29.

Colmer, J, I. Hardman, J. Shimshack, J.Voorheis. 2020. Disparities in $PM_{2.5}$ air pollution in the United States. *Science* 369, 575-578.

Congressional Research Service. 2022. The Supplemental Poverty Measure: Its Core Concepts, Development, and Use. Report R45031. Retrieved from: https://crsreports.congress.gov/product/pdf/R/R45031.

Corburn, J. 2002. Environmental Justice, Local Knowledge, and Risk: The Discourse of a Community-Based Cumulative Exposure Assessment. *Environmental Management,* 29(4): 451-466.

Corlin, L., Rock, T., Cordova, J., Woodin, M., Durant, J. L., Gute, D, Ingram, J., and Brugge, D. 201). Health effects and environmental justice concerns of exposure to uranium in drinking water. *Current Environmental Health Reports* 3: 434-442.

Couch, S. R., and C.J. Coles. 2011. Community Stress, Psychosocial Hazards, and EPA Decision-Making in Communities Impacted by Chronic Technological Disasters. *American Journal of Public Health,* 101(S1), S140-S148.

Council on Environmental Quality (CEQ). 1997. *Environmental Justice: Guidance Under the National Environmental Policy Act*. Washington, D.C.: Executive Office of the President. Retrieved from https://www.epa.gov/environmentaljustice/ceq-environmental-justice-guidance-under-national-environmental-policy-act.

Deere, B.P., and K.C. Ferdinand. 2020. Hypertension and race/ethnicity. *Current Opinion in Cardiology* 35(4): 342-350.

deSouza, P. and P.L. Kinney. 2021. On the distribution of low-cost PM2.5 sensors in the US: demographic and air quality associations. *J Expo Sci Environ Epidemiol* 31: 514–524.

Di Fonzo, D., A. Fabri, and R. Pasetto. 2022. Distributive justice in environmental health hazards from industrial contamination: A systematic review of national and near-national assessments of social inequalities. *Social Science & Medicine* 297: 114834.

Ding, N., C. A. Karvonene-Gutierrez, A.R. Zota, B. Mukherjee, S.D. Harlow, and S.K. Park. 2023. The role of exposure to per- and polyfluoroalkyl substances in racial/ethnic disparities in hypertension: Results from the study of women's health across the nation. Environmental Research 227(15): 115813.

Dosemagen, S., and E. Williams. 2022. Data Usability: The Forgotten Segment of Environmental Data Workflows. *Frontiers in Climate* 4: 785269.

Executive Order 12866: Regulatory Planning and Review. *Federal Register* 58:190 (4 October 1993) p. 51735. Retrieved from http://www.archives.gov/federal-register/executive-orders/pdf/12866.pdf.

Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. *Federal Register* 59:32 (16 February 1994) p. 7629. Retrieved from http://www.archives.gov/federal-register/executive-orders/pdf/12898.pdf.

Executive Order 13175: Consultation and Coordination with Indian Tribal Governments. *Federal Register* 65:218 (9 November 2000) p. 67249. Retrieved from https://federalregister.gov/a/00-29003.

Executive Order 14094: Modernizing Regulatory Review 88:69 (6 April 2023). p. 21879. Retrieved from: https://www.govinfo.gov/content/pkg/FR-2023-04-11/pdf/2023-07760.pdf.

Executive Order 14096: Revitalizing Our Nation’s Commitment to Environmental Justice for All. Federal Register 88:80 (21 April 2023). p. 23231. Retrieved from: https://www.govinfo.gov/content/pkg/FR-2023-04-26/pdf/2023-08955.pdf.

Faber, D.R., and E.J. Krieg. 2002. Unequal Exposure to Ecological Hazards: Environmental Injustices in the Commonwealth of Massachusetts. *Environmental Health Perspectives,* 110(S2), 277-288.

Faber, D.R., and E.J. Krieg. 2005. *Unequal Exposure to Ecological Hazards 2005: Environmental Injustices in the Commonwealth of Massachusetts: A Report by the Philanthropy and Environmental Justice Research Project*. Boston, MA: Northeastern University. Retrieved from https://www.issuelab.org/resources/2980/2980.pdf.

Fann, N., H. A. Roman, C.M. Fulcher, M.A. Gentile, B.J. Hubbell, K. Wesson, J.I. Levy. 2011. Maximizing Health Benefits and Minimizing Inequality: Incorporating Local-Scale Data in the Design and Evaluation of Air Quality Policies. *Risk Analysis,* 31(6), 908-922.

Fedinick, K.P., S. Taylor, and M. Roberts. 2019. Watered Down Justice: Communities of Color And the SDWA. Natural Resources Defense Council Report R-19-09-A.

Fernández-Llamazares, Á., M. Garteizgogeascoa, N. Basu, E.S. Brondizio, M. Cabeza, J. Martínez-Alier, P. McElwee, and V. Reyes-García. 2020. A State-of-the-Art Review of Indigenous Peoples and Environmental Pollution. *Integrated Environmental Assessment and Management* 16: 324-341.

Fox, L. and K. Burns. 2021. The Supplemental Poverty Measure: 2020. *Current Population Reports*, No. P60-275. Retrieved from https://www.census.gov/content/dam/Census/library/publications/2021/demo/p60-275.pdf.

Freudenberg, N., M. Pastor, and B. Israel. 2011. Strengthening Community Capacity to Participate in Making Decisions to Reduce Disproportionate Environmental Exposures. *American Journal of Public Health,* 101(S1), S123-130.

Fullerton, D. 2011. Six Distributional Effects of Environmental Policy. *Risk Analysis,* 31(6), 923-929.

Gee, G.C., and D.C. Payne-Sturges. 2004. Environmental Health Disparities: A Framework Integrating Psychosocial and Environmental Concepts. *Environmental Health Perspectives,* 112(17), 1645-1653.

Gilbert, A., and J. Chakraborty. 2011. Using geographically weighted regression for environmental justice analysis: Cumulative cancer risks from air toxics in Florida. *Social Science Research* 40(1): 273-286.

Gochfeld, M., and J. Burger. 2011. Disproportionate Exposures in Environmental Justice and Other Populations: The Importance of Outliers. *American Journal of Public Health,* 101(S1), S53-63.

Gonzalez, D. J., Nardone, A., Nguyen, A. V., Morello-Frosch, R., & Casey, J. A. (2023). Historic redlining and the siting of oil and gas wells in the United States. Journal of exposure science & environmental epidemiology, 33(1), 76-83.

Grineski, S.E., and T.W. Collins. 2018. Geographic and social disparities in exposure to air neurotoxicants at U.S. public schools. *Environmental Research161*:580-587.

Grineski, S.E. 2009. Human-environment interactions and environmental justice: How do diverse parents of asthmatic children minimize hazards? *Society and Natural Resources,* 22(8), 727-743.

Grove, M., L. Ogden, S. Pickett, C. Boone, G. Buckley, D. Locke, C. Lord, and B. Hall. 2017. The legacy effect: Understanding how segregation and environmental injustice unfold over time in Baltimore. *Annals of the American Association of Geographers* 108(2): 524-537.

Helm J., M. Nishioka, J. Brody, R. Rudel, and R. Dodson. 2018. Measurement of endocrine disrupting and asthma-associated chemicals in hair products used by Black women. *Environmental Research* 165: 448-458.

Hoyt, D., and L. Raun. 2015. Measured and estimated benzene and volatile organic carbon (VOC) emissions at a major US refinery/chemical plant: Comparison and prioritization. *Journal of the Air & Waste Management Association* 65(8): 1020-1031.

Hyland, C., and O. Laribi. 2017. Review of take-home pesticide exposure pathway in children living in agricultural areas. Environmental Research 156: 559-570.

Iceland, J. 2003. *Dynamics of Economic Well-Being: Poverty 1996-1999*. Current Population Reports, pp. 70-91. Washington, DC: U.S. Census Bureau.

Ingram, J. C., Jones, L., Credo, J., & Rock, T. (2020). Uranium and arsenic unregulated water issues on Navajo lands. Journal of Vacuum Science & Technology A, 38(3).

Institute of Medicine 2013. Environmental Decisions in the Face of Uncertainty. National Academies Press.

Interagency Microbial Risk Assessment Guideline Workgroup. 2012. *Microbial Risk Assessment Guideline: Pathogenic Microorganisms with Focus on Food and Water* (EPA/100/J-12/001). Washington, DC: U.S. EPA and United States Department of Agriculture. Retrieved from http://www.epa.gov/sites/production/files/2013-09/documents/mra-guideline-final.pdf.

Intergovernmental Panel on Climate Change (IPCC). 2014. Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IPCC. 2018. Global Warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Cambridge University Press, Cambridge.

Jbaily, A., X. Zhou, J. Liu, T. Lee, L. Kamareddine, S. Verguet and F. Dominici. 2022. Air pollution exposure disparities across US population and income groups. *Nature* 60: 228–233.

Jimenez, M.P., N.V. DeVille, E.G. Elliott, J.E. Schiff, G.E. Wilt, J.E. Hart, and P. James. 2021. Associations between Nature Exposure and Health: A Review of the Evidence. *Int. J. Environ. Res. Public Health* 18: 4790.

Kim, Y., and Y. Chun. 2018. Revisiting environmental inequity in Southern California: Does environmental risk increase in ethnically homogeneous or mixed communities? *Urban Studies* 56(9): 1748–1767.

Knapp, E.A., A.M. Kress, C.B. Parker, G.P. Page, K. McArthur, and others. 2023. The Environmental influences on Child Health Outcomes (ECHO)-wide Cohort. *American Journal of Epidemiology*. Forthcoming.

Konisky, D. M., C. Reenock, and S. Conley. 2021. Environmental injustice in Clean Water Act enforcement: Racial and income disparities in inspection time. *Environmental Research Letters* 16(8): 084020.

Kuminoff, N. V., Schoellman, T., & Timmins, C. (2015). Environmental regulations and the welfare effects of job layoffs in the United States: A spatial approach. Review of Environmental Economics and Policy.

Lall, U., T. Johnson, P. Colohan, A. Aghakouchak, C. Brown, G. McCabe, R. Pulwarty, and A. Sankarasubramanian. 2018. Water, In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. U.S. Global Change Research Program, Washington, DC. pp. 145–173.

Landrigan, P.J., J.L. Sly, M. Ruchirawat, E. R. Silva, X. Huo, F. Diaz-Barriga, H.J. Zar, M. King, E. Ha, K.A. Asante, H. Ahanchian and P.D. Sly. 2016. Health Consequences of Environmental Exposures: Changing Global Patterns of Exposure and Disease. *Annals of Global Health* 82(1).

Lewis, J., Hoover, J., & MacKenzie, D. (2017). Mining and environmental health disparities in Native American communities. Current environmental health reports, 4, 130-141.

Liu, Y., and H. Eicher-Miller. 2021. Food insecurity and cardiovascular disease. Current Atherosclerosis Reports 23(24).

Maantay, J. 2001. Zoning, Equity, and Public Health. *American Journal of Public Health,* 91(7), 1033-1041.

Maguire, K., and G. Sheriff. 2011. Comparing Distributions of Environmental Outcomes for Regulatory Environmental Justice Analysis. *International Journal of Environmental Research and Public Health,* 8, 1707-1726.

Mani A., S. Mullainathan, E. Shafir, and J. Zhao. 2013. Poverty impedes cognitive function. *Science*. 341(6149): 976-80.

Mansur E., and G. Sheriff. 2021. On the Measurement of Environmental Inequality: Ranking Emissions Distributions Generated by Different Policy Instruments. *Journal of the Association of Environmental and Resource Economists* (8)4.

Manuck, T.A. 2017. Racial and ethnic differences in preterm birth: A complex, multifactorial problem. *Semin Perinatol* 41(8): 511–518.

Martinez-Morata, I., B.C. Bostick, O. Conroy-Ben, D.T. Duncan, M.R. Jones, M. Spaur, K.P. Patterson, S.J. Prins, A. Navas-Acien & A.E. Nigra. 2022. Nationwide geospatial analysis of county racial and ethnic composition and public drinking water arsenic and uranium. *Nature Communications* 13(1): 7461.

Mascarenhas, M., R. Grattet, and K. Mege. 2021. Toxic Waste and Race in Twenty-First Century America, *Environment and Society* 12(1): 108-126.

McDonald, Y.J., and N.E. Jones. 2018. Drinking water violations and environmental justice in the United States, 2011–2015. *American Journal of Public Health* 108(10): 1401-1407.

McEwen, B.S., and P. Tucker. 2011. Critical Biological Pathways for Chronic Psychosocial Stress and Research Opportunities to Advance the Consideration of Stress in Chemical Risk Assessment. *American Journal of Public Health,* 101(S1), S131-S139.

McHale C., G. Osborne, R. Morello-Frosch A.G. Salmon, M.S. Sandy, G. Solomon, L. Zhang, M.T. Smith, and L. Zeise. 2018. Assessing health risks from multiple environmental stressors: Moving from G × E to I × E. Mutation Research/Reviews in Mutation Research 775 (Jan.–March): 11-20.

McPartland, J., R.M. Shaffer, M.A. Fox, K.E. Nachman, T.A. Burke, and R.A. Denison. 2022. Charting a Path Forward: Assessing the Science of Chemical Risk Evaluations under the Toxic Substances Control Act in the Context of Recent National Academies Recommendations. *Environ Health Perspectives* 130(2).

Mohai, P., and B. Bryant. 1992. *Race and the Incidence of Environmental Hazards*. Boulder, CO: Westview Press.

Mohai, P., Lantz, P. M., Morenoff, J., House, J. S., Mero, R. P. 2009. Racial and Socioeconomic Disparities in Residential Proximity to Polluting Industrial Facilities: Evidence From the Americans' Changing Lives Study. American Journal of Public Health 99(3): S649-S656.

Mohai, P. and R. Saha. 2006. Reassessing Racial and Socioeconomic Disparities in Environmental Justice Research. *Demography,* 43(2): 383-399.

Mohai, P., and R. Saha. 2007. Racial Inequality in the Distribution of Hazardous Waste: A National Level Reassessment. *Social Problems,* 54(3), 343-370.

Mohai, P., and R. Saha. 2015. Which came first, people or pollution? A review of theory and evidence from longitudinal environmental justice studies. *Environmental Research Letters* 10(12): 125011.

Morello-Frosch, R., and O.K. Obasogie. 2023. The Climate Gap and the Color Line—Racial Health Inequities and Climate Change. *New England Journal of Medicine* 388(10): 943-949

Mueller, J.T., and S. Gasteyer. 2021. The widespread and unjust drinking water and clean water crisis in the United States. *Nature Communications* 12(1): 3544.

Munoz-Pizza, D.M., M. Villada-Canela, M.A. Reyna, J.L. Texcalac-Sangrador, and A.R. Osornio-Vargas. 2020. Air pollution and children's respiratory health: a scoping review of socioeconomic status as an effect modifier. *Int J Public Health* 65: 649–660.

National Academies of Sciences, Engineering, and Medicine (NASEM). 2016. *A Framework for Educating Health Professionals to Address the Social Determinants of Health*. Washington, D.C.: National Academy Press.

NASEM. 2017. *Communities in Action: Pathways to Health Equity*. Washington, DC: The National Academies Press.

NASEM. 2023. *Building Confidence in New Evidence Streams for Human Health Risk Assessment: Lessons Learned from Laboratory Mammalian Toxicity Tests*. Washington, D.C.: National Academy Press.

National Environmental Justice Advisory Council (NEJAC). 2014. Proposed Advice and Recommendations on Implementation of the EPA Policy on Environmental Justice for Tribes and Indigenous Peoples. Retrieved from https://www.epa.gov/sites/default/files/2015-12/documents/recommendations-tribal-policy-2014.pdf.

National Research Council (NRC). 1983. *Risk Assessment in the Federal Government: Managing the Process*. Washington, DC: National Academy Press.

NRC. 1991. *Environmental Epidemiology, Volume 1: Public Health and Hazardous Wastes*. Washington, DC: National Academy Press.

NRC. 2009. *Science and Decisions: Advancing Risk Assessment*. Washington, DC: National Academy Press.

NRC. 2011a. *Improving Health in the United States: The Role of Health Impact Assessment*. Washington, DC: National Academy Press.

NRC. 2011b. America's Climate Choices. Washington, DC: The National Academies Press.

Navajo Cancer Workgroup. 2018. *Cancer Among the Navajo 2005 – 2013*. Navajo Epidemiology Center, Navajo Department of Health, Navajo Nation. Retrieved from https://nec.navajo-nsn.gov/Portals/0/Reports/Cancer%20Among%20Navajo%202018%20Spread.pdf

Nolte, C.G., P. Dolwick, N. Fann, L. Horowitz, V. Naik, R. Pinder, T. Spero, D. Winner, and L. Ziska. 2018. Air quality, In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II.* U.S. Global Change Research Program, Washington, DC, pp. 513–516.

Nweke, O.C., D. Payne-Sturges, L. Garcia, C. Lee, H. Zenick, P. Grevatt, W.H. Sanders, H. Case, and I. Dankwa-Mullan. 2011. Symposium on Integrating the Science of Environmental Justice into Decision-Making at the Environmental Protection Agency: An Overview. *American Journal of Public Health,* 101(S1), S19-26.

Office of Management and Budget (OMB). 1978. Statistical Policy Directive No. 14, Definition of Poverty for Statistical Purposes. *Federal Register* 43:87 (4 May 1978) p. 19269.

OMB. 1997. Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity. *Federal Register* 62:210 (30 October 1997) p. 58782.

OMB. 2003. *Circular A-4, Regulatory Analysis*. Retrieved from https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/ .

OMB. 2019. *Improving Implementation of the Information Quality Act*. Retrieved from https://www.whitehouse.gov/wp-content/uploads/2019/04/M-19-15.pdf.

OMB. 2023. Broadening Public Participation and Community Engagement in the Regulatory Process. July 19, 2023. Memorandum. Retrieved from: https://www.whitehouse.gov/wp-content/uploads/2023/07/Broadening-Public-Participation-and-Community-Engagement-in-the-Regulatory-Process.pdf.

Pace, C., C. Balazs, K. Bangia, N. Depsky, A. Renteria, R. Morello-Frosch, L.J. Cushing. 2022. Inequities in drinking water quality among domestic well communities and community water systems, California, 2011–2019. *American Journal of Public Health* 112(1): 88-97

Padula, A.M., Z. Rivera-Núñez, and E.S. Barrett. 2020. Combined Impacts of Prenatal Environmental Exposures and Psychosocial Stress on Offspring Health: Air Pollution and Metals. *Current Environmental Health Report* 7: 89–100.

Pastor, Jr, M., Sadd, J. L., & Morello-Frosch, R. (2002). Who's minding the kids? Pollucion, public schools, and environmental justice in Los Angeles. Social science quarterly, 83(1), 263-280. Payne-Sturges, D. 2011. Humanizing Science at the US Environmental Protection Agency. *American Journal of Public Health*, Supplement 1, 101(S1), S8-S12.

Payne-Sturges D., M. Scammell, J. Levy, D. Cory-Slechta, E. Symanski, J. Carr Shmool, R. Laumbach, S. Linder, J. Clougherty. 2018. Methods for Evaluating the Combined Effects of Chemical and Nonchemical Exposures for Cumulative Environmental Health Risk Assessment. *International Journal of Environmental Research and Public Health*.15(12): 2797.

Pelacho, M., H. Rodríguez, F. Broncano, R. Kubus, F. Sanz García, B. Gavete, and A. Lafuente. 2021. Science as a Commons: Improving the Governance of Knowledge Through Citizen Science, In K. Vohland, et al. (Eds.) *The Science of Citizen Science*. Springer Press. Switzerland. pp. 57-78.

Rao, P., S.A. Quandt, A.M. Doran, B.M. Snively, and T.A. Arcury. 2007. Pesticides in the homes of farmworkers: Latino mothers' perceptions of risk to their children's health. *Health Education and Behavior,* 34(2), 335-353.

Redding, Stephen J., and Esteban Rossi-Hansberg. "Quantitative spatial economics." Annual Review of Economics 9 (2017): 21-58.

Ringquist, E. 2005. Assessing Evidence of Environmental Inequities: A Meta-Analysis. *Journal of Policy Analysis and Management,* 24(2), 223-247.

Rocha, J.I., S.E. Grineski, and T.W. Collins. 2017. A qualitative examination of factors shaping high and low exposures to hazardous air pollutants among Hispanic households in Miami. *Local Environment* 22(10): 1252-1267.

Sandman P. 1989. Hazard versus outrage in the public perception of risk. In *Effective Risk Communication: The role and responsibility of government and non-government organizations*. Pp.45-49.

Schwartz, J., D. Bellinger, and T. Glass. 2011a. Exploring Potential Sources of Differential Vulnerability and Susceptibility in Risk from Environmental Hazards to Expand the Scope of Risk Assessment. *American Journal of Public Health,* 101 Suppl 1, S94-101.

Schwartz, J., D. Bellinger, and T. Glass, 2011b. Expanding the Scope of Risk Assessment: Methods of Studying Differential Vulnerability and Susceptibility. *American Journal of Public Health,* 101, S102-S109.

Schwartz, N.A., C.A. von Glascoe, V. Torres, L. Ramos, and C. Soria-Delgado. 2015. Where They (Live, Work and) Spray: Pesticide Exposure, Childhood Asthma and Environmental Justice Among Mexican-American Farmworkers. *Health and Place,* 32, 83-92.

SAB. 2015. SAB Review of the EPA's Draft Technical Guidance for Assessing Environmental Justice in Regulatory Analysis, April 23, 2015.

Schultz A., N. Stanton, R. Pomazal, M. Lange, R. Irving, J. Meiman, B. Shelton, and K.C. Malecki. 2023. Biomonitoring of perflouroalkyl and polyflouroalkyl substances (PFAS) from the Survey of the Health of Wisconsin (SHOW) 2014-2016 and comparison with the National Health and Nutrition Examination Survey (NHANES).

Sexton, K., and S. Linder. 2010. The Role of Cumulative Risk Assessment in Decisions about Environmental Justice. *Int. J. Environ. Res. Public Health* 7(11), 4037-4049.

Sexton, K. 2013. Evolution of Public Participation in the Assessment and Management of Environmental Health Risks: A Brief History of Developments in the United States. J Public Health Res. 2(2): e18

Shadbegian, R. J., and W. B. Gray. 2012. Spatial patterns in regulatory enforcement. In Banzhaf, S. (Ed.), *The Political Economy of Environmental Justice*, pp. 225-248.

Shadbegian, R. and A. Wolverton. 2015. Evaluating Environmental Justice: Analytic Lessons from the Academic Literature and in Practice. In Konisky, D. (Ed.). *A False Promise of Justice? Evaluating the Federal Government's Response to Environmental Inequity*. MIT Press.

Shao, S., L. Liu, and Z. Tian. 2022. Does the environmental inequality matter? A literature review. *Environ Geochem Health* 44: 3133–3156.

Shkembi, A., L. Smith, and R. Neitzel. 2022; Linking environmental injustices in Detroit, MI to institutional racial segregation through historical federal redlining. *Journal of Exposure Science & Environmental Epidemiology*.

Short, K. 2012. The Research Supplemental Poverty Measure: 2011. *Current Population Reports*, pp. 60-244. Washington, DC: U.S. Census Bureau.

Solar O., and A. Irwin. 2010. *A Conceptual Framework for Action on the Social Determinants of Health: Social Determinants of Health Discussion Paper 2*. Geneva: World Health Organization. Retrieved from https://iris.who.int/bitstream/handle/10665/44489/9789241500852_eng.pdf?sequence=1.

Stephens, B. 2016. What have we learned about the microbiomes of indoor environments? *mSystems* 1(4): e00083-16.

Switzer, D. 2019. Citizen partisanship, local government, and environmental policy implementation. *Urban Affairs Review* 55(3): 675-702.

Swope, C.B., D. Hernández, and L.J. Cushing. 2022. The Relationship of Historical Redlining with Present-Day Neighborhood Environmental and Health Outcomes: A Scoping Review and Conceptual Model. *Journal of Urban Health* 99: 959–983.

Teodoro, M.P., M. Haider, and D. Switzer. 2018. US environmental policy implementation on Tribal lands: trust, neglect, and justice. *Policy Studies Journal* 46(1): 37-59.

Terry, A., K. Herrick, J. Afful, and N. Ahluwalia. 2018. Seafood Consumption in the United States, 2013–2016. NCHS Data Brief. No. 32.

Tesch, R. 2013. *Qualitative Research*. Routledge Falmer. New York, New York.

Tessum, C.W., D.A. Paolella, S.E. Chambliss, J.S. Apte, J.D. Hill, J.D. Marshall. 2021. $PM_{2.5}$ polluters disproportionately and systemically affect people of color in the United States. *Science Advances* 7(18).

Triantafyllidou, S., J. Burkhardt, J. Tully, K. Cahalan, M. DeSantis, D. Lytle, and M. Schock. 2021. Variability and sampling of lead (Pb) in drinking water: Assessing potential human exposure depends on the sampling protocol. *Environment International*146.

U.S. Census Bureau. 2020a. *Understanding and Using American Community Survey Data: What Users of Data for Rural Areas Need to Know*. Retrieved from: www.census.gov/programs-surveys/acs/library/handbooks/rural.html.

U.S. Census Bureau. 2020b. *Understanding and Using American Community Survey Data: What All Data Users Need to Know*. Retrieved from: https://www.census.gov/content/dam/Census/library/publications/2020/acs/acs_general_handbook_2020.pdf.

U.S. Census Bureau. 2022. *How the Census Bureau Measures Poverty*. Retrieved from https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html.

U.S. Environmental Protection Agency (EPA). 1980. Hazardous Waste Management System: Identification and Listing of Hazardous Waste; Final Rule. *Federal Register* 45:98 (19 May 1980) p. 33084. Retrieved from http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=10003N6F.TXT .

U.S. EPA. 1986. *Guidelines for the Health Risk Assessment of Chemical Mixtures*. Retrieved from http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=22567.

U.S. EPA 1990. *Technical Support Document on Risk Assessment of Chemical Mixtures* (EPA/600/8-90/064). Washington, DC: U.S. EPA, Office of Research and Development. Retrieved from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=35770.

U.S. EPA. 1997. Guidance on Cumulative Risk Assessment: Planning and Scoping. Retrieved from https://www.epa.gov/sites/default/files/2015-01/documents/cumrisk2_0.pdf.

U.S. EPA. 2000a. *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures.* Retrieved from https://cfpub.epa.gov/ncea/raf/chem_mix.htm.

U.S. EPA. 2000b. *Risk Characterization Handbook* (EPA 100-B-00-002). Washington, DC: U.S. EPA, Office of Research and Development. Retrieved from http://www.epa.gov/sites/production/files/2015-10/documents/osp_risk_characterization_handbook_2000.pdf.

U.S. EPA. 2001. *General Principles for Performing Aggregate Exposure and Risk Assessments*. Washington, DC: U.S. EPA, Office of Pesticide Programs. Retrieved from http://www.epa.gov/sites/production/files/2015-07/documents/aggregate.pdf.

U.S. EPA. 2002a. *Guidance on Cumulative Risk Assessment of Pesticide Chemicals that have a Common Mechanism of Toxicity*. Washington, DC: U.S. EPA, Office of Pesticide Programs. Retrieved from http://www.epa.gov/sites/production/files/2015-07/documents/guidance_on_common_mechanism.pdf.

U.S. EPA. 2002b. *Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by the Environmental Protection Agency* (EPA/260R-02-008). Washington, DC: U.S. EPA, Office of Environmental Information. Retrieved from http://www.epa.gov/sites/production/files/2015-08/documents/epa-info-quality-guidelines.pdf.

U.S. EPA. 2003a. *Framework for Implementing EPA's Public Involvement Policy* (EPA-233-F-03-001). Washington, DC: U.S. EPA, Office of Policy, Economics, and Innovation. Retrieved from http:nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=40000PHY.TXT.

U.S. EPA. 2003b. *Framework for Cumulative Risk Assessment* (EPA-630-P-02-001F). Washington, DC: U.S. EPA, Risk Assessment Forum. Retrieved from http://www.epa.gov/sites/production/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf.

U.S. EPA. 2005. *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (EPA/630/R-03/003F). Washington, DC: U.S. EPA, Risk Assessment Forum. Retrieved from https://www.epa.gov/sites/default/files/2013-09/documents/childrens_supplement_final.pdf.

U.S. EPA. 2006. *Framework for Assessing Health Risk of Environmental Exposures to Children* (EPA/600/R-05/093F). Washington, DC: U.S. EPA. Retrieved from https://assessments.epa.gov/risk/document/&deid=158363.

U.S. EPA. 2007a. *Considerations for Developing a Dosimetry-Based Cumulative Risk Assessment Approach for Mixtures of Environmental Contaminants (Final Report)*. Retrieved from http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=172725.

U.S. EPA. 2007b. *Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document (Final Report)* (EPA/600/R-06/013F). Washington, DC: U.S. EPA, Office of Research and Development. Retrieved from https://assessments.epa.gov/risk/document/&deid=190187.

U.S. EPA. 2010a. *Guidelines for Preparing Economic Analyses* (EPA-240-R-10-001). Washington, DC: U.S. EPA, National Center for Environmental Economics. Retrieved from https://www.epa.gov/sites/default/files/2017-08/documents/ee-0568-50.pdf.

U.S. EPA. 2010b. Responses to Significant Comments on the 2009 Proposed Rule on the Primary National Ambient Air Quality Standards for Nitrogen Dioxide. OAR-2006-0922. Retrieved from: http://www3.epa.gov/ttn/naaqs/standards/nox/data/20100122rtc.pdf

U.S. EPA. 2011a. *Plan EJ 2014*. Washington, DC: U.S. EPA, Office of Environmental Justice. Retrieved from https://www.epa.gov/environmentaljustice/plan-ej-2014.

U.S. EPA. 2011b. *Exposure Factors Handbook: 2011 Edition* (EPA-600-R-090-052F). Washington, DC: U.S. EPA, Office of Research and Development. Retrieved from http://www.epa.gov/expobox/exposure-factors-handbook-2011-edition.

U.S. EPA. 2011c. An Update on Ongoing and Future EPA Actions to Empower Communities and Advance the Integration of Environmental Justice in Decision-Making and Research. Accessed at https://www.epa.gov/sites/default/files/2015-02/documents/100-day-challenge-2011-10-26.pdf.

U.S. EPA. 2011d. *EPA Policy on Consultation and Coordination with Indian Tribes*, May 4, 2011. Retrieved from https://www.epa.gov/sites/default/files/2013-08/documents/cons-and-coord-with-indian-tribes-policy.pdf.

U.S. EPA. 2011e. *Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards* (EPA-452-R-11-011). Research Triangle Park: U.S. EPA, Office of Air Quality Planning and Standards. Retrieved from https://www3.epa.gov/ttnecas1/regdata/RIAs/matsriafinal.pdf.

U.S. EPA. 2012a. *Guidance for Evaluating and Documenting the Quality of Existing Scientific and Technical Information*. Washington, DC: U.S. EPA, Science and Technology Policy Council. Retrieved from http://www.epa.gov/sites/production/files/2015-05/documents/assess3.pdf.

U.S. EPA. 2012b. Microbial Risk Assessment Guideline: Pathogenic Microorganisms with Focus on Food and Water. EPA/100/J-12/001. Retrieved from: https://www.epa.gov/sites/default/files/2013-09/documents/mra-guideline-final.pdf

U.S. EPA. 2012c. *Chlorpyrifos - Evaluation of the Potential Risks from Spray Drift and the Impact of Potential Risk Reduction Measures*. Memorandum. Washington, DC: U.S. EPA, Office of Chemical Safety and Pollution Prevention. Retrieved from https://www.regulations.gov/document/EPA-HQ-OPP-2008-0850-0105

U.S. EPA. 2013a. *America's Children and the Environment, Third Edition* (EPA-240-R-13-001). Washington, DC: U.S. EPA. Retrieved from http://www.epa.gov/ace.

U.S. EPA. 2013b. Model Guidelines for Public Participation: An Update to the1996 NEJAC Model Plan for Public Participation. Retrieved from: https://www.epa.gov/environmentaljustice/model-guidelines-public-participation.

U.S. EPA. 2013c. *Residential Exposure Assessment Standard Operating Procedures. Addenda 1: Consideration of Spray Drift*. Office of Pesticide Programs. EPA-HQ-OPP-2013-0676.

U.S. EPA. 2014a. *Policy on Environmental Justice for Working with Federally Recognized Tribes and Indigenous Peoples.* Washington, DC: U.S. EPA. Retrieved from https://www.epa.gov/sites/production/files/2015-02/documents/ej-indigenous-policy.pdf.

U.S. EPA. 2014b. *Framework for Human Health Risk Assessment to Inform Decision-Making* (EPA/100/R-14/001). Washington, DC: U.S. EPA, Office of the Science Advisor, Risk Assessment Forum. Retrieved from https://www.epa.gov/sites/production/files/2014-12/documents/hhra-framework-final-2014.pdf.

U.S. EPA. 2014c. Disposal of Coal Combustion Residuals from Electric Utilities Final Rule. Washington, D.C.; U.S. EPA, Office of Resource Conservation and Recovery. Retrieved from: https://www.federalregister.gov/documents/2015/04/17/2015-00257/hazardous-and-solid-waste-management-system-disposal-of-coal-combustion-residuals-from-electric.

U.S. EPA 2015a. Guidance on Considering Environmental Justice During the Development of an Action. Retrieved from: https://www.epa.gov/environmentaljustice/guidance-considering-environmental-justice-during-development-action.

U.S. EPA. 2015b. Better Decisions Through Consultation and Collaboration. U.S. EPA: Conflict Prevention and Resolution Center. Retrieved from: https://www.epa.gov/sites/default/files/2015-09/documents/better_decisions.pdf.

U.S. EPA. 2015c. Risk and Technology Review - Petroleum Refineries Fact Sheet for Communities. Retrieved from https://www.epa.gov/sites/default/files/2016-06/documents/2010-0682_factsheet_communities_09292015.pdf.

U.S. EPA 2015d. *Peer Review Handbook*. Science and Technology Policy Council. 4th Edition. EPA/100/B-15/001. Retrieved from http://www.epa.gov/osa/peer-review-handbook-4th-edition-2015.

U.S. EPA. 2015e. *Economic Analysis of the Agricultural Worker Protection Standard Revisions.* Washington, D.C.: U.S. EPA, Office of Pesticide Programs. Retrieved from https://www.epa.gov/pesticide-worker-safety/agricultural-worker-protection-standard-wps.

U.S. EPA. 2016a. Guidance for Conducting Fish Consumption Surveys (823B16002). U.S. EPA. Office of Water. Retrieved from: https://www.epa.gov/sites/default/files/2016-12/documents/guidance-fish-consumption-surveys.pdf.

U.S. EPA. 2016b. Petroleum Refinery Fenceline Monitoring Stakeholder Engagement: Webinar for EJ Groups, Fenceline Communities and the Public. June 22. Retrieved from: https://www.epa.gov/sites/default/files/2016-06/documents/community_webinar_june_2016.pdf.

U.S. EPA. 2016c. Environmental Justice Research Road Map. EPA 601/R-16/006. December. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/researchroadmap_environmentaljustice_508_compliant.pdf.

U.S. EPA. 2019a. Guidelines for Human Exposure Assessment (EPA/100/B-19/001). Washington, D.C: U.S. EPA. Risk Assessment Forum. Retrieved from: https://www.epa.gov/sites/default/files/2020-01/documents/guidelines_for_human_exposure_assessment_final2019.pdf.

U.S. EPA. 2019b. Integrated Science Assessment (ISA) for Particulate Matter. Final Report. December. Retrieved from: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534#tab-3.

U.S. EPA. 2020a. National Emission Standards for Hazardous Air Pollutants: Iron and Steel Foundries Major Source Residual Risk and Technology Review. Final Rule. Retrieved from: https://www.epa.gov/stationary-sources-air-pollution/iron-and-steel-foundries-national-emissions-standards-hazardous.

U.S. EPA. 2020b. Steam Electric Reconsideration. Final Rule. Retrieved from: https://www.epa.gov/eg/2020-steam-electric-reconsideration-rule.

U.S. EPA. 2020c. EJ 2020 Glossary. Retrieved from: https://www.epa.gov/environmentaljustice/ej-2020-glossary#:~:text=Overburdened%20Community%20%2D%20Minority%2C%20low%2D,disproportionate%20environmental%20harms%20and%20risks.

U.S. EPA 2020d. Economic Analysis of the Final Rule to Revise the TSCA Dust-Lead Hazard Standards.

U.S. EPA. 2021a. Phase Down of Hydrofluorocarbons. Proposed Rule. Retrieved from: https://www.federalregister.gov/documents/2021/05/19/2021-09545/phasedown-of-hydrofluorocarbons-establishing-the-allowance-allocation-and-trading-program-under-the

U.S. EPA. 2021b. Phase Down of Hydrofluorocarbons. Final Rule. Retrieved from: https://www.epa.gov/climate-hfcs-reduction/final-rule-phasedown-hydrofluorocarbons-establishing-allowance-allocation

U.S. EPA. 2021c. EJScreen Technical Documentation. Washington, D.C.: U.S. EPA. Retrieved from: https://www.epa.gov/sites/default/files/2021-04/documents/ejscreen_technical_document.pdf.

U.S. EPA. 2021d. Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review. Proposed Rule. Retrieved from: https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry/epa-proposes-new-source-performance

U.S. EPA. 2021e. Revised Definition of Waters of the United States. Proposed Rule. Retrieved from: https://www.federalregister.gov/documents/2021/12/07/2021-25601/revised-definition-of-waters-of-the-united-states.

U.S. EPA. 2021f. Indoor Air Quality. Retrieved from: https://www.epa.gov/report-environment/indoor-air-quality.

U.S. EPA. 2021g. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts. Retrieved from: https://www.epa.gov/system/files/documents/2021-09/climate-vulnerability_september-2021_508.pdf

U.S. EPA. 2021h. Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards. Final Rule.

U.S. EPA. 2021i. Using All Appropriate Injunctive Relief Tools in Civil Enforcement Settlements. Memo. April 26. Retrieved from: https://www.epa.gov/sites/default/files/2021-04/documents/usingallappropriateinjunctiverelieftoolsincivilenforcementsettlement0426.pdf

U.S. EPA. 2022a. EPA Legal Tools to Advance Environmental Justice. May. Retrieved from: https://www.epa.gov/ogc/epa-legal-tools-advance-environmental-justice.

U.S. EPA. 2022b. Learn about Environmental Justice. Retrieved from: https://www.epa.gov/environmentaljustice/learn-about-environmental-justice

U.S. EPA. 2022c. Exposure Assessment Tools by Lifestages and Populations - Highly Exposed or Other Susceptible Population Groups. Retrieved from: https://www.epa.gov/expobox/exposure-assessment-tools-lifestages-and-populations-highly-exposed-or-other-susceptible.

U.S. EPA. 2022d. Supplement to 2019 Integrated Science Assessment (ISA) for Particulate Matter. Retrieved from: https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=354490#tab-3

U.S. EPA. 2022e. Cumulative Impacts Research: Recommendations for EPA's Office of Research and Development. EPA 600/R-22/014a. September. Retrieved from: https://www.epa.gov/system/files/documents/2022-09/Cumulative%20Impacts%20Research%20Final%20Report_FINAL-EPA%20600-R-22-014a.pdf

U.S. EPA. 2022f. Using Participatory Science at EPA: Vision and Principles. June. Retrieved from: https://www.epa.gov/system/files/documents/2022-06/EPA%20Vision%20for%20Participatory%20Science%206.23.22.pdf

U.S. EPA. 2022g. Regulatory Impact Analysis for Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards. Retrieved from: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1016A9N.pdf

U.S. EPA. 2022h. Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons. Retrieved from: https://www.epa.gov/system/files/documents/2022-07/RIA%20for%20Phasing%20Down%20Production%20and%20Consumption%20of%20Hydrofluorocarbons%20%28HFCs%29.pdf

U.S. EPA. 2022i. Economic Analysis of the TSCA Section 6 Proposed Rule for Asbestos Risk Management, Part 1. Retrieved from: https://www.regulations.gov/docket/EPA-HQ-OPPT-2021-0057

U.S. EPA. 2022j. Analysis of Demographic Factors for Populations Living Near Hazardous Organic NESHAP (HON) Facilities. Retrieved from: https://www.regulations.gov/document/EPA-HQ-OAR-2022-0730-0082

U.S. EPA. 2023a. EPA Legal Tools to Advance Environmental Justice: Cumulative Impacts Addendum. Retrieved from: https://www.epa.gov/ogc/epa-legal-tools-advance-environmental-justice.

U.S. EPA. 2023b.Principles and Best Practices for Oversight of State Implementation and Enforcement of Federal Environmental Laws. Memo from the Administrator. February 17. Retrieved from: https://www.epa.gov/system/files/documents/2023-03/principles-and-best-practices-oversight-federal-environmental-programs-2023.pdf.

U.S. EPA. 2023c. Exposure Assessment Tools by Media - Aquatic Biota. Retrieved from: https://www.epa.gov/expobox/exposure-assessment-tools-media-aquatic-biota.

U.S. EPA. 2023d. Economic Analysis of the Proposed Reconsideration of the Dust-Lead Hazard Standards and Post-Abatement Clearance Levels. Retrieved from: https://www.regulations.gov/docket/EPA-HQ-OPPT-2023-0231/document.

U.S. EPA. 2023e. Regulatory Impact Analysis for Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals from Electric Utilities; Legacy Surface Impoundments. Retrieved from: https://www.regulations.gov/document/EPA-HQ-OLEM-2020-0107-0163

U.S. Global Change Research Program (USGCRP). 2016. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Washington, D.C.

USGCRP. 2018. Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. Washington, DC

United Church of Christ. 1987. *Toxic Waste and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities with Hazardous Waste Sites*. United Christ Church, Commission for Racial Justice.

Varshavsky, J.R., S.D. Rayasam, J.B. Sass, D.A. Axelrad, C.F. Cranor and others. 2023. Current practice and recommendations for advancing how human variability and susceptibility are considered in chemical risk assessment. *Environ Health* 21 (Suppl 1): 133.

White, K., F. Khan, C. Peck, and M. Corbin. 2013. Guidance on Modeling Offsite Deposition of Pesticides via Spray Drift for Ecological and Drinking Water Assessments. Draft. EPA-HQ-OPP-2013-0676.

Williamson, D.H., E X. Yu, C.M. Hunter, J.A. Kaufman, K. Komro, N. Osborne Jelks, D.A. Johnson, M.O. Gribble, and M.C. Kegler. 2020. A Scoping Review of Capacity-Building Efforts to Address Environmental Justice Concerns. *International Journal of Environmental Research and Public Health* 17(11): 3765.

Wilson, S.M., F. Howell, S. Wing, and M. Sobsey. 2002. Environmental Injustice and the Mississippi Hog Industry. *Environmental Health Perspectives* 110(S2): 195-201.

Wilson, S.M., K. Burwell-Naney, C. Jiang, H. Zhang, A. Samantapudi, R. Murray, L. Dalemarre, L. Rice, Eand E. Williams 2015. Assessment of sociodemographic and geographic disparities in cancer risk from air toxics in South Carolina. *Environmental Research* 140:562-568

Wolverton, A. 2009. Effects of Socio-Economic and Input-Related Factors on Polluting Plants' Location Decisions. *Berkeley Electronic Journal of Economic Analysis and Policy Advances,* 9(1), Article 14.

World Health Organisation (WHO). 2006. Principles for Evaluating Health Risks in Children. Environmental Health Criteria 237.

WHO. 2023. Air quality and health. Accessed at https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts .

Zwickl, K., Ash, M., & Boyce, J. K. (2014). Regional variation in environmental inequality: Industrial air toxics exposure in US cities. *Ecological Economics* 107: 494-509.

Appendix A: Select EPA Guidance Documents

This appendix contains a list of EPA technical guidance documents that may be helpful to analysts when evaluating EJ concerns for regulatory actions.

TOPIC AREA	TITLE	PUBLICATION YEAR	WEB LINK
Economics	*Guidelines for Preparing Economic Analyses*	2010a	https://www.epa.gov/sites/default/files/2017-08/documents/ee-0568-50.pdf
Human Health Risk Framework	*Framework for Human Health Risk Assessment to Inform Decision-Making*	2014b	https://www.epa.gov/sites/production/files/2014-12/documents/hhra-framework-final-2014.pdf
Human Health Risk Framework	*Framework for Assessing Health Risk of Environmental Exposures to Children*	2006	https://assessments.epa.gov/risk/document/&deid=158363
Other Health Risk Guidance	*Microbial Risk Assessment Guideline: Pathogenic Microorganisms with Focus on Food and Water*	2012b	http://www.epa.gov/sites/production/files/2013-09/documents/mra-guideline-final.pdf
Other Health Risk Guidance	*Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens*	2005	https://www.epa.gov/sites/default/files/2013-09/documents/childrens_supplement_final.pdf
Other Health Risk Guidance	*Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*	2000a	http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=4486
Other Health Risk Guidance	*Technical Support Document on Risk Assessment of Chemical Mixtures*	1990	http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=35770
Other Health Risk Guidance	*Guidelines for the Health Risk Assessment of Chemical Mixtures*	1986	http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=22567
Exposure Assessment	*Guidelines for Human Exposure Assessment*	2019	https://www.epa.gov/risk/guidelines-human-exposure-assessment

TOPIC AREA	TITLE	PUBLICATION YEAR	WEB LINK
Exposure Assessment	*Exposure Factors Handbook*	2011[93]	https://www.epa.gov/expobox/about-exposure-factors-handbook
Risk Characterization	*Risk Characterization Handbook*	2000b	http://www.epa.gov/risk/risk-characterization-handbook
Cumulative Risk Assessment	*Considerations for Developing a Dosimetry-Based Cumulative Risk Assessment Approach for Mixtures of Environmental Contaminants (Final Report)*	2007a	http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=172725
Cumulative Risk Assessment	*Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures, and Effects: A Resource Document (Final Report)*	2007b	https://assessments.epa.gov/risk/document/&deid=190187
Cumulative Risk Assessment	*Framework for Cumulative Risk Assessment*	2003	http://www.epa.gov/sites/production/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf
Cumulative Risk Assessment	*Guidance on Cumulative Risk Assessment of Pesticide Chemicals that have a Common Mechanism of Toxicity*	2002a	http://www.epa.gov/sites/production/files/2015-07/documents/guidance_on_common_mechanism.pdf
Cumulative Risk Assessment	*General Principles for Performing Aggregate Exposure and Risk Assessments*	2001	http://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/general-principles-performing-aggregate-exposure-and
Cumulative Risk Assessment	*Guidance on Cumulative Risk Assessment: Planning and Scoping*	1997	https://www.epa.gov/sites/default/files/2015-01/documents/cumrisk2_0.pdf

[93] While the latest edition of the Exposure Factors Handbook was published in 2011, EPA has updated several individual chapters more recently: Soil and Dust Ingestion in 2017; Intake of Fruits and Vegetables, Intake of Meat, Dairy Products, and Fats, Intake of Grain Products, and Building Characteristics in 2018; and Ingestion of Water and Other Select Liquids was updated in 2019.

Appendix B: Incorporating EJ Concerns When Conducting Exposure and Effects Assessments

The planning, scoping, and problem formulation phases provide a key opportunity to ensure that EJ concerns are incorporated into a human health risk assessment (HHRA). This appendix provides several key EJ-specific questions to consider when planning for an exposure or dose-response assessment. It describes the implications of each question for the data gathering and analytic work that may be necessary to address them. Also included are examples of analyses from the peer-reviewed literature and/or U.S. government analyses, which may suggest approaches for an analyst to consider during planning, scoping, and problem formulation.

Planning for an Exposure Assessment

Patterns of exposure to stressors across population groups of concern may vary for several reasons. Variation may be predominantly a spatial phenomenon, if exposure is highest within close proximity to pollution sources and that is where the population group of concern is most likely to reside. Exposure differences may reflect variation in behaviors (e.g., subsistence anglers) or exposures due to specific dietary or cultural practices of a population group (e.g., exposures to pesticides in reeds used for basket weaving). Exposure may reflect unique aspects of the use or application of the chemical (e.g., exposures to pesticide applicators) or it may be affected by other factors that increase susceptibility for a specific population group (e.g., greater prevalence of a pre-existing health condition such as asthma).

Questions and Key Considerations

1. Based on the use and release patterns of the environmental stressors of concern, are there population groups that might be more highly exposed?

Environmental stressors may be used and released in a variety of circumstances. However, even when the stressor is intended for use in a particular circumstance or location, unintended releases can result. For instance, the stressor could migrate to an unintended location. One example of this is spray drift from pesticide applications that result in pesticides falling on “off-target” locations, which may then lead to increased exposure for certain populations that live in close proximity to the treated fields (e.g., farmers, migrant workers, children). Text Box B.1 discusses how the potential risk for exposure due to pesticide application and residues can be calculated using drift modeling and other methods while accounting for evaporation of aerosols (i.e., volatilization), and the potential effects to bystanders. Some factors for consideration when evaluating the use and release patterns of environmental stressors include evaluating the potential for risks due to intended use and potential migration of the stressor, prevalence of use, environmental fate, and the toxicological characteristics of the stressor.

2. Are exposure variabilities predominantly a spatial phenomenon (e.g., due to contaminant hot spots)? Is proximity to a source a reasonable proxy for estimating exposure to stressors of concern?

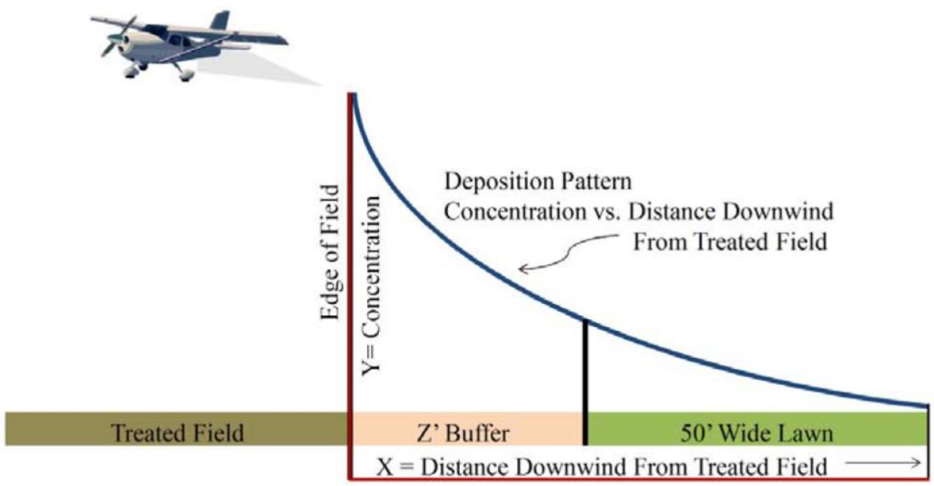
Text Box B.1: Pesticide Spray Drift Risk Assessment to Bystanders

Farm workers and their families often live near the fields where they work and can be exposed to pesticides in a manner different from other population groups because of this proximity. While direct measures of the degree of drift in the vicinity of fields may be difficult or impossible to obtain, exposure estimates from these residues may be calculated using drift modeling and methods employed for typical residential risk assessments.

Spray drift can be characterized as the movement of aerosols and volatile components away from a treated area as a result of the application process. Bystanders, defined as those who live on, work in, or frequent areas adjacent to treated fields, can be exposed to spray drift directly or by contact with resulting deposited residues (e.g., children playing on lawns next to treated fields). The degree of such effects is governed by many processes (e.g., application method, nozzles used, release height) and the conditions at the time of application (e.g., wind speed and direction).

To model potential high-end exposure to people living near treated agricultural fields (e.g., via deposition on residential turf), the EPA used AgDRIFT (V2.1.1) and AgDISP (V8.26) to provide deposition values for residential lawns, as a fraction of the application rate, at different distances downwind of a treated field. Analysis of spray drift evaluates risks from pesticides similar to how they are evaluated for use on turf because this scenario represents the highest potential for exposure associated with spray drift and considers different life stages, including children at different developmental stages. Data from pesticide studies that determined turf residue levels and dissipation rates after application are often available, and in the absence of these data, default assumptions can be used. This information is used in conjunction with the standard residential methods to estimate exposure from treated turf, including exposures from all pertinent routes for both adults and children.

Conceptual Model for Spray Drift Modeling (U.S. EPA, 2012c)



See draft EPA guidances on the consideration of spray drift in pesticide risk assessment (White et al., 2013; U.S. EPA, 2013c).

For environmental stressors that are dispersed locally in ambient media, exposure may be effectively captured using proximity to the source as a surrogate measure. Further detail about these methods can be found in Chakraborty et al. (2011) and in Chapter 6 of this technical guidance.

3. Can exposure variability be estimated using ambient contaminant concentrations, either measured or modeled? Are data available or can data be modeled at a reasonable spatial scale appropriate for available demographic data?

Ambient concentrations can be used to identify and assess spatial variability in exposure that may contribute to exposure differences between population groups. Two types of ambient concentration information exist: data from ambient air quality monitors, and modeled estimates of ambient concentrations averaged over a period of time. Monitoring data generally offer a more accurate estimate of the level of exposure to a stressor. However, obtaining monitoring data at a level of geospatial resolution that allows for the evaluation of differences may not be feasible for a number of reasons, including: (1) some environmental stressors may not be routinely monitored; and (2) coverage for routinely monitored stressors is insufficient to provide the level of geospatial resolution required to discern differences as most monitoring data are available only down to the county level. This lack of detail is problematic given that racial, ethnic, and income diversity, as well as differences in ambient concentrations, could vary widely with the level of geospatial resolution. An example of an alternative strategy for evaluating multi-pollutant settings is provided in Text Box B.2.

Modeled data can sometimes serve as a surrogate for monitoring data when high quality data inputs are used. Ambient air quality modeling methods have been developed to estimate ambient concentrations of a plume beyond its point of release, based on relevant factors such as meteorology and chemical characteristics (e.g., reactivity and solubility). However, the predictive accuracy of models is not comparable across stressors. Important considerations for using modeled data should include the predictive accuracy of the model for the stressor in question, and the ability to predict ambient concentrations for smaller geospatial units such as census tracts. Data provided at a larger geospatial scale than the census tract may not support assessment of differences in exposure. An analyst may consider the use of screening models to highlight concerns about exposure differences, which can be evaluated in greater detail with more sophisticated models at a later stage.

4. Are bio-monitoring data available for population groups of concern, including those with potentially elevated exposures?

Although analysis using bio-monitoring data can be time consuming, it may be the most accurate way to estimate exposures for population groups of concern. A literature search for previous assessments of differential exposure using survey data should be conducted prior to beginning of such an analysis. An important resource to consider is the National Report on Human Exposure to Environmental Chemicals generated by the U.S. Centers for Disease Control and Prevention (CDC, 2022). Human exposure data in this report are presented by life stage, race, ethnicity, and income to the extent that such detailed breakouts are possible.

When using exposure biomarkers to draw inferences about exposure differences for a source-specific regulatory action, an analyst should carefully consider the extent to which measured levels reflect exposure, and also whether biomarkers represent total exposure to an environmental stressor from multiple sources. Comparisons at this stage are often focused on point estimates or, at most, deterministic models rather than complex probabilistic models. An analyst may use simple, well-established comparative methods such as ratios to examine between-population group comparisons or may apply more complex approaches such as analysis of variance or regression techniques as

Text Box B.2: Understanding Environmental Inequality Using Different Policy Instruments

Using a case study approach, the EPA evaluated the viability of a multi-pollutant, risk-based pollution control strategy as an alternative to a traditional pollutant-by-pollutant approach to air quality (Fann et al., 2011). The study used spatially resolved air quality, population, and baseline health data from the Detroit metropolitan area to perform within- and across-group comparisons of exposure and risk. The objective of the study was to demonstrate how states might design air quality attainment strategies that: (1) attain tighter standards; (2) maximize human health benefits of air quality improvements; and (3) achieve a more equitable distribution of air pollution-related risk.

The assessment of EJ concerns followed four steps: (1) identify and model exposure to population groups susceptible and/or vulnerable to $PM_{2.5}$-related mortality and morbidity impacts in the baseline, based on fine scale air quality modeling and population characteristics such as education attainment, race, and poverty level; (2) design an emission control strategy that maximizes air quality improvements among these population groups, primarily by reducing emissions of directly-emitted $PM_{2.5}$; (3) compare the multi-pollutant, risk-based strategy with the traditional pollution control strategy for attainment by modeling the air quality impacts of each strategy and comparing the results with the baseline scenario; and (4) calculate the change in exposure/risk inequality from the baseline to assess whether a multi-pollutant risk-based strategy results in a more equal distribution of exposure and risk than a traditional pollution control strategy. The findings from this study revealed that the population risk reduction approach produced greater net benefits.

Risk-Based, Multi-Pollutant Modeling Framework (Fann et al., 2011)

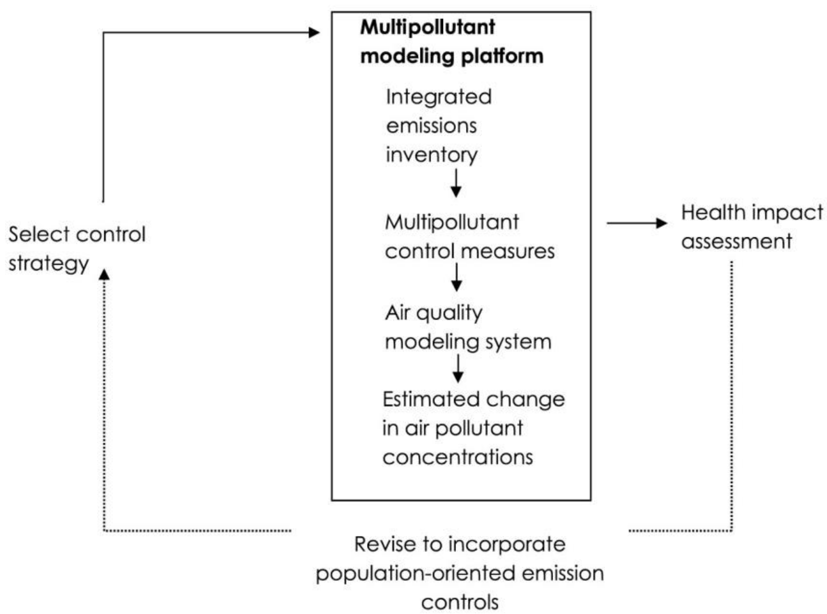


Fig. 1. Risk-based, multipollutant modeling framework.

Using similar indicators of inequality as Fann et al. (2011), Mansur and Sheriff (2021) compare the distributions of nitrogen oxide (NOx) emissions from California's Regional Clean Air Incentives Market cap-and-trade program to estimated counterfactual emissions under a prescriptive regulatory approach. Using U.S. Census data, they estimate individual exposure from facility emissions using NOx emissions as a proxy for health impacts by race, ethnicity, and poverty status. They find that trading led to a more equitable distribution of emissions reductions across all groups.

Additional information about the Detroit multi-pollutant project can also be found at https://www.epa.gov/sites/default/files/2021-01/documents/detroitpres_final09.pdf.

needed. Comparisons may focus on specific segments of the distribution or on the percent of a population group represented within a percentile group. At times, several years of data may need to be combined to obtain sufficient sample size to conduct analysis in the tail of the distribution, subject to resource, analytic, and data constraints.

As discussed in Section 5.3.3, use of biomonitoring data has both benefits and limitations. While a large population survey (e.g., 2014-2016 Survey of the Health of Wisconsin (SHOW) or the National Health and Nutrition Examination Survey (NHANES)) may suggest the existence of exposure difference, locale- or site-specific surveys (e.g., New York City Health and Nutrition Examination Survey (NYCHANES)) can yield more detailed insights into the dimensions of the differences. For example, analysis of NHANES and SHOW data demonstrate that Wisconsin residents have lower per-and polyfluoroalkyl substances (PFAS) levels in serum than the U.S. as a whole. More data are needed to evaluate the effects of PFAS on non-White or low-income populations (Schultz, 2023).

5. Are there population groups that may experience greater exposure to stressors because of their unique food consumption patterns, behaviors, or use of specific products?

An analyst can consider whether the population group of concern has higher levels of exposure to a stressor due to food consumption patterns that differ from those of the general population (e.g., unique diets or greater reliance on hunting and fishing for food), behaviors (e.g., hand-to-mouth behavior of young children), or through greater use of specific products (e.g., personal care and cleaning products). Understanding potential exposures from these types of sources will allow for more accurate estimates of exposures to the stressor(s) of concern. Differences in exposures from ingestion may be due to several factors, including regional variation in dietary habits, and cultural, ethnic, or religious practices. A population group of concern may consume certain foods at higher rates than members of other groups or consume parts of animals or plants not commonly consumed by the general population. For example, children in Tribal communities may consume as much as fifteen times more fish than children in the general population (U.S. EPA, 2011b). Additionally, some population groups may eat food predominantly from specific locations. Likewise, subsistence fishers may consume fish far more frequently and obtain it only from local waterways. If fish from these waterways have higher levels of a contaminant, they may have higher exposure levels due to increased consumption of fish and dependence on specific water sources (U.S. EPA, 2011b). Similarly, some cosmetics may contain lead. An analyst can evaluate the exposure pathway (e.g., dermal or inhalation), frequency of use, and identify the populations most likely to use these products in unique ways (Burger and Gochfield, 2011).

Text Box B.3 illustrates how the five scoping questions for integrating EJ into an exposure assessment could be posed to evaluate dietary risks from pesticide residues.

Text Box B.3: Example of Scoping Questions for Integrating EJ Considerations into Assessments of Dietary Risk from Pesticide Residues

To ensure that EJ considerations are explicitly considered in dietary risk assessments for pesticides, risk assessors could consider the following scoping questions when evaluating whether risk concerns may exist.

- Based on the pesticide use patterns, are there population groups that might be more highly exposed to pesticide residues because of their unique consumption patterns (e.g., subsistence diets or other cultural practices)?
- Is it likely that the pesticide or its metabolites/degradates will bioaccumulate such that increased exposure and risk might be expected for certain population groups (e.g., life stages; regular consumers of fish, shellfish, or game)?
- Is the pesticide used on, or likely to be found in, foods that are consumed in substantially higher amounts by certain ethnic or other population groups (e.g., lemon grass)?
- Does the pesticide have an atypical or unusual use pattern that could result in unusual exposures for certain population groups (e.g., use in non-traditional agriculture, or locally-restricted use)?
- Do the physical and/or chemical properties of the pesticide indicate a potential for long range transport (e.g., volatility, persistence), especially pesticides that may also bioaccumulate?
- Are there other groups within the population groups of concern (e.g. based on life stage) who might be more highly exposed to the pesticide through their diet?

Planning For an Effects Assessment

As noted in Chapter 7, an effects assessment includes hazard identification and dose-response assessment. Planning, scoping, and problem formulation for the effects assessment of HHRA present other opportunities to incorporate EJ concerns into a risk assessment. Planning, scoping, and problem formulation play key roles in identifying population groups of concern that may exhibit a particular sensitivity to a stressor. This is also the point at which the analyst can consider how demographic characteristics might modify effects seen in the general population. The analyst can consider whether factors particular to a population may alter dose-response relationships for the contaminants in question. For example, stress level is a recognized effect-modifier that may alter the dose-response curve for lead.

Below are a few key questions and sample responses that highlight the types and scale of analytic work that may be required to adequately integrate EJ concerns into an effects assessment.

Questions and Key Considerations

1. What population groups are most relevant from a risk perspective for the stressor(s) in question?

The purpose of asking this question is two-fold: (1) defining the susceptible and/or vulnerable population groups, and (2) considering what dose-response or concentration-response information is available for those population groups. The goal should be to achieve as close a match as possible between the information available in the literature and the characteristics of the population (i.e., care should be taken not to fit a dose-response function to a population group to which it does not apply). To answer this question, the analyst may need to consider stratification by race, ethnicity, and income, or factors such as educational level, access to health care, and baseline disease prevalence.

2. Are there population-specific effect assessments for the population groups of concern?

In answering this question, an analyst can investigate these factors: (1) Are there known or identified effect modifiers?; (2) For identified factors that modify hazards of interest, how are they distributed among population groups of concern?; and (3) Are effect modifiers distributed differently among various life stages within population groups? To answer these questions, a review of relevant literature is necessary to identify potential sources of population group-specific dose-response information or data on effect modifiers (see Text Box B.4).

3. Are the spatial and temporal scales of the studies supplying the dose-response function consistent with the spatial scale needed to incorporate EJ concerns, from both an exposure and outcome perspective?

Ideally, the dose-response functions chosen should match as closely as possible the geographic scale of the proposed analysis incorporating EJ concerns. An analyst may introduce measurement errors if dose-response functions from studies conducted over smaller geographic areas are applied at a more aggregate scale. For example, if the study assigned each subject in the cohort a county-level average, the study could underestimate the true relationship between exposure and outcome at a finer spatial scale. Likewise, if the exposure in the study is acute, it cannot be applied directly to incorporate EJ concerns where the exposure of interest is chronic; rather, the exposure duration being modeled in the regulatory analysis should be considered.

Analysts may consider adjusting the geographic scale to incorporate EJ concerns for this reason, and also may need to change the scope if detailed data on factors such as baseline health are available only at a certain scale (e.g., at the local urban level or at the acute exposure level).

Text Box B.4: Concentration-Response Functions Stratified by Demographic Factors

The literature on particulate matter (PM) provides examples of concentration-response functions stratified by demographic factors including age and race that may be indicative of socioeconomic status. Di et al. (2017) analyzed the relationship between air pollution exposure and mortality in the Medicare population, specifically working to understand concentration-response relationships by race and Medicaid eligibility. For $PM_{2.5}$, the risk of death among men, Black individuals, and people with Medicaid eligibility was notably higher than for the rest of the population.

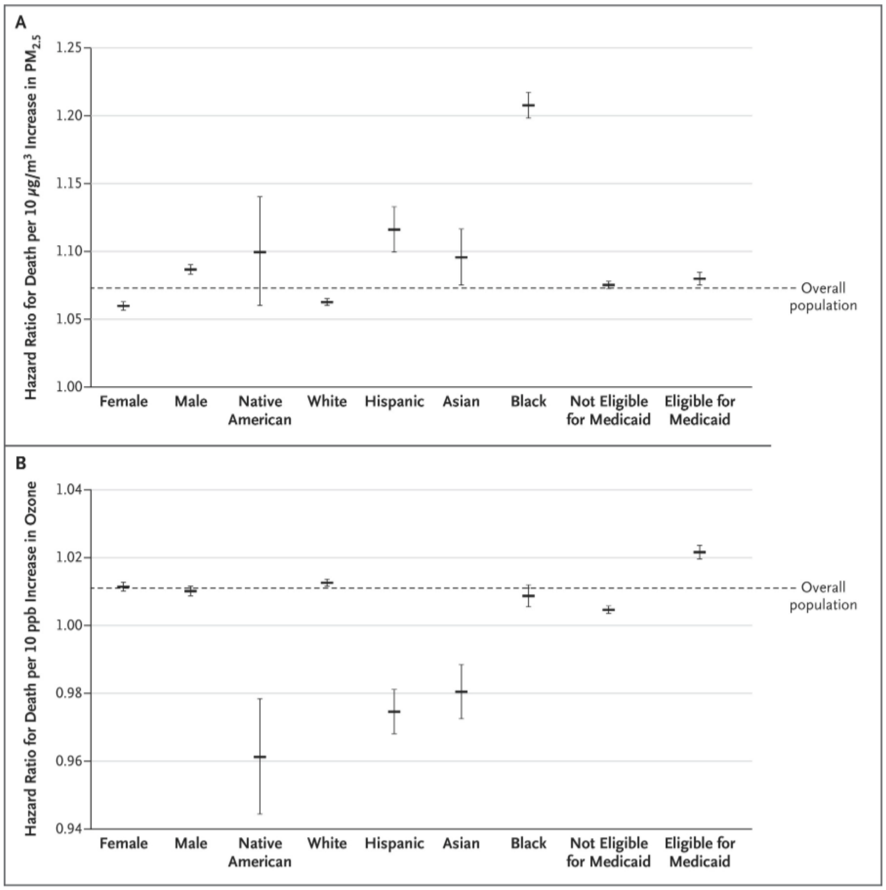


Figure. Risk of death associated with an increase of 10 µg/m3 in $PM_{2.5}$ concentrations (top) and an increase of 10 ppb in ozone exposure (bottom)

The proposed PM NAAQS (U.S. EPA, 2022) includes a distributional analysis of the estimated relative risk of $PM_{2.5}$-related mortality using the dose-response functions stratified by race and ethnicity from Di et al. (2017). This analysis improved upon assessments performed in previous NAAQS regulatory impact assessments by combining these differentiated concentration-response functions with county-level baseline mortality rates. Using this approach, the EPA found that the same $PM_{2.5}$ exposure reduction will reduce the risk of mortality approximately three times more in Black populations than in White populations.