CAPHE PHAP-RM

3. AIR QUALITY, HEALTH AND ENVIRONMENTAL JUSTICE

2016

This work is made possible by National Institute of Health and Environmental Sciences, RO1ES022616, and the Fred A. and Barbara M. Erb Family Foundation. Additional support was provided by the Michigan Center on Lifestage Environmental Exposures and Disease (M-LEEaD), #P30ES017885.

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3. AIR QUALITY, HEALTH, AND ENVIRONMENTAL JUSTICE

3.1 Environmental justice and cumulative risk

Environmental Justice (EJ) is social movement that works toward the fair or equitable distribution of environmental burdens and benefits. Advocates working toward environmental justice have long argued that environmental risk assessments that examine the health risks associated with a single environmental exposure (e.g. a single air pollutant, at a single point in time) provide only a partial assessment of risk or burden.[1] Individuals and communities are exposed to more than one air pollutant (e.g., mixtures of chemicals in air) and at more than one time (e.g., exposures occur throughout life). In addition to pollution, people and communities are also exposed to life conditions that can affect health, for example, poverty, or stressful work conditions, and there is a strong body of evidence documenting excess exposure to environmental burdens in communities that also experience other adverse conditions such as poverty and poor quality schools.[2,3,4] Furthermore, there is increasing evidence that the effects of those exposures may vary, with some individuals or communities experiencing more adverse health effects at any given level of exposure (e.g., people with asthma are more likely to have a more negative reaction to ozone exposure than those without asthma).[5,6,7,8] This is sometimes referred to as "susceptibility." Assessing the combinations of exposures to pollutants, susceptibility to their adverse effects, and their combined implications for health, is central to efforts to promote environmental justice and health equity.

Over the past decade, the Environmental Protection Agency (EPA) has worked with environmental advocates to create a framework for assessing the combined effects of multiple exposures and vulnerabilities. In 2003 the EPA created the *Framework for Cumulative Risk Assessment*[9], offering guidelines for assessing the cumulative

[1] NEJC (National Environmental Justice Council). 2004. Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts. https://www3.epa.gov/environmentaljustice/resources/publications/nejac/nejac-cum-risk-rpt-122104.pdf [accessed 23 March 2016].

[2] Morello-Frosch R, Lopez R. 2006. The riskscape and the color line: examining the role of segregation in environmental health disparities. Environ Res. 102(2):181-96.

[3] Mohai P, Lantz PM, Morenoff J, House JS, Mero RP. 2009. Racial and socioeconomic disparities in residential proximity to polluting industrial facilities: evidence from the Americans' Changing Lives Study. Am J Public Health 99(S3):S649-56.

[4] Sadd JL, Pastor M, Morello-Frosch R, Scoggins J, Jesdale B. 2011. Playing it safe: Assessing cumulative impact and social vulnerability through an environmental justice screening method in the south coast air basin, California. Int J Environ Res Public Health 8(5):1441-59.

[5] Bell ML, Zanobetti A, Dominici F. 2013. Evidence on vulnerability and susceptibility to health risks associated with short-term exposure to particulate matter: a systematic review and meta-analysis. Am J Epidemiol 178(6):865-876.

[6] Kelishadi R, Poursafa P. 2010. Air pollution and non-respiratory health hazards for children. Arch Med Sci. 6(4):483-95.

[7] Sacks JD, Stanek LW, Luben TJ, Johns DO, Buckley BJ, Brown JS, Ross M. 2011. Particulate matter-induced health effects: who is susceptible? Environ Health Perspect 119(4):446.

[8] Solomon GM, Morello-Frosch R, Zeise L, Faust J. 2016. Cumulative Environmental Impacts: Science and Policy to Protect Communities. Annual Review of Public Health 37:83-96. Available: http://www.annualreviews.org.proxy.lib.umich.edu/doi/full/10.1146/annurev-publhealth-032315-021807. Published [6 Jan 2016].

[9] EPA (Environmental Protection Agency). 2003. Framework for Cumulative Risk Assessment. Available: https://www.epa.gov/sites/production/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf [accessed 23 March 2016].

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(or combined) risks associated with multiple exposures and vulnerabilities.[10] The National Environmental Justice Action Council (NEJAC)[11] reviewed EPA's *Framework* and recommended including social and cultural as well as economic indicators into the assessment process. Building on this work, in 2007 the EPA released *Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document*[12]. Since that time, the EPA has developed specific plans for deepening the commitment of the Agency to environmental justice issues, and for assessment of progress in this regarding, most recently articulated in the EPA's EJ 2020 Action Agenda.[13]

Below, we summarize and define several key concepts that have emerged from the Environmental Justice Movement and the efforts of members of the scientific community to develop metrics that capture the combined risks or impacts experienced by communities.

Cumulative Risk: Cumulative risk refers to the combined risks from multiple exposures to multiple agents or stressors.[14] [15] Agents or stressors are variously defined, and can include physical stressors (e.g., malnutrition, noise), chemical (e.g., exposure to nitrous oxides), biological (e.g., illness, injury), economic (e.g. poverty) or psychosocial stressors (e.g., chronic concerns about safety). Chemical exposures can occur via multiple pathways, e.g., you may be exposed to lead in air, water, food and dust.

For example, an elderly person with a limited income who lives near a freeway and does not have access to health care may be exposed to multiple agents or stressors that contribute to health risks. These include exposure to near-road air pollutants, road or traffic noise, psychosocial stress due to financial concerns, and unmet medical needs due to limited access to health care.

Cumulative risk assessment attempts to predict how these multiple stressors combine to affect health, by attempting to quantify the combined risks to health that would occur as a result of exposure to these multiple agents or stressors. Cumulative risk assessments generally focus on these combined risks in a *population*, rather than in a particular individual. Thus, they might estimate the cumulative risks in a community with a greater

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[10] Sexton, Ken. 2012. Cumulative Risk Assessment: An overview of methodological approaches for evaluating combined health effects from exposure to multiple environmental stressors. International Journal of Environmental Research and Public Health. 9, pp. 370-390.

[11] NEJC (National Environmental Justice Council). 2004. Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts. https://www3.epa.gov/environmentaljustice/resources/publications/nejac/nejac-cum-risk-rpt-122104.pdf [accessed 23 March 2016].

[12] EPA (Environmental Protection Agency). 2007. Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document.

https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=190187 [accessed 23 March 2016].

[13] Draft EJ 2020 Action Agenda: Environmental Justice Strategic Plan 2016-2020. https://www.epa.gov/sites/production/files/2016-05/documents/052216_ej_2020_strategic_plan_final_0.pdf. Accessed August 7, 2016.

[14] Another relevant term is **Cumulative Exposure.** The EPA defines cumulative exposure as the combined exposure to a substance over a period of time, for example, over a lifetime. For example, the total amount of radiation that a person is exposed to over a lifetime from multiple sources (e.g. airport x-ray machines, dental x-rays) (EPA 2003). Generally, this definition of cumulative exposure addresses exposure to chemical stressors and only one specific type of vulnerability, that of differential exposure. Specifically, differential exposure to both point and mobile sources throughout an individual's lifetime.

[15] **Cumulative Impact** - This term refers to the combined public health or environmental effects from the combined emissions or discharges in a geographic area. This would include pollution from all sources, whether routinely or accidentally released. An assessment of impacts takes into account population vulnerability (e.g., existing health conditions, poverty) which may increase the adverse effects of exposures on health (California EPA, p. v). Cumulative impacts can result from emissions that are individually small, but which when combined with other emissions or combined over a period of time, can be significant collectively.

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proportion of people above the age of 65, with multiple freeways located in or near the community, and with high rate of poverty.

Assessing these combined risks and comparing them to, for example, population risks in a community with fewer residents who live near to roadways with heavy traffic, and with greater economic resources, allows comparison of the differences in the level of combined risk in the two communities. Such comparisons offer an opportunity to assess the extent to which there may be environmental inequalities or injustices.

The EPA's 2007 *Cumulative Health Risk Assessment*[16] identifies three key 'initiating factors' that would indicate that a cumulative risk assessment is necessary. These include:

- Multiple pollutant sources or releases;
- Elevated concentrations that are apparent from environmental monitoring or biomonitoring of chemicals;
- Increased population illness in a community.

Note that the EPA definition above uses more traditional risk assessment language, which tends to focus on population exposures to chemical, physical and biological (illness) stressors. Recommendations from NEJAC (2004) suggested that cumulative risk assessment should explicitly recognize both population **exposures (stressors)** and **vulnerability** factors. These terms are defined below.

Stressors*:* Stressors are exposures that can cause adverse effects for people or the environment. Since our emphasis is on health, we focus on adverse health effects in human populations. As noted above, stressors can include physical (e.g., malnutrition, noise), chemical (e.g., exposure to nitrogen oxides), biological (e.g., illness, injury), economic (e.g. poverty) or psychosocial (e.g., chronic concerns about safety) exposures). They can also involve the absence of a necessity, such as lack of access to health care, nutritious foods, clear air or water.

Many risk assessments only examine a single stressor. The United States Environmental Protection Agency (EPA) attempts to understand the combined effects of multiple exposures, and has expanded efforts to include multiple factors. They sometimes refer to these as chemical (e.g., nitrous oxides) and non-chemical (e.g., poverty) exposures. This has expanded the range of factors (stressors) that can be included in assessing community risk and community health.[17]

Community risk can be heightened due to higher levels of ***exposure*** to a single chemical, to multiple chemicals, and to non-chemical exposures. Some of these factors can also increase ***vulnerability*** to the adverse effects of those exposures (see below).

Vulnerability: Vulnerability recognizes that some communities (or individuals) experience more adverse effects from environmental exposures than others. These may result from: 1) higher levels of exposure; 2) increased susceptibility or sensitivity (that is, a stronger adverse effect at any given level of exposures); 3) fewer resources

[16] EPA (Environmental Protection Agency). 2007. Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document.

https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=190187 [accessed 23 March 2016], p. xxv.

[17] NEJC (National Environmental Justice Council). 2004. Ensuring Risk Reduction in Communities with Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts. https://www3.epa.gov/environmentaljustice/resources/publications/nejac/nejac-cum-risk-rpt-122104.pdf [accessed 23 March 2016], p. 22.

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with which to respond to the exposures; and 4) reduced ability to recover from the exposure.[18] These four categories of vulnerability recognize both chemical and non-chemical stressors.

In subsequent years, the National Environmental Justice Action Council (NEJAC) has continued to provide substantive input into EPA's plans for addressing environmental justice, including recommendations on the EPA's EJ 2014 Action Agenda[19] that were subsequently incorporated and reflected in the 2020 Action Agenda.[20] These recommendations recognize that environmental burdens and benefits are inequitably distributed across geographic communities, reflecting process of race-based residential segregation and their implications for socioeconomic opportunity. These variations ultimately contribute to racial, ethnic, and socioeconomic inequities in health outcomes.

3.2 Health effects of air pollutants

There is substantial evidence for adverse health effects of exposure to multiple air pollutants. Health effects associated with seven common air pollutants are briefly summarized in Table 3-1, and discussed in greater detail in Section 5.5 of this manual.

[18] EPA (Environmental Protection Agency). 2003. Framework for Cumulative Risk Assessment. Available: https://www.epa.gov/sites/production/files/2014-11/documents/frmwrk_cum_risk_assmnt.pdf [accessed 23 March 2016], pp. 39-41.

[19] National Environmemtal Justice Action Council (NEJAC) comments on EPAs 2014 EJ Action Agenda, https://www.epa.gov/sites/production/files/2015-02/documents/plan-ej-2014-comments-0511.pdf. Accessed August 8, 2016.

[20] Draft EJ 2020 Action Agenda: Environmental Justice Strategic Plan 2016-2020. https://www.epa.gov/sites/production/files/2016-05/documents/052216_ej_2020_strategic_plan_final_0.pdf. Accessed August 7, 2016.

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Table 3-1. Health effects for the six criteria pollutants (ozone, lead, nitrogen oxide, particulate matter, carbon monoxide, sulfur dioxide) and diesel. Drawn from the EPA's Integrated Science Assessments.

	Ozone	Lead	NO_x	$PM_{2.5}$	CO	SO_2	Diesel
Respiratory Effects							
Lung diseases (COPD, chronic bronchitis, emphysema, and/or cancer)	X		X			X	X
Asthma incidences, attacks, hospitalizations, and aggravations	X			X			X
Aggravation of bronchitis	X						X
Impaired lung growth				X			X
Decreased lung function			X	X			
Difficulty breathing	X			X	X	X	
Lung irritation (airway hyper responsiveness and inflammation)			X	X		X	X
Lung related emergency visits	X		X				
Irritation of the nose and throat; coughing	X			X		X	X
Cardiovascular Effects							
Coronary heart disease		X					
Heart attacks				X			X
Hypertension or increases in blood pressure		X		X			X
Reduce oxygen carrying capacity of the blood		X			X		
Aggravation of existing heart disease					X	X	
Reproductive Effects							
Decreased fertility (men and women)		X				X	
Birth Outcomes & Childhood Development							
Adverse birth outcomes (premature birth, low birth weight, or miscarriage)	X	X	X	X	X		
Brain damage and other birth defects	X	X					
Behavioral and emotional problems		X					
Cognitive impairments		X			X		
Other							
Cancer		X		X			
Increased risk of premature death	X	X	X	X	X	X	X
Fever, convulsions, dizziness						X	
Headaches, nausea, vomiting		X			X	X	
Inhibition of thyroid functions						X	
Kidney damage		X					X
Loss of Smell						X	
Visual impairment					X		
Cognitive decrements in adults		X			X		
Immune system impairments		X					

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3.3 Factors associated with increased susceptibility to adverse health effects

As noted above, there is also substantial evidence that some subgroups of the population experience more adverse effects when exposed to air pollutants. That is, they are more "susceptible" to adverse health effects at any given level of exposure. Table 3-2 shows the evidence base to date regarding the characteristics or conditions that may results in more adverse health effects of exposure to specific air pollutants. The information in this table is extracted from the EPA's most current Integrated Science Assessments at the time of this writing.

Table 3-2. Factors associated with increased susceptibility to adverse health effects. Based on the EPA's Integrated Science Assessments identify potential risk factors for the six criteria pollutants (ozone, lead, nitrogen oxide, particulate matter, carbon monoxide, sulfur dioxide).

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	CRITERIA POLLUTANTS					
Potential Risk Factors	**Ozone[1]**	**Lead[2]**	**NO_2[3]**	**PM[4]**	**CO[5]**	**SO_2[6]**
Example risk factor	Level of Evidence (section in PHAP)					
Genetic						
Genetic Factors	Adequate (8.1)[7]	Suggestive (5.3.3)	Inadequate (4.3.4, 4.3.5)	Suggestive (8.1.5)		Inadequate (4.2.2)
Behavioral						
Diet /Nutrition	Adequate (8.4.1)	Adequate (5.3.10)		Suggestive	Diet /Nutrition	Adequate (8.4.1)
Exercise			Inadequate (4.3.5)		Inadequate (5.7.5)	Suggestive (4.2.5)
Alcohol Consumption		Inadequate (5.3.9)				
Smoking Status	Inadequate (8.4.3)	Inadequate (5.3.5)				
Outdoor Workers	Adequate (8.4.4)		Inadequate (4.3.5)			Adequate (4.2.5)
Existing Health Conditions						
Obesity , BMI	Suggestive (8.4.2)	Inadequate (5.3.8)	Suggestive (4.3.5)	Inadequate (8.1.6.4)		Suggestive (4.2.4)
Chronic Obstructive Pulmonary Disease (COPD)	Inadequate (8.2.3)		Inadequate (4.3.5)	Suggestive (8.1.6.2)	Suggestive (5.7.1.2)	
Influenza/Infection	Inadequate (8.2.1)					
Anemia					Inadequate (5.7.1.4)	
Cardiovascular Disease (CVD)	Inadequate (8.2.4)		Suggestive (4.3.1.2)	Suggestive (8.1.6.1)	Suggestive (5.7.1.1)	Inadequate (4.2.1.2)
Respiratory Contributions to Cardiovascular Disease				Inadequate (8.1.6.3)		
Respiratory Illness			Suggestive (4.3.1, 4.3.5)	Suggestive (8.1.6.2)		Adequate (4.2.1.1)
Hyperthyroidism	Inadequate (8.2.6)					
Diabetes	Inadequate (8.2.5)	Inadequate (5.3.4.2)	Suggestive (4.3.5)	Inadequate (8.1.6.4)	Suggestive (5.7.1.3)	Suggestive (4.2.4)

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Potential Risk Factors Continued	Ozone	Lead	NO_2	PM	CO	SO_2
Pre-Existing Disease*	Suggestive[8] (8.2)	Suggestive[9] (5.3.4)	Suggestive[10] (4.3.1)	Suggestive[11] (8.1.6)	Suggestive[12] (5.7.1, 5.7.7)	Adequate[13] (4.2.1, 4.2.1.1)
Age Related						
Children	Adequate (8.3.1.1)	Adequate (5.2.1, 5.3.1)	Adequate (4.3.2)	Suggestive (8.1.1.2)		Suggestive (4.2.3, 4.2.5)
Older Adults	Adequate (8.3.1.2)	Suggestive (5.2.1, 5.3.1)	Suggestive (4.3.2)	Suggestive (8.1.1.1)	Suggestive (5.7.2.1)	Suggestive (4.2.3)
Pregnant Women and Infants						
Maternal Self-Esteem		Inadequate (5.3.12)				
Pregnancy and Developmental Effects			Suggestive (4.3.5)	*Inodequate (8.1.2)*	Suggestive (5.7.2.2)	Suggestive (4.2.4)
Demographic Characteristics						
Sex	Suggestive (8.3.2)	Suggestive (5.2.2, 5.3.2)	Inadequate (4.3.3, 4.3.5)	Evidence of no effect (8.1.3)	Inadequate (5.7.3)	
SES	Suggestive (8.3.3)	Suggestive (5.2.4, 5.3.6)	Inadequate (4.3.5)	Adequate (8.1.7)		Suggestive (4.2.5)
Race/ethnicity	Inadequate (8.4.3)	Adequate (5.2.3, 5.3.7)	Inadequate (4.3.5)	Inadequate (8.1.4)		
Educational Attainment			Inadequate (4.3.5)	Suggestive(8.1.7)		
Housing, residential, living conditions						
Air Conditioning Use (8.4.5)	Inadequate (8.4.5)		Inadequate (4.3.5)			Suggestive (4.2.5)
Proximity to Source		Adequate (5.2.5)	Inadequate (4.3.5)		Suggestive (5.7.6)	Suggestive (4.2.6)
Residential Factors		Adequate [14](5.2.6)	Inadequate [15] (4.3.5)	Suggestive[16] (8.1.7)		Suggestive[17] (4.2.5)
Altitude					Suggestive (5.7.4)	
Other, miscellaneous						
Stress		Suggestive (5.3.11)				
Cognitive Reserve*		Inadequate (5.3.13)				
Other metals		Suggestive (5.3.14)				

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[1] All information for Ozone is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-ozone [accessed 2-2-16]

[2] All information for Lead is taken from the 2013 Integrated Science Assessment. Available: All information for Ozone is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-ozone [accessed 2-2-16]

[3] All information for Nitrogen Dioxide is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-nitrogen-dioxide-health-criteria [accessed 2-2-16]

[4] All information for Particulate Matter is taken from the 2013 Integrated Science Assessment. https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter Available: [accessed 2-2-16]

[5] All information for Carbon Monoxide is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-carbon-monoxide [accessed 2-2-16]

[6] All information for Sulfur Dioxide is taken from the 2013 Integrated Science Assessment. Available: https://www.epa.gov/isa/integrated-science-assessment-isa-sulfur-dioxide-health-criteria [accessed 2-2-16]

[7] The numbers associated with each factor reference the chapter of the specific ISA, where the information can be found. For example, if you want more information about genetic factors and ozone, see chapter 8.1.

[8] There is adequate evidence from epidemiologic, controlled human exposure, and toxicological studies that asthma is a risk factor for ozone related health effects.

[9] Overall, studies of lead related health effects related to pre-existing conditions have some evidence of a potential increased risk of lead related health effects. The evidence is consistent for lead related renal effects and hypertension, but is limited for other preexisting conditions.

[10] There is suggestive evidence that preexisting asthma, cardiovascular related conditions, diabetes, hypertension, and coronary artery disease may lead to heightened susceptibility to the effects of NO2 exposure.

[11] Epidemiological evidence suggests that individuals with respiratory illness, cardiovascular disease, and diabetes are more susceptible to the effect of PM exposure.

[12] Evidence from controlled human exposure and epidemiological studies provides coherence and biological plausibility for the association between CO exposure and cardiovascular morbidity in individuals with CAD, particularly those with IHD. Additionally, limited evidence suggests that individuals COPD, diabetes, and/or anemia may be more susceptible to health effects due to ambient CO exposure, with less available evidence for anemia. Finally, evidence indicates that individuals ingesting medications and other substances that enhance endogenous or metabolic CO production may be more susceptible to increased health effects due to additional exposure to ambient CO.

[13] There is substantial evidence that individuals with preexisting respiratory diseases, particularly asthma, are more susceptible to respiratory health effects, though not mortality, from S02 exposures than the general public.

[14] Numerous studies show an inverse association between blood Pb and residence in homes being built after 1950. Renovation activities on older homes have been shown to produce excess Pb dust concentrations.

[15] It was briefly stated that geographic location (west versus east) may be a potential risk factor for NOx; however, this requires further research.

[16] Residential factors, in relation to SES, may predict susceptibility to PM as one study found that the neighborhoods with the lowest SES characteristics had the largest health effects from exposure to PM.

[17] The EPA ISA only generally states, "Other factors that may potentially increase vulnerability to SO2 are residential or geographic location. However, residential location is not as strong of a predictor of exposure vulnerability for SO2 as for traffic-related pollutants, because meteorological conditions have a greater impact on pollutant plume direction from primary point sources such as coal-fired power plants."

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