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Understanding The Cumulative Impacts Of Inequalities In Environmental Health: Implications For Policy

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ABSTRACT Racial or ethnic minority groups and low-income communities have poorer health outcomes than others. They are more frequently exposed to multiple environmental hazards and social stressors, including poverty, poor housing quality, and social inequality. Researchers are grappling with how best to characterize the cumulative effects of these hazards and stressors in order to help regulators and decision makers craft more-effective policies to address health and environmental disparities. In this article we synthesize the existing scientific evidence regarding the cumulative health implications of higher rates of exposure to environmental hazards, along with individual biological susceptibility and social vulnerability. We conclude that current environmental policy, which is focused narrowly on pollutants and their sources, should be broadened to take into account the cumulative impact of exposures and vulnerabilities encountered by people who live in neighborhoods consisting largely of racial or ethnic minorities or people of low socioeconomic status.

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The persistence of health disparities and environmental inequalities in the United States has placed environmental health science and policy at a crossroads. Innovative scientific and regulatory approaches are needed to understand and address the cumulative, and potentially synergistic, effects of environmental and social stressors on the health of communities whose populations are mostly composed of racial or ethnic minorities or people of low socioeconomic status.

Advocates for such communities have long argued that their neighborhoods are beset by multiple environmental stressors, which could include air and water pollution and substandard housing. These community leaders also contend that existing regulations fail to protect residents adequately because the regulations are focused narrowly on pollutants and their sources.[1] Growing evidence shows that social stressors—including poverty, racial discrimination, crime, malnutrition, and substance abuse—also affect these communities.[2] Research is beginning to show how the cumulative effects of social and environmental stressors can work in combination to produce health disparities.[3]

With encouragement from scientists, policy makers, and environmental justice groups, regulatory agencies are beginning to consider the methodological challenges of addressing cumulative impacts in science and decision making.[4–6] These methodological challenges include how to evaluate and characterize the combined health effects of multiple environmental and social stressors on vulnerable populations, including the stressors' sources and the pathways of diseases. For example, the US Environmental Protection Agency has proposed a model for including psychological and social factors as integral components of cumulative risk assessment for predicting the potential health effects of pollu-

tion exposures in vulnerable populations.[7]

This article presents a synthesis of relevant research from the fields of social and environmental epidemiology, exposure assessment, and environmental justice. We believe that four key concepts underlie the emerging knowledge about the cumulative impacts of exposure to environmental hazards and social stressors.

First, health disparities between groups of different racial or ethnic makeup or socioeconomic status are significant and persistent, and exist for diseases that are linked to social and environmental factors. Second, inequalities in exposures to environmental hazards are also significant and persistent, and are linked to adverse health outcomes. Third, intrinsic biological and physiological factors—for example, age or genetic makeup—can modify the effects of environmental factors and contribute to differences in the frequency and severity of environmentally related disease. And fourth, extrinsic social vulnerability factors at the individual and community levels—such as race, sex, and socioeconomic status—may amplify the adverse effects of environmental hazards and can contribute to health disparities.

We highlight the evidence for these four concepts and conclude with a discussion of how this scientific foundation can help reshape regulatory science and decision making to reduce environmental health disparities and promote environmental justice among diverse communities.

Health Disparities

Research has documented systemic disparities in the incidence and severity of diseases between socioeconomic and racial or ethnic groups. A wide range of material, behavioral, psychosocial, environmental, and biological factors have been proposed to explain why social status is persistently linked to health.[2] Three health outcomes have been shown to be associated with both social and environmental stressors: adverse perinatal outcomes such as low birthweight and prematurity, cardiovascular disease, and self-rated health.

PERINATAL OUTCOMES African American infants are more likely to be delivered preterm and have low birthweight than white infants. These differences can result in higher risks of long-term health problems such as cognitive deficits, cardiovascular disease, and diabetes.[8] Socioeconomic and behavioral factors such as the mother's education, access to prenatal care, and substance use have been shown to contribute to poor perinatal outcomes—again, low birthweight and prematurity among them.[8] Research also indicates that prenatal stress resulting from maternal perceived discrimination, neighborhood deprivation, segregation, and income inequality are also linked to these poor perinatal outcomes, which suggests the importance of psychosocial pathways in the production of these racial or ethnic disparities.[9,10]

CARDIOVASCULAR DISEASE African Americans and people of low socioeconomic status have significantly higher rates of hypertension, heart disease, and stroke than whites and people of higher socioeconomic status.[11] Cardiovascular disease disparities have been linked to differences in biological risk factors such as diabetes, behavior such as physical inactivity, and the availability and use of primary and secondary preventive services.[12] Neighborhood environments have been linked to both the prevalence of heart disease and its risk factors.[13] Environmental pollutants, such as lead and ambient particulate matter—for example, extremely fine particles released into the air by vehicles and industrial plants that burn fossil fuels—have been linked to higher risk of cardiovascular disease.[14,15]

Emerging research has also linked the risk of developing cardiovascular disease in adulthood to early life events such as prenatal stress, which can disrupt development and cause heritable changes in gene expression. These so-called epigenetic changes can affect which genes are switched "on" or "off," which in turn can be associated with heightened disease risk.[16]

SELF-RATED HEALTH Self-rated health—a well-validated predictor of mortality, physical disability, chronic disease status, and health behavior[17]—is lower among racial and ethnic minorities and people of low socioeconomic status than others.[18] Researchers have found that racial disparities in self-rated health persist even after differences in socioeconomic status are controlled for.[19] The neighborhood people live in has been found to account for a large portion of the disparities between the way African Americans and whites rate their own health status.[20] This difference may be related to factors such as individual socioeconomic status, perceptions of neighborhood quality, health behavior, environmental quality, and psychosocial stress.[21]

Environmental Hazard Inequalities

Greater exposure to environmental hazards is one driver of health disparities found among communities of racial or ethnic minorities and those of low socioeconomic status. Research in this field has expanded from an initial focus on how close residents live to an environmental hazard, such as a highway or a major industrial facility, to encompass a broader investigation of

Poor communities suffer from a dearth of health-promoting resources.

the role that place plays in health. For example, a poor community populated by racial or ethnic minorities may also lack healthy food options,[22] high-quality green spaces, and recreational programs.[23] The lack of these positive factors can contribute to poor health.

PROXIMITY TO POLLUTING LAND USES AND TOXIC EMISSIONS Numerous studies have documented the disproportionate location of hazardous waste sites, industrial facilities, sewage treatment plants, and other locally undesirable and potentially polluting land uses in communities of racial or ethnic minorities and in socially disadvantaged neighborhoods.[24–26] Residents living near such facilities can be exposed to more pollutants than people who live in more affluent neighborhoods located farther from these sources of pollution.[27]

The residents of communities near industrial and hazardous waste sites experience an increased risk of adverse perinatal outcomes, respiratory and heart diseases, psychosocial stress, and mental health impacts.[28,29] Members of racial or ethnic minority groups and people of low socioeconomic status are also more likely than others to live near busy roads, where traffic-related air pollutants concentrate.[30] Research has linked a wide array of adverse health outcomes to residential proximity to traffic, including asthma,[31] low birthweight,[32] cardiovascular disease,[33] and premature mortality.[34]

EXPOSURES TO POLLUTANTS The poor and racial or ethnic minorities are disproportionately exposed to ambient air pollutants, which have been linked to respiratory and cardiovascular disease, adverse perinatal outcomes, diabetes, premature mortality, and other adverse effects.[35–38] Indoor environments also contribute to exposure disparities. Studies have found higher levels of indoor pollutants such as lead-based paint[39] and pollutants from industrial and transportation sources[40] in poor, African American, and Hispanic households than in other households.

Occupational exposures also constitute a source of environmental inequalities. For instance, Mexican American farm workers experience heightened exposure to organophosphate pesticides, which are associated with increased risk of cancer; preterm birth; and neurological, cardiovascular, and respiratory diseases.[41]

NEIGHBORHOOD ENVIRONMENTS Poor communities have an excess of health-damaging factors and a shortage of health-promoting amenities.[42] For example, residents of disadvantaged neighborhoods are exposed to more fast-food restaurants[43] and liquor stores than members of other communities. In particular, the presence of neighborhood liquor stores can influence health behavior and violence and can affect health both directly and indirectly.[44]

As noted above, poor communities also suffer from a dearth of health-promoting resources such as healthy food,[22] green spaces, and recreational programs,[23] whose lack can contribute to disparities in obesity rates and stress levels.[45,46] The confluence of these and other place-based factors contribute to the association between neighborhood socioeconomic status and adverse health outcomes.[20]

Intrinsic Factors: Biological Susceptibility

We use the term *susceptibility* to refer to intrinsic biological traits related to age, genetics, or preexisting health conditions that can create much variability in response to environmental stressors within a population.

AGE Children and the elderly experience heightened risk of pollution-related morbidity and mortality. The elderly are more susceptible to pollutant exposures because of their altered immune response and weakened respiratory and cardiovascular systems.[47] Children's susceptibility is associated with differences in rates of absorption, distribution, metabolism, and excretion of chemicals.[48] Exposure to stressors during childhood can greatly affect the development and functioning of organ systems well into adulthood.[49] Children have the potential for increased exposures to pollution because of their physical and behavioral activities, such as playing outside and frequent hand-to-mouth activity. Thus, their biological susceptibility combined with greater exposure to potentially toxic substances may put them at increased risk.

GENETICS AND GENE EXPRESSION Studies have found that certain genetic variants increase the effect of air pollution on respiratory symptoms, lung functioning, and asthma.[50] Where a child lives early in life, and the substances he or she is exposed to, can affect the development of disease in later life. These exposures may modify the patterns of gene expression—that is, turn genes "on" or "off"—which in turn triggers physiologic

changes and can potentially launch disease processes such as asthma or cancer.[16]

PREEXISTING HEALTH CONDITIONS Preexisting health conditions including diabetes, obesity, and cardiovascular disease can increase individual susceptibility to pollutant exposures. Studies have found that people with diabetes or a history of myocardial infarction are at heightened risk of cardiovascular morbidity and mortality associated with exposure to particulate matter.[51,52] In the United States, African Americans, Hispanics, and people of low socioeconomic status have higher rates of obesity, cardiovascular disease, and type 2 diabetes and are therefore more susceptible to environmental stressors.[11,53] Research is just beginning to link these disparities in preexisting conditions with neighborhood conditions.[45]

Extrinsic Factors: Social Vulnerability

We use the term *vulnerability* when describing how social constructs of race and class can amplify the effects of environmental exposures, with a focus on the pathway of psychosocial stress. We classify race as a social construct and not as a proxy for biological differences because research has consistently shown that race is a poor indicator for genetic variation in human populations and therefore should be understood as a social rather than biological category.[54]

Studies are uncovering the heightened vulnerability of people who belong to racial or ethnic minority groups or are of low socioeconomic status to environmental agents—a disparity that is not attributable to biological factors. Extrinsic factors that are socially related—such as race, ethnicity, socioeconomic status, and sex—can enhance the adverse effects of environmental exposures, such as short- and long-term exposures to air pollution.[55] Low neighborhood-level socioeconomic status may also amplify the risk of air pollution–related preterm births,[56] lower birthweight,[57] and adult mortality.[58]

Psychosocial pathways may link race and socioeconomic measures at the individual and area levels with the increased adverse impacts of environmental stressors. For example, studies indicate that exposure to violence and family stress increases the effects of traffic-related air pollution exposures on childhood asthma.[59,60] Low socioeconomic status and race or ethnicity have been linked to perceived stress as well as to biological markers of chronic stress.[61]

In addition to the direct effects of discrimination, social exclusion, and low socioeconomic status, the social and physical conditions of disadvantaged neighborhoods are also thought to contribute to psychosocial stress levels.[3] Researchers have proposed that the cumulative biological burden exacted by ongoing disruption of the body's stress-response system may explain the self-reinforcing effects or synergies observed among environmental and psychosocial stressors and may produce health disparities.[62,63]

Preexisting health conditions can increase individual susceptibility to pollutant exposures.

The cumulative physiological "wear and tear" resulting from chronic overactivity of the body's stress-response system may impair immune functioning and increase vulnerability to stressors[64] by increasing the absorption of toxicants into the body through increased respiration, perspiration, and consumption;[65] compromising the body's defense systems against toxicants; affecting the same physiological processes as environmental agents; and directly causing illness.[62]

Discussion

We have synthesized the scientific evidence underlying the cumulative impacts of environmental and social stressors and the multiple ways they can have a greater impact on communities of people who belong to racial or ethnic minority groups or are of low socioeconomic status. The four concepts of cumulative impacts that we outlined above have complex interrelationships and feedback loops (see the Appendix).[66]

Regulatory science and decision making must better integrate these four elements of cumulative impacts as a result of combined exposures, possible overlapping mechanisms and pathways for adverse health effects, and the potential for synergistic effects.[7] The National Research Council has also supported expanding scientific efforts to understand and address the multiple environmental and social stressors affecting community health.[67]

CUMULATIVE IMPACT ASSESSMENTS Regulatory agencies at the federal, state, and local levels are beginning to incorporate elements of cumulative impacts such as those described above into

The burden of proof is now placed on communities to demonstrate cumulative impacts.

assessment and planning procedures.[4,6] Nevertheless, the complexity of the task and the scarcity of scientific information and specific methodologies for assessing these cumulative effects have limited the scope of this work to date.[67]

One important challenge is how to characterize and mathematically model the interactions among environmental and social stressors, sources, pathways, and routes. Researchers are beginning to develop indices for aggregating environmental and social stressors. For example, Jason Su and colleagues developed an index to characterize social inequities in the cumulative effects of multiple air pollutants from both mobile and stationary sources at the regional level.[68] Still, the work to develop more sophisticated tools for assessing cumulative impacts and environmental disparities is in its infancy, and investigators are uncertain about the best way to cumulate and deal with interactions and overlapping components or pathways.

Fundamental to further work in this area is the need to better incorporate vulnerability into environmental health research, assessments, policies, and actions.[1] Current risk assessment practices address differential susceptibility for certain intrinsic biological factors (for example, age) by applying safety or default factors to protect biologically sensitive populations (such as children) in limited cases. However, the environmental risk assessment process does not apply such approaches to extrinsic factors—including neighborhood poverty, unemployment, lack of food security, and other psychosocial stressors—that can contribute to the heightened vulnerability of disadvantaged communities).[1,7,67] One potential reason for this omission is the persistent debate over pathways linking social vulnerability to environmental exposures. Researchers have established many dimensions of social vulnerability such as human and political capital, discrimination, and features of the built environment,[2] which should be taken into account in environmental health research and assessment practices.

Health impact assessment is an interdisciplinary approach to assessing the consequences of proposed policies, plans, and projects. This type of assessment features an explicit concern for socially excluded or vulnerable populations and uses a combination of quantitative, qualitative, and participatory techniques.[68–70] Health impact assessment may provide a promising path for incorporating cumulative impacts into assessments to guide decision making.

By considering together the baseline environmental conditions, health status, and vulnerabilities of the communities potentially affected by decisions, health impact assessments have the potential to address the complex causal pathways through which decisions can affect health.[71] Compared to risk assessment, which is mostly quantitative, health impact assessment is better able to deal with a scarcity of scientific information because it uses a diverse array of evidence for analysis—for example, epidemiological evidence along with qualitative observations of neighborhood social conditions and physical environments.

The inclusion of a broader array of evidence may result in more efficient and proactive measures than risk assessments, which rely heavily on toxicological evidence.[71,72] A key challenge, however, will be systematically integrating the health impact assessment process into environmental regulation and decision making.

POLICIES TO ADDRESS CUMULATIVE IMPACTS

The evidence that environmental and social stressors converge in disadvantaged communities and that residential context plays an important and independent role in health disparities indicates the need for targeted place-based and proactive approaches to policy making. One approach is to use cumulative impact screening to map, characterize, and target vulnerable communities for interventions that improve existing conditions and prevent future harm.[1]

The burden of proof is now placed on communities to demonstrate cumulative impacts, yet many disadvantaged neighborhoods may lack political clout or the capacity for civic engagement to push for regulatory action. The use of cumulative impact screening could remove this burden of proof from vulnerable communities and increase the likelihood that disadvantaged neighborhoods will receive focused regulatory attention.

Several agencies, such as the Environmental Protection Agency, are beginning to develop such tools to target enforcement and compliance activities nationally,[73] guide land use planning in California,[74] and inform regulatory programs at the California Air Resources Board.[75] As with health impact assessments, a critical issue will

be the linkage between assessments and the decision making authorities of the agencies.

Progressive approaches coming from local governments can provide some guidance for ways to systematically address cumulative impacts in vulnerable communities. The Environmental Justice Ordinance in Cincinnati, Ohio, for instance, requires new or expanding industrial facilities to demonstrate that they will not cause a "cumulative adverse impact" to the health and environment of the community in order to receive a permit.[76]

Similarly, Los Angeles is considering a "green zones" ordinance, which would use cumulative impact screening to guide municipal planning, the issuing of permits, and enforcement strategies to mitigate and reduce environmental hazards in disproportionately affected neighborhoods.[77,78] Such strategies could provide a more place-based, holistic, and proactive approach to environmental protection.

Conclusion

Communities of racial or ethnic minorities or people of low socioeconomic status are particularly vulnerable to environmental and social stressors. More holistic and transparent approaches to the regulatory science underlying decision making that affects such communities are needed. Screening methods can help regulators and policy makers more efficiently target efforts to remediate the cumulative effects of these exposures and environmental inequities, and to focus regulatory action at the neighborhood and regional levels. Because industrial and transportation development, as well as other land-use planning decisions, are often rooted within metropolitan regions and neighborhoods, regulatory interventions to mitigate the cumulative impact of environmental and social stressors on the health of disadvantaged communities will require multilevel, placed-based strategies.[79] ■

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In this issue of *Health Affairs*, Rachel Morello-Frosch and coauthors make the case that regulators need to consider the cumulative effects of various environmental and social stressors on poorer communities or those populated by racial and ethnic minorities. It's not enough to look just at the impact of exposure to a particular chemical, for example. Studies have found that chronic social stress, such as being poor or being discriminated against racially, can make individuals and communities more vulnerable to environmental hazards.

Yet "policy makers have been slow to respond to the scientific evidence," Morello-Frosch says. She hopes that this article will encourage them to take a broader view of the causes of health concerns and look into the cumulative effect of various stressors.

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