Environmental justice and allergic disease: A Work Group Report of the AAAAI Environmental Exposure and Respiratory Health Committee and the *Diversity, Equity and Inclusion Committee*

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Environmental justice is the concept that all people have the right to live in a healthy environment, to be protected against environmental hazards, and to participate in decisions affecting their communities. Communities of color and low-income populations live, work, and play in environments with disproportionate exposure to hazards associated with allergic disease. This unequal distribution of hazards has contributed to health disparities and is largely the result of systemic racism that promotes segregation of neighborhoods, disinvestment in predominantly racial/ethnic minority neighborhoods, and discriminatory housing, employment, and lending practices. The AAAAI Environmental Exposure and Respiratory Health Committee and Diversity, Equity and Inclusion Committee jointly developed this report to improve allergy/immunology specialists' awareness of environmental injustice, its roots in systemic racism, and its impact on health disparities in allergic disease. We present evidence supporting the relationship between exposure to environmental hazards, particularly at the

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neighborhood level, and the disproportionately high incidence and poor outcomes from allergic diseases in marginalized populations. Achieving environmental justice requires investment in at-risk communities to increase access to safe housing, clean air and water, employment opportunities, education, nutrition, and health care. Through policies that promote environmental justice, we can achieve greater health equity in allergic disease. (J Allergy Clin Immunol 2023;151:656-70.)

Key words: *Environmental justice, race, ethnicity, systemic racism, segregation, health disparities, asthma, allergic rhinitis, atopic dermatitis, pollution, allergen, psychosocial stress, obesity, nutrition*

Abbreviations used

AR:	Allergic rhinitis
CAFO:	Concentrated animal feeding operation
ED:	Emergency department
PM:	Particulate matter
SHS:	Secondhand smoke
TRAP:	Traffic-related air pollution

Exposure to environmental hazards is linked with poor health outcomes. Communities of color and low-income populations experience higher rates of exposure to environmental hazards, the result of centuries-old structural racism, and societal hierarchies, which shaped the built and social environments in which they live.[1-3] Racial and ethnic minority and impoverished communities also experience disproportionately high prevalence of allergic diseases and worse outcomes compared with more affluent and White communities.[4] Already vulnerable groups experience this "double-hit" of increased exposure to hazards that causes further deterioration in health and well-being.

The AAAAI Committee on the Underserved, now the AAAAI Diversity, Equity and Inclusion Committee, in its recent Work Group Report described the available medical literature on atopic disease disparities in racial and ethnic minority and other underserved populations and identified areas in which further work is needed to reduce health disparities.[5] Building on this report, the Environmental Exposure and Respiratory Health Committee and the Diversity, Equity and Inclusion Committee jointly present a report on the impact of disproportionate exposure to environmental hazards on allergic disease prevalence and severity in marginalized communities, including communities of color and those living in poverty. Furthermore, we will discuss the origins of this uneven distribution of environmental hazards and the factors that continue to perpetuate this inequality, leading to poorer health in some while other groups are less affected. Our review of communities differentially impacted by environmental hazards is by no means comprehensive, but we have chosen to focus on groups on which there is a significant amount of scientific literature addressing the relationship between environment and allergic disease. The goal of this report was to improve practicing allergy/immunology specialists' awareness of environmental injustice, its roots in systemic racism, and its impact on health disparities in allergic disease.

Throughout this report, multiple terms are used to describe racial and ethnic identities that are not necessarily interchangeable. For example, an individual may identify as Black but not as African American or as Latinx but not Hispanic. Methods for classifying racial and ethnic identity differ across publications and are dependent on whether information was obtained through self-report, interviewer observation, or electronic health records or databases. When summarizing the literature, we have included the descriptors of racial and ethnic identity reported in the referenced publication. Sometimes the term "person (or people) of color" is used to refer to non-White persons or groups, recognizing the shared experiences of racism within multiple racial and ethnic identity groups.

DISPARITIES IN ALLERGIC DISEASE PREVALENCE AND OUTCOMES

Marked disparities in asthma prevalence and morbidity have been recognized for decades, particularly among African American and multiracial populations who experience 1.5- to 2-fold greater prevalence of asthma and 2- to 3-fold greater risk of emergency department (ED) visits, hospitalization, and death compared with non-Hispanic White populations.[5-7] Asthma prevalence is also higher among people living below 100% of the federal poverty line.[6] Black and Hispanic respondents to the 2018 National Health Interview Survey self-reported allergic rhinitis (AR) less frequently than did non-Hispanic White respondents,[8] yet AR among racial and ethnic minority populations may be significantly underrecognized and underdiagnosed. Studies of predominantly Black and Hispanic urban children found that they experienced higher AR symptom burden and lower quality of life compared with White children.[9,10] The prevalence[11] and incidence[8] of eczema or atopic dermatitis (AD) was higher in non-Hispanic Black populations compared with Hispanic and non-Hispanic White individuals, and children living in poverty also had a higher prevalence of AD compared with children from higher-income families.[8]

Most environmental exposure literature relevant to allergy/immunology is focused on asthma, AR, and, to a lesser degree, AD. The remainder of this report will focus on the differential exposure of certain groups to environmental hazards and the potential impact on allergic disease prevalence and outcomes.

CONCEPTUAL FRAMEWORK FOR RACIAL/ETHNIC HEALTH AND ENVIRONMENTAL EXPOSURE DISPARITIES

As with most health conditions, allergic disease is influenced by a combination of genetic and environmental factors. Many studies of health disparities fail to adequately account for contextual factors and the portion of the disparity that is explained by these often-unmeasured factors. In Fig 1, we present a conceptual model for understanding the different factors that contribute to racial and ethnic health disparities and their interconnectedness.

Genetics

Although historical use of the term "race" has implied an underlying distinct biology, race is a social construct and not a biologic or genetic classification.[12] A worldwide study of human

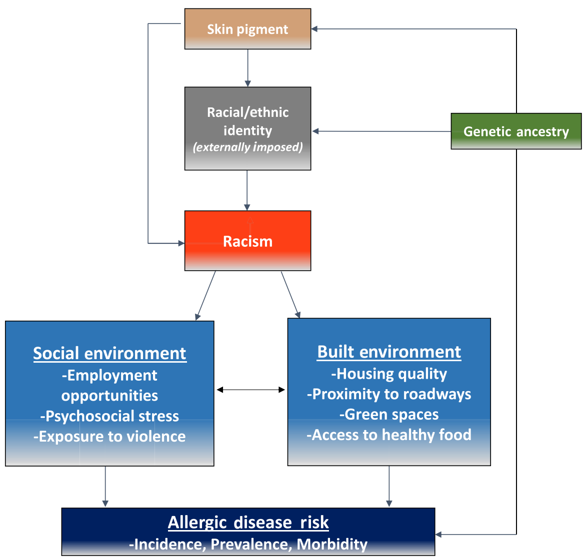

FIG 1. Conceptual framework for race/ethnicity, environmental exposure disparities, and allergic disease burden.

populations found that 95% of human genetic diversity is accounted for by *within*-population differences, with only a minor component of variability attributable to *between*-population differences.[13] This means that genetic variability between racial groups is much smaller than the variability seen between individuals from the same racial group.[14] To date, there has been little evidence that genetic differences between racial and ethnic groups explain health disparities between the groups. There have been multiple studies of the association between differences in genetic ancestry and allergic disease prevalence and morbidity within racial and ethnic groups.[15-22] Attempts to estimate the proportion of a health disparity *between* racial/ethnic groups that is explained by genetic ancestry is complicated by the fact that genetic associations observed within one population are not "portable" to another population[12,14] and any observed differences between groups are confounded by sociocultural and economic differences that exist between groups. Even in genetic studies done within groups, special care must be taken to avoid assuming that associations between ancestry and disease risk are causal because ancestry is confounded by environmental and other contextual factors that are difficult to fully control for. Adjustment for contextual factors is often limited to crude measures of socioeconomic status such as income and educational attainment that may not capture other important predictors of disease susceptibility and health outcomes. Gene-environment interaction as a contributor to asthma morbidity among residents of poor urban neighborhoods is a burgeoning area of research.[23,24]

Built and social environments and the role of neighborhoods in health

Environmental exposures are often narrowly defined to include exposures to contaminants in air, water, and soil as well as chemicals through foods, personal care products, and other consumer products and materials. However, the environment defined by broader terms includes both the physical and social environments and encompasses the complex interplay between exposures that contributes to health inequities. Elements of the physical, or built, environment include location of residence (inner-city, rural, suburban), housing quality, proximity to major roadways, and neighborhood zoning among many others. Elements of the social environment include poverty, opportunities for employment, availability of transportation, access to quality health care, access to green spaces for recreation, availability of nutritious food, and exposure to neighborhood violence and crime. Neighborhoods represent the intersection of the built and social environments. The role of neighborhood-level exposure is increasingly recognized as an important contributor to health,[25] in some cases independently of individual factors.[26] Neighborhood-level exposures are often driven by factors such as poverty and residential segregation by race and ethnicity. Living in highly segregated neighborhoods has been associated with higher prevalence and severity of allergic diseases such as asthma[25] and AD.[27] Evidence suggests that neighborhood allergic disease burden is not fully explained by income and racial and ethnic composition, though these can serve as markers of other environmental characteristics and contextual factors that may explain a larger proportion of health disparities.[28]

The spatial patterning of racial and ethnic minority neighborhoods, the built and social environments created by concentration of poverty in these areas, and disproportionate exposure to pollution sources in predominantly low-income neighborhoods with high percentages of people of color all stem from specific structural forces at work in the United States for many years.

How structural racism created racially and economically segregated neighborhoods

Residential segregation and concentration of poverty in America's inner cities originated during "The Great Migration" of the early to mid-20th century, when millions of African Americans moved from the rural South to large industrialized cities in the Northeast and Midwest for better employment opportunities.[29] To deal with housing shortages following the Great Depression, the Federal Housing Administration enacted policies that promoted moving working-class White families out of depression-era inner-city public housing developments and to the suburbs, while restricting African Americans from purchasing suburban homes.[30,31] Through the practice of "red-lining," racial and ethnic minority neighborhoods were color-coded to indicate areas of increased risk to insure mortgages, therefore ensuring that residents could not purchase homes with federally insured loans. The elevated risk inferred by red-lining also restricted community investment, resulting in fewer businesses, fewer job opportunities, lower property values, less money for public schools, and reduced access to health care services. Unequal access to education and employment created environments of concentrated poverty, isolation, and high crime rates that are still present today.[30-32]

These activities were not restricted to inner cities. Restrictive covenants and red-lining pushed many people of color into unincorporated communities located outside of municipal boundaries, often lacking sanitation and water services and without elected officials to represent them.[33] To this day, suburban housing developments frequently restrict or prohibit the construction of low-income housing, resulting in continued segregation and concentration of low-income individuals and families in less desirable neighborhoods.[34] In 2019, only 47% of public housing was located in low to moderate poverty areas.[35] Real estate agents influence buyers by showing them homes in certain neighborhoods while directing them away from others based on racial or ethnic composition through a practice called "steering," and though outlawed by the Fair Housing Act of 1968, evidence suggests that the practice continues.[36,37] Neighborhoods inhabited by predominantly minority and low-income families often have a higher concentration of industrial zones compared with affluent, predominantly White neighborhoods. These disparities originated from practices meant to restrict undesirable activities from affluent areas with political power and influence, while rezoning existing residential areas with high proportions of people of color and low-income families to allow for more industrial use. The result is further deterioration in neighborhood value and increased exposure of residents to environmental hazards. Meanwhile, ongoing racial prejudice in employment, housing, and lending practices continues to pose a barrier to home ownership and wealth building for people of color.[38,39] This is reflected in the fact that as of 2019, approximately 1 in 3 Black and 1 in 4 Latinx children in the United States lived in poverty.[40]

EFFECTS OF ENVIRONMENTAL EXPOSURES ON ALLERGIC DISEASE AND THE ROLE OF UNEQUAL DISTRIBUTION OF ENVIRONMENTAL HAZARDS ON ALLERGY-RELATED HEALTH DISPARITIES

In this section, we will discuss categories of environmental hazards linked to allergic disease and present evidence that certain groups are more exposed than others to hazards (Table I). Although increased exposure to environmental hazards may be *associated* with or play a causal role in allergic disease prevalence and severity, there are very few studies that have examined whether or to what extent disparate exposure to hazards explains disparities in allergic disease. More research is needed to understand the extent to which exposure to hazards or groups of hazards explains health disparities and how these exposures might affect different populations in distinct ways.

AIR POLLUTION

In much of the United States, people of lower socioeconomic status and racial and ethnic minority populations tend to live in areas with the poorest air quality.[41-43] In this section, we will discuss the major sources of ambient air pollution relevant to human health and the disproportionate exposure of some groups to these hazards.

Pollution and allergic disease

Fixed-source emissions. Exposure to environmental hazards associated with living near industrial sites is associated with higher all-cause[44,45] and disease-specific mortality.[46] Coal-fired power generation, steel production, and refining of petroleum products release a host of hazardous byproducts including sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM),[47-49] which have been extensively studied for their contribution to respiratory disease and have been linked with higher asthma prevalence,[50] asthma exacerbations,[51-55] lower lung function,[48,56-58] and all-cause and respiratory mortality.[45] In rural areas, concentrated animal feeding operations, or CAFOs, are sources of PM and gaseous emissions as well as noxious odors from open waste lagoons and the practice of spraying waste on fields.[59,60] Residing near large- scale industrial livestock operations has been associated with adverse health effects including higher all-cause and infant mortality and disease-specific mortality (anemia, kidney disease, tuberculosis, and sepsis).[46] Residing near swine CAFOs has been associated with increased prevalence of asthma[61-63] and nasal allergies[63] and with increased odds of uncontrolled asthma[63] and reduced lung function.[59] Rural communities are also increasingly the sites of hydraulic "fracking" for extraction of oil and natural gas, which involves use of chemicals, many of which are toxic to humans, to facilitate drilling and extraction. Traffic exhaust from trucks and equipment used in extraction has an additional environmental impact. Because of their concentration in rural areas, many fracking sites are out of range of air quality monitoring sites.[64]

Groups with disproportionate exposure to fixed-source air pollution

A study examining air quality across the United States found that monitored counties with the worst airway quality in terms of PM of diameter less than 2.5 μm had higher percentages of non-Hispanic Black residents and people living in poverty compared with counties with the best air quality.[43] A 2017 joint report prepared by the Clean Air Task Force, the National Association for the Advancement of Colored People, and the National Medical Association reported that Black people in the United States are exposed to 38% more air pollution than are Whites.[65] Historical land-use patterns in the United States have resulted in siting of industrial facilities such as solid waste disposal sites[66] and power-generating facilities[67] in predominantly Black and Hispanic neighborhoods.[68,69] An examination of demographic characteristics of people residing near hazardous waste facilities in the United States found that as distance from the facility decreased, the proportion of residents of color increased; socioeconomic disparities were also identified but were less extensive than racial disparities.[70]

In 2019, rural areas of the United States had higher rates of poverty than urban areas among all racial/ethnic groups but particularly among Black (30.7%) and American Indian or Alaskan Native (29.6%) populations, compared with White populations (13.3%).[71,72] CAFOs are typically sited in rural areas and are often located in high-poverty neighborhoods and communities with a high proportion of people of color.[61] Ten times as many CAFOs in North Carolina are located within census blocks with the highest poverty rates and proportion of non-White residents, compared with census blocks with the lowest poverty and non-White populations.[60,73] The environmental impact of fracking, including the chemicals used, their persistence in the environment, and effects on nearby residents, is not well understood[64,74-76] but is likely to disproportionately affect residents of rural areas.

Mobile-source emissions. Mobile sources of air pollution include cars, trucks, buses, construction equipment, airplanes, trains, and watercraft. Traffic-related air pollution, or TRAP, is a major source of air pollution composed of products of fossil fuel combustion, including gases (nitrogen oxides, carbon monoxide, carbon dioxide) and particulate emissions (PM, including diesel exhaust particles and black carbon). TRAP exposure has been linked to various negative health outcomes, including respiratory morbidity, cancer, and heart disease.[77] TRAP exposure has been

TABLE I. Summary of disparities in exposure to environmental hazards by race, ethnicity, and income level

Environmental hazards	Groups with disproportionate exposure
Exposure to violence and psychological stress	● Higher psychological stress and exposure to community violence among populations of color[240,241] ● Increased risk of aggravated assault and homicide among Black youth compared with White youth[242,243] ● Higher reported exposure to adverse childhood experiences among Black and Hispanic/Latinx children[242,245,246] ● Black youth more likely to miss school because of safety concerns[242] ● Experience of racial discrimination as a source of psychological stress linked to poor health[247-249]
Air pollution	● Poorest air quality in US counties with high percentages of non-Hispanic Black residents[43] ● African Americans and families living in poverty live closer to industrial emission sources[68] ● Proportion of residents from racial/ethnic minority groups increases with decreasing distance from hazardous waste facilities in the United States[70] ● Larger proportion of non-Hispanic Black and Hispanic/Latinx children exposed to neighborhood traffic[97] and live in close proximity to major roadways[116] ● Bus depots commonly located in low-income neighborhoods[117] ● Neighborhood disadvantage strengthens associations between pollution and respiratory disease[119-122] ● Black and Hispanic/Latinx populations exposed to higher levels of volatile organic compounds compared with White populations[219] ● Low educational attainment and lower income associated with higher rates of current smoking and maternal smoking in pregnancy[220-222] ● Exposure to SHS higher in Black and high-poverty populations[193,223]
Substandard housing and indoor allergens	● People of color and low-income families more likely to live in poor housing compared with White and higher-income families[162-164] ● Racial/ethnic minority and low-income families more likely to experience pests in the home[131,166,167] and are exposed to higher levels of indoor allergens in home and school environments[128,160,168-176] ● High rates of sensitization to pest allergens in Black and Hispanic/Latinx populations[143,168]
Access to health care	● Racial/ethnic minority populations less likely to have health insurance[250] ● People of color attend fewer doctor visits and experience greater fragmentation of care and less continuity of care[250,251] ● Black children and children from non–English-speaking families less likely to have a usual source of care[256] ● Minority populations less likely to receive guidelines-based asthma care[258-260] ● Pharmacy deserts in predominantly minority and low-income neighborhoods limit access to medications[257] ● African American and Hispanic/Latinx patients reported having fewer choices in where they receive medical care[250] ● Minority populations more likely to receive care from safety net hospitals[254] including EDs as opposed to office-based care, even after controlling for insurance coverage[255]
Diet and food security	● Fewer supermarkets in predominantly Black neighborhoods[271] ● Targeting of African Americans for marketing of high-calorie, poorly nutritious foods[275,276]
Green space access	● Less access to green space in low-income and minority neighborhoods[297-299] ● Smaller average size of parks in Black neighborhoods compared with White neighborhoods[297]

linked with increased risk of allergic sensitization,[78-80] AR,[81] skin barrier dysfunction[82] and AD,[83] asthma,[84-97] and exacerbation of established asthma.[98-101]

Children may be particularly susceptible to the harmful effects of TRAP, especially during the prenatal period and during the first few years of life.[102] The relationship between prenatal and early-life TRAP exposure and risk of wheeze and asthma is somewhat controversial, with many studies showing a significant association[84-96] and others reporting no association.[103-109] Multiple prospective studies have shown positive associations between early-life exposure to TRAP and risk of reduced lung function[110] and asthma,[111-113] AR, and AD.[93] Some of this discrepancy may be related to differences in the way exposure was assessed as well as the window of exposure, timing of outcomes, effects of weather, or composition of air pollutants. Traffic-related pollution is highly localized, and air quality monitoring stations may not accurately capture the burden of pollutants experienced by those who live closest to major roadways.[114]

Groups with disproportionate exposure to TRAP

Racial and ethnic minority and low-income populations incur greater exposure to neighborhood traffic than do White and higher-income populations.[69,97,114,115] Among the US national Environmental Influences on Child Health Outcomes Consortium, Commodore et al[97] found that a larger proportion of non-Hispanic Black and Hispanic children were exposed to neighborhood traffic compared with non-Hispanic White children (39.5%, 34.9%, and 12.4%, respectively) and were also more likely to report asthma symptoms (40.1%, 31.5%, and 19.3%, respectively). Approximately 40% of inner-city children of predominantly racial and ethnic minority status participating in the School Inner-City Asthma Study lived within 100 m of major roadways, and more than half attended a school that was also located within this buffer.[116] These children had higher odds of experiencing asthma symptom days, poor asthma control, and health care utilization compared with children living/attending school more than 100 m from major roadways.

In urban centers, bus depots and major truck routes are often located in or near low-income neighborhoods with high percentages of people of color.[117] Residents of these communities often spend significant amounts of time on city sidewalks for transportation, recreation, and socializing and are therefore more at risk of exposure to traffic exhaust. In addition, lack of central air conditioning, which is twice as prevalent among urban Black people than among White people,[118] forces residents to spend more time outdoors where they are exposed to higher levels of traffic-related pollution. Several studies have reported that neighborhood disadvantage strengthens the association between air pollution exposure and respiratory disease.[119-121] For example, in one study of households from the Panel Study of Income Dynamics, neighborhood poverty was a significant moderator of the association between early-life pollutant exposure and childhood asthma risk, with significant associations in moderate- and high-poverty neighborhoods but not in low-poverty neighborhoods.[122]

HOUSING AND THE INDOOR ENVIRONMENT

Characteristics of poor-quality housing include cracks in walls and doors that allow pests to enter (cockroaches, rodents), leaky pipes with resultant mold and mildew growth, inadequate ventilation, lack of air conditioning and/or heating, and exposure to volatile organic compounds from building materials. A secondary analysis of 33,201 households surveyed in the 2011 American Housing Survey found that poor-quality housing was independently associated with diagnosis of asthma and with asthma-related ED visits.[123] Single-site studies in different US urban centers showed associations between dilapidated housing or housing code violations and elevated asthma hospitalization rates[124,125]; remediation of housing conditions to limit indoor asthma triggers resulted in significant improvements in asthma-related health care utilization.[126] In this section, we will discuss the indoor environment and the groups most affected by environmental hazards that come with poor quality, delapidated housing.

Allergen

Mouse and cockroach allergen sensitization and exposure are clearly linked with pediatric asthma morbidity, with the strongest evidence for these associations seen in studies of inner-city children.[127-130] Older homes, mobile homes, and high-rise apartments including public housing structures were associated with frequent reports of pests and higher concentrations of pest allergens.[131] Exposure to cockroach allergen in sensitized individuals was associated with asthma prevalence in a dose-dependent manner.[132-135] Children who were sensitized and exposed to cockroach allergen were more likely to be hospitalized for asthma[136] and missed more school days.[130,137] Mouse sensitization and exposure in urban children were associated with greater asthma severity,[138,139] increased symptom frequency,[131,140-142] asthma-related acute care visits,[141,143,144] hospitalizations,[131,141,142,145] low lung function,[140] and elevated fractional exhaled nitric oxide.[143,145] Mouse sensitization was also associated with rhinitis symptoms in urban children with asthma.[146] Mouse allergen remediation interventions successfully reduced allergen levels, and this corresponded to reductions in asthma morbidity[147] and increased lung function growth[148] in mouse-sensitized children.

Mold is also a common allergen found in increased concentrations in dilapidated structures,[149] often due to condensation from inadequate heating or improperly repaired roofs or plumbing leaks that create conditions favorable to fungal growth. Indoor fungal exposure was associated with increased respiratory symptoms in adults and children, including cough and wheeze[150-154] and rhinitis symptoms.[155,156] Moisture damage in school buildings was associated with increased odds of nocturnal cough, wheeze, nasal symptoms, and school absences in children.[157,158] *Alternaria alternata*, found in indoor and outdoor environments, was associated with increased prevalence of asthma[159] and with increased asthma symptoms in sensitized children.[160] In addition to allergic inflammation, inflammatory fungal components such as β-1,3-D-glucan, mycotoxins, and volatile compounds were associated with nonallergic cough and nasopharyngeal and ocular irritation.[161]

Groups with disproportionate exposure to allergens associated with poor housing conditions. People of color and low-income families are more likely than others to live in poor housing conditions,[162] with more than twice as many non-Hispanic Black individuals reporting living in substandard housing as White individuals according to the American Housing Survey.[163] An even larger racial disparity in housing was found in nonmetropolitan areas of the United States, with African American households 3 times as likely to live in low-quality housing.[164] Low-income and non-White students are more likely to attend schools with dilapidated infrastructure.[165] Racial/ethnic minority identity, low educational attainment, renting a home, and living in neighborhoods with high poverty were associated with increased odds of the presence of pests in the home.[131,166,167] Multiple single-site studies have shown higher levels of cockroach and mouse allergen in the homes of racial and ethnic minority families compared with White, English-speaking families[128,168,169] and higher rates of sensitization to pest allergens in Black and Hispanic populations.[168] Exposure to cockroach and mouse allergens was also highly prevalent in the school environment among children living in socioeconomically disadvantaged urban neighborhoods.[160,170-175] Visible mold, water damage, and damp conditions were common in low-income homes with children enrolled in a Seattle, Wash, Healthy Homes project. African American children had more than 2 times the odds of sensitization to *A alternata*, compared with White children,[176] and mold sensitization was identified as a significant predictor of asthma-related ED visits in Black children.[177]

Indoor pollutants

Common indoor sources of pollution include combustion products such as NO_2 and PM from fossil fuel–powered stoves and heaters, secondhand smoke (SHS), and infiltration of polluted outdoor air.[178,179] Poor ventilation may contribute to concentration of pollutants within indoor spaces where people spend up to 90% of the day.[180,181] In cross-sectional studies, the presence of a gas stove in the home was associated with increased odds of current asthma[182] and wheezing in the last 12 months.[183] Indoor NO_2 exposure was associated with a dose-dependent increase in asthma symptoms, rescue medication use and airflow obstruction in inner-city children[178,184-186] and those living in multifamily housing units,[187] and increased airway hyperresponsiveness.[188,189] Volatile organic compounds such as formaldehyde are emitted from consumer products such as furniture, insulation materials, combustion appliances, and cigarette smoking[179,190] and were associated with asthma prevalence in cross-sectional studies; prospective studies examining this relationship are lacking.[191]

SHS exposure is common, with 14% of the US adult population identifying as current smokers[192] and 30% of all US children living in a household with a smoker.[193] SHS exposure during the prenatal period was associated with low birth weight,[194-197] preterm birth,[198,199] reduced lung function shortly after birth,[200] and increased incidence of childhood asthma or wheezing.[201-203] Postnatal parental smoking during a child's early life was associated with increased odds of wheezing illness and asthma diagnosis in children,[201,204-206] low lung function during childhood,[202,207,208] increased ED visits,[190,209] and increased risk of allergic sensitization.[210] In addition, a systematic review found that both active and passive smoking were associated with AR and AD in children and adolescents,[211] whereas in adults active smoking was associated with increased odds of adult-onset AD and chronic rhinitis, but *decreased* prevalence of AR.[212-214]

Groups with disproportionate exposure to indoor pollutants. African Americans are more likely than other groups to live in older, less energy-efficient homes[215] and are more likely to use natural gas appliances.[216] African Americans in the United States are also less likely to own their homes (43%) compared with non-Hispanic White populations (65%), and landlords have fewer incentives to retrofit properties with more energy-efficient electric appliances.[217,218] People living in poor-quality housing with insufficient insulation and other defects that contribute to energy inefficiency will sometimes use their gas stoves or ovens to heat their homes in winter,[181] increasing exposure to byproducts of combustion such as NO_2. Racial/ethnic identity was significantly associated with volatile organic compound exposures in a secondary analysis of personal exposure monitoring data from the National Health and Nutrition Examination Survey 1999-2000, with Black and Hispanic participants having significantly higher exposures than non-Hispanic White participants.[219]

People self-identifying as American Indian/Alaska Native (20.9%) or Other (19.7%) were more likely to be current smokers compared with non-Hispanic White (15.5%), non-Hispanic Black (14.9%), Hispanic (8.8%), and non-Hispanic Asian individuals (7.2%).[192] Low educational attainment and lower annual household income were also associated with higher prevalence of current smoking and with maternal smoking during pregnancy.[220-222] SHS exposure among Black children and those from households with high poverty and low parental education was 3 times higher than for Hispanic children (the reference group), low-poverty, and high-education households.[193,223] Living in multiunit housing was associated with higher rates of SHS exposure (assessed by serum cotinine levels) in children compared with living in detached homes, even among those without known SHS exposure, suggesting potential passage of tobacco smoke through ventilation systems or defects in walls.[224]

OTHER ENVIRONMENTAL EXPOSURES RELEVANT TO ALLERGIC DISEASE

Psychosocial stress

Neighborhood safety and caregiver psychosocial stress have been linked to health outcomes in children.[225-227] Increased caregiver psychosocial stress was associated with higher prevalence of childhood asthma,[228] higher frequency of asthma symptoms,[229,230] lower bronchodilator reversibility,[231] and poorer adherence to asthma medications.[232] A meta-analysis of observational studies found that children of women who experienced psychological stress during pregnancy had higher prevalence of wheezing and asthma than children born to mothers who did not report psychological stress.[228] Stressful life events were associated with increased risk of new-onset asthma in children from the Tucson Children's Respiratory Study,[233] and a study of a nationally representative sample of children found a positive relationship between number of adverse childhood experiences and odds of asthma.[234] A history of physical or sexual abuse was associated with increased odds of current asthma, asthma-related health care visits, and asthma medication use among Puerto Rican children.[235] Exposure to community violence and low caregiver-perceived safety of the neighborhood were associated with higher odds of asthma[236] and poor asthma control in children.[237] Neighborhood violence has also been linked with depression in children and caregivers,[238] which may contribute to increased asthma-related ED visits[239] and difficulty using asthma medications correctly.[232] Higher perceived neighborhood safety, lower caregiver stress, and lower depressive symptoms were associated with lower rates of asthma symptoms in children.[227]

People of color experience higher exposure to psychosocial stress and community violence than do other groups.[240,241] Black adolescents and adults were at increased risk of violence resulting in homicide or physical injury compared with White adolescents and adults.[242,243] In-depth interviews of predominantly Black inner-city adolescents revealed that 42% had witnessed someone being shot or knifed and 22% had witnessed someone being killed.[244] Black children and adults were more likely to report experiencing adverse childhood experiences compared with White children and adults.[242,245,246] Discrimination based on racial/ethnic identity is a significant source of psychological distress linked to poor health in adults and children,[247] including asthma.[248] The experience of racism can vary with skin color, leading some investigators to include percent African ancestry as a potential modifier of the relationship between discrimination and disease outcomes. African American children from the Study of African Americans, Asthma, Genes, and Environments II and Genes-environments and Admixture in Latino Americans trials reporting discrimination experienced nearly 80% higher odds of having asthma and nearly 2 times the odds of poor asthma control than did those who reported no discrimination, regardless of amount of African ancestry or socioeconomic status.[249]

Health care access

Despite greater need for health care services, racial/ethnic minority populations and the poor are less likely than White populations to receive care and are less likely to have health insurance, attend fewer doctors visits, and receive greater fragmentation of care due to limited options in care providers and less continuity of care between visits.[250,251] Throughout the 1960s to 1990s, America's inner cities saw a decline in the number of outpatient primary care providers as well as private hospitals, whose emergency rooms served as primary care sources for a large proportion of the mostly minority and poor population.[252-255] Remaining private hospitals sometimes limit the number of Medicaid and Medicare patients they will serve.[253] However, public hospitals are often overcrowded and underresourced and require long wait times to see a health care provider, leading some patients to forgo preventive care services. Black children and children from non–English-speaking Hispanic families with a diagnosis of asthma were less likely than White children to have a "usual source of care" and to identify a specific provider.[256] Evidence suggests that some communities with high proportions of racial and ethnic minorities are "pharmacy deserts," which reduces access to prescription medications.[257] Black people were more likely to receive care for asthma in the ED[250] and were less likely to receive guidelines-based asthma care including prescriptions for controller medications.[258-260] Rural minority individuals experienced similar barriers to accessing health care and in some cases had less access to care than urban minority and rural White individuals.[261-263]

Diet and food security

Poor diet quality is an important contributor to chronic disease and to obesity. Diet quality in the United States varies by demographic and socioeconomic factors, with White adults estimated to consume more vegetables, whole grains, and milk than do Black adults and low-income adults having generally lower diet quality than higher-income adults.[264-266] Nutrition during early life may have immunomodulating effects that influence development of allergic diseases such as asthma and food allergy.[267] Maternal diets high in fresh fruits, vegetables, and fish (Mediterranean diet) were consistently associated with reduced risk of allergic disease in children, whereas maternal intake of vegetable oils and margarines was associated with higher risk. Maternal intake of fat-soluble vitamins such as A and E was associated with reduced risk of AR.[268] Eating a diverse diet in the first year of life was associated with lower prevalence of childhood asthma, food allergy, and food sensitization up to age 6 years.[269]

Access to nutritious food is affected by the local food environment, including geographic distance to stores, access to transportation to get to a store, the variety of food choices available, and the price of food. In 2019, food insecurity affected 34.9% of US families living below the poverty line, 15.6% of Hispanic/Latinx, and 19.1% of Black households, compared with 7.9% of White households.[270] Increasing poverty and higher neighborhood racial segregation were associated with fewer supermarkets, with census tracts with a high percentage of Black residents having the fewest supermarkets and White census tracts having the most.[271] Low-income neighborhoods tend to have more convenience stores, corner markets, and fast food options that tend to offer fewer healthy food choices such as fresh produce. Food prices are another major determinant of diet because healthier fresh foods tend to be more expensive than processed foods. In addition to the loss of health benefits associated with a healthy diet, food insecurity impacts health in other ways. Households are sometimes forced to make the choice between buying food and buying medication to treat chronic illnesses. An analysis of data from the National Health Interview Survey showed that food insecurity and chronic illness in adults were associated with underuse of medications because of cost constraints, and these individuals were more likely to identify as Hispanic or non-Hispanic Black.[272]

Food insecurity is also associated with increased risk of obesity.[273] In addition to an increased risk for food insecurity, a larger proportion of non-Hispanic Black and Hispanic children and adults in the United States are obese compared with non-Hispanic White individuals.[274] Differences in the sources and types of food available as well as targeting African Americans for marketing of high-calorie and poorly nutritious foods are both potential contributors to the racial disparities in obesity rates.[275,276] There is a large literature linking obesity with increased risk of asthma,[277-279] increased asthma severity,[280-282] and AD.[279,283]

Green space

The health benefits of public green spaces such as parks, sporting fields, greenways, and community gardens are well-described and have become particularly important during the coronavirus disease 2019 pandemic with the need for physical distancing when socializing.[284-286] Urban green spaces provide benefits such as access to space for physical activity, which may influence obesity development[287] and psychological well-being.[288] Some have hypothesized that reduced exposure to environmental microbiota due to urbanization leads to immune dysfunction and impaired tolerance due to loss of biodiversity.[289,290] Green space was inversely associated with risk of allergic sensitization,[291] AD, AR,[292] and asthma,[293] though it is unclear whether greenness has a direct effect on allergic disease risk and morbidity or whether it mediates other factors that contribute to allergic disease.[294] For example, green spaces may partially mitigate the negative effects of TRAP on risk of asthma in children.[295] Living near green spaces in early life was associated with higher lung function up to age 24 years.[296]

Access to urban green spaces and their health benefits are not equally distributed among populations, and low-income and racial/ethnic minority groups tend to have the least access to these spaces.[297-299] The average size of parks in predominantly White neighborhoods in New York City was more than 3 times the size of parks in predominantly Black neighborhoods.[297] Race, ethnicity, and income are important modifiers of the health-protective effects of green space. In a study of pregnant women in South Carolina, women from low-income Black communities with the lowest amount of green space experienced excess risk for poor pregnancy outcomes compared with White women from economically privileged White communities with similarly low green space.[300] In addition to the amount of green space available, other factors lead to inequities in use of green spaces including lack of transportation, quality of parks, and safety concerns.

ENVIRONMENTAL JUSTICE

Environmental injustice is the disproportionate exposure of vulnerable groups to environmental hazards and their resultant negative health effects as well as unequal protection against these hazards by laws, policies, and regulatory agencies.[67] Beyond the more obvious hazards such as pollution and toxic waste, environmental hazards include poverty, psychosocial stress, exposure to violence, and lack of access to resources and services such as quality health care, healthy food choices, and green space. The cumulative effects of these hazards may have profound implications for health, life opportunity, life expectancy, and quality of life.[301,302] The goal of the environmental justice movement is to provide equal protection from environmental health hazards to all people regardless of race, ethnicity, or income level and to ensure that all people have the opportunity to be involved in decision-making processes impacting their communities.[303]

Community engagement is a key component of successful environmental intervention programs for asthma,[126] but accomplishing this goal will require investment in environmental justice beyond the community level, with state and federal government resources needed to identify at-risk communities and implement solutions. State and community-based urban asthma programs have demonstrated improved asthma outcomes through home environmental interventions and education[304-306] but require stable funding to continue their work and expand to other at-risk communities. With respect to hazards such as air pollution, land-use planning and proposed zoning changes should be carefully and thoughtfully evaluated with involvement of public health professionals and input from community members.[307] Unincorporated communities, which typically do not have local elected officials, should be recognized as particularly vulnerable due to their limited ability to participate in decision making about their communities.[33] Governments should consider policies that limit idling of school and city buses and replace public transportation vehicles with newer, lower emission vehicles. State and federal environmental regulations on industry should be strictly enforced. Strategies for mitigation of indoor environmental hazards include education campaigns focused on reducing asthma triggers in homes and schools, housing mobility programs, and improvements in quality inspection of public housing.[308] Integrated pest management interventions and education programs in homes[147] and schools[309] have shown benefit in children with asthma in well-designed studies. Poverty is a key driver of exposure to environmental hazards such as violence and psychosocial stress, food insecurity, and lack of access to health care services. There is a large need for community development through investment in affordable housing, schools, and health clinics as well as small businesses that create jobs and help residents to build wealth.[226] Government programs similar to the Obama administration's "Let's Move!" program can help communities improve access to healthy food and prevent obesity by incentivizing the placement of supermarkets, farmers markets, food banks, and pantries in underserved areas, establishing nutrition standards for school lunches, and improving access to outdoor spaces for physical activity.[310] Increased rates of psychosocial stress should be met with better screening for patient and caregiver stress and improved access to mental health care, including school-based resources for children, with social workers and school nurses assisting with identification of mental health care needs. Better collaborations between health care providers and community-based organizations will assist children and families with significant needs.

In this report, we have emphasized that the neighborhood is a key determinant of the overall health of its inhabitants, including asthma and other allergic diseases. Racial *and* economic integration (avoiding gentrification) of neighborhoods can create more equitable access to quality affordable housing, better education and employment opportunities, and nutrition and green spaces and should be prioritized by public policymakers and housing industry leaders.

REMAINING KNOWLEDGE GAPS AND DIRECTIONS FOR FUTURE RESEARCH

There is abundant evidence that exposure to environmental hazards is associated with poorer health, but more studies are needed to understand the extent to which exposure to hazards (or groups of hazards) explains health disparities. Future research should account for contextual factors as determinants of the distribution of allergic disease burden in a population and should be cognizant that the impact of environmental characteristics on allergic disease may vary by race and ethnicity (and plan their study's analysis strategy to account for this).[28] There is a need to identify community-level interventions that are most impactful for improving the health of community members. Interventions capable of effectively reducing exposure to hazards should be studied to determine whether these interventions also reduce allergic disease burden among populations and whether they reduce health disparities among groups within a population. Finally, most studies of environmental exposures have focused more on short-term health outcomes, such as acute asthma exacerbations, for example. But there is a major gap in knowledge regarding the impact of long-term exposure on health later in life, such as the effect of early-life exposures on adult lung health disparities in racial and ethnic minority populations. In conclusion, the scientific literature is clear that when it comes to health, where you live matters. Everyone has the right to live in a community that promotes health and opportunity.

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