

SUPPLEMENTAL MATERIAL

Data S1. Supplemental methods.

Health disparities in the United States have spurred a growing interest in environmental justice (EJ) to achieve health equity.⁴⁰ Screening tools that map cumulative environmental burdens in communities can help agencies prioritize those populations facing the most significant injustices for supportive policies and initiatives.¹⁶ State and federal EJ indices considering holistic health impacts are needed. The Environmental Justice Index (EJI) is the first nationwide EJ index examining cumulative environmental and health equity effects, building on previous place-based methods like CalEnviroScreen after accounting for salutogenic features of the environment.¹⁶ The EJI identifies communities with the highest combined environmental burden and vulnerability for focused action addressing hazards and disparities.

The EJI model incorporates measurements of distributive and procedural justice factors and their cumulative health impacts. Census tracts, which provide neighborhood-level data, are the analytical unit.¹⁶ The EJI sums ranked scores across three modules (Environmental Burden, Social Vulnerability, Health Vulnerability) and ten domains representing critical aspects of injustice [Table 1].¹⁶ The cumulative score generates the final tract-level EJI ranking. This approach elucidates total EJ impacts on community health and well-being nationwide.

Table S1. Various indicators contributing to Environmental Justice Index¹⁶

Overall Environmental Justice Index ¹⁶	Social vulnerability	
	Racial/Ethnic minority	<ul style="list-style-type: none"> • Minority status
	Socio-economic status	<ul style="list-style-type: none"> • Poverty • No High School Diploma • Unemployment • Housing Tenure • Housing Burdened Lower-Income Households • Lack of Health Insurance • Lack of Broadband access
	Household characteristics	<ul style="list-style-type: none"> • Age 65 and Older • Age 17 and Younger • Civilians with a Disability • Speak English "Less than Well"
	Housing type	<ul style="list-style-type: none"> • Group Quarters • Mobile Homes
	Environmental Burden	
	Air pollution	<ul style="list-style-type: none"> • Ozone • PM 2.5 • Diesel Particulate matter • Air Toxics cancer risk
	Potentially Hazardous & Toxic sites	<ul style="list-style-type: none"> • National priority list sites • Toxic Release Inventory sites • Treatment, Storage, and Disposal • Risk Management Plan Sites • Coal Mines • Lead Mines
	Built Environment	<ul style="list-style-type: none"> • Recreational Parks • Houses Built pre-1980.

		<ul style="list-style-type: none"> • Walkability
	Transportation Infrastructure	<ul style="list-style-type: none"> • High Volume roads • Railways • Airports
	Water pollution	<ul style="list-style-type: none"> • Impaired Surface water
Health Vulnerability		
	Pre-existing Chronic Disease Burden	<ul style="list-style-type: none"> • Asthma • Cancer • High blood Pressure • Diabetes • Poor Mental Health

Specifically, the national data sources used for each indicator needed to satisfy several standards to be incorporated, such as the data must come from trusted, stable sources and accurately represent the intended exposure or outcome; the data must be methodologically robust and capture the phenomenon of interest in an analytically sound way; the data must be available or easily calculated at fine geographic scales of census tract or below; and the data must be regularly updated to enable ongoing updates to the index.¹⁶ By carefully vetting all data sources on these criteria - accuracy, analytical quality, geographic scale, and timeliness - the index was built using only the most rigorous, validated measures to allow reliable tracking of environmental justice dynamics on a national scale.¹⁶

Overall EJI calculation

Environmental Burden Module (Percentile Ranked Sum of Environmental Burden Indicators (range = 0 – 1)) + Social Vulnerability Module (Percentile Ranked Sum of Social Vulnerability Indicators (range = 0 - 1)) + Health Vulnerability Module (Ranking* Calculated from Health Vulnerability Flags (range = 0 - 1))= Overall EJI Score (range = 0-3) → Final EJI Ranking (range = 0-1).¹⁶

Socio-Environmental EJI (SE-EJI)

The EJI database provides a secondary Social-Environmental Ranking (SER) metric, referred to as EJI in the manuscript, which combines the Environmental Burden and Social Vulnerability Module rankings while excluding the Health Vulnerability Module. The EJI SER enables research examining associations between environmental and social factors and health outcomes since it does not directly incorporate health data. Visualizing the EJI SER alongside High-Prevalence Flags illustrating rates of specific health conditions can elucidate relationships between environmental/social injustice and health that warrant further investigation.¹⁶ This alternative ranking facilitates secondary analyses where the exposure-

outcome relationship is of interest rather than the cumulative impacts encapsulated in the full EJ model.¹⁶

Calculation of SE-EJ

Environmental Burden Module (Percentile Ranked Sum of Environmental Burden Indicators (range = 0 – 1)) + Social Vulnerability Module (Percentile Ranked Sum of Social Vulnerability Indicators (range = 0 - 1))= EJ SE Score (range = 0-2) → Final EJ SER (range = 0-1)¹⁶

Note: Social Environmental Scores are percentile ranked to produce a final Social Environmental Ranking (EJ SER) with a range of between 0-1.¹⁶

The Environmental Burden Module contains indicators representing environmental exposures that impact health, reflecting the unequal distribution of hazards (distributive injustice) among communities with varying decision-making influences. Indicators capture potential contact with harmful substances, proximity to pollution, and lack of amenities detrimental to well-being. The inclusion criteria were,

- To be able to have a quantifiable health effect.¹⁶
- To have a plausible scientific rationale for the health effect caused.¹⁶
- Should have no overlap with other health metrics in the contribution of the health effect.¹⁶

The Social Vulnerability Module comprises indicators of characteristics that potentially reduce a community's ability to respond to environmental threats or make decisions (procedural injustice). These social factors constitute health risk factors that may interact with environmental burdens, exacerbating cumulative health impacts, as multiple stressors increase susceptibility to harm from economic fluctuations, environmental risks, and disasters.⁴¹⁻⁴³ Coupled environmental and social vulnerability work synergistically to heighten disease burden and health inequities.⁴⁴⁻⁴⁷ Social Vulnerability indicators represented disadvantaged populations with limited environmental advocacy.¹⁶ Capturing both modules elucidates multiple dimensions of environmental injustice and vulnerability to characterize cumulative health impacts in communities comprehensively.⁴⁵

Indicators of Socioenvironmental EJI have been summarized in Table S2.

Table S2. Indicators of Socioenvironmental EJI

	Indicators	Data Source	Description
1.	Minority status	U.S. Census Bureau American Community Survey (ACS)	Past and present racial residential segregation, income disparities, and institutional racism have frequently restricted non-white populations from effectively advocating against unwanted land use or participating in environmental decision-making processes, as evidenced by the disproportionate siting of contaminated sites near communities of color. ^{41,48} The CDC has labeled systemic racism a severe public health threat (https://www.cdc.gov/media/releases/2021/s0408-racism-health.html).
2.	<ul style="list-style-type: none"> • Poverty • No High School Diploma • Unemployment • Housing Tenure • Housing Burdened Lower-Income Households • Lack of Health Insurance • Lack of Broadband access 	U.S. Census Bureau American Community Survey (ACS)	Poverty indicates economic hardship that can impede a community's ability to influence environmental decisions, contributing to disproportionate siting of contamination in low-income areas. ^{49,50} Low-income populations are also more susceptible to adverse health effects due to stress and limited healthcare access. ^{51,52} Specifically, research shows stronger associations between air pollution and poor birth outcomes for mothers in impoverished neighborhoods. ⁵³ Educational attainment, an important socioeconomic factor, may affect the navigation of environmental health information and resources needed to impact decisions. ⁵⁴ Lower education also increases vulnerability, being tied to a higher risk of mortality and adverse birth outcomes. ⁵⁵ Unemployment indicates community disadvantage through lost income and social capital, further decreasing environmental advocacy capacity. Joblessness may prevent opposition to polluting industries that provide

			<p>employment.⁵⁶ Associated stress and inflammation may raise susceptibility to health effects.⁵⁷</p> <p>Renters are often considered more transitory and may have less social capital for environmental advocacy than homeowners invested in property values. Research also shows renters experience worse health outcomes, potentially due to interactions between socioeconomic status and housing quality differences.⁵⁸ Populations spending over 30% of income on housing costs (termed "housing burdened") may lack time or resources for environmental efforts. Housing instability also associates with reduced healthcare access, stress, and adverse child outcomes.⁵⁹ Approximately 11% of Americans remain uninsured despite recent expansions, disproportionately affecting lower-income, minority, and undocumented groups . Lacking insurance reduces environmental decision-making capacity and healthcare access following environmental exposures, increasing morbidity/mortality risk.⁶⁰ Finally, inadequate broadband access can impede informed civic participation and emergency communication on environmental issues.⁶¹</p>
--	--	--	--

<p>3.</p>	<ul style="list-style-type: none"> • Age 65 and Older • Age 17 and Younger • Civilians with a Disability • Speak English "Less than Well" 	<p>U.S. Census Bureau American Community Survey (ACS)</p>	<p>Adults over 65 have higher social isolation, potentially decreasing environmental advocacy, and accumulated exposures may increase physiological susceptibility.⁶² Those under the voting age have limited civic participation and resources but a heightened vulnerability to pollution due to developmental physiology and behaviors.⁴⁶ People with disabilities often face barriers to full environmental decision-making participation and disproportionate disaster impacts.⁶³ Specific disabilities also correlate with increased air pollution susceptibility.⁶⁴ Limited English proficiency can hamper environmental awareness and engagement since materials are often English-only.⁶⁵ Discrimination and language barriers are also associated with stress and exclusion.⁶⁵ Non-English speakers may be more vulnerable during environmental emergencies without translated materials.⁶⁵</p>
<p>4.</p>	<ul style="list-style-type: none"> • Group Quarters • Mobile Homes 	<p>U.S. Census Bureau American Community Survey (ACS)</p>	<p>Institutionalized groups like prisoners, nursing home residents, and psychiatric patients have limited autonomy and ability to influence environmental decisions but often face hazardous exposures from poor facilities, work programs, and neglect in planning.⁶⁶ Non-institutionalized residents of group quarters such as military bases, group homes, and shelters may have similarly constrained socioeconomic status, legal standing, time, and resources reducing environmental advocacy.⁶⁷ Mobile home communities are frequently zoned into low-value areas and occupied by disadvantaged groups like migrant farmworkers beholden to employers' pesticide decisions.⁶⁸ Stigma, land non-ownership, and housing quality issues, including poor construction, energy inefficiency, and unreliable water access, also diminish procedural justice capacities while increasing</p>

			mobile home residents' health vulnerability to pollution, heat, and inadequate sanitation.
5.	<ul style="list-style-type: none"> • Ozone • PM 2.5 • Diesel Particulate matter • Air Toxics cancer risk 	<p>U.S. Environmental Protection Agency National Air Toxics Assessment (NATA: modeled data)- -Diesel Particulate matter</p> <p>U.S. Environmental Protection Agency National Air Toxics Assessment (NATA; modeled data)</p> <p>U.S. Environmental Protection Agency Air Quality System (AQS; combined monitoring and modeled data) (PM 2.5 and Ozone)</p>	<p>Short- and long-term exposure to elevated ozone levels is associated with increased respiratory and cardiovascular morbidity and mortality.⁶⁹ Particulate matter 2.5 microns or less (PM2.5) can irritate eyes and airways acutely and heightens cardiovascular risks. Chronic PM2.5 exposure links to higher mortality across conditions, including cancer and cardiopulmonary disease, accounting for approximately 130,000 deaths in the U.S. in 2005.⁷⁰ Diesel particulate matter (DPM) comprises carbon cores with adsorbed organics, inducing inflammation and oxidative stress.⁷¹ DPM associates with acute coronary syndrome and contains carcinogenic compounds.⁷²</p> <p>The air toxicity-related cancer risk metric assesses lifetime cancer risk from inhaling 140 hazardous air pollutants (HAPs), including known carcinogens like benzene, dioxin, formaldehyde, and ethylene oxide.⁷³ Risks are estimated based on modeled concentrations, pollutant potency, and inhalation. Notably, diesel particulate matter (DPM) is one of the HAPs incorporated but also has non-cancer health effects, so it is indexed separately despite being a cancer risk component. DPM represents only one of 140 HAPs to construct the cumulative air toxicity-associated cancer risk value.</p>
6.	<ul style="list-style-type: none"> • National priority list sites • Toxic Release Inventory sites • Treatment, Storage, and Disposal 	<p>U.S. Mine Safety and Health Administration Mine Data Retrieval System (MDRS) (coal mines)</p> <p>U.S. Environmental Protection Agency Facility Registry Service (FRS) -Treatment, Storage, Disposal,</p>	<p>EPA National Priorities List (NPL) sites designated as cleanup priorities based on hazard assessments can present health risks to neighboring communities through multiple exposure pathways. While site-specific, proximity associates with stress and perceived risk.⁷⁴Contaminants may impact air, soil, and water, potentially exposing communities. EPA Toxics Release Inventory (TRI) sites reporting chemical manufacture or use above thresholds can also harm nearby residents through routine emissions. Proximity to</p>

	<ul style="list-style-type: none"> • Risk Management Plan Sites • Coal Mines • Lead Mines 	<p>Toxic Release Inventory sites, National Priorities List (NPL) sites.</p>	<p>TRI sites correlates with COPD hospitalizations and increased cancer risks.⁷⁵ Odors, noise, and stress may also burden neighborhoods with clustered noxious sites.⁷⁶ Treatment, Storage, and Disposal Facilities (TSDF) handle hazardous waste, which can volatilize or leach, leading to exposure through vapor intrusion or groundwater contamination.⁷⁷ Proximity to waste sites has been tied to increased rates of diseases like stroke, diabetes, and heart disease.⁷⁸</p> <p>Coal mining, including underground and surface methods like mountaintop removal (MTR), remains hazardous for nearby communities. Studies find elevated inflammation, cardiopulmonary disease, lung cancer, and mortality in heavy mining regions from air pollution.⁷⁹ Proximity to MTR is explicitly associated with impaired respiratory health and risks for mental illness and substance abuse.⁸⁰ In-utero exposures link to low birth weight.⁸¹ Groundwater contamination can occur from underground slurry disposal.⁸² Lead mines also endanger nearby residents by contaminating soil and dust. In the U.S. and globally, proximity to active lead mines correlates with increased blood lead in children.⁵⁸</p>
7.	<ul style="list-style-type: none"> • Recreational Parks • Houses Built pre-1980. • Lack of Walkability • Transportation Infrastructure 	<p>TomTom MultiNet® Enterprise Dataset (Airports, Railways, High Volume roads, Recreational parks)</p> <p>U.S. Environmental Protection Agency National Walkability Index (walkability)</p>	<p>Parks and greenspaces provide health benefits as settings for physical activity, urban heat mitigation, and mental health.^{83,84} However, quality, safety, and gentrification can mediate impacts.⁸⁵ Still, the lack of access to these spaces constitutes an environmental injustice.⁸⁶ Housing built before 1978, when lead paint was banned, can expose residents to lead risks if paint chips or flakes. Older housing consistently predicts children's blood lead, which has no safe levels and causes neurodevelopmental harm.⁸⁷ Walkability describes the extent to which environments</p>

		U.S. Census Bureau American Community Survey (ACS)-Houses Built pre-1980.	<p>encourage walking and physical activity through connectivity, land use mix, and transit density. Walkability associates with increased activity, lower BMI, glycemic control, and mortality.⁸⁸ It also correlates with accessibility for those with disabilities.⁸⁹ Thus, walkability provides health benefits, though rural-urban differences exist.⁸⁹</p> <p>High-traffic roads constitute hazards through vehicular emissions contributing to air pollution, runoff depositing metals and chemicals, and noise elevating stress and cardiovascular risks.⁹⁰ Like roads, railways generate noise pollution that combines with traffic noise to create annoyance and stress, disrupting sleep and blood pressure.⁹¹ Airports also impose noise burdens that heighten community stress and sleep disruption.⁹¹ Airports contaminate air, soil, and water through chemical releases from storage tanks, firefighting, and stormwater.⁹²</p>
8.	<ul style="list-style-type: none"> Impaired surface water 	U.S. Environmental Protection Agency Watershed Index Online (WSIO)	<p>Surface waters like rivers and lakes have recreational and subsistence value. Impairment from pathogens or toxic substances can pose nuisances or hazards to nearby communities. Pathogen contamination creates infection risks from recreational contact.⁹³ Chemical contamination enables bioaccumulation of pollutants in fish that can expose residents to ingesting contaminated fish.⁹⁴</p>