GLOBAL HEART

Environmental Stressors and Cardiovascular Health: Acting Locally for Global Impact in a Changing World

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A statement of the European Society of Cardiology, the American College of Cardiology, the American Heart Association, and the World Heart Federation

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ABSTRACT

Non-communicable diseases (NCDs) account for 70% of global mortality and are responsible for over 38 million deaths annually, with cardiovascular disease (CVD) constituting most of these fatalities. While traditional risk factors for CVD have long been recognized, there is growing evidence that a rising prevalence of ubiquitous environmental risk factors (ERFs) may play an increasingly significant role in the genesis and rising prevalence of NCDs. ERFs include many interconnected anthropogenic exposures with cumulative compound health impacts, including air pollution, noise exposure, artificial light at night, plastic pollution, chemical pollution and the various effects of climate change, such as heat extremes, desert storms, floods and wildfires. Urbanization has intensified the impact of many ERFs and created intense exposure environments, highlighting the urgency and the opportunity to address these for maximum public health benefit. Impactful intervention often requires regulatory and policy-driven efforts addressing the genesis of exposures and minimizes their health impact, particularly in vulnerable populations who may contribute the least but may be impacted the most. Solutions must involve the development of resiliency and adaptation measures to a changing world, where the probability of sudden catastrophic and cascading events is much more likely. Political will and international cooperation are essential in establishing and enforcing regulations that promote cleaner air and water, quieter and natural biodiverse environments, and sustainable infrastructure in urban, and rural medical facilities. Integration of planetary and environmental health into cardiovascular care will be vital in reducing the burden of NCDs globally. By addressing the root causes of environmental stressors, it is possible to reduce the incidence of CVDs and promote healthier, just and sustainable societies.

KEYWORDS:
Environmental stressors; Cardiovascular disease; Noise; air pollution; Climate change; Mitigation; public health awareness

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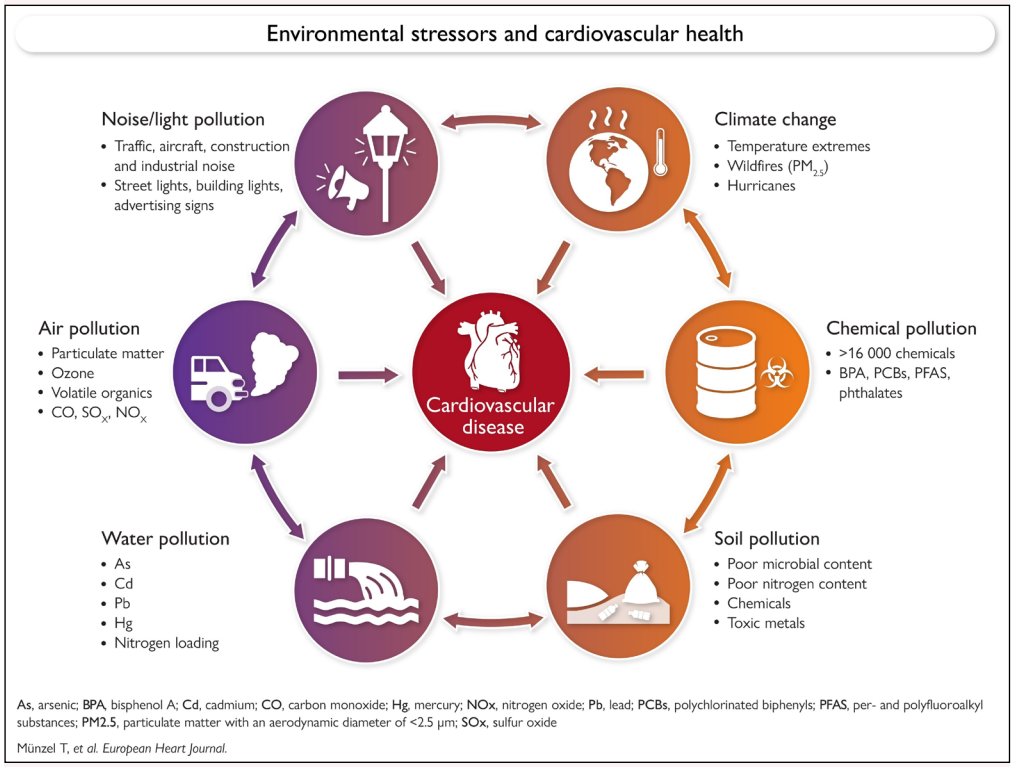
GRAPHICAL ABSTRACT



Environmental stressors and cardiovascular health multiple environmental exposures, including noise and light pollution, air pollution, water and soil contamination, chemical pollution, and climate change, contribute to cardiovascular disease (CVD) through shared and interacting pathways involving oxidative stress, inflammation, autonomic imbalance, and endothelial dysfunction. The interplay among these stressors amplifies overall cardiovascular risk and underscores the need for integrated exposome-based prevention strategies.

NONCOMMUNICABLE DISEASES AND ENVIRONMENTAL RISK FACTORS

Noncommunicable diseases (NCDs) are the leading cause of mortality globally, accounting for 70% of deaths, with cardiovascular disease (CVD) constituting 44% of these fatalities (1). While traditional risk factors such as diabetes, hypertension, smoking, hypercholesterolemia, and genetic predisposition are well-established, environmental risk factors (ERFs) are emerging as critical contributors to NCDs (2, 3). Residual environmental cardiovascular risk refers to the portion of unaccounted cardiovascular risk after addressing traditional factors (4). ERFs include a range of exposures such as air and noise pollution, chemical contamination, artificial light at night, and climate change effects like heat extremes, floods, wildfires, and desert storms (*Graphical Abstract*) (5). Urbanization intensifies these exposures, creating diverse, compounded, and cumulative health impacts (6–9). The diversity and scale of these stressors in urban areas further underscore the urgency and opportunity to address environmental risks comprehensively and at scale for the largest public health impact (6, 7). Ultimately, healthy, resilient populations are critical to prosperous and sustainable economies.

GLOBAL BURDEN OF ERFS AND CARDIOVASCULAR HEALTH

Recent estimates suggest that cardiovascular risk from ERFs now exceed many conventional risk factors, contributing to ~20 million deaths annually through ischemic heart disease, stroke, hypertension, and type 2 diabetes (3, 10). Pollution alone is responsible for 9–12.6 million deaths yearly, depending on the metric (3). However, these figures likely underestimate the actual burden, as they do not fully account for ERFs like plastic pollution or their interactions with cardiovascular risk factors like hypertension and diabetes.

ERFs often stem from provisioning systems, food, energy, water, housing, and transportation, essential for human sustenance but inherently linked to resource extraction and environmental degradation. The sustainable development goals (SDGs) in 2015 and the planetary boundary framework injected a nature-society–economy framing for the health impact of environmental and climate risk factors, helping endorse the concept that conserving nature and the planet is foundational for cardiovascular health (11, 12). The dramatic rise in climate-related events such as flooding, wildfires and pandemics has intensified the realization that integrating planetary and environmental health into cardiovascular care will be vital in reducing the burden of NCDs globally (6, 9, 13, 14). Nature-positive strategies, which prioritize the restoration, preservation, and sustainable management of ecosystems, offer a powerful approach to achieving planetary health goals while mitigating pollution and its associated cardiovascular health impacts.

SYSTEMS-LEVEL FRAMEWORK FOR CUMULATIVE EXPOSURES

Understanding the cumulative impact of ERFs requires a systems-level framework that integrates socio-ecological and infrastructural factors (7, 15). Traditional single-exposure models fail to address the reality of combined exposures, such as concurrent air pollution, noise (16), and chemical contaminants (17), interacting with social determinants like income and access to green spaces (18).

The exposome is an integrating concept developed to capture lifetime exposures from many sources (8, 18, 19). Current epidemiologic studies focus on operationalizing a more practical idea of the exposome to improve our understanding of the health impact of multiple exposures in the external environment (20).

A framework for understanding multiple exposures also necessitates a socio-ecological-infrastructural approach, which links key provisioning systems that determine exposures and cumulative health impacts. The socio-ecological aspect of the framework considers how demographic factors, community structures, and social inequalities shape exposure profiles (21). This framework also accounts for how social and technical factors influence health resilience or vulnerability (Figure 1). Key provisioning systems such as transportation, energy production, food systems, waste management, and industrial activities create distinct exposure profiles based on proximity and intensity and also distinctive hazards (6, 21, 22). For example, transportation systems emit noise air and chemical pollutants, exposing nearby populations to continuous low-level stressors linked to adverse cardiovascular and respiratory outcomes. Energy systems reliant on fossil fuels contribute to greenhouse gases and particulate matter, exacerbating air, soil and water pollution and amplifying health risks. Lack of green spaces is associated with increased exposure to urban heat islands and pollutants while reducing opportunities for physical activity, which can buffer against stress-induced health impacts (7). Disruption of and vulnerabilities in infrastructure and provisioning systems predisposes to substantial health risks (Figure 1). Emerging methodologies and tools are revolutionizing our ability to understand complex systems, predict outcomes, and design interventions.

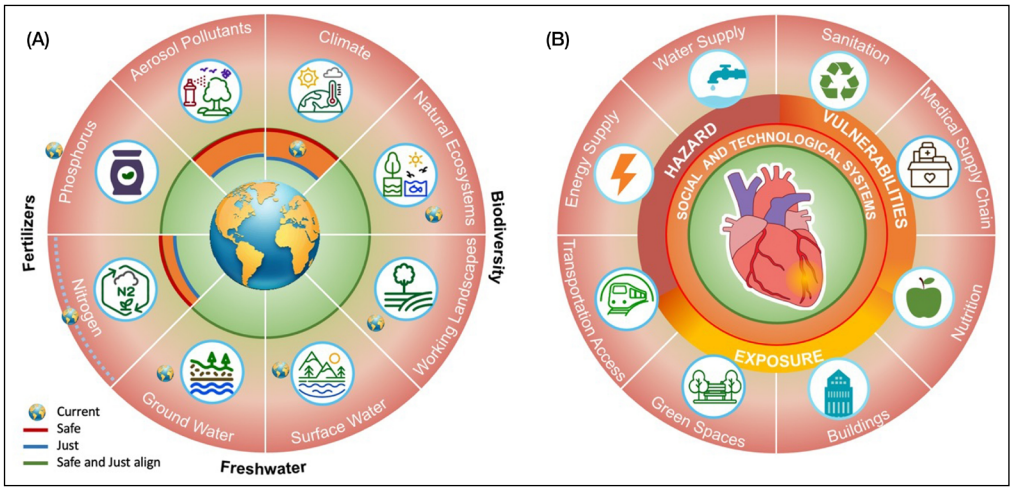


Figure 1 Planetary and cardiovascular health, the two indivisible parts of the same token to health. **(A)** The New Planetary Boundary Framework of Earth System Boundaries, where safe and just boundaries and current global states (Earth icons) are depicted. Minimum access to water, food, energy and infrastructure for all humans could constitute the foundation of a safe and just 'corridor'. **(B)** Globally, key provisioning systems that provide food, energy, mobility-connectivity, housing, green infrastructure, water management and waste management and access to health care, lie at the core of human well-being, equity and sustainability. Adapted from Nature. 2023 Jul;619(7968):102–111, an Open Access article distributed under the terms of the Creative Commons CC BY License.

PUBLIC HEALTH AWARENESS AND HEALTHCARE TRAINING

Public awareness of ERFs as contributors to serious illnesses, including CVD, remains limited, hindering the adoption of protective behaviours. While air quality indices (AQIs) provide generalized warnings, they lack consensus definitions and are often insufficiently personalized to guide individual actions (23). There is no accepted international consensus or standardization of approaches to communicate air pollution levels and risk, resulting in a myriad of AQIs worldwide (24). Similarly, education and alerts for noise exposure and most known pollutants and toxins are scarce but critical for at-risk populations.

While exposures to many toxins and chemical exposures may warrant their avoidance, especially when combined with ecological benefits, for many ERFs, the lack of knowledge on safe thresholds and the appropriate methods to reduce exposure limits large-scale deployment of ERF reduction measures. There continues to be a gap in medical provider awareness of the role of ERFs in cardiovascular health (23). While prior guidelines recognized the environmental origins of CVD, typically only factors in the diet, lifestyle and air pollution are acknowledged (25). Most guidelines do not integrate environmental assessments and considerations into risk assessments (26). Incorporation of screening for ERFs and integration in clinical risk assessment is needed to address individual risk seamlessly (23, 27).

Indigenous knowledge and wisdom of the ancients, which emphasize holistic and systems thinking, remain underutilized despite their alignment with planetary health principles (28).

Public health campaigns should bridge these gaps by promoting community engagement and offering practical interventions, such as indoor air purifiers or sustainable transportation options. Educating individuals about the cumulative impacts of ERFs empowers them to make informed decisions and advocate for regulatory change.

URBAN PLANNING AND PUBLIC HEALTH

With nearly 70% of the global population expected to live in urban areas by 2050, cities are pivotal in addressing environmental and health challenges (29). Urban environments contribute disproportionately to CVD and type 2 diabetes through pollution, sedentary lifestyles, and poor nutrition (2, 30, 31).

Cities also produce 75% of global greenhouse gas emissions, exacerbating environmental and health risks (32). Urban design initiatives, such as the '15-Minute City' and low-traffic zones, promote walkability, reduce pollution, and encourage healthier lifestyles (8, 33). Compact cities, which integrate active transport and green spaces, can avoid significant health impacts, including 400–800 disability-adjusted life-years per 100000 annually (34).

Integrated urban planning with a health perspective can reduce carbon emissions while improving access to heart-healthy foods, recreational spaces, and efficient waste systems. Policies emphasizing health co-benefits, such as the Health in All Policies (HiAP) framework, are critical for aligning urban transformation with public health goals (35).

POLICY SOLUTIONS FOR ERF MITIGATION

Holistic policies addressing ERFs must target both direct drivers, like fossil fuel use, and indirect drivers, such as inequality and unsustainable consumption. For instance, air pollution control policies should include stricter emission standards, promote renewable energy sources, and expand urban green spaces (36).

Addressing noise pollution involves urban planning strategies like noise barriers and green buffers. Soil and chemical pollution require regulations to reduce pesticide use and promote sustainable farming practices (17). Combating plastic pollution necessitates bans on single-use plastics, financial incentives for biodegradable alternatives, and recycling programs. The built environment can be improved through sustainable urban planning that emphasizes walkability, cycling, and public transport, reducing dependency on cars and improving overall environmental health.

These interventions must integrate socio-ecological dimensions, promoting equity while reducing the cumulative health burden of ERFs. Collaboration across governments, businesses, and communities is essential for successful implementation.

HEALTHCARE ORGANIZATIONAL SUSTAINABILITY

Healthcare organizations (HCOs), which in this document also refer to the pharmaceutical and medical ancillary industry, contribute substantially to environmental pollution. Over 4% of global greenhouse gas emissions are also attributed to healthcare activities (37). Sustainability initiatives, such as switching to renewable power in health care, energy-efficient technologies, green building designs, waste reduction strategies, can all lower operational costs while enhancing environmental health and meeting climate goals (38, 39, 40). The incorporation of circular economic principles of reduce, reuse, recycle and recover, reducing the use of single-use plastics in healthcare and food waste and switching to sustainable foods and sourcing in HCOs are all imperative steps that not only meet the triple mandate of sustainable practices including economic, environmental/climate and social objectives but in many ways the larger objectives of health care (40). Approximately 10%–15% of hospital waste is food-related, underscoring the need for sustainable transformation of food in HCOs (41). Healthful plant-based diets that reduce or eliminate intake of animal products, may help meet climate objectives while maximize favorable impacts on human, animal and environmental health (42). Advocacy for global policies limiting plastic production and promoting recycling can significantly reduce environmental and health risks (36). The reduction in plastic use will also help reduce environmental pollution including from toxic chemical exposures (36).

The environmental footprint in cardiovascular practice is also related to the diagnosis and treatment of disease. In particular, the use of devices and surgeries are large sources of emissions (e.g. percutaneous coronary intervention, coronary artery bypass grafting, ablations, etc.). As such, rearranging the current therapeutic paradigm in CVD treatment, and shifting towards primordial and primary prevention becomes an important target to achieve environmental, social, and financial sustainability (40). Primordial prevention—targeting lifestyle changes and early interventions—reduces healthcare utilization and emissions. Policies like removing cost barriers for preventive services and limiting sugary beverages and tobacco sales, align environmental and health benefits (40).

Healthcare providers can educate patients and engage in sustainability efforts within HCOs. As authoritative voices on health, HCOs can advocate for policies addressing the root causes of environmental health risks. They can support research and public policy initiatives to reduce emissions, limit industrial pollution, and promote green urban planning.

CLIMATE ADAPTATION AND HEALTH SYSTEM RESILIENCE

Funding for climate adaptation in healthcare remains limited, with only 35% of countries implementing heat-related health early warning systems (43). The WHO Health System Resilience Framework and the new Operational Framework for Climate-Resilient and Low Carbon Health Systems outline components vital to adaptation and health system resilience to the climate crisis (44, 45). These include governance and leadership, health workforce training, upgrades to climate sensitive technologies and medical products, community engagement and reduction in carbon emissions. Resilient health systems can help absorb challenges posed by climate change, ensuring essential health services in times of climate crisis and promoting sustainable well-being. A recent scoping review documented efforts toward resilient health systems, primarily in developed nations (46). Across the world, only a minority of countries have initiated plans for adaptation and resilience.

Successful disaster response includes emergency risk communication including a strengthening linkage between early warning systems and healthcare facilities to ensure a timely adaptive response also allowing rapid disease-specific responses (9). This requires a mapping of care pathways for CVDs related to exacerbation of ERFs and establishment of health system resilience to climate shocks and escalation of other ERFs. This also includes upgrading health infrastructure, ensuring medical equipment resilience, and establishing backup and off-grid power sources for uninterrupted healthcare during climate events. Improving ventilation for thermal comfort, enhancing health supply chains to reduce pollution, quickly identifying needed supplies, and stockpiling essentials are key strategies (9).

Integrated response plans must involve marginalized communities to enhance equity and resilience. Strengthening primary healthcare and multisectoral coordination can improve adaptability to climate challenges.

Investments in resilient healthcare infrastructure, such as improved ventilation and backup power systems, are necessary to ensure service continuity during climate events. Table 1 depicts critical pathways to build resilient health systems (46).

Table 1 Health System Adaptation and Resilience Measures.

DOMAIN	MEASURE	DESCRIPTION
Governance	Policy and Legislation	Establish legal frameworks for emergency response and resilience building.
	Multisectoral Collaboration	Foster partnerships across government, private sector, and civil society.
	Risk Communication Strategies	Implement effective communication protocols to inform and engage stakeholders.
Infrastructure	Climate-Resilient Facilities	Design health facilities to withstand climate extremes (e.g. floods, heatwaves).
	Disaster Preparation	Securing Supply Chains
	Decentralized Services	Increase the reach of health services by decentralizing healthcare delivery systems.
	Sustainable Energy Sources	Equip health facilities with renewable energy systems to ensure continuity during crises.
Healthcare Workforce	Workforce Training	Train healthcare providers on emergency preparedness, climate impact mitigation, and adaptive care.
	Retention Strategies	Incentivize healthcare professionals to remain in underserved or crisis-prone areas.
	Mental Health Support	Provide psychological support to healthcare workers during and after crises.
Service Delivery	Integrated Care Models	Incorporate preventative, curative, and rehabilitative care into resilience strategies.
	Telemedicine Implementation	Expand telemedicine to ensure access during emergencies or in remote areas.
	Stockpiling and Supply Chain Management	Develop robust systems for securing and distributing medical supplies and essentials.
Health Information	Early Warning Systems	Use surveillance systems to detect and respond to health threats early.
	Data Sharing and Interoperability	Create platforms for sharing health data among institutions and regions.
	Community-Based Reporting	Engage communities in health monitoring and reporting for real-time insights.
Community Engagement	Public Awareness Campaigns	Educate communities on health risks and resilience strategies.
	Empowerment of Local Leaders	Train local leaders to take proactive roles in crisis management.
	Behavioral Change Interventions	Promote sustainable behaviours to reduce health risks (e.g. sanitation, handwashing).
Financial Resilience	Emergency Funds	Allocate specific budgets for health system adaptation and crisis response.
	Health Insurance Schemes	Enhance access to healthcare through universal health coverage or targeted schemes.
	Cost-Effective Technologies	Invest in low-cost, high-impact interventions for resource-limited settings.

OCCUPATIONAL HEALTH AND CLIMATE

Occupational health assessments should incorporate climate-related risks like heat stress and hazardous exposures. Protecting healthcare workers involves optimizing ergonomics,

enhancing staffing policies, and improving health care coverage. Beyond the WHO framework, social support systems and community-oriented approaches are essential for addressing broader resilience challenges.

CALL TO ACTION: TACKLING NCDS AND ENVIRONMENTAL RISK FACTORS GLOBALLY THROUGH LOCAL ACTION

The rising global burden of NCDs, and the accelerating threats posed by ERFs demand immediate, coordinated, and courageous actions. to reduce pollution, mitigate climate change, adopt sustainable practices, and reduce personal and societal exposure to harmful ERF's—particularly in low- and middle-income countries that disproportionately bear the brunt of global environmental degradation. Governments, HCOs, communities, civil society, and individuals must urgently prioritize environmental health as a central pillar of public health strategy. Concrete and concerted actions are needed immediately, given that the world is already hurling towards unprecedented changes. Some of the most important initiatives are highlighted below.

(1) Advocacy and Policy Influence. Strengthen, align, and advocate local and national policies that prioritize environmental effects on CVD.

- **(a)** Advocate for international funding that support low- and middle-income countries disproportionately affected by the **pollution paradox**: those contributing least to environmental degradation yet suffering the greatest health consequences.
- **(b)** Integrate environmental cardiovascular health into national climate policy, urban policy, and planetary health dialogues.

(2) Research and Data-Driven Initiatives. Develop an integrated global evidence base on ERFs and NCDs that informs targeted action.

- **(a)** Advocate for global environmental health observatories to monitor air, water, noise, and temperature stressors and their cardiovascular impacts.
- **(b)** Prioritize funding for transdisciplinary and translational research that connects bench-to-bedside science with planetary-scale environmental data.
- **(c)** Incentivize implementation science initiatives by connecting communities with researchers, systems scientists and indigenous traditions to develop understanding and context-specific solutions

(3) Education and Capacity Building. Expand global awareness and clinical competence in environmental cardiology.

- **(a)** Embed environmental determinants of cardiovascular health into core curricula for all health professionals—positioning ERFs alongside traditional risk factors.
- **(b)** Build capacity within health systems for anticipatory governance, climate resilience, and disaster preparedness.
- **(c)** Support community health workers and citizen science networks to detect, report, and respond to environmental threats to cardiovascular health.

(4) Local-Global Partnerships. Accelerate South-South and North-South collaborations to create global response and shared resources to combat ERFs.

- **(a)** Establish international consortia of care providers, researchers, public health leaders, and impacted communities to share data, co-design interventions, and advocate for systemic change.
- **(b)** Foster regional Centres of Excellence in Environmental Health and CVD across Africa, South Asia, and Latin America to tailor solutions to local realities.
- **(c)** Promote equitable technology transfer and capacity exchange, especially for low-resource settings facing escalating environmental exposures.

(5) Implementation of Actionable Strategies. Translate science into policy, and policy into practice.

- **(a)** Align environmental health interventions with global frameworks including the SDGs, the Paris Agreement, and the WHO Roadmap for NCDs.

(b) Advocate low-emission zones, green infrastructure, sustainable transport, and clean energy as co-benefit solutions for both heart and planet.
(c) Promote just transition policies that prioritize health equity in environmental reforms, ensuring that no community is left behind.

(6) Development of Global Guidelines. Establish authoritative, harmonized standards for environmental cardiovascular health.

(a) Support the World Health Organization, European Society of Cardiology (ESC), American Heart Association (AHA), World Heart Foundation (WHF), and American College of Cardiology (ACC) in developing harmonized global guidelines that address air, noise, chemical pollution, climate stressors, and their cardiovascular impacts.
(b) Promote widespread adoption and implementation of these guidelines through regulatory bodies and professional societies.
(c) Ensure guidelines reflect cultural contexts, vulnerable populations, and emerging threats

By addressing these challenges collectively, organizations such as the ESC, ACC, AHA, and WHF can help promote healthier populations, mitigate environmental degradation, and ensure a sustainable future for future generations.

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