The Impact of Climate and Environmental Change on Brain Health

Banyan Commons

Neuro Climate WORKING GROUP

EcoNeuro

NEURO CLIMATE SCIENCE AND POLICY REPORT 2026

Table of Contents

Foreword

When we think about the health impacts of climate change, we often think of our lungs, our hearts, or the spread of infectious diseases. Rarely do we think about the organ that allows us to learn, remember, create, care for one another, and adapt to an uncertain future: the brain.

Yet our brains are constantly shaped by the environments in which we live. The air we breathe, the food and water we consume, the temperatures we experience, the disasters we endure, and the communities in which we grow all influence brain development, cognitive function, mental wellbeing, neurological health, and healthy aging. As climate change reshapes these environments, it is also reshaping brain health in ways we are only beginning to understand.

As a neuroscientist, I found it striking that despite a rapidly growing body of research linking climate-related environmental exposures to brain health, this evidence remained scattered across disciplines, diseases, and environmental risk factors. Neurologists, psychiatrists, psychologists, environmental scientists, epidemiologists, pediatricians, public health experts, and policymakers were often asking different questions, speaking different scientific languages, and working in parallel rather than together. There was no common framework, no shared research agenda, and no roadmap for translating this knowledge into action.

The International Neuro Climate Working Group (NCWG) was created to help change that. From the very beginning, our vision has extended beyond building a scientific network. We wanted to build a global community capable of connecting science with policy, lived experience, education, and action. We believed that understanding climate change's impacts on the brain required not only interdisciplinary collaboration, but also meaningful partnership with those living through these changes every day. This is why this report brings together scientific evidence alongside lived experience narratives, youth perspectives, expert insights, and case studies from around the world. It is also why we have prioritized perspectives from low- and middle-income countries and communities disproportionately affected by climate change, recognizing that the greatest burdens are often borne by those who have contributed least to the crisis.

This report reflects more than two years of collaborative work by an international interdisciplinary Expert Committee and many contributors across the broader NCWG community. It synthesizes what we know, identifies what we still need to learn, and offers practical pathways forward through the Neuro Climate Framework, the Neuro Climate Research Agenda, and the Neuro Climate Action Roadmap. Our goal is not simply to document the problem, but to help accelerate solutions.

Perhaps the most hopeful message to emerge from this work is that protecting brain health and protecting the planet are deeply aligned. Many of the actions that reduce greenhouse gas emissions and strengthen climate resilience, cleaner air, greener and cooler cities, healthier food and water systems, resilient healthcare, and more equitable communities, also protect and promote brain health. To invest in brain health is to invest in our collective capacity to innovate, cooperate, and respond to the challenges ahead.

We hope this report serves as a resource for researchers, healthcare professionals, educators, policymakers, community leaders, and all those working toward a healthier, more resilient future. Most importantly, we hope it helps ensure that brain health offers a foundational lens through which we understand, address, and ultimately overcome one of the defining challenges of our time.

Burcin Ikiz, PhD

Founder and Chair,
International Neuro
Climate Working Group

About Us

About the International Neuro Climate Working Group

The International Neuro Climate Working Group (NCWG) is the first global interdisciplinary action tank dedicated to advancing research, policy, and action at the intersection of climate change and brain health. Founded in 2024, the NCWG has grown into a global community of more than 500 scientists, clinicians, public health professionals, policymakers, educators, designers, architects, youth leaders, advocates, and people with lived experience from over 60 countries.

United by the shared goal of protecting and promoting brain health on a changing planet, the NCWG serves as a platform for collaboration, knowledge exchange, capacity building, and collective action. Through research, education, policy engagement, and community partnerships, the NCWG works to translate scientific evidence into practical solutions that improve health, strengthen resilience, and reduce inequities worldwide.

About the Report

This report was developed by an interdisciplinary Expert Committee convened by the NCWG. Over more than two years, it underwent multiple rounds of writing, expert review, revision, and consensus-building, while also drawing on contributions from the broader NCWG community, invited experts, and an international call for case studies, lived experience narratives, youth perspectives, and expert insights. Several components of this report have also undergone, or are undergoing, independent peer review through publication as scientific reviews and policy commentaries in academic journals.

The report synthesizes the current scientific evidence on how climate-related environmental exposures affect neurological health, mental health, cognition, neurodevelopment, and healthy brain aging. In addition to presenting the Neuro Climate Framework, it identifies priority directions for future research through the Neuro Climate Research Agenda and outlines stakeholder-specific recommendations through the Neuro Climate Action Roadmap, providing practical guidance for researchers, policymakers, healthcare professionals, educators, communities, individuals, and international organizations.

Executive Summary

Brain health is a missing dimension of the climate crisis.

Climate change is one of the defining public health challenges of the twenty-first century. While its impacts on cardiovascular, respiratory, and infectious diseases are well recognized, a rapidly expanding body of evidence demonstrates that climate change and environmental degradation also affect neurological health, cognition, mental health, neurodevelopment, and healthy brain aging across the lifespan. These impacts extend beyond health, influencing education, productivity, wellbeing, resilience, and economic prosperity.

This report synthesizes the current scientific evidence on how climate-related environmental exposures affect brain health and translates that evidence into practical guidance for researchers, policymakers, advocates, and community members. Developed by an international interdisciplinary Expert Committee convened by the International Neuro Climate Working Group (NCWG), the report combines scientific evidence with lived experience narratives, international case studies, youth perspectives, and expert insights to provide an integrated roadmap for protecting brain health in a changing climate.

Key Findings

Climate change affects brain health through six major environmental exposures:

- **Extreme heat** impairs cognition, sleep, mental wellbeing, and neurological function while increasing risks of heat-related neurological illness.
- **Air pollution** contributes to neurodevelopmental disorders, stroke, dementia, neurodegenerative diseases, cognitive decline, and adverse mental health outcomes.
- **Extreme weather events** affect brain health through injury, trauma, displacement, disruption of healthcare, chronic stress, and long-term neurological and psychological consequences.
- **Food insecurity and malnutrition** impair brain development, cognition, and mental wellbeing.
- **Water and soil contamination** increase exposure to neurotoxic contaminants that affect neurological development and function.
- **Vector-borne diseases** can spur acute and chronic neurological complications.

Executive Summary

Brain health impacts accumulate across the lifespan and across generations.

Climate-related environmental exposures influence brain health before birth and through older adulthood. Prenatal and early childhood exposures can alter brain development with lifelong consequences, while repeated exposures throughout life may contribute to cumulative neurological injury, cognitive decline, and increased risk of neurodegenerative disease. Climate change therefore has the potential to influence brain health both within and across generations through biological, psychological, and social pathways.

Climate change disproportionately affects vulnerable populations.

Although climate change affects everyone, its impacts are not distributed equally. Social and economic disruptions associated with climate change amplify brain-health risks through poverty, displacement, educational disruption, and reduced access to healthcare. Children, pregnant women, older adults, people living with neurological and mental health conditions, Indigenous peoples, displaced populations, outdoor workers, and communities experiencing environmental and socioeconomic disadvantage often face the greatest exposures while possessing the fewest resources to adapt.

What is new in this report?

This report provides the first integrated roadmap for understanding and addressing climate change and brain health through three complementary contributions:

The Neuro Climate Framework illustrating the interconnected biological, psychological, and social pathways linking climate change and brain health.

The Neuro Climate Research Agenda identifying priorities for the next generation of interdisciplinary, globally representative, and solutions-oriented research.

The Neuro Climate Action Roadmap outlining practical recommendations for policymakers, healthcare professionals, educators, communities, individuals, people with lived experience, and international organizations.

A Call to Action

Many of the interventions needed to address climate change—including cleaner air, greener and cooler cities, resilient food and water systems, healthy schools, climate-resilient healthcare, and equitable community investments—also protect and promote brain health. Integrating brain health into climate research, policymaking, healthcare, and community action represents an opportunity to reduce disease burden, strengthen resilience, improve quality of life, and support healthier, more sustainable societies. For these reasons, protecting brain health must become a central objective of climate action.

At a Glance

6	Major climate-related environmental exposures
Across generations	Early-life exposures and repeated climate-related hazards can have lifelong and intergenerational consequences
Across the lifespan	From prenatal brain development to healthy brain aging
626,000	Estimated dementia deaths attributable to air pollution globally in 2023[1]
2.2%	Every 1°C above local baseline is associated with roughly a 2.2% rise in mental-health-related mortality[2]
0	Across 160 countries, not a single national adaptation policy addresses children's mental health[3]
Up to 45%	Dementia cases may be preventable or delayed through addressing modifiable risk factors, including environmental exposures such as air pollution[4]
3 Major contributions	• Neuro Climate Framework • Neuro Climate Research Agenda • Neuro Climate Action Roadmap

Key Terms

Blood-brain barrier: A layer of tightly packed cells that controls what can pass between the blood and the brain, allowing needed substances through while helping block harmful ones.

Brain health: A multidimensional concept encompassing the structure and function of the brain across the lifespan. Throughout this report, brain health is used as an umbrella term to include neurological health, mental health, cognition, memory, neurodevelopment, behavior, and healthy brain aging, recognizing that these domains are interconnected and influenced by biological, psychological, social, and environmental factors.

Climate-related environmental exposures: Environmental conditions influenced directly or indirectly by climate change, including extreme heat, air pollution, extreme weather events, food insecurity, water and soil contamination, and vector-borne diseases.

Climate resilience: The ability of individuals, communities, institutions, and systems to anticipate, adapt to, respond to, and recover from climate-related challenges while maintaining health and wellbeing.

Co-benefits: Positive outcomes arising from a single intervention across multiple sectors. Many climate actions provide co-benefits by simultaneously reducing greenhouse gas emissions, protecting brain health, improving physical health, strengthening resilience, and promoting health equity.

Intergenerational: Occurring or having effects across generations, including when the experiences, environments, or health of one generation influence the health and well-being of subsequent generations.

Lived experience: Knowledge and perspectives gained through direct personal experience of climate-related environmental change and its impacts on brain health. Throughout this report, lived experience is recognized as an essential source of knowledge that complements scientific evidence and informs research, policy, and practice.

Mental health: A state of emotional, psychological, and social wellbeing that enables individuals to cope with life's challenges, build relationships, and contribute to society. Mental health is one important component of overall brain health.

Neurodegeneration: The progressive loss of nerve cells and brain tissue, which can lead to a decline in brain function over time.

Neurological health: The healthy structure and function of the brain, spinal cord, and peripheral nervous system, including the prevention and management of neurological disorders such as stroke, dementia, neurodegenerative disease, epilepsy, migraine, and multiple sclerosis.

Oxidative stress: A condition that occurs when there are too many unstable molecules called free radicals in the body and not enough antioxidants to remove them, which can damage cells and tissues.

The Neuro Climate Framework: A conceptual framework describing how climate-related environmental exposures influence brain health through interconnected biological, psychological, and social-structural pathways, providing an integrated approach to research, policy, and action.

01

Introduction

Introduction

Climate change represents one of the most significant global health challenges of the 21st century. While its effects on some bodily systems, such as cardiovascular, respiratory, and immune function, are well recognized, growing evidence points to parallel and often underappreciated consequences for the brain, including both neurological and mental health domains. As rising global temperatures intensify the severity and frequency of extreme weather events, their direct and indirect impacts on brain health are exacerbated.[1-3]

Brain health, which encompasses neurological function, mental health, cognitive abilities, and psychosocial behavior, serves as the foundation for human productivity, social relationships, creativity, wellbeing, and overall quality of life. Emerging evidence reveals concerning risks to brain health from climate-related stressors, but the field lacks comprehensive understanding of these relationships, highlighting a need for systematic research approaches and a coordinated research agenda to address these critical knowledge gaps.

In recent years, the evidence linking climate change and environmental degradation to brain health has expanded rapidly. Studies have documented associations between climate-related environmental exposures and a broad range of brain health outcomes, including neurological disease,[3-5] mental health conditions,[2,6,7] and the effects of environmental exposures such as air pollution[8] and heat.[9] Integrating evidence across exposures, outcomes, disciplines, and stages of the life course can help illuminate cumulative and interacting risks, identify shared biological mechanisms, reveal opportunities for prevention and resilience, and inform more coordinated research, policymaking, and practice. Throughout this report, we seek to provide an integrated overview of the current evidence, highlight cross-cutting themes and knowledge gaps, and identify opportunities for collective action to protect and promote brain health in a changing climate.

The present report has been prepared by an interdisciplinary expert committee of the International Neuro Climate Working Group (NCWG), a global network of over 500 scientists, clinicians, public health professionals, and policy experts working at the intersection of climate change and brain health. With this work, we offer a uniquely integrated perspective on the effects of climate change across neurological, mental, and cognitive domains of brain health. Our goal is to create a foundational resource for a broad range of stakeholders, including scientists, clinicians, public health leaders, and policymakers, and to highlight urgent research priorities that can guide future inquiry and action. We have intentionally selected studies with robust methodologies, including meta-analyses, longitudinal cohorts, and other evidence syntheses where available, to highlight the most rigorous and policy-relevant evidence, rather than attempting to be exhaustive.

Building on this evidence base, we then turn from characterizing risks to charting a response, outlining priorities for research, surveillance, and policy development. In particular, we emphasize the need to translate existing scientific knowledge into actionable guidance through targeted investments, cross-sectoral collaboration, and equitable approaches that prioritize vulnerable populations and low- and middle-income countries (LMICs), where compounded exposures and limited adaptive capacity magnify risk. Such an approach is aligned with the NCWG goals of integrating brain health into the global climate and health agenda, enhancing understanding of relevant risk factors, reducing health disparities exacerbated by environmental exposures, and catalyzing both adaptive and mitigatory policy responses.

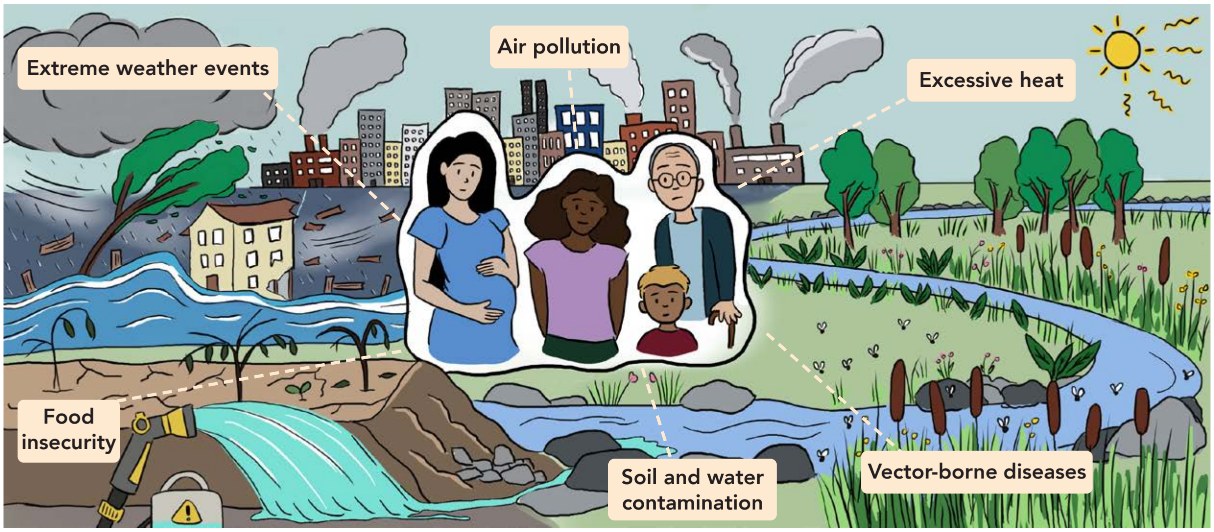
We first synthesize evidence concerning six major climate- and environmental-change-related threats to brain health (Figure 1). We then draw these findings together in an integrative model of biological, psychological, and social-structural pathways and identify policy levers across municipal, national, and multilateral governance.

"Climate change is an ongoing, deep emotional and psychological crisis; one that is defining our sense of safety, connection, work, home, and future in unprecedented ways compared to past generations. It is ever-present in our lives. Young people (and everyone) deserve greater literacy around how climate change affects our minds and bodies. Many of us are moving through these experiences without language or understanding. Access to awareness is helpful and a right."

Muskan Lamba

Co-Chair, Child & Youth Working Group, Global Mental Health Action Network & NCWG Youth Council Member, India

Six climate change-related factors affecting brain health



Outcome domains

● Neurodevelopmental ■ Neurodegenerative ▲ Mental health ⬟ Intergenerational ✦ Other neurological

Factors	Domains	Brain health outcomes
Excessive heat	● ■ ▲ ✦	Higher stroke and dementia admissions; worse symptoms in epilepsy, multiple sclerosis, migraine; impaired cognition; increased suicide risk, psychiatric visits, and aggression
Extreme weather events	● ▲ ⬟	Altered neurodevelopment after prenatal exposure; acute and chronic stress responses lead to post-traumatic stress disorder, depression, anxiety, substance abuse, and suicidality
Air pollution	● ■ ▲ ⬟ ✦	Particulate matter and nitrogen oxides cause inflammation and neuronal injury, linked to dementia, cognitive decline, depression, anxiety, and psychosis
Food insecurity	● ▲ ⬟	Maternal-fetal and childhood undernutrition disrupt brain development; psychological distress and increased symptoms of depression and anxiety
Soil and water contamination	● ■ ▲ ⬟ ✦	Heavy metals disrupt synaptic transmission and neurotransmitter balance; pesticides impair neurodevelopment and cause behavioral change
Vector-borne diseases	● ▲ ⬟ ✦	Meningitis, encephalitis, congenital microcephaly, and Guillain-Barré syndrome; neurocognitive deficits and mental health disorders in affected populations

Figure 1. Climate change affects our brain health directly and through secondary effects on cognition and behavior. Climate change and related environmental factors affect brain health through direct and indirect pathways, influencing neurological function, cognition, and mental health across the lifespan.

02

Exposure to Excessive Heat

Climate change is raising average global temperatures and increasing the frequency, intensity, and duration of heat waves. Extreme heat poses threats to overall brain health and function (Figure 2). In 2024, heat-related fatalities among individuals over 65 years of age rose by 63% compared to the average per year in the 1990s.[13] As climate change progresses, heat-related morbidity and mortality are expected to rise further. Significant temperature fluctuations strain the body's thermoregulatory abilities, affecting multiple physiological systems, including the nervous system.[5] Hyperthermia, failure of thermoregulatory processes, typically at body core temperatures exceeding 40° C, can lead to heat stroke, circulatory collapse, seizures, and other life-threatening outcomes.[14]

Extreme heat exacerbates symptoms in individuals with existing neurological disorders and is associated with higher hospital admissions, with evidence of increased risk of stroke, migraines, Alzheimer's disease, epilepsy, and worsened multiple sclerosis symptoms.[5,9] Modeling studies predict an increase in neurodegenerative diseases like Alzheimer's, other dementias, and Parkinson's as planetary warming continues.[15] Extreme heat disrupts sleep cycles and circadian rhythms, which can affect neurological conditions such as epilepsy and stroke.[7] Temperature extremes also pose developmental consequences. For example, one recent study found that prenatal and early-childhood exposure to both unusually cold and hot ambient temperatures is linked to slower microstructural maturation of children's brain white matter, especially among those in socioeconomically disadvantaged neighborhoods.[16]

Higher ambient temperatures and heatwaves are significantly linked to worsened mental health outcomes for individuals and populations,[17] such as increased rates of depression, anxiety, and suicide, with meta-analysis indicating that every 1°C rise is associated with an approximately 2.2 -percent increase in mental health–related mortality[2] and additional studies showing increased associations between temperature variability and heightened risk of suicide.[18] Extreme heat has been linked to an increase in acute presentations of psychiatric disorders and increased emergency department visits for substance use disorders, anxiety, stress-related and somatoform disorders, mood disorders, schizophrenia, schizotypal and delusional disorders, self-harm, and childhood-onset behavioral disorders.[5,19] Importantly, some psychiatric medications can impair thermoregulation, making individuals more sensitive to heat-related illness.[20]

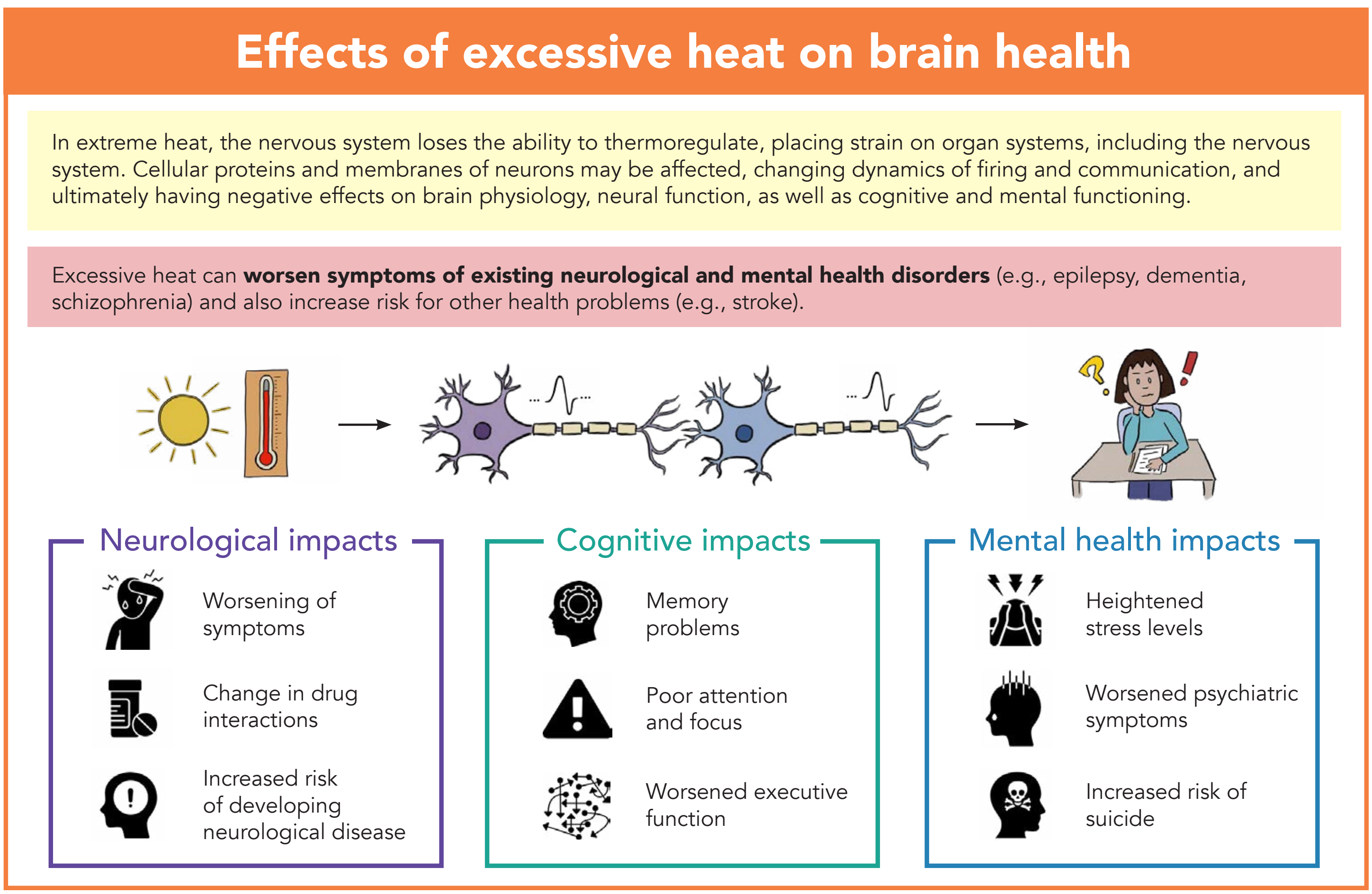


Figure 2. Exposure to extreme heat can disrupt brain function and worsen symptoms of existing neurological and mental conditions. Extreme heat can disrupt brain function by impairing thermoregulation, altering neural activity, and triggering neuroinflammatory responses, which can exacerbate existing neurological and psychiatric conditions and impair cognition and behavior.

Heat can also disrupt the gut microbiome, which is associated with neurodegenerative diseases,[21,22] highlighting an additional indirect link between climate change and neurological disease. Moreover, heat stress may independently disrupt gut barrier integrity, driving endotoxaemia and systemic inflammation that compounds the neuroinflammatory burden already present in populations with impaired renal clearance of gut-derived uremic neurotoxins. This is a pathway with particular relevance for the rapidly growing number of people with chronic kidney disease in climate-vulnerable regions.[23]

Prolonged exposure to high temperatures can impair cognitive functions, including selective attention, executive function, and overall mental acuity.[24,25] Evidence from 58 countries suggests heat exposure has a direct effect on the rate of learning.[26] The effects of excessive heat on cognition and executive function are widespread across various sectors. For instance, judges issue harsher verdicts[27] and in workplaces, higher temperatures correlate with decreased productivity.[28] In addition to impairing cognitive functions, extreme heat exposure has been associated with behavioral changes such as increased impulsivity, aggression, and violent crime.[29,30]

The neurobiological and physiological mechanisms linking immediate impacts of heat to mental health outcomes (e.g. increased risk of suicide during heatwaves) are unknown. To understand the underlying physiology of heat effects on brain function, studies have relied on animal models, with evidence suggesting that high temperatures disrupt neural-circuit activity, resulting in seizure-like states.[31,32]

In addition, heat exposure triggers neuroinflammatory responses and complex cellular changes, including oxidative stress and mitochondrial dysfunction, all of which are linked to neurodegeneration at long timescales.[33] Further evidence from animal research suggests that during hyperthermia, the integrity of the blood-brain barrier, which separates the brain from the bloodstream, is weakened,[34] potentially making the brain more susceptible to toxin exposure and inflammation. Blood-brain barrier dysfunction has been implicated in neurodegenerative diseases and contributes to pathology in a range of neurological conditions,[35] highlighting a potential risk connecting heat exposure to development of neurological dysfunction, though more research is needed to investigate this link. High ambient temperature also tends to disrupt functional connectivity patterns in the brain, potentially offering a system-level explanation of cognitive and behavioral changes, such as poor decision-making and impulsivity, observed during hyperthermia.[36]

"As a climate epidemiologist studying the effects of extreme heat on mental and brain health, the cutting edge of our field is currently exploring the mechanisms which drive the links between depression, anxiety, suicidal ideation, and cognitive decline, potentially via disruptions to HPA axis regulation, the epigenome, and the permeability of the blood brain barrier."

Robbie Parks, PhD

Assistant Professor,
Environmental Health Sciences

Columbia University, USA

Chronic Heat: Mental and Brain Suffering in Mauritania and the Sahel

Case study from Mauritania, Sahel, West Africa

Extreme and continuous heat in the Sahel exceeds human adaptation thresholds. It lasts all year round, with no nighttime respite, and increases the vulnerability of populations. As a Mauritanian psychiatrist, I observe the impact of continuous extreme heat on the mental and brain health of populations in Mauritania and the Sahel on a daily basis, particularly the most vulnerable.

It is a suffering hidden behind smiles and apparent resilience.

The migratory aspect is visible: villages emptied of their vital force because their land has become foreign to them. Only elders remain. Deaths, where burial becomes a problem for lack of able bodies. I also see the emergence of inter-community conflicts, because the common enemy, heat and scarcity of resources, remains invisible.

In the Sahel and in Mauritania, heat worsens inequalities in brain health. Without access to coolness, the poorest tire out faster. Psychosocial support alone is no longer enough. Ignoring this link means letting an entire region age and suffer in silence.

As a solution, I propose applied research studies on heat and brain suffering in the Sahel, raising awareness among populations and decision-makers about the medical aspect of thermal suffering, and taking action on the ground: heat-adapted housing, training for health workers, and moving beyond the psychosocial threshold to integrate medical understanding.

– Moktar Sissako, MD

Did She Swim in Cold Water as a Child?

Case study from Northeastern United States

Episodes of extreme heat have been noted to be increasingly prevalent. For my mom, Elsie, extreme heat was more than an abstract concept. Instead, it was a preventable environmental hazard that I believe hastened her decline.

Elsie was the eldest daughter of an Indigenous woman. My grandmother did her best to expose her children to her culture, teaching them to live in harmony with nature, including having her children spend as much time as possible in the frigid Atlantic Ocean waters off the coast of the Northeastern United States during the hot summer months. Decades later, when Elsie was diagnosed with Alzheimer's Disease, she lost many memories of her recent life. What she didn't lose was the drive to return to the nature that nurtured her as a child. During periods of extreme heat exacerbated by her inability to afford the extra energy costs for air conditioning, Elsie's cognition drastically declined. She lost her capacity to care for all daily care needs. The next summer, during another period of extreme heat, she exhibited another notable decline, almost never recognizing her children or grandchildren anymore. During one particularly hot day, one of the nurses at the facility at which she now lives asked me, "Did she swim in cold water as a child?" Elsie had screamed at the staff that she needed to get to the ocean to cool down. Despite efforts to use cool cloths or cold drinking water to calm Elsie down on very hot days, nothing seems to work.

It's not only instances of extreme heat that are increasingly prevalent. Instances of dementia are, too. I have observed the harm of extreme heat on the overall well-being of individuals like my mom, whose deteriorating cognitive capacities are stressed by environmental factors like extreme heat. For individuals like Elsie, whose cultural values incorporated regular environmental exposure as part of a wellness regimen, the detrimental impact of extreme heat may result in additional harm, one not necessarily measured by traditional health metrics.

For people like Elsie, and countless others whose aging minds are impacted by dementia, they – and those involved in their care – should not have to be additionally harmed by preventable changes in the environment. The cold waters of my mother's youth - and the comparatively cooler summer temperatures - should still be a reality. But, in order for that to happen, we need to do what my grandmother and mother did – remember that each of us is part of the environment, and care for it so that it – like us – remains healthy for years to come.

– Anonymous

"As a researcher and consultant, I see the built environment as our first line of defense against the health impacts of climate change. As someone living with epilepsy, that line of defense is currently failing. When urban heat islands spike, so does the physiological stress on the brain, lowering seizure thresholds and compromising neurological safety. By bridging the gap between environments (architectural and climatic) and brain health, we move beyond sustainable buildings toward environments that actively protect cognitive resilience and neurological stability."

Jessie Buckle

Inclusive Research and Design Specialist & PhD Candidate in Architectural Design

University College London, United Kingdom

03

Extreme Weather Events

Aside from heat waves, extreme weather and climate events include droughts, floods, hurricanes, and severe storms, all of which are increasing in frequency and/or intensity due to climate change in some regions of the world.[37] These events have far-reaching consequences for human health and well-being, including brain health.[7,33]

The connection between extreme weather, climatic variation, and neurological disorders is a growing concern in the context of climate change. Extreme weather phenomena can trigger acute stress, trauma responses, fatigue, and sleep disruptions due to home displacement, food insecurity or contamination, and the rise of water- or vector-borne infections. Following extreme weather events such as increased rainfall and flooding, an increased incidence of water-borne diseases like leptospirosis, shigellosis, and hepatitis A can lead to severe neurological complications.[33] Moreover, extreme weather events can hinder access to essential medical care, disrupt healthcare systems, and interrupt the continuity of care for individuals with neurodegenerative disorders and other medical conditions, exacerbating symptoms and accelerating disease progression. This impact is particularly severe for those with limited resources to mitigate the effects of the events, such as those living in low- and middle-income countries.[9,38]

Extreme weather events intensified by climate change cause substantial physical and psychological distress by increasing exposure to trauma and compounding acute stress.[6]

As climate change increases the frequency of extreme weather events, individuals are increasingly likely to experience multiple disaster exposures, with significant implications for mental health.[39] Secondary stressors include financial burden, displacement, community disruption, property damage; and losses in education, healthcare, food and water security, and social networks. Events like floods and typhoons are strongly associated with poor mental health, with evidence showing long-term mental disorders in survivors.[40] Experiencing climate-change-related disasters and their disruptive effects on the lives of residents can lead to mental health conditions like depression, anxiety, and PTSD.[41] Extreme weather can also worsen pre-existing mental health conditions, particularly for those who sustain physical or property damage.[42] Forced displacement, infrastructure loss, livelihood disruption, and prolonged recovery periods can contribute to a pervasive sense of despair, with vulnerable populations, including children, the elderly, low-income, and racial minorities, facing higher risk.[43]

Emerging evidence suggests experiences with extreme weather events can also lead to impairments in cognitive function. For example, extreme weather event exposure has been associated with deficits in working memory,[44] cognitive processing, mental flexibility, and sustained attention.[45] One recent study showed that experiencing a wildfire is associated with diminished cognitive performance, particularly with respect to interference processing, i.e. distractibility, and heightened stimulus-evoked fronto-parietal activity 6 to 12 months after the disaster,[46] highlighting that these negative effects are not short-lived.

Neurobiological processes can be altered by extreme weather events. Recent research indicates that extreme weather events may spur structural alterations in the brains of individuals exposed in utero, specifically in the amygdala, caudate, and hippocampus, leading to longer-term behavioral phenotypes.[47] Extreme weather exposure during pregnancy has been associated with alterations in placental gene expression related to neuroinflammation, which in turn are linked to changes in infant temperament.[48] Adult PTSD that has developed as a result of exposure to climate-related disasters also appears to have a somewhat unique neurobiological signature as compared to PTSD from other causes (e.g., in war veterans).[49] This disparity might suggest that treatments need to be tailored based on the origin of the underlying trauma; however, research in this area is limited.[50]

"In Malaysia, climate-related changes, including monsoons, flooding, and prolonged dry seasons, are already disrupting food systems, fisheries, livestock care, and access to clean drinking water. These cascading impacts are contributing to malnutrition as well as rising rates of obesity, hypertension, and diabetes, which in turn increase the risk of stroke, cognitive impairment, and mental illness. Efforts are now underway to better understand these links and implement preventive strategies, starting with strengthening food security and water sustainability."

Prof. Jafri Abdullah, MD

Professor of Neurosurgery & Chairman, Brain Behaviour Cluster

Universiti Sains Malaysia, Malaysia

What a Flood Leaves Behind

Case study from Nigeria

Recurrent seasonal flooding in flood-prone communities across Nigeria destroys homes, displaces families, disrupts healthcare, and contaminates water sources, creating conditions that amplify outbreaks of waterborne diseases such as cholera. For children and caregivers, the consequences can extend beyond the immediate emergency, disrupting routines, safety, and emotional well-being.

During a flood season, a four-year-old boy was brought to our community health post by his grandmother because his mother was wading through knee-deep water with what remained of their belongings.

The flood had displaced the family and contaminated the water around their community. The boy developed cholera and had been vomiting for a day, becoming severely dehydrated. Then his small body suddenly went rigid. His arms locked, his eyes rolled back, and he started seizing.

He did survive after urgent treatment, but the grandmother stayed with me. She sat outside for hours, waiting for news. When someone finally came to update her, she did not cry. Her hands simply would not stop shaking.

She had already buried a grandchild during the previous outbreak, three years earlier. So for her, this was not just another rainy season. It was another flood, another displacement, another outbreak and another fear of losing someone she loved.

The effects of a flood can continue long after the water recedes. When flooding forces a family from home, the loss is more than physical. Children can lose routines, familiar surroundings, and a sense of security, while caregivers carry the responsibility of keeping families safe amid uncertainty. There is also the risk of repeated exposure to illness. Repeated displacement and health emergencies can compound psychological distress, particularly where mental-health services are already scarce. Climate resilience must therefore consider the emotional aftermath of displacement alongside disease prevention.

Solutions don't have to be complicated. It starts with things like clearing blocked gutters before the rains start or keeping rehydration salts stocked at community health posts. This can stop cases like this from reaching crisis points. When families are displaced, mental-health support should travel with them to give children and caregivers access to psychosocial support and help bridge gaps where specialists are scarce.

– Miracle Adesina

Chronic and Daily: Canadian Wildfire Season and Migraine

Case study from Northwest Territories, Canada

In July 2026, dozens of active wildfires contributed to devastating air quality in Yellowknife. The air quality index exceeded 200 and the PM2.5 concentration was more than 60 times the World Health Organization annual PM2.5 guideline value.

As a chronic daily migraine patient, the pain I experience is tied directly to my environment. As climate change renders wildfires more frequent and severe, I find myself bracing for impact during seasons I could previously thrive. While temporarily living in Yellowknife in July 2026, I was debilitated by wildfire smoke. My sleep was interrupted by choking fits due to the poor air quality. I woke up each morning with irritation in my eyes, nose, and throat. The smoke gave me a throbbing migraine before even getting out of bed in the morning. I would exhaust my daily medication limit before noon, finding no relief. For weeks, I was ineffective at work and absent from social gatherings because my pain was unbearable. The changing climate has also robbed me of my coping mechanisms: I can no longer find solace in nature or participate in light exercise outside.

As a young person, I deserve to feel optimistic about my future. Instead, I fear a future where climate change disables me completely. I worry that as the air quality plummets, my migraines will become so severe that I can no longer live an enjoyable life. Beyond me, migraine patients may experience major gaps in health equity and become unable to fully participate in society. Given that migraine is among the most common causes of missed work in Canada, the workforce may be dramatically altered. In remote and Northern regions of Canada, such as Yellowknife, health disparities will be especially dramatic due to the limited number of healthcare professionals and treatment options available within the territory.

– Shannon Bird

Box 1. Wildfires as a Neuro-Climatic Syndemic

Wildfires exemplify the convergence of multiple climate-related stressors, heat exposure, toxic air pollution, displacement, and exposure to trauma, creating a "syndemic" of interrelated physiological and psychological harms.[141] Following one of the largest wildfires in California, researchers found significant impacts on mental health,[130] and over 7 million Californians affected by wildfires from 2011 to 2018 saw increased prescriptions for antidepressants, anxiolytics, and mood stabilizers.[142] Beyond these psychiatric effects, recent evidence also points to enduring cognitive consequences: Individuals exposed to wildfires demonstrate reductions in interference processing, the ability to filter out distraction, and sustained impairments in executive function more than a year after the disaster.[143] Studies investigating wildfire particulate matter exposure have illustrated increased risk of dementia and cerebrovascular disease and reductions in cognitive function.[144] However, such studies have focused solely on PM2.5 and investigated limited neurological outcomes. A significant gap remains in understanding how the combined and interacting stressors associated with wildfires collectively affect neurological function,[144] underscoring the urgent need for integrated research on this topic. Several potential mechanisms of harm are ripe for investigation, including thermal stress compromising the blood–brain barrier, PM2.5 and heavy metals inducing oxidative damage, and chronic psychosocial stress altering neuroendocrine regulation.

As the evidence base continues to grow, the urgency of climate-related brain health risks demands proactive strategies. Integrating brain health into disaster risk reduction frameworks is essential. Such efforts include mapping vulnerable populations (e.g., individuals with dementia, epilepsy, or severe mental illness), ensuring continuity-of-care plans for those reliant on medication or assistive devices, and developing early-warning systems that include neurocognitive and psychosocial risk indicators. Training healthcare and emergency personnel to recognize neurological vulnerabilities and incorporating air-quality alerts and evacuation support for high-risk groups can further enhance resilience. In the immediate response phase, integrating brain health monitoring for pregnant women, children, and people with pre-existing neurological or psychiatric conditions into emergency protocols—alongside neurocognitive screening programs and mental health first aid—can reduce acute harms. During the recovery phase, mobile clinics, insurance coverage for post-disaster cognitive assessments, and community-based interventions can support early detection and rehabilitation. In the long term, urban planning that incorporates green infrastructure, wildfire buffers, and air-filtration systems can reduce chronic exposure, while incorporating brain health indicators into disaster-impact assessments can ensure neurological and mental health outcomes are systematically tracked.

"Our research has quantitatively shown that wildfires drive community wide climate trauma - nearly a third of the impacted community can experience symptoms of PTSD, anxiety and depression, alongside cognitive impacts on attention and decision-making. There needs to be greater awareness of these impacts so we can continue to strengthen vital mental health supports for affected communities."

Jyoti Mishra, PhD

Associate Professor in Psychiatry
University of California San Diego

Co-Director, UC Climate Resilience Initiative, USA

04

Air Pollution

Air pollution is the number one risk factor for health loss worldwide[51] and the second leading risk factor for death, linked to 7.9 million premature deaths annually.[1] Air pollution and climate change form a reinforcing cycle: many pollutants worsen climate change, and climatic factors such as heat and wildfire smoke degrade air quality, thereby amplifying health and environmental impacts.[52] Air pollution impacts brain health across the life course (Figure 3). It is also a risk factor for cognitive decline and neurodegenerative diseases, with most recent estimates suggesting that more than 1 in 4 dementia deaths are attributable to air pollution.[1]

Long-term exposure to pollutants, such as ultrafine particles, particulate matter less than 2.5 μm in diameter (PM2.5), nitrogen oxides, and polycyclic aromatic hydrocarbons, significantly harms the central nervous system.[53] In-utero exposure to air pollution has been associated with neural tube defects and changes in brain structure and function.[54,55] In older adults, PM2.5 exposure accelerates brain aging and increases dementia risk, particularly in countries with high socioeconomic inequality.[56] Air pollution also raises stroke risk, with a 13-percent increase in ischemic stroke per 10 μg/m^3 PM2.5.[57] Other pollutants, such as carbon monoxide and sulfur dioxide, further correlate with stroke hospitalizations and mortality.[58] One large U.S. study showed that long-term PM2.5 exposure is linked to higher hospitalizations for Parkinson's disease and Alzheimer's disease, with dementia risk rising 3 percent per 1 μg/m^3 increase in PM2.5.[59]

Both outdoor and indoor pollutants from sources like cooking, vehicles, industry, and wildfires have been linked to adverse mental health outcomes. In a most recent example, PM2.5 pollution caused by lake desiccation was also linked to psychiatric outcomes such as major depressive episodes.[60] These effects are not equally distributed across the lifespan, with research indicating that the most detrimental effects are seen in children and older adults.[61,62] Prenatal PM2.5 exposure is linked to later psychotic and depressive symptoms in youth[63] and early exposure to PM2.5, ozone, or heavy metals is associated with neurodevelopmental disorders.[53,64,65] Repeated exposure to pollutants such as PM2.5, nitrogen dioxide, and sulfur dioxide can also increase the risk of schizophrenia, depression, anxiety, and suicide,[66,67] and even low-level PM2.5 exposure correlates with higher depression and anxiety prevalence.[68]

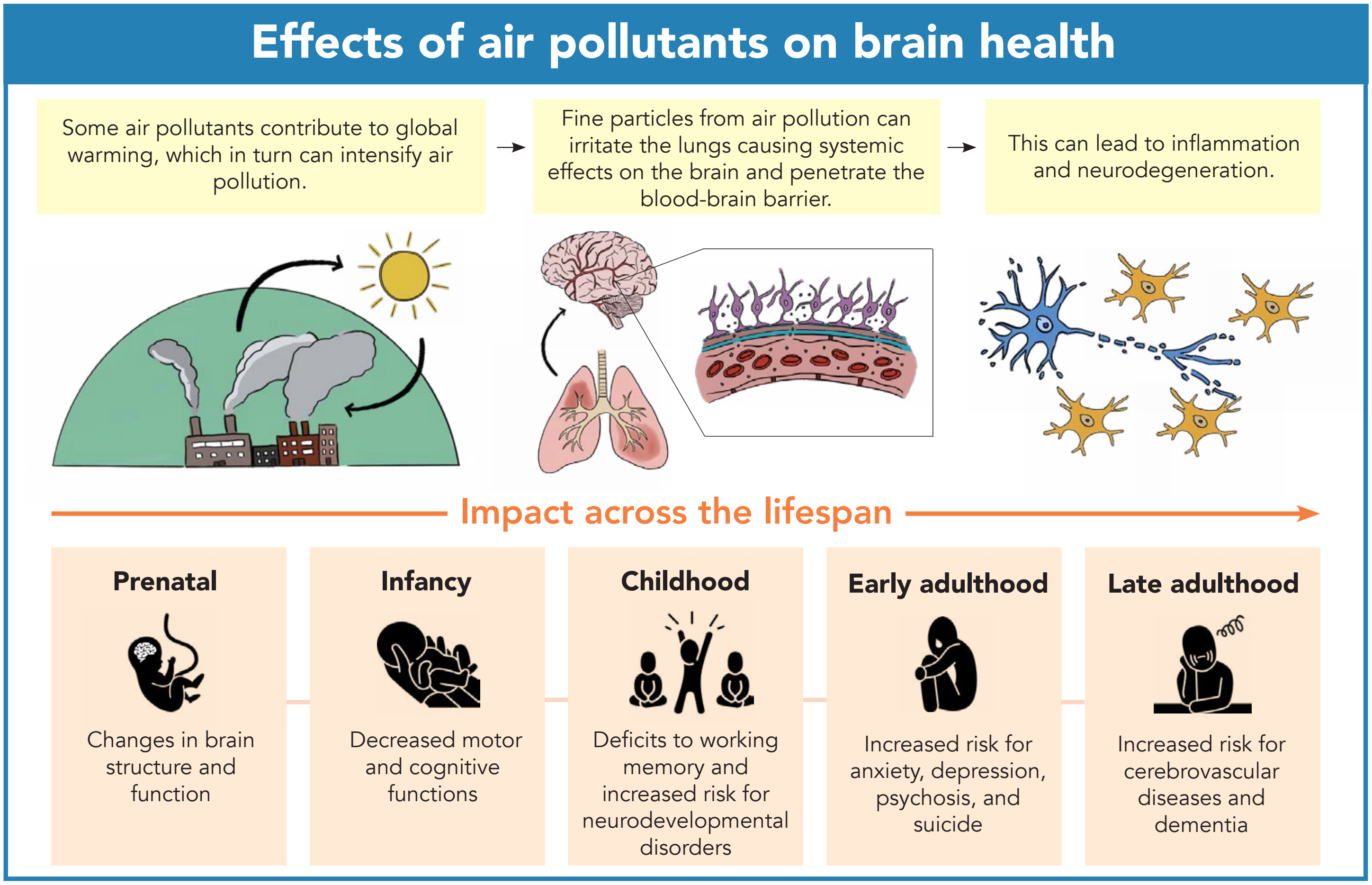


Figure 3. Exposure to air pollution can have long-lasting impacts on brain health throughout the lifespan and across generations. Long-term exposure to air pollution contributes to neuroinflammation, oxidative stress, and structural brain changes, increasing the risk of cognitive decline, mental health disorders, and neurodegenerative disease across the lifespan and into future generations.

Air pollution can also worsen mental health in people living with pre-existing mental health conditions.[63,69] Air pollution has also been associated with impaired cognitive function, executive control, decision-making and memory performance.[70-72]

Air pollutants contribute to neurological disorders primarily through oxidative stress and neuroinflammation.[73] Several pollutants, including PM2.5, can cross the blood-brain barrier, activating immune responses in astrocytes, microglia, and neurons, ultimately leading to neurotoxic effects.[74,75] PM2.5 exposure is associated with changes in white matter microstructure and subcortical brain volume.[76] Ultrafine particles smaller than PM2.5 can also bypass the blood-brain barrier, carrying neurotoxins with them.[77,78] Evidence also links PM exposure to epigenetic changes in neurons, some of which may have intergenerational implications.[79,80]

Historically, technical limitations in air pollution monitoring have hindered studies on long-term brain health impacts. However, advancements in remote sensing and satellite technology now allow for detailed tracking of exposure, improving research precision and accuracy.[81,82] Because air pollution exposure often correlates with socioeconomic factors like population density and poverty, rigorous study designs are essential to control for these variables.

"As a neurologist, what concerns me most is the risk of ischemic heart disease, stroke, and dementia caused by air pollution from the burning of fossil fuels. Many physicians and patients are unaware of this association. The risk can be reduced by reducing time on busy roadways, choosing a residence away from those roadways, and advocating societal change away from fossil fuels."

Larry Junck, MD

Professor Emeritus of Neurology

University of Michigan, USA

05

Food Insecurity and Malnutrition

Climate change affects food systems through extreme weather and climate events (e.g. floods and droughts), ocean acidification, soil degradation, and elevated atmospheric carbon dioxide, which decreases the nutritional value of food crops.[83] Estimates from 2024 suggest that 2.33 billion people experienced moderate or severe food insecurity and over 3.1 billion could not afford a healthy diet that year.[84] Limited access to diverse and nutritious food sources, or growing dependence on food sources with neurotoxic potential, can have severe consequences for brain health.[85-87]

The link between nutritional status and brain development is particularly poignant during critical developmental periods. Malnutrition during these times can cause long-lasting cognitive deficits. Essential nutrients such as iron, iodine, and essential fatty acids play crucial roles in brain development and function, and deficiencies in these nutrients can lead to significant impairments. For example, iron deficiency is associated with delayed cognitive development and behavioral issues,[88] while iodine deficiency can lead to brain damage and irreversible cognitive decline.[89] Due to the vulnerability of the developing brain to nutritional deficits, malnutrition during the first 1,000 days of life can trigger lasting impacts, including impaired brain structural and functional development and subsequent motor, behavioral, and cognitive problems.[85,90] These developmental risks may begin before birth, as maternal food insecurity during pregnancy has been associated with adverse outcomes in offspring.[91] Beyond these early developmental effects, food insecurity has also been associated with an increased likelihood of depressive symptoms and poorer cognitive function.[92] Additionally, food insecurity in low-income families could intensify the socioeconomic disparities in brain development, perpetuating a cycle of inequality and disadvantage.[93]

According to projections, the availability of docosahexaenoic acid (DHA), an essential omega-3 long-chain polyunsaturated fatty acid critical for vertebrate brain function, could significantly decrease due to climate change as fish populations decline.[94] By 2100, it is estimated that 96 percent of the global population may not have adequate access to DHA. This decline will disproportionately affect vulnerable groups, particularly fetuses and infants, with the most severe impacts anticipated in inland regions of Africa.[94]

One proposed modulating factor between malnutrition and brain health is the microbiome–gut–brain axis,[95] as it has been shown to influence neurological function, psychopathology, and cognition.[96] In cases of severe malnutrition, the infant's gut microbiome composition and the biochemicals exchanged through the gut–brain axis differ from those in healthy infants.[97]

"As climate change disrupts food systems and saps the nutritional value of our crops, food insecurity deepens and diets lose the nutrients that are the building blocks of a child's cognitive future. This damage often begins before birth, when maternal food insecurity during pregnancy can already set a child on a harder developmental path, and it deepens during the first 1,000 days of life, the very window when a child's brain is being built.

We know from decades of research that early malnutrition can leave lasting effects on cognition, learning, and lifetime opportunity. Those effects fall hardest on children in low-income communities who face the steepest barriers to good nutrition, compounding inequality across generations. If we're serious about protecting the next generation's minds, we have to treat climate action and food security as brain development policy."

Lisa Patel, MD, MESc, FAAP

Clinical Associate Professor of Pediatrics, Stanford Children's Health

Executive Director, Medical Society Consortium on Climate and Health at the Center for Climate Change Communication at George Mason University

Uncertainty Has Become the Season

Case study from Çukurova, Adana, Türkiye

From the Hittites and Assyrians to the Romans and present day Türkiye, Çukurova has, for thousands of years, been one of the Mediterranean's most fertile agricultural plains. These lands have nourished far more than crops; they have sustained cultures, identities, and ways of life passed down across generations even across civilizations. Today, however, Çukurova is experiencing the impacts of climate change with increasing intensity. Some years bring prolonged droughts and relentless heat; others, unusually severe rainfall that upends the rhythms of cultivation.

Tuna's family has lived and farmed these lands for more than a century, in the shadow of the ancient city of Anavarza, one of the great cities of ancient Cilicia, whose ruins have borne witness to centuries of the region's history. Here, their identity has been shaped by the soil itself. His childhood holidays were marked by the rhythms of harvest. Today, as a psychiatrist working on climate change and mental health, he returns to these same landscapes with different eyes. He no longer sees only the changing rivers, trees, and seasons; he also witnesses the traces these transformations leave on people's inner worlds, on their daily lives, and on their hopes for the future.

In this region, conversations have always found their way back to the land to the harvest, the weather, and the seasons. There was once a quiet confidence woven into those conversations. People knew which wind foretold rain, when the clouds would break, and which crops would flourish in each season. In recent years, however, those conversations have come to revolve around a single word: uncertainty. No one knows how the weather will unfold, whether the harvest will arrive on time, which crops will survive, whether hard work will be rewarded, or perhaps most painfully whether future generations will be able to continue their lives on these lands.

This uncertainty touches everyone, but it does not do so equally. Women carry not only the work of cultivation but also much of the responsibility for caring for children, supporting older family members, and holding together the emotional fabric of everyday life. Children may not yet have the words to describe climate change, but they absorb their parents' anxieties, the disruptions to daily routines, and the quiet unease surrounding the future. It is not only the environmental climate that is changing; the emotional climate in which women strive to sustain balance and children grow up is changing as well.

Yet the stories shared across Çukurova speak not only of vulnerability. They also reveal a remarkable resilience built over generations. Families continue to cultivate the land. Neighbours continue to support one another. Communities continue searching for ways to adapt to an uncertain future while holding on to the values that have long sustained them.

– Tuna Eker, MD; Selin Tanyeri Kayahan, MD

06

Water and Soil Contamination

Climate change spreads neurotoxic pollution. Extreme weather events such as storms, floods, high winds, and fires release and spread pollutants over large areas. Wildfires and floods that rip through homes scatter large amounts of lead, asbestos, e-waste, and other toxicants. These extreme weather events mobilize and remobilize pollution.[103] Even low level exposures can be toxic during early life.

Rising global temperatures and changes in precipitation patterns lead to more frequent floods and droughts, contributing to the increased contamination of water sources. Such contamination includes surges in pathogens, various pesticides, and microplastics in water supplies, which are hazardous to brain health.[33] Soil contamination, intensified by climate change, also poses a significant threat to brain health.[33] Warmer temperatures can lead to increased pest populations, prompting farmers to use more pesticides.[98] These chemicals, especially during more frequent and severe storms, floods, and other extreme weather events, can flow into water bodies and permeate soils. This cascade results in these chemicals entering the food chain and posing significant health risks.[99,100]

Among the contaminants, heavy metals like lead and mercury are especially concerning due to their neurotoxic effects. Lead has been shown to cause neurodevelopmental delays and cognitive impairments in children,[101] while mercury exposure can lead to severe neurological and behavioral disorders due to its impacts on the central nervous system.[102] Additionally, climate change acts on soil quality and composition, potentially increasing the bioavailability of other toxic substances like arsenic.[103] These materials can leach into groundwater and accumulate in food crops, further jeopardizing brain health.

Additionally, climate-change-driven warming and contamination of water increase the incidence of harmful algal blooms, which produce neurotoxins such as β-N-Methylamino-L-alanine (BMAA) and domoic acid.[104,105] For instance, domoic acid has been shown to cause neurological symptoms, such as seizures, limbic system degeneration, and memory impairment.[106] Rising temperatures also enhance the solubility and mobility of toxins, further complicating the scenario by increasing the spread and impact of these neurotoxins.[107] Furthermore, microplastics in water may act as carriers for other toxic substances, including heavy metals and organic pollutants, leading to their bioaccumulation in marine and terrestrial ecosystems,[108] with recent evidence illustrating microplastic accumulation in the human brain.[109] All these factors lead to increased and sustained exposure to harmful contaminants, intensifying their neurological risks.

Increased rainfall and flooding can wash pesticides and industrial chemicals into water bodies. Organophosphates, in particular, are potent neurotoxicants that inhibit acetylcholinesterase, an enzyme essential for breaking down the excitatory neurotransmitter acetylcholine in the brain. Such inhibition leads to overstimulation of nerve cells, which can cause neurodevelopmental and neurobehavioral issues and cognitive impairments.[110] Exposure to organophosphates has also been shown to increase the risk of developing neurodegenerative diseases.[111] In coastal regions, rising sea levels cause saltwater intrusion into freshwater aquifers, increasing water contamination risks and underscoring the urgent need for comprehensive public health strategies to mitigate climate-driven water and soil contamination.[112]

Childhood exposure to certain environmental toxicants such as lead and organophosphate pesticides has been linked to increased rates of mental health conditions such as anxiety, depression, and mood disorders in adolescence and adulthood.[113,114] The mechanisms behind these effects include the disruption of neurotransmitter systems that regulate mood and cognition, as well as the direct neurotoxic effects that alter brain function. The cumulative and synergistic effects of various waterborne and soil-based contaminants call for a broad approach to health assessments and interventions, especially considering vulnerable populations like pregnant women, whose developing fetuses are highly sensitive, and young children, whose brains are still undergoing critical periods of neurodevelopment.

"Climate change has enormous potential to undermine development gains and livelihood options for today's children. Children on the front lines of climate change often live in communities hit hardest by pollution, so-called sacrifice zones. To protect brain development of the next generation from climate change and pollution, bold action is needed at a much larger scale on air quality, food safety, water and sanitation, sustainable production, and waste management."

Kam Sripada, PhD

Associate Professor

Norwegian University of Science and Technology, Norway

07

Vector-borne Diseases

Zoonotic diseases, including vector-borne diseases (VBDs), are increasing in frequency and distribution as a direct result of climate change, with significant evidence linking changing environmental conditions, such as temperature, humidity, and precipitation patterns, to rising outbreaks globally.[115]

Climate change influences the life cycles and transmission dynamics of pathogens and vectors, affecting survival rates, distribution, and interactions between hosts and vectors.[116] For example, Aedes mosquitoes, primary vectors for diseases such as dengue, Zika, and yellow fever, have expanded their range due to warmer global temperatures, with the most significant impacts in tropical and subtropical regions, though recent expansions have also been observed in parts of Europe and North America.[117] Climate change also prompts shifts in human behavior, such as altered settlement patterns, outdoor activity, and occupational exposure, which can increase contact with disease-carrying vectors, further threatening brain health.[118]

VBDs can directly target the brain, as seen in Japanese encephalitis and tick-borne encephalitis, or cause neurological complications as a secondary effect of the pathogenic infection, as in the case of yellow fever. For instance, Dengue, the fastest-spreading tropical infection, is known to cause neurological complications, including encephalitis and encephalopathy, in between 0.5 and 21% of hospitalized patients.[119] Chikungunya, a mosquito-borne virus, can cause severe neurological complications, including encephalitis, myelopathy, neuropathy, and Guillain-Barré syndrome. Long-term neurological sequelae include cognitive impairments. Zika virus is associated with severe neurodevelopmental conditions, including microcephaly and cortical thinning, as well as neurological outcomes in adults like meningoencephalitis and Guillain-Barré syndrome.[120] West Nile virus poses a growing risk, particularly to vulnerable populations such as infants and the elderly, with severe encephalitis outbreaks observed globally.[121] Cerebral malaria, caused by Plasmodium falciparum, leads to severe neurological effects, including epilepsy and cognitive deficits,[122] with shifting climate patterns expected to alter its distribution.[123] Similarly, rising temperatures are increasing the spread of tick-borne diseases like Lyme disease, which can spur neurological complications such as neuroborreliosis,[124] as well as deleterious impacts on mental health,[125] with evidence suggesting long-term deficits in cognitive function in some cases.[126]

08
Socioeconomic and Demographic Factors

Climate change's impacts on brain health are unequally distributed across populations, with significant disparities both within and between countries. Socioeconomic, demographic, and geographic factors play a crucial role in determining vulnerability to climate-related neurological risks, as vulnerability arises from a combination of increased sensitivity (due to age or existing medical conditions), greater exposure to hazards (often linked to geographic location and existing infrastructure), and a lack of adaptive capacity (such as the inability to afford air conditioning or relocate from areas with poor air quality).[127-129]

Several demographic groups face disproportionate risks from climate change's impact on brain health,[7,11,131] including pregnant women, children, older adults, people with pre-existing health conditions, disabled populations, and low-income and Indigenous communities. Children and fetuses, for example, are particularly susceptible to air pollution, extreme heat, and nutritional deficits due to their developing bodies and brains,[132-134] while the elderly face increased risks from their reduced ability to regulate heat and typically smaller social support networks.[135] Between 2016 and 2023, extreme weather events displaced 62.1 million children, underscoring the profound challenges climate change and the downstream events pose for youth.[136]

Systemic inequities place marginalized communities at the epicenter of climate-related brain health risks, with limited healthcare access, heightened exposure to extreme temperatures, resource scarcity, and insufficient adaptive resources compounding their vulnerability.[137-139] The evidence provided in this report emphasizes the need for public health strategies that address immediate brain health risks and invest in long-term resilience and equitable outcomes. Recent evidence suggests that addressing the social determinants of mental health can yield not only substantial health improvements but also notable economic benefits,[140] offering a compelling rationale for investing in equitable interventions that enhance resilience among the most vulnerable populations.

Additionally, individuals who have suffered from early life trauma, such as adverse childhood experiences, are more likely to develop trauma-related disorders from exposure to climate change-related extreme events.[130]

"In my work with developing communities, particularly in rural and coastal areas, I see how climate change disrupts young people's connection to land, culture, and livelihood, which deeply affects their mental health and sense of identity.

When environments change or are damaged, it can create anxiety, grief, and uncertainty about the future, especially where support services are already limited. Understanding these impacts matters because climate policy must account for psychological well-being, not just physical and economic recovery."

Chris Wainwright

Associate Lecturer and PhD Candidate in Public Health

Griffith University, Australia

"Brain health is deeply intertwined with the environments people live in. The exposome framework helps reveal how climate, pollution, and social inequality shape brain aging and dementia risk across populations. This approach is particularly critical for Latin America and the Global South, where environmental and social exposures are both intense and understudied."

Agustin Ibáñez, PhD

Scientific Director, Latin American Brain Health Institute
Universidad Adolfo Ibáñez, Santiago, Chile

Professor in Global Brain Health, Global Brain Health Institute Trinity College, Dublin, Ireland

Healing Young Minds by Healing Country

Case study from Brisbane, Australia

Across the communities in Australia where Yiliyapinya works, extreme heat, floods and changing seasons are adding pressure to sleep, housing, schooling, family life and access to support. Climate change is also felt as grief when Country, cultural places and familiar seasonal patterns are altered.

Working alongside Aboriginal and Torres Strait Islander peoples, we see that climate stress never arrives on its own. It lands in the brain, in the body, in our relationships and in our sense of belonging. After a hot, sleepless night or a flood that upends a household, there is less room for attention, for steady emotions, for hope. However, we also see strength, and it moves both ways between the generations. When Elders, families and young people share stories, seasonal knowledge and ways of reading Country, climate knowledge becomes living evidence, and part of who our young people are. Yarning, movement and time on Country sit comfortably beside brain literacy. Together they shift the question from 'What is wrong with me?' to 'What happened to me - and what can my brain do now?' In that shift, story gives back pride, relationship builds safety, and healing becomes something we do together.

This matters because climate adaptation cannot stop at infrastructure, emergency plans or physical health. We also need to protect the conditions that allow people to feel safe, connected and hopeful. For First Nations communities, Country, culture and relationships are not optional extras; they are part of the health system.

We can build resilience through Indigenous-led, place-based climate and brain health responses: safe and cool community spaces; brain literacy in culturally meaningful language; On-Country ranger programs; intergenerational storytelling and seasonal knowledge exchange; and long-term partnerships that respect cultural authority, Indigenous data sovereignty, and local definitions of thriving. Healing Country and healing the brain are not separate tasks, they are the same relational work.

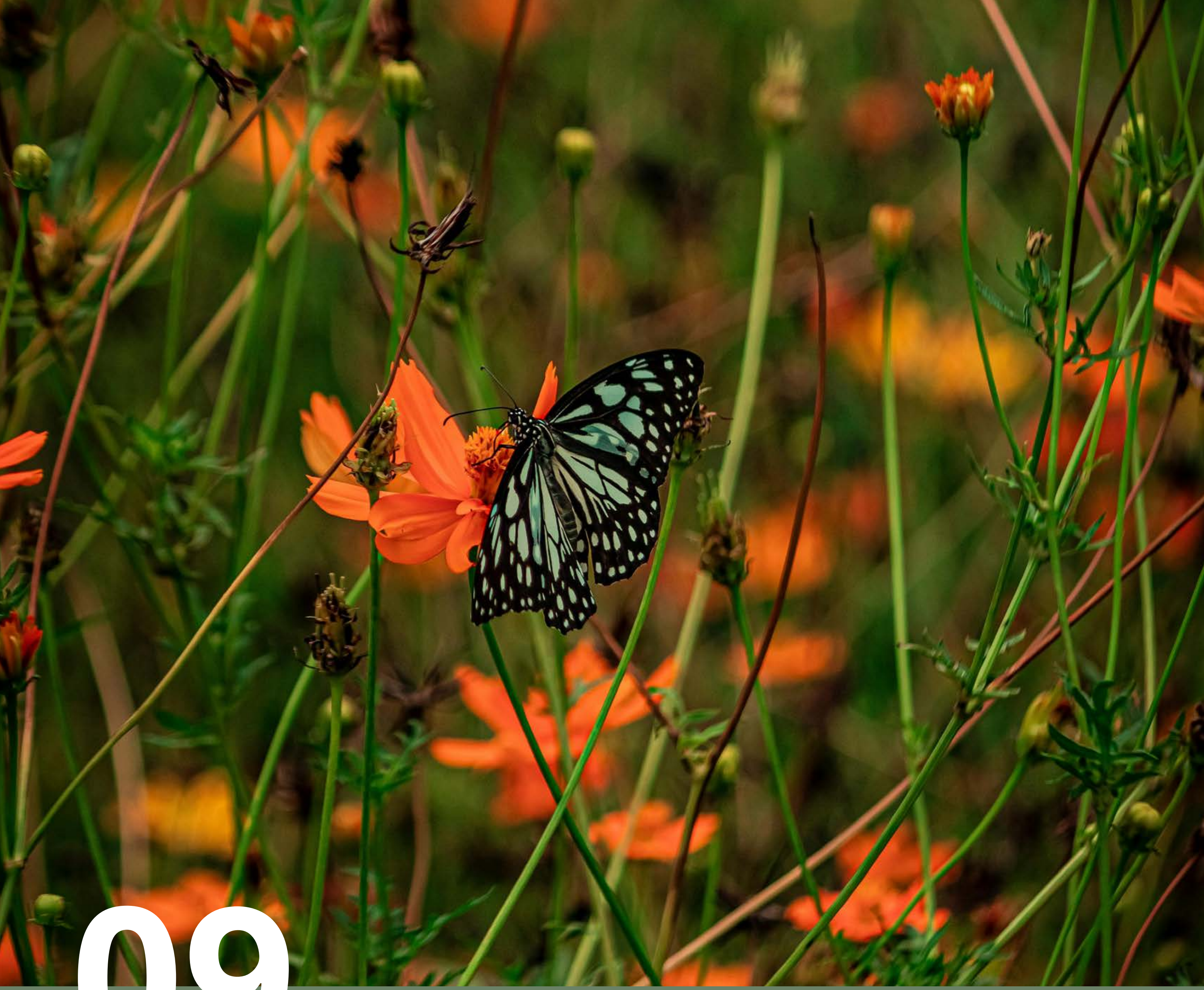
– Sheryl Batchelor

"When people think about the impacts of climate change, brain health is not something that comes to their mind. Bringing the focus to the damage done to the very thing that makes us human is a powerful way to make an abstract crisis feel personal and immediate."

Boryana Todorova

Postdoctoral Researcher in Psychology and NCWG Research Coordinator

University of Vienna, Austria



09

Beyond Climate Change: Planet in Crisis

Everything is Connected

Brain health is shaped by far more than climate change alone. A growing body of evidence demonstrates how our brains respond to the degradation of Earth's natural cycles and life-support systems. Planetary Health examines the many ways in which the health of planet and people are intertwined. Air, water, and soil pollution; land-use change and biodiversity loss; and unsustainable consumption of scarce resources, including freshwater and arable land, are pushing our planet beyond its safe operating limits with cascading consequences for human health.

But the relationship between brain and planetary health is bidirectional. Environmental disruption can affect how we think, feel, learn, and function, while healthy brains underpin our capacity to understand complex challenges, make sound decisions, cooperate, innovate, and take collective action. Protecting brain health is also part of our

"By understanding the interconnected impacts of environmental harm, we can identify solutions that cross sectors, disciplines, and borders to support brain health and build a future where all can flourish."

Jessica Kronstadt

Program Director of the Planetary Health Alliance

Just as the Earth's systems are deeply interconnected, so too are the ways these disruptions affect our mental and neurological health, and our ability to respond to them. The complexity of the brain, it turns out, reflects the complexity of the world it inhabits.[145]

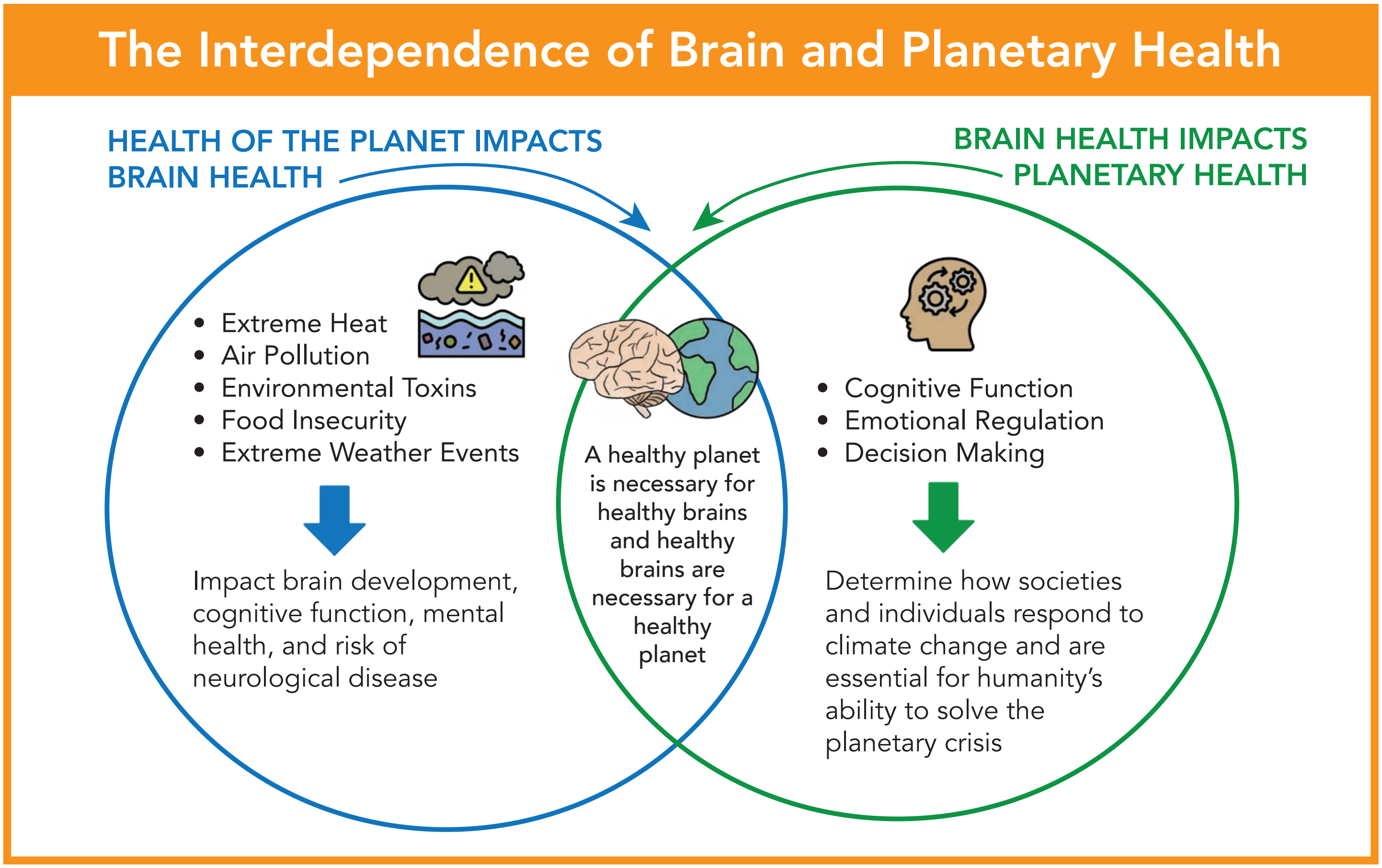


Figure 4. The Interdependence of Brain and Planetary Health. This conceptual model illustrates the bidirectional relationship between brain health and change to the health of the planet: environmental stressors impact brain health (left), while human cognition and behavior contribute to Planetary Health (right).

10

A Neuro-Climate Framework for Research and Policy Integration

The evidence base points to three conclusions with direct implications for policy. First, climate-related threats to brain health rarely occur in isolation: Heat, pollution, food and water insecurity, displacement, and psychological stress frequently coincide and may compound. Second, their effects arise through interconnected biological, psychological, and social-structural pathways. Third, current responsibility for addressing these pathways is distributed across environmental regulation, healthcare, mental health services, social policy, urban planning, education, labor, and disaster preparedness. Yet sector-specific responses are unlikely to be sufficient. We therefore introduce an integrative model linking the underlying evidence to distinct policy levers.

Brain health spans neurology, psychiatry, psychology, neuroscience, neurodevelopment, and public mental health (and intersects with other disciplines). These domains are frequently governed by separate institutions with siloed budgets, and this fragmentation helps explain why the policy gap persists. The integrative model we propose (Figure 5) maps three interconnected pathways through which climate change affects the brain. Each pathway motivates policy levers that cut across multiple institutional portfolios. A central design challenge is coordination across those portfolios.

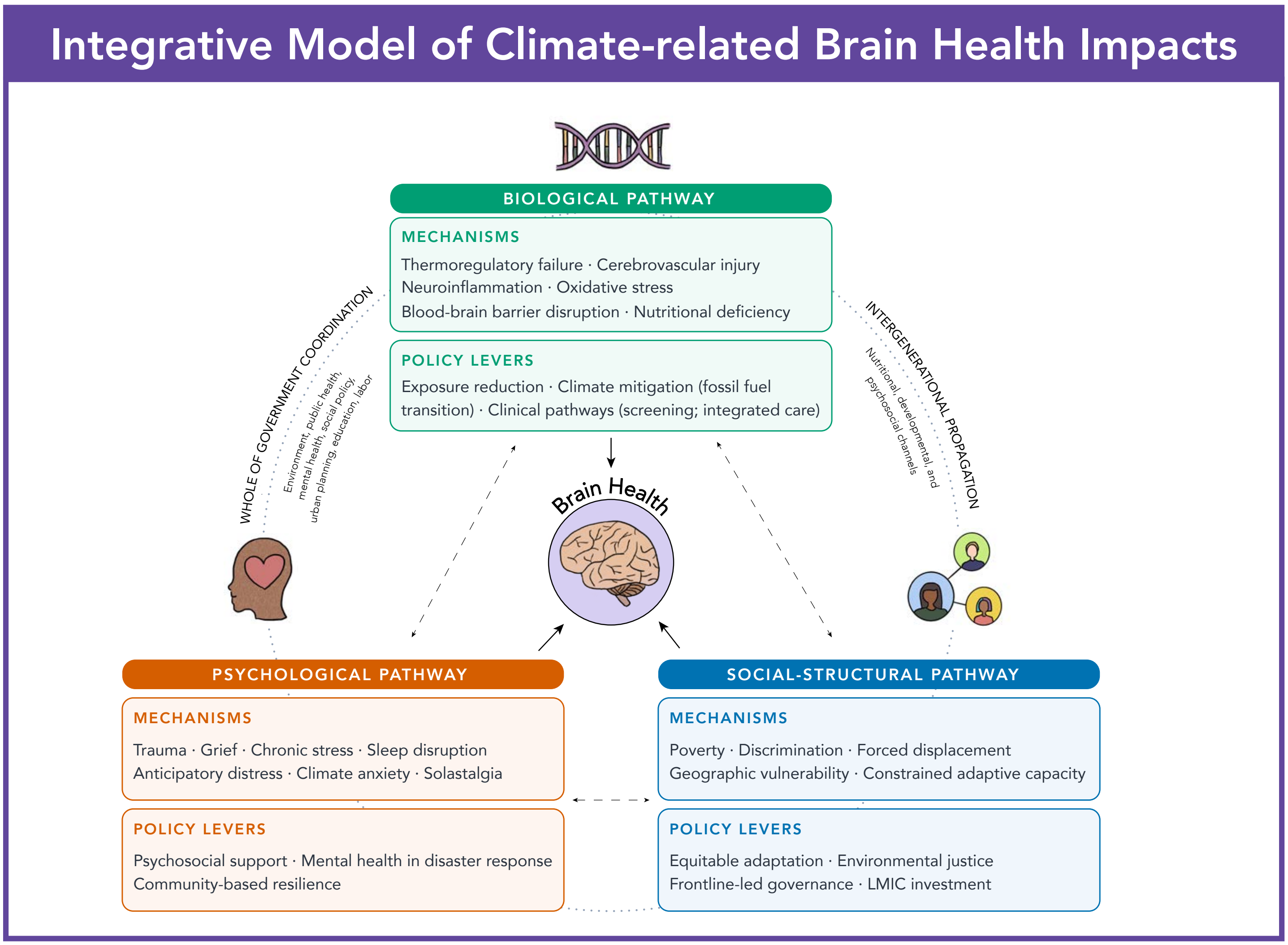


Figure 5. An integrative model of climate-related brain health impacts. Three interconnected pathways link climate-related environmental exposures to brain health outcomes across the life-course. Each pathway implies policy levers that cut across multiple institutional portfolios (environmental regulation, public health, mental health, social policy, urban planning, education, and labor), so whole-of-government coordination is required. Solid arrows indicate convergent effects on brain health; dashed arrows indicate bidirectional interactions among pathways. The dotted ring marks the conditions that operate across all three pathways: whole-of-government policy coordination and intergenerational propagation of effects through nutritional, developmental, and psychosocial channels.

The biological pathway encompasses the direct physiological mechanisms by which environmental exposures damage the brain, including neuro-inflammation, oxidative stress, vascular injury, blood-brain barrier disruption, and nutritional deficiency. These mechanisms operate from prenatal development through late-life neurodegeneration. Reducing such harms requires climate mitigation (particularly fossil fuel transition), stringent air quality standards, urban heat mitigation, climate-resilient food and water systems, and clinical pathways such as screening, adapted prescribing, and brain-health-integrated chronic disease management.

The psychological pathway captures the acute and chronic stress responses that climate instability produces, from disaster-related trauma and displacement to the sustained distress of persistent eco-anxiety. The corresponding interventions, such as mental health services integrated into disaster preparedness and community-based programs that strengthen social cohesion, fall under health and social service agencies that rarely coordinate with environmental regulators.

The social-structural pathway reflects how poverty, discrimination, and geographic vulnerability amplify both biological and psychological burdens while constraining adaptive capacity. Addressing this pathway requires directing resources where the burden is greatest via environmental justice frameworks in planning, targeted investment in underserved communities, and governance that centers frontline populations in decision-making.

Figure 5 depicts the interactions among these pathways, illustrating why interventions that target only one of them fall short. Consider, for example, a child growing up in a low-income neighborhood in a warming coastal city. They breathe higher concentrations of polluted air (biological), live in a household under economic stress with limited access to green space, cooling infrastructure, or quality healthcare (social-structural), and face an increased risk of anxiety and trauma due to exposure to a natural disaster (psychological). Interventions that target only one pathway—reducing ambient pollutant concentrations without addressing the social determinants that shape exposure, for example, or scaling mental health services without reducing the environmental stressors that generate demand—will remain structurally insufficient. Recognizing these interactions reframes the policy challenge: from whether to integrate brain health into the climate-health response to how to design strategies that address the convergence of biological, psychological, and structural harms, and which government institutions must coordinate to do so.

Translating this understanding into meaningful progress will require coordinated investment and efforts across multiple fronts: from the research infrastructure needed to close critical knowledge gaps, to the surveillance systems that can track population-level risks, to the policy frameworks that can turn evidence into sustained, equitable action. Several priorities emerge, which we outline in the next section.

"As a student bridging neuroscience and urbanism while working as a consultant on state-level climate resilience strategies in Brazil, I've observed that frameworks often address socioeconomic vulnerabilities while leaving brain health as an invisible variable. This oversight ignores a cycle where climate-driven neurological stressors undermine the cognitive resilience and collective decision-making required for long-term adaptation. Protecting the 'neurological landscape' of our communities is not just a health mandate, but a strategic necessity for a truly resilient future."

Bianca Gonçalves Flores

Senior Strategy Specialist

Deloitte, Brazil

Box 2. Future Research Priorities: Building the Neuro Climate Research Agenda

Despite rapid advances in our understanding of climate change and brain health, substantial knowledge gaps remain. Addressing these gaps will require coordinated investment in interdisciplinary, international, and solutions-oriented research that integrates neuroscience, epidemiology, environmental science, public health, engineering, implementation science, economics, and community engagement. The next generation of neuro climate research should move beyond documenting associations to identifying mechanisms, evaluating interventions, and generating evidence that can directly inform policy and practice.

Priority Research Areas

1 Understanding multiple and interacting environmental exposures

Most existing studies examine a single environmental exposure, despite the reality that people are simultaneously exposed to multiple climate-related stressors. Future research should investigate the cumulative and synergistic effects of combinations such as extreme heat and air pollution, wildfire smoke and psychological trauma, food insecurity and environmental contamination, and repeated climate disasters across the life course.

2 Advancing mechanistic neuroscience

Although epidemiological evidence has expanded rapidly, considerably less is known about the biological pathways linking climate-related exposures to brain health outcomes. Future studies should integrate epidemiology with neuroimaging, biomarkers, multi-omics, and neurobiology to better understand mechanisms such as neuroinflammation, oxidative stress, vascular injury, blood-brain barrier dysfunction, mitochondrial dysfunction, altered brain connectivity, and epigenetic changes.

3 Adopting a life-course and intergenerational perspective

Climate-related environmental exposures affect the brain differently across stages of development and aging. Longitudinal studies following individuals from the prenatal period through older adulthood are needed to understand sensitive developmental windows, cumulative exposures, resilience, and intergenerational transmission of risk.

4 Expanding research in low- and middle-income countries and climate-vulnerable populations

Many of the populations experiencing the greatest climate-related risks remain substantially underrepresented in brain health research. Future investments should support research led by investigators in low- and middle-income countries and prioritize vulnerable populations, including children, older adults, Indigenous peoples, displaced populations, outdoor workers, and communities disproportionately affected by environmental injustice.

Priority Research Areas

5 Co-designing research with communities

People experiencing the impacts of climate change should be partners in research rather than simply research participants. Community engagement, citizen science, Indigenous knowledge systems, and lived experience perspectives should be incorporated throughout the research process, from defining priorities and designing studies to interpreting findings and disseminating results.

6 Moving from documenting harms to evaluating solutions

While considerable evidence now documents the health impacts of climate change, far fewer studies evaluate interventions that can protect brain health. Future research should assess the effectiveness of climate adaptation and mitigation strategies, including urban greening, cooling interventions, air filtration, climate-resilient schools and healthcare facilities, early warning systems, disaster preparedness, community resilience programs, and policies that reduce environmental exposures.

7 Standardizing brain-health measurement across settings

A major barrier is the lack of standardized, comparable brain-health data across countries. Researchers should work toward harmonized definitions, core outcome sets, and common measurement protocols for neurological, cognitive, and mental health outcomes. These data can then be linked with existing environmental and socioeconomic datasets to enable cross-country comparisons, improve estimates of population-level risk, and generate evidence that is more readily usable for climate-health monitoring and policy.

8 Quantifying economic impacts and policy co-benefits

The economic burden of climate-related neurological, cognitive, and mental health outcomes remains poorly understood. Future studies should quantify healthcare costs, productivity losses, caregiving burden, educational impacts, and the economic benefits of interventions that simultaneously improve climate resilience and brain health.

9 Understanding resilience and protective factors

Much of the existing literature focuses on disease and vulnerability. Greater attention should be given to factors that promote resilience, including healthy urban design, access to nature, social connectedness, physical activity, nutrition, education, cultural practices, and other environmental and psychosocial resources that strengthen brain health in the face of climate change.

Addressing these priorities will require a new generation of neuro climate research that is interdisciplinary, collaborative, globally inclusive, and solution-oriented, integrating mechanistic and population science to generate evidence that can be translated into equitable policy and practice.

11

Brain Health: The Blind Spot in Climate Policy

The Gaps in Climate Policy

Despite the available evidence, brain health remains largely absent from climate mitigation and adaptation frameworks. This omission represents a critical blind spot, and addressing it requires embedding brain health across policy and governance at all levels.

The gap is visible even for mental health, the subdomain with the most policy traction. Only 3 percent of nationally determined contributions (NDCs) include adaptation provisions for mental health, versus 25 percent that reference injury and mortality from extreme weather events, and fewer still specify protective actions.[146,147] A 2025 review of national adaptation plans found that roughly 58 percent do not mention mental health at all, with existing coverage typically superficial.[148] Across 160 countries, not a single national adaptation plan addresses children's mental health.[3] Three-quarters of heat-health action plans mention mental health, but only about a third acknowledge its specific impacts and roughly a fifth include targeted interventions.[149] Neurological outcomes, including neurodevelopmental harm, short-term cognitive and emotional impairment, and longer-term cognitive decline and dementia, are further still from the policy agenda.

Even before accounting for climate-related harms, the global welfare loss from mental ill-health is valued at approximately $5 trillion annually, a burden that could account for between 4 and 8 percent of regional GDP.[150] Climate change adds to this baseline. A 2026 analysis across 34 countries found that aggregated exposome models explained up to 15.5 times more variance in brain aging than individual exposures, with the physical exposome associated primarily with accelerated structural aging and the social exposome with accelerated functional aging.[151] Heat-related reductions in labor capacity alone cost $1.09 trillion in potential income worldwide in 2024,[13] a figure that is likely due in part to cognitive impairment. Major economic assessments of climate-attributable health costs, including the World Bank's most recent global estimate, explicitly exclude mental health.[152]

Policy architecture for climate-health action can be found for many health outcomes and at many levels of governance. However, this architecture is often siloed, and no current systems exist that directly address brain health. Here, we propose a multi-level policy framework for closing this gap.

Embedding brain health in climate policy

The policy landscape is not starting from zero, though the implementation gap remains wide. Figure 6 maps where and how brain health can be embedded across governance levels and through which pathway (biological, psychological, or social-structural) each measure acts.

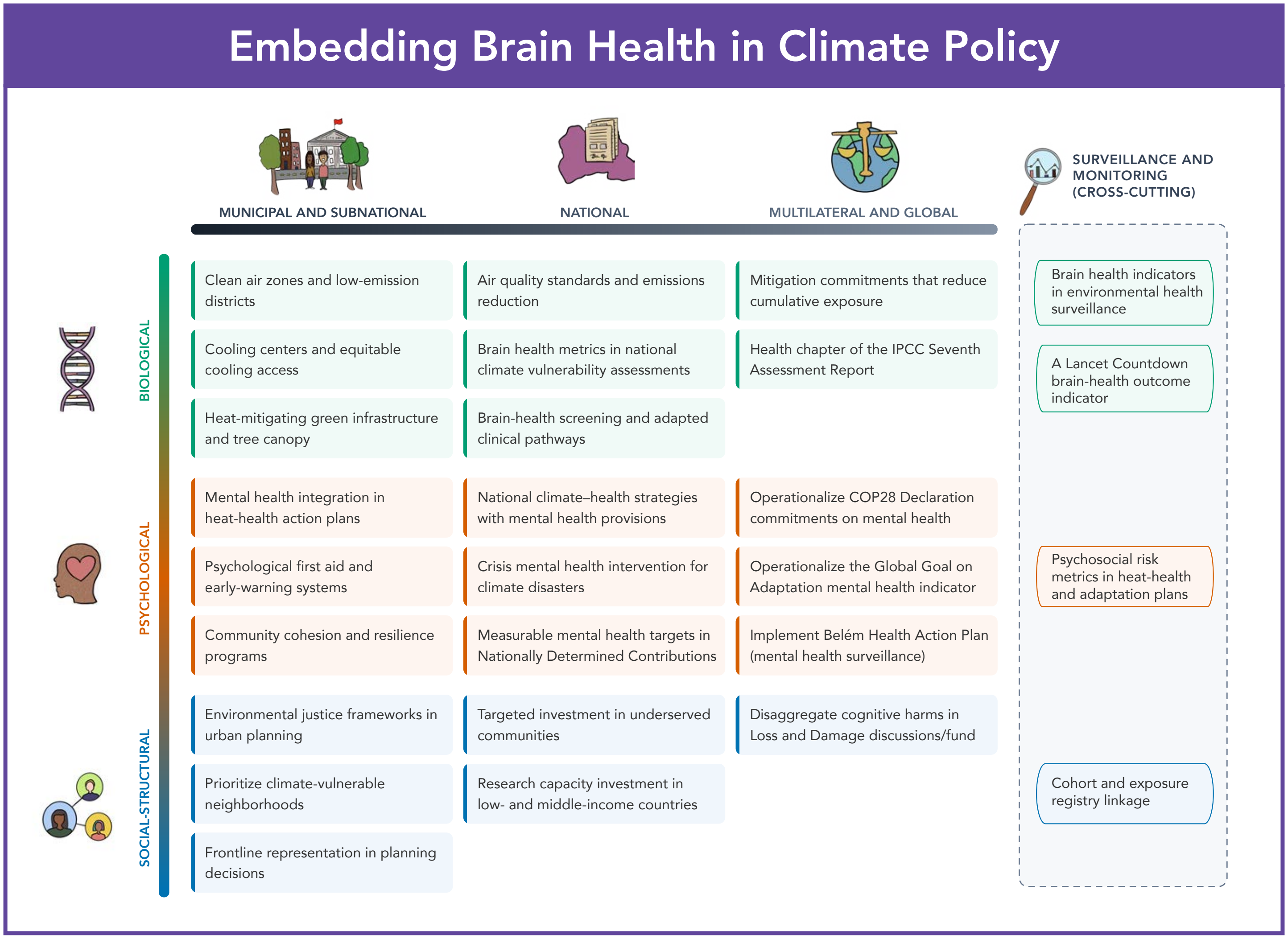


Figure 6. Embedding brain health in climate policy. Concrete policy actions arranged by the exposure–outcome pathway they primarily engage (vertical axis) and the governance scale at which they operate (horizontal axis), with surveillance and monitoring as a cross-cutting layer. Axes are drawn as continuous spectra, as pathways blend into one another and governance opportunities may overlap. Most actions engage more than one pathway and scale; placement indicates the primary fit.

Municipal and subnational. The building blocks of brain-health-protective policy are local: clean air zones, heat-mitigating green infrastructure and trees, equitable cooling access, and social infrastructure that strengthens community cohesion. Environmental exposures drive neuroinflammation and elevate neurodegenerative and mental health risk, with spatial disparities concentrating hazards in low-income communities.[151,153] Heat-health and air-quality warning systems should identify neurological and psychiatric risk explicitly, support continuity of medication and care, and trigger targeted outreach to people with dementia, epilepsy, severe mental illness, and other conditions that increase vulnerability. Psychological first aid should be built into municipal emergency response. Community engagement efforts should refine and localize practical guidance on recognizing heat-related cognitive or behavioral deterioration, medication-related risks, hydration, cooling, and when to seek medical assistance. Equity must be codified at this scale: Measures developed without input from frontline residents risk reinforcing the structural inequities that amplify climate-related brain health harms, as when green gentrification displaces the residents a newly cooled neighborhood was meant to protect.

National. A small but significant number of countries have begun closing this policy gap. China's National Climate Change Health Adaptation Action Plan (2024–2030), endorsed by 13 ministries, includes provisions to strengthen psychological intervention services for

affected populations under its health-security action task.[154] Australia's National Health and Climate Strategy (2023) and New Zealand's Health National Adaptation Plan (2024) both include mental health provisions. Globally, however, most countries that have updated NDCs or NAPs since 2023 continue to omit brain health.
What national action should contain is reasonably clear. With respect to exposure, air quality standards and emissions reduction targets should be calibrated against neurological and psychiatric endpoints (in addition to cardiovascular and respiratory measures), and brain health metrics should be written into national climate vulnerability and adaptation assessments, where they are currently absent. Health systems require brain-health screening for climate-exposed populations and clinical pathways adapted to heat, wildfire smoke, and displacement (including medication review for drugs that impair thermoregulation). National implementation also requires workforce preparedness, with climate-related brain-health risks incorporated into the curricula and continuing professional education of healthcare, mental-health, aged-care, disability-support, and emergency personnel. Crisis mental health intervention should be a planned component of national disaster response, and adaptation commitments should carry measurable mental health targets.

These omissions should be corrected, not least because the co-benefits of national action can be substantial. Analysis of China's earlier Air Pollution Action Plan estimated it prevented roughly 46,000 suicides (95% CI 13,000 to 79,000) between 2013 and 2017.[155] Realizing comparable returns elsewhere depends on evidence that does not yet exist for most of the world, because longitudinal cohorts linking environmental exposures to brain health remain concentrated in high-income countries. National funding decisions are therefore equity decisions—and should include investment targeted to the communities carrying the heaviest cumulative exposure burden, as well as sustained support for research capacity led by LMICs.

Multilateral and global. International commitments are advancing but remain largely declarative. The COP28 Declaration on Climate and Health (2023), endorsed by 150 signatories, was the first climate declaration on climate and health agreed at a UN climate conference, and it explicitly commits to addressing mental health and psychosocial wellbeing. The UN Political Declaration on NCDs and Mental Health (2025), adopted with 175 votes in favor, named air pollution among the modifiable risk factors for noncommunicable diseases, committed states to address the environmental determinants of both, and set 2030 targets. The Belém Health Action Plan, launched at COP30 in November 2025, devotes a subsection to mental health, asking Parties to build the evidence base and the tracking indicators for climate-related mental health impacts. Also at COP30, the Global Goal on Adaptation (GGA) indicator framework added an indicator on access to mental health and psychosocial support for climate-vulnerable populations. The Pan-European Commission on Climate and Health, in its May 2026 Call to Action, went further, urging governments to build mental health and psychosocial support into national adaptation plans and heat-health action plans as "a core component of climate resilience." These declarations establish promising normative precedent, but they lack the operational specificity needed to drive implementation.

What would specificity look like?

Three opportunities sit squarely within current UNFCCC processes. The first is operationalization and measurement of the GGA mental health indicator, which will determine whether it serves as an accountability instrument or remains symbolic. The second is follow-up on the Belém Health Action Plan, particularly its recommendations regarding mental health and psychosocial support. The third is the representation of brain health within Loss and Damage discussions and the Fund for Responding to Loss and Damage; the UNFCCC's current guidance on non-economic losses names health among them without disaggregating neurological or cognitive dimensions. Beyond the UNFCCC, the World Bank's Climate and Health Vulnerability and Adaptation Assessments and the World Health Organization's Vulnerability and Adaptation Assessments should incorporate brain health metrics explicitly. Working Group II of the IPCC's Seventh Assessment Report will include a dedicated health chapter, as in AR6, and brain health evidence largely absent from the previous cycle is now available for inclusion. Its publication date is still under negotiation, and the second Global Stocktake concludes in November 2028.

Surveillance and monitoring

Measurement cuts across every level of governance. Without standardized indicators, brain health remains difficult to track, compare, or prioritize within climate policy. The Lancet Countdown, for example, despite tracking 57 indicators, still lacks a dedicated brain-health outcome measure, relying on a mental-health-adjacent sentiment proxy derived from social media data.[13] Progress on a brain-health-specific indicator depends on upstream investment in data collection infrastructure, itself a persistent gap in climate-health research funding. Embedding a measurement program within the GGA indicator workstream offers one operational channel; sustained funding for cohort studies and exposure-registry linkage represents another.

Investment follows measurement. The absence of brain health from climate-economic models creates a vicious cycle: Without data on climate-attributable cognitive and psychological harms, the economic case for investment cannot be made, and without investment, the data cannot be generated. The returns are likely to be significant. In the European Union, stronger air quality measures reduced PM2.5-attributable premature deaths by 57 percent between 2005 and 2023, meeting the Zero Pollution Action Plan's 2030 target of at least 55 percent seven years early.[156] The brain-health share of that benefit has never been counted.

A Roadmap for Action: Protecting Brain Health in a Changing Climate

The evidence presented throughout this report demonstrates that protecting brain health in a changing climate requires coordinated action across governments, healthcare systems, researchers, educators, communities, individuals, and international organizations. While important knowledge gaps remain, many opportunities already exist to reduce climate-related risks, strengthen resilience, and promote healthier brains across the lifespan. The actions below build on the evidence and policy priorities outlined throughout this report.

For Policymakers

Integrate brain health into climate adaptation, mitigation, disaster preparedness, and public health strategies, recognizing neurological, cognitive, mental, and neurodevelopmental health as essential components of climate resilience.

Include defined and measurable brain health provisions in nationally determined contributions, national adaptation plans, and heat-health action plans, specifying protective actions and the indicators by which progress will be tracked.

Identify and prioritize populations at greatest risk of climate-related brain health impacts—including children, pregnant women, older adults, people living with neurological and mental health conditions, Indigenous Peoples, displaced populations, outdoor workers, and communities experiencing environmental and socioeconomic disadvantage.

Reduce harmful environmental exposures through cleaner air, urban heat mitigation, climate-resilient food and water systems, sustainable transportation, healthier built environments, and expanded access to green infrastructure.

Embed brain health considerations across sectors, including health, environment, urban planning, housing, education, labor, transportation, and emergency preparedness, to support coordinated, whole-of-government approaches.

Strengthen climate-resilient healthcare and social support systems through surveillance, continuity-of-care planning, early warning systems, and sustained neurological and mental health support before, during, and long after climate-related disasters.

Build climate-related brain health into professional education and workforce development, so that healthcare, mental-health, public-health, aged-care, disability-support, and emergency personnel are trained to recognize the neurological, cognitive, and psychiatric risks associated with heat, pollution, disasters, food insecurity, and infectious disease, including medication-related vulnerabilities and continuity-of-care planning.

For Policymakers

Develop standardized brain health indicators and surveillance systems to monitor climate-related neurological, cognitive, and mental health outcomes, identify populations at greatest risk, and evaluate the effectiveness and co-benefits of climate adaptation and mitigation policies, including within the cost-effectiveness and cost-benefit analyses used to appraise them.

Invest in equitable adaptation, implementation, and interdisciplinary research, particularly in low- and middle-income countries and communities experiencing the greatest climate-related burdens.

For Healthcare Professionals

Recognize climate-related environmental exposures as important determinants of brain health across the lifespan.

Identify patients at increased risk from extreme heat, air pollution, environmental contaminants, food insecurity, infectious diseases, and climate-related disasters.

Incorporate environmental exposure history and climate-related risks into clinical assessment where appropriate.

Develop continuity-of-care plans for individuals living with neurological and mental health conditions before climate-related emergencies.

Provide ongoing neurological, cognitive, and mental health assessment and support following climate-related disasters, recognizing that many impacts may emerge or persist long after the acute event.

Educate patients and caregivers on strategies to reduce environmental risks and strengthen resilience.

For Researchers

Advance the research priorities outlined in this report through interdisciplinary, collaborative, and globally representative research.

Foster collaborations across neuroscience, environmental science, climate science, public health, engineering, economics, and policy to accelerate discovery and translation.

Partner with patients, caregivers, youth, Indigenous communities, and people with lived experience throughout the research process.

For Researchers

Translate scientific discoveries into clinical guidance, public health practice, educational resources, and evidence-informed policy.

Share data, methods, and resources to strengthen international collaboration and accelerate scientific progress.

Mentor and support the next generation of neuro climate researchers, particularly in low- and middle-income countries and climate-vulnerable regions.

For Schools and Educators

Create learning environments that protect children from extreme heat, poor air quality, and other environmental hazards.

Incorporate climate resilience into school planning, including cooling strategies, clean indoor air, emergency preparedness, and continuity of learning during climate-related disruptions.

Equip teachers and school staff to recognize heat-related cognitive, emotional, and behavioural changes in students, and to know when and how to escalate concerns to families and health services.

Recognize and support the cognitive, neurological, and mental health needs of students affected by climate-related disasters through both immediate and long-term educational and psychosocial support.

Promote climate and brain health literacy to help young people understand environmental risks while fostering resilience, hope, agency, and opportunities for collective action.

For Communities and Civil Society

Steward and activate local environments: community gardens, tree planting and maintenance, greening of vacant and neglected lots, and opening cooled, filtered-air spaces in libraries, places of worship, schools, and community centers during heat waves and smoke events.

Strengthen community preparedness before, during, and after climate-related disasters, with particular attention to individuals living with neurological and mental health conditions.

Develop long-term community support systems that promote neurological recovery, mental wellbeing, social connectedness, and resilience throughout disaster recovery, not only during the immediate emergency response.

For Communities and Civil Society

Support education and public awareness on climate and brain health, delivered through community members, community health workers, and trusted local organizations, whose reach matters most where formal neurological and mental health services are limited.

Advocate for equitable environmental policies and public investments— including policies that reduce fossil fuel emissions and investments in green space, cooling infrastructure, safe housing, and clean indoor air—that reduce harmful exposures and strengthen community wellbeing, and hold decision-makers to those commitments once made.

For Individuals and Families

Stay informed about heat, air quality, and extreme weather alerts, and reduce exposure during periods of elevated environmental risk whenever possible.

Prioritize hydration, sleep, nutrition, physical activity, and social connection, all of which support brain health and resilience**.**

Seek medical care if neurological, cognitive, or mental health symptoms worsen following environmental exposures or climate-related disasters.

Check on and support family members, neighbors, and others who may be particularly vulnerable during extreme weather events and throughout disaster recovery.

Participate in community initiatives and support policies that promote healthier, more resilient environments, recognizing that meaningful change depends on both individual and collective action.

For People with Lived Experience

Share lived experiences, including those of children, youth, caregivers, and frontline communities, to help shape research priorities, healthcare, education, and policy.

Participate as partners in research, advisory groups, advocacy efforts, and community engagement initiatives from project design through implementation and dissemination.

For People with Lived Experience

Help identify practical solutions and priorities that reflect the needs of affected individuals and communities.

Contribute to peer support, community recovery, and public awareness efforts that strengthen resilience after climate-related disasters.

For International Organizations and Funders

Integrate brain health into global climate, health, and sustainable development agendas.

Ensure neurological and cognitive harms are disaggregated within Loss and Damage and non-economic loss frameworks, and support the operationalization of mental health and psychosocial support indicators within adaptation frameworks.

Increase investment in interdisciplinary, implementation-focused, and solution-oriented research.

Strengthen research capacity and scientific leadership in low- and middle-income countries.

Support development of harmonized brain health indicators for climate surveillance and international reporting.

Foster international collaboration, open data sharing, and coordinated action across science, policy, healthcare, education, and communities.

Protecting brain health is a shared responsibility. From governments and healthcare systems to schools, communities, researchers, and individuals, every sector has a role to play in reducing climate-related risks, strengthening resilience, and ensuring that future generations can thrive on a healthier planet.

12

Conclusion

Conclusion

The evidence presented throughout this report demonstrates that climate change and environmental degradation affect brain health across the lifespan, influencing neurological disease, mental health, cognition, neurodevelopment, and healthy brain aging through interconnected biological, psychological, and social pathways. Together, the scientific evidence, lived experiences, and expert perspectives presented in this report underscore that brain health is a fundamental dimension of the climate crisis with profound implications for individuals, communities, and societies.

At the same time, this report offers a message of opportunity. The Neuro Climate Framework highlights pathways through which climate change affects the brain, while the research agenda identifies priorities for advancing scientific understanding and the action roadmap outlines practical steps that governments, healthcare systems, researchers, educators, communities, and individuals can take today.

Many of the actions that reduce greenhouse gas emissions and strengthen climate resilience, including cleaner air, greener and cooler cities, healthier food and water systems, resilient healthcare systems, and more equitable communities, also promote healthier brains. Protecting brain health should therefore become a central objective of climate action.

Healthy brains depend on healthy environments. At the same time, healthy brains are among humanity's greatest assets for addressing the climate crisis, enabling learning, innovation, resilience, compassion, and collective action. Protecting brain health is therefore not only an outcome of climate action, but also one of its foundations. By protecting our planet, we help create the conditions for healthier brains, stronger communities, and a more resilient future for present and future generations.

Resources

Additional reports, books, educational resources, and curated scientific literature are available through the International Neuro Climate Working Group Resources Library.

Foundational Reports

- WHO Risk Reduction of Cognitive Decline and Dementia Guidelines (2nd edition, 2026)
- State of Global Air 2025 Report *(Health Effects Institute, Institute for Health Metrics and Evaluation, and NCD Alliance)*
- Lancet Countdown on Health and Climate Change 2025 Report
- Mental Health and Our Changing Climate: Children and Youth Report (2023) *(American Psychological Association & ecoAmerica)*

Recommended Books

- Aldern, Clayton Page. (2024). *The Weight of Nature: How a Changing Climate Changes Our Brains*. Dutton.
- Berman, Marc. (2025). *Nature and the Mind: The Science of How Nature Improves Cognitive, Physical, and Social Well-Being.* S&S/Simon Element.
- Doherty, Thomas. (2025). *Surviving Climate Anxiety: A Guide to Coping, Healing, and Thriving.* Little, Brown Spark.
- Kühn, Simone (Editor). (2024). *Environmental Neuroscience*. Springer.
- Perera, Frederica. (2022). *Children's Health and the Peril of Climate Change.* Oxford University Press.

Scientific Literature and Educational Resources

- NCWG Key Scientific Studies - Curated collection of key scientific studies on climate change, environmental exposures, and brain health
- WHO Air Pollution and Health Training Toolkit for Health Workers
- UNICEF Health Tomorrows Video Series
- The CliCBrain Project: Climate, Cities and Brain health

Organizations

- International Neuro Climate Working Group
- World Health Organization
- Planetary Health Alliance
- Global Consortium on Climate and Health Education
- Climate Cares Centre
- Climate Mental Health Network
- Global Mental Health Action Network
- Climate Psychiatry Alliance

Report Contributors

This report was developed through an interdisciplinary, collaborative, and iterative process coordinated by the International Neuro Climate Working Group (NCWG). Unless otherwise indicated, individuals are listed alphabetically by surname.

Authors

Chair
Burcin Ikiz (Stanford University)

Lead Authors
Angie Matonte
Clayton P. Aldern (University of Washington)
Christina Chen (Duke-NUS Medical School)
Burcin Ikiz (Stanford University)
Boryana Todorova (University of Vienna/University of Queensland)

Expert Committee Members (including the Chair and Lead Authors)
Shazia Adalat (King's College London)
Marc G. Berman (University of Chicago)
Ameli Breuer (Charite Berlin)
Kimberly C. Doell (University of Konstanz)
Harris Eyre (Rice University and UTMB)
Renzo R. Guinto (Duke-NUS Medical School)
Alexandra K. Heaney (University of California San Diego)
Agustín Ibáñez (Universidad Adolfo Ibáñez and Trinity College Dublin)
Inez Jabalpurwala (Public Policy Forum)
Larry Junck (University of Michigan)
Simone Kühn (Max Planck Institute for Human Development)
Claus Lamm (University of Vienna)
Emma L. Lawrance (University of Oxford)
Alessandro Massazza (United for Global Mental Health)
Kimberly L. Meidenbauer (Washington State University)
Jyoti Mishra (University of California San Diego)
Djibril Moussa (Amoud University)
Joanne B. Newbury (University of Bristol)
Yoko Nomura (CUNY Queens College)
Frederica Perera (Columbia University)
Mohamed Salama (American University in Cairo)
Cecilia Sorensen (Columbia University)
İlayda Tüter (Uskudar University)

Additional Contributors

Expert Quote Contributors
Jafri Malin Abdullah (Academy of Sciences, Malaysia and Brain Behaviour Cluster, Universiti Sains Malaysia)
Jessie Buckle (University College London)
Agustín Ibáñez (Universidad Adolfo Ibáñez and Trinity College Dublin)
Larry Junck (University of Michigan)
Jyoti Mishra (University of California San Diego)
Robbie Parks (Columbia University)
Lisa Patel (Stanford University)
Kam Sripada (Norwegian University of Science and Technology)
Chris Wainwright (Griffith University)
Bianca Gonçalves Flores (Deloitte)

Lived Experience Coordinator
Julianna Gwiszcz (George Mason University)

Lived Experience/Case Study Contributors
Miracle Adesina (University of Ibadan)
Sheryl Batchelor (Yiliyapinya Indigenous Corporation)
Shannon Bird
Tuna Eker (Turkish Ministry of Health)
Moktar Sissako
Selin Tanyeri Kayahan (Turkish Ministry of Health)

NCWG Youth Council Contributors
Muskan Lamba (Global Mental Health Action Network)
Boryana Todorova (University of Vienna)

Planetary Health Box Contributors
Hannah Blair (Planetary Health Alliance)
Jessica Kronstadt (Planetary Health Alliance)

Design and Production

Cat Lau (graphic design and scientific illustrations)
Clayton P. Aldern (webpage development)

Partners

The International Neuro Climate Working Group gratefully acknowledges the following organizations for their partnership in supporting the development and dissemination of this report.

Funding

Preparation of this report was supported in part by the Stanford Human and Planetary Health Center Catalyst Award, which provided support for the development of selected scientific illustrations, the report webpage, and dissemination activities.

Acknowledgments

This report reflects the collective efforts of a global community committed to advancing understanding of the connections between climate change and brain health. We extend our sincere gratitude to the members of the International Neuro Climate Working Group for their expertise, collaboration, and thoughtful engagement throughout the development of this report. We also thank Angie Michaiel for her valuable scientific input and contributions to the report.

We are deeply grateful to the individuals who generously shared their lived experiences, personal stories, and perspectives, as well as to the youth contributors, whose voices remind us of the human dimensions of the climate crisis and the importance of building a healthier and more resilient future. We also thank the researchers, clinicians, public health professionals, policymakers, advocates, and partner organizations who contributed their expertise, case studies, and insights to enrich this work.

Finally, we thank everyone working to advance research, policy, clinical care, education, and community action at the intersection of climate change and brain health. We hope this report serves as a catalyst for collaboration, innovation, and collective action to protect both brain health and the planet for present and future generations.

References

1. State of Global Air Report 2025 [Internet]. 2025. Available from: https://www.stateofglobalair.org/resources/report/state-global-air-report-2025

2. Liu J, Varghese BM, Hansen A, Xiang J, Zhang Y, Dear K, et al. Is there an association between hot weather and poor mental health outcomes? A systematic review and meta-analysis. Environ Int. 2021 Aug 1;153:106533. doi:10.1016/j.envint.2021.106533

3. Zangerl KE, Hoernke K, Andreas M, Dalglish SL, Kelman I, Nilsson M, et al. Child health prioritisation in national adaptation policies on climate change: a policy document analysis across 160 countries. Lancet Child Adolesc Health. 2024 Jul 1;8(7):532–44. doi:10.1016/S2352-4642(24)00084-1 PubMed PMID: 38848733.

4. Risk reduction of cognitive decline and dementia: WHO guidelines. Geneva: World Health Organization; 2026. Report 2nd edition.

5. Sisodiya SM, Gulcebi MI, Fortunato F, Mills JD, Haynes E, Bramon E, et al. Climate change and disorders of the nervous system. Lancet Neurol. 2024 Jun;23(6):636–48. doi:10.1016/S1474-4422(24)00087-5 PubMed PMID: 38760101.

6. Crandon TJ, Dey C, Scott JG, Thomas HJ, Ali S, Charlson FJ. The clinical implications of climate change for mental health. Nat Hum Behav. 2022 Nov;6(11):1474–81. doi:10.1038/s41562-022-01477-6

7. Gulcebi MI, Leddy S, Behl K, Dijk DJ, Marder E, Maslin M, et al. Imperatives and co-benefits of research into climate change and neurological disease. Nat Rev Neurol. 2025 Apr;21(4):216–28. doi:10.1038/s41582-024-01055-6

8. Zammit C, Torzhenskaya N, Ozarkar PD, Calleja Agius J. Neurological disorders vis-à-vis climate change. Early Hum Dev. 2021 Apr;155:105217. doi:10.1016/j.earlhumdev.2020.105217

9. Louis S, Carlson AK, Suresh A, Rim J, Mays M, Ontaneda D, et al. Impacts of Climate Change and Air Pollution on Neurologic Health, Disease, and Practice: A Scoping Review. Neurology. 2023 Mar 7;100(10):474–83. doi:10.1212/WNL.0000000000201630 PubMed PMID: 36384657; PubMed Central PMCID: PMC9990849.

10. Burrows K, Denckla CA, Hahn J, Schiff JE, Okuzono SS, Randriamady H, et al. A systematic review of the effects of chronic, slow-onset climate change on mental health. Nat Ment Health. 2024 Feb;2(2):228–43. doi:10.1038/s44220-023-00170-5

11. Lawrance EL, Thompson R, Newberry Le Vay J, Page L, Jennings N. The Impact of Climate Change on Mental Health and Emotional Wellbeing: A Narrative Review of Current Evidence, and its Implications. Int Rev Psychiatry. 2022 Jul 4;34(5):443–98. doi:10.1080/09540261.2022.2128725

12. Buoli M, Grassi S, Caldiroli A, Carnevali GS, Mucci F, Iodice S, et al. Is there a link between air pollution and mental disorders? Environ Int. 2018 Sep 1;118:154–68. doi:10.1016/j.envint.2018.05.044

13. Romanello M, Walawender M, Hsu SC, Moskeland A, Palmeiro-Silva Y, Scamman D, et al. The 2025 report of the Lancet Countdown on health and climate change: climate change action offers a lifeline. The Lancet. 2025 Dec 13;406(10521):2804–57. doi:10.1016/S0140-6736(25)01919-1 PubMed PMID: 41175887.

14. Zhang Z, Wu X, Zou Z, Shen M, Liu Q, Zhangsun Z, et al. Heat stroke: Pathogenesis, diagnosis, and current treatment. Ageing Res Rev. 2024 Sep 1;100:102409. doi:10.1016/j.arr.2024.102409

15. Yin P, Gao Y, Chen R, Liu W, He C, Hao J, et al. Temperature-related death burden of various neurodegenerative diseases under climate warming: a nationwide modelling study. Nat Commun. 2023 Dec 12;14(1):8236. doi:10.1038/s41467-023-44066-5

References

16. Granés L, Essers E, Ballester J, Petricola S, Tiemeier H, Iñiguez C, et al. Early life cold and heat exposure impacts white matter development in children. Nat Clim Change. 2024 Jul;14(7):760–6. doi:10.1038/s41558-024-02027-w

17. Thompson R, Lawrance EL, Roberts LF, Grailey K, Ashrafian H, Maheswaran H, et al. Ambient temperature and mental health: a systematic review and meta-analysis. Lancet Planet Health. 2023 Jul;7(7):e580–9. doi:10.1016/S2542-5196(23)00104-3

18. Thompson R, Hornigold R, Page L, Waite T. Associations between high ambient temperatures and heat waves with mental health outcomes: a systematic review. Public Health. 2018 Aug 1;Special issue on Health and high temperatures161:171–91. doi:10.1016/j.puhe.2018.06.008

19. Nori-Sarma A, Sun S, Sun Y, Spangler KR, Oblath R, Galea S, et al. Association Between Ambient Heat and Risk of Emergency Department Visits for Mental Health Among US Adults, 2010 to 2019. JAMA Psychiatry. 2022 Apr 1;79(4):341–9. doi:10.1001/jamapsychiatry.2021.4369 PubMed PMID: 35195664; PubMed Central PMCID: PMC8867392.

20. Caroff SN, Watson CB, Rosenberg H. Drug-induced Hyperthermic Syndromes in Psychiatry. Clin Psychopharmacol Neurosci. 2021 Feb 28;19(1):1–11. doi:10.9758/cpn.2021.19.1.1

21. Heidari H, Lawrence DA. An integrative exploration of environmental stressors on the microbiome-gut-brain axis and immune mechanisms promoting neurological disorders. J Toxicol Environ Health Part B. 2024 Oct 2;27(7):233–63. doi:10.1080/10937404.2024.2378406

22. Loh JS, Mak WQ, Tan LKS, Ng CX, Chan HH, Yeow SH, et al. Microbiota–gut–brain axis and its therapeutic applications in neurodegenerative diseases. Signal Transduct Target Ther. 2024 Feb 16;9(1):37. doi:10.1038/s41392-024-01743-1

23. Adalat S, Giannakou K, Valderrama B, Cárdenas-Aguilera JG, Sakkas GK, Overeem J, et al. Global environmental change and the gut–kidney–brain axis: a review and framework of vulnerability and resilience. Lancet Planet Health. 2026 Apr 13;0(0). doi:10.1016/j.lanplh.2026.101453

24. Yin B, Fang W, Liu L, Guo Y, Ma X, Di Q. Effect of extreme high temperature on cognitive function at different time scales: A national difference-in-differences analysis. Ecotoxicol Environ Saf. 2024 Apr 15;275:116238. doi:10.1016/j.ecoenv.2024.116238

25. Tan XR, Stephenson MC, Alhadad SB, Loh KWZ, Soong TW, Lee JKW, et al. Elevated brain temperature under severe heat exposure impairs cortical motor activity and executive function. J Sport Health Sci. 2024 Mar;13(2):233–44. doi:10.1016/j.jshs.2023.09.001 PubMed PMID: 37678507; PubMed Central PMCID: PMC10980903.

26. Park RJ, Behrer AP, Goodman J. Learning is inhibited by heat exposure, both internationally and within the United States. Nat Hum Behav. 2021 Jan;5(1):19–27. doi:10.1038/s41562-020-00959-9

27. Behrer AP, Bolotnyy V. Heat and law enforcement. PNAS Nexus. 2024 May 1;3(5):pgad425. doi:10.1093/pnasnexus/pgad425

28. Flouris AD, Dinas PC, Ioannou LG, Nybo L, Havenith G, Kenny GP, et al. Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. Lancet Planet Health. 2018 Dec 1;2(12):e521–31. doi:10.1016/S2542-5196(18)30237-7 PubMed PMID: 30526938.

29. Meidenbauer, K. L., Schertz, K. E., Janey, E. A., Stier, A. J., Samtani, A. L., Gehrke, K., Tucker, R., Hasan, M. M., & Berman, M. G. (2025). Evidence for environmental influences on impulsivity and aggression. Urban Forestry & Urban Greening, 103(128594), 128594. https://doi.org/10.1016/j.ufug.2024.128594

References

30. Choi HM, Heo S, Foo D, Song Y, Stewart R, Son J, et al. Temperature, Crime, and Violence: A Systematic Review and Meta-Analysis. Environ Health Perspect. 2024 Oct;132(10):106001. doi:10.1289/EHP14300 PubMed PMID: 39404825; PubMed Central PMCID: PMC11477092.

31. Schapiro K, Marder E. Resilience of circuits to environmental challenge. Curr Opin Neurobiol. 2024 Aug 1;87:102885. doi:10.1016/j.conb.2024.102885

32. Michaiel AM, Bernard A. Neurobiology and changing ecosystems: Toward understanding the impact of anthropogenic influences on neurons and circuits. Front Neural Circuits. 2022 Nov 30;16:995354. doi:10.3389/fncir.2022.995354

33. Ruszkiewicz JA, Tinkov AA, Skalny AV, Siokas V, Dardiotis E, Tsatsakis A, et al. Brain diseases in changing climate. Environ Res. 2019 Oct;177:108637. doi:10.1016/j.envres.2019.108637 PubMed PMID: 31416010; PubMed Central PMCID: PMC6717544.

34. Yamaguchi T, Shimizu K, Kokubu Y, Nishijima M, Takeda S, Ogura H, et al. Effect of heat stress on blood-brain barrier integrity in iPS cell-derived microvascular endothelial cell models. PloS One. 2019;14(9):e0222113. doi:10.1371/journal.pone.0222113 PubMed PMID: 31483843; PubMed Central PMCID: PMC6726235.

35. Sweeney MD, Sagare AP, Zlokovic BV. Blood-brain barrier breakdown in Alzheimer disease and other neurodegenerative disorders. Nat Rev Neurol. 2018 Mar;14(3):133–50. doi:10.1038/nrneurol.2017.188 PubMed PMID: 29377008; PubMed Central PMCID: PMC5829048.

36. Sun G, Qian S, Jiang Q, Liu K, Li B, Li M, et al. Hyperthermia-induced disruption of functional connectivity in the human brain network. PloS One. 2013;8(4):e61157. doi:10.1371/journal.pone.0061157 PubMed PMID: 23593416; PubMed Central PMCID: PMC3620175.

37. Calvin K, Dasgupta D, Krinner G, Mukherji A, Thorne PW, Trisos C, et al. IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland. [Internet]. First. Intergovernmental Panel on Climate Change (IPCC); 2023 Jul [cited 2024 Jul 3]. Available from: https://www.ipcc.ch/report/ar6/syr/ doi:10.59327/IPCC/AR6-9789291691647

38. Naidoo K, Manyangadze T, Lokotola CL. Primary care disaster management for extreme weather events, South Africa. Afr J Prim Health Care Fam Med. 2022 Dec 19;14(1):e1–2. doi:10.4102/phcfm.v14i1.3778 PubMed PMID: 36546500; PubMed Central PMCID: PMC9772755.

39. Li A, Leppold C. Long-term mental health trajectories across multiple exposures to climate disasters in Australia: a population-based cohort study. Lancet Public Health. 2025 May;10(5):e391–400. doi:10.1016/S2468-2667(25)00068-4

40. Patwary MM, Bardhan M, Haque MA, Moniruzzaman S, Gustavsson J, Khan MMH, et al. Impact of extreme weather events on mental health in South and Southeast Asia: A two decades of systematic review of observational studies. Environ Res. 2024 Jun 1;250:118436. doi:10.1016/j.envres.2024.118436 PubMed PMID: 38354890.

41. Beaglehole B, Mulder RT, Frampton CM, Boden JM, Newton-Howes G, Bell CJ. Psychological distress and psychiatric disorder after natural disasters: systematic review and meta-analysis. Br J Psychiatry. 2018;213(6):716–22.

42. Zhao D, Epel E, Allen E, Hwong AR. Exposure to climate events and mental health: Risk and protective factors from the California Health Interview Survey. PLOS Clim. 2024 Aug 7;3(8):e0000387. doi:10.1371/journal.pclm.0000387

References

43. Benevolenza MA, and DeRigne L. The impact of climate change and natural disasters on vulnerable populations: A systematic review of literature. J Hum Behav Soc Environ. 2019 Feb 17;29(2):266–81. doi:10.1080/10911359.2018.1527739

44. Cherry KE, Brown JS, Marks LD, Galea S, Volaufova J, Lefante C, et al. Longitudinal Assessment of Cognitive and Psychosocial Functioning After Hurricanes Katrina and Rita: Exploring Disaster Impact on Middle-Aged, Older, and Oldest-Old Adults. J Appl Biobehav Res. 2011;16(3–4):187–211. doi:10.1111/j.1751-9861.2011.00073.x

45. Walling E, Tucker P, Pfefferbaum B, Nguyen C, Mistry A. Neuropsychological Outcomes of Exposure to Hurricane Katrina and Relocation. Disaster Med Public Health Prep. 2020 Feb;14(1):89–92. doi:10.1017/dmp.2019.110

46. Grennan GK, Withers MC, Ramanathan DS, Mishra J. Differences in interference processing and frontal brain function with climate trauma from California's deadliest wildfire. PLOS Clim. 2023 Jan 18;2(1):e0000125. doi:10.1371/journal.pclm.0000125

47. Demirci GM, DeIngeniis D, Wong WM, Shereen AD, Nomura Y, Tsai CL. Superstorm Sandy exposure in utero is associated with neurobehavioral phenotypes and brain structure alterations in childhood: A machine learning approach. Front Neurosci. 2023;17:1113927. doi:10.3389/fnins.2023.1113927 PubMed PMID: 36816117; PubMed Central PMCID: PMC9932505.

48. Buthmann J, Huang D, Casaccia P, O'Neill S, Nomura Y, Liu J. Prenatal Exposure to a Climate-Related Disaster Results in Changes of the Placental Transcriptome and Infant Temperament. Front Genet. 2022 Apr 29;13. doi:10.3389/fgene.2022.887619

49. Boccia M, D'Amico S, Bianchini F, Marano A, Giannini AM, Piccardi L. Different neural modifications underpin PTSD after different traumatic events: an fMRI meta-analytic study. Brain Imaging Behav. 2016 Mar;10(1):226–37. doi:10.1007/s11682-015-9387-3 PubMed PMID: 25913645.

50. Doell KC, Berman MG, Bratman GN, Knutson B, Kühn S, Lamm C, et al. Leveraging neuroscience for climate change research. Nat Clim Change. 2023 Dec;13(12):1288–97. doi:10.1038/s41558-023-01857-4

51. GBD 2021 Risk Factors Collaborators. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024 May 18;403(10440):2162–203. doi:10.1016/S0140-6736(24)00933-4 PubMed PMID: 38762324; PubMed Central PMCID: PMC11120204.

52. Kinney PL. Interactions of Climate Change, Air Pollution, and Human Health. Curr Environ Health Rep. 2018 Mar 1;5(1):179–86. doi:10.1007/s40572-018-0188-x

53. Costa LG, Cole TB, Dao K, Chang YC, Garrick JM. Developmental impact of air pollution on brain function. Neurochem Int. 2019 Dec 1;131:104580. doi:10.1016/j.neuint.2019.104580

54. Yi C, Wang Q, Qu Y, Niu J, Oliver BG, Chen H. In-utero exposure to air pollution and early-life neural development and cognition. Ecotoxicol Environ Saf. 2022 Jun 15;238:113589. doi:10.1016/j.ecoenv.2022.113589

55. Peterson BS, Bansal R, Sawardekar S, Nati C, Elgabalawy ER, Hoepner LA, et al. Prenatal exposure to air pollution is associated with altered brain structure, function, and metabolism in childhood. J Child Psychol Psychiatry. 2022;63(11):1316–31. doi:10.1111/jcpp.13578

References

56. Moguilner S, Baez S, Hernandez H, Migeot J, Legaz A, Gonzalez-Gomez R, et al. Brain clocks capture diversity and disparities in aging and dementia across geographically diverse populations. Nat Med. 2024 Dec;30(12):3646–57. doi:10.1038/s41591-024-03209-x

57. Alexeeff SE, Liao NS, Liu X, Van Den Eeden SK, Sidney S. Long-Term PM2.5 Exposure and Risks of Ischemic Heart Disease and Stroke Events: Review and Meta-Analysis. J Am Heart Assoc. 2021 Jan 5;10(1):e016890. doi:10.1161/JAHA.120.016890 PubMed PMID: 33381983; PubMed Central PMCID: PMC7955467.

58. Shah ASV, Lee KK, McAllister DA, Hunter A, Nair H, Whiteley W, et al. Short term exposure to air pollution and stroke: systematic review and meta-analysis. BMJ. 2015 Mar 24;350:h1295. doi:10.1136/bmj.h1295 PubMed PMID: 25810496; PubMed Central PMCID: PMC4373601.

59. Abolhasani E, Hachinski V, Ghazaleh N, Azarpazhooh MR, Mokhber N, Martin J. Air Pollution and Incidence of Dementia: A Systematic Review and Meta-analysis. Neurology. 2023 Jan 10;100(2):e242–54. doi:10.1212/WNL.0000000000201419 PubMed PMID: 36288998.

60. Neelam M, Bhui K, Cowan T, Freitag B. Association between Great Salt Lake desiccation, air quality, and major depressive episodes: an ecological study. Lancet Planet Health. 2026 Mar 1;10(3). doi:10.1016/j.lanplh.2025.101405 PubMed PMID: 41926976.

61. Zhang X, Chen X, Zhang X. The impact of exposure to air pollution on cognitive performance. Proc Natl Acad Sci. 2018 Sep 11;115(37):9193–7. doi:10.1073/pnas.1809474115

62. Chandra M, Rai CB, Kumari N, Sandhu VK, Chandra K, Krishna M, et al. Air Pollution and Cognitive Impairment across the Life Course in Humans: A Systematic Review with Specific Focus on Income Level of Study Area. Int J Environ Res Public Health. 2022 Jan 27;19(3):1405. doi:10.3390/ijerph19031405 PubMed PMID: 35162428; PubMed Central PMCID: PMC8835599.

63. Newbury JB, Heron J, Kirkbride JB, Fisher HL, Bakolis I, Boyd A, et al. Air and Noise Pollution Exposure in Early Life and Mental Health From Adolescence to Young Adulthood. JAMA Netw Open. 2024 May 1;7(5):e2412169. doi:10.1001/jamanetworkopen.2024.12169 PubMed PMID: 38805229; PubMed Central PMCID: PMC11134215.

64. McGuinn LA, Windham GC, Kalkbrenner AE, Bradley C, Di Q, Croen LA, et al. Early Life Exposure to Air Pollution and Autism Spectrum Disorder: Findings from a Multisite Case-Control Study. Epidemiol Camb Mass. 2020 Jan;31(1):103–14. doi:10.1097/EDE.0000000000001109 PubMed PMID: 31592868; PubMed Central PMCID: PMC6888962.

65. Dickerson AS, Rahbar MH, Bakian AV, Bilder DA, Harrington RA, Pettygrove S, et al. Autism spectrum disorder prevalence and associations with air concentrations of lead, mercury, and arsenic. Environ Monit Assess. 2016 Jul 1;188(7):1–15. doi:10.1007/s10661-016-5405-1

66. Braithwaite I, Zhang S, Kirkbride JB, Osborn DPJ, Hayes JF. Air Pollution (Particulate Matter) Exposure and Associations with Depression, Anxiety, Bipolar, Psychosis and Suicide Risk: A Systematic Review and Meta-Analysis. Environ Health Perspect. 2019 Dec;127(12):126002. doi:10.1289/EHP4595 PubMed PMID: 31850801; PubMed Central PMCID: PMC6957283.

67. Go TH, Kim MH, Choi YY, Han J, Kim C, Kang DR. The short-term effect of ambient particulate matter on suicide death. Environ Health Glob Access Sci Source. 2024 Jan 3;23(1):3. doi:10.1186/s12940-023-01042-2 PubMed PMID: 38169380; PubMed Central PMCID: PMC10763266.

68. Lyons S, Nolan A, Carthy P, Griffin M, O’Connell B. Long-term exposure to PM2.5 air pollution and mental health: a retrospective cohort study in Ireland. Environ Health. 2024 Jun 10;23(1):54. doi:10.1186/s12940-024-01093-z

References

69. Hu Q, Feng Y, Xu M. Are There Heterogeneous Impacts of Air Pollution on Mental Health? Front Public Health. 2021;9:780022. doi:10.3389/fpubh.2021.780022 PubMed PMID: 34869193; PubMed Central PMCID: PMC8640523.

70. Wood D, Evangelopoulos D, Beevers S, Kitwiroon N, Demakakos P, Katsouyanni K. Exposure to ambient air pollution and cognitive function: an analysis of the English Longitudinal Study of Ageing cohort. Environ Health. 2024 Apr 5;23(1):35. doi:10.1186/s12940-024-01075-1

71. Lu JG. Air pollution: A systematic review of its psychological, economic, and social effects. Curr Opin Psychol. 2020 Apr;32:52–65. doi:10.1016/j.copsyc.2019.06.024 PubMed PMID: 31557706.

72. Sakhvidi MJZ, Yang J, Lequy E, Chen J, Hoogh K de, Letellier N, et al. Outdoor air pollution exposure and cognitive performance: findings from the enrolment phase of the CONSTANCES cohort. Lancet Planet Health. 2022 Mar 1;6(3):e219–29. doi:10.1016/S2542-5196(22)00001-8 PubMed PMID: 35278388.

73. Zhu X, Guo C, Zhang Y, Wei Y. Air pollution as a key risk factor for alzheimer's disease: A comprehensive review. Environ Technol Innov. 2025 Nov 1;40:104555. doi:10.1016/j.eti.2025.104555

74. Wang J, Ma T, Ma D, Li H, Hua L, He Q, et al. The Impact of Air Pollution on Neurodegenerative Diseases. Ther Drug Monit. 2021 Feb 1;43(1):69–78. doi:10.1097/FTD.0000000000000818 PubMed PMID: 33009291.

75. Iqubal A, Ahmed M, Ahmad S, Sahoo CR, Iqubal MK, Haque SE. Environmental neurotoxic pollutants: review. Environ Sci Pollut Res. 2020 Nov 1;27(33):41175–98. doi:10.1007/s11356-020-10539-z

76. Binter AC, Kusters MSW, van den Dries MA, Alonso L, Lubczyńska MJ, Hoek G, et al. Air pollution, white matter microstructure, and brain volumes: Periods of susceptibility from pregnancy to preadolescence. Environ Pollut. 2022 Nov 15;313:120109. doi:10.1016/j.envpol.2022.120109

77. Peeples L. How air pollution threatens brain health. Proc Natl Acad Sci. 2020 Jun 23;117(25):13856–60. doi:10.1073/pnas.2008940117

78. Zaitseva NV, Zemlyanova MA, Gekht AB, Dedaev SI, Kol'dibekova YuV, Peskova EV, et al. Neurotoxic effects of aluminum and manganese: From molecular to clinical effects. J Neurol Sci. 2025 Jun 15;473:123480. doi:10.1016/j.jns.2025.123480

79. Solaimani P, Saffari A, Sioutas C, Bondy SC, Campbell A. Exposure to ambient ultrafine particulate matter alters the expression of genes in primary human neurons. Neurotoxicology. 2017 Jan;58:50–7. doi:10.1016/j.neuro.2016.11.001 PubMed PMID: 27851901.

80. Calderón-Garcidueñas L, Herrera-Soto A, Jury N, Maher BA, González-Maciel A, Reynoso-Robles R, et al. Reduced repressive epigenetic marks, increased DNA damage and Alzheimer's disease hallmarks in the brain of humans and mice exposed to particulate urban air pollution. Environ Res. 2020 Apr;183:109226. doi:10.1016/j.envres.2020.109226 PubMed PMID: 32045727.

81. Seesaard T, Kamjornkittikoon K, Wongchoosuk C. A comprehensive review on advancements in sensors for air pollution applications. Sci Total Environ. 2024 Nov 15;951:175696. doi:10.1016/j.scitotenv.2024.175696

References

82. Su JG, Aslebagh S, Vuong V, Shahriary E, Yakutis E, Sage E, et al. Examining air pollution exposure dynamics in disadvantaged communities through high-resolution mapping. Sci Adv. 10(32):eadm9986. doi:10.1126/sciadv.adm9986 PubMed PMID: 39110789; PubMed Central PMCID: PMC11305374.

83. Myers SS, Smith MR, Guth S, Golden CD, Vaitla B, Mueller ND, et al. Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. Annu Rev Public Health. 2017 Mar 20;38:259–77. doi:10.1146/annurev-publhealth-031816-044356 PubMed PMID: 28125383.

84. FAO, IFAD, UNICEF, WFP, WHO. The State of Food Security and Nutrition in the World 2024 [Internet]. FAO ; IFAD ; UNICEF ; WFP ; WHO ; 2024 [cited 2025 Apr 23]. Available from: https://openknowledge.fao.org/handle/20.500.14283/cd1254en

85. Kirolos A, Goyheneix M, Kalmus Eliasz M, Chisala M, Lissauer S, Gladstone M, et al. Neurodevelopmental, cognitive, behavioural and mental health impairments following childhood malnutrition: a systematic review. BMJ Glob Health. 2022 Jul;7(7):e009330. doi:10.1136/bmjgh-2022-009330 PubMed PMID: 35793839; PubMed Central PMCID: PMC9260807.

86. Pourmotabbed A, Moradi S, Babaei A, Ghavami A, Mohammadi H, Jalili C, et al. Food insecurity and mental health: a systematic review and meta-analysis. Public Health Nutr. 2020 Jul;23(10):1778–90. doi:10.1017/S136898001900435X

87. Palmer VS, Tshala-Katumbay DD, Spencer PS. Plants with neurotoxic potential in undernourished subjects. Rev Neurol (Paris). 2019 Dec 1;175(10):631–40. doi:10.1016/j.neurol.2019.07.015

88. Jáuregui-Lobera I. Iron deficiency and cognitive functions. Neuropsychiatr Dis Treat. 2014 Nov 10;10:2087–95. doi:10.2147/NDT.S72491 PubMed PMID: 25419131.

89. Kapil U. Health Consequences of Iodine Deficiency. Sultan Qaboos Univ Med J. 2007 Dec;7(3):267–72. PubMed PMID: 21748117; PubMed Central PMCID: PMC3074887.

90. Cusick SE, Georgieff MK. The Role of Nutrition in Brain Development: The Golden Opportunity of the "First 1000 Days." J Pediatr. 2016 Aug;175:16–21. doi:10.1016/j.jpeds.2016.05.013 PubMed PMID: 27266965; PubMed Central PMCID: PMC4981537.

91. Specchia ML, Beccia F, Cacciuttolo MG, Petrella L, Mungo T, Thiella S, et al. Maternal and child nutrition insecurity, microbiome, and early neurodevelopment: an intricate interplay. Results from a systematic review. Eur J Public Health. 2026 Apr 1;36(2):ckaf246. doi:10.1093/eurpub/ckaf246

92. McMichael AJ, McGuinness B, Lee J, Minh HV, Woodside JV, McEvoy CT. Food insecurity and brain health in adults: A systematic review. Crit Rev Food Sci Nutr. 2022;62(31):8728–43. doi:10.1080/10408398.2021.1932721 PubMed PMID: 34047662.

93. Gallegos D, Eivers A, Sondergeld P, Pattinson C. Food Insecurity and Child Development: A State-of-the-Art Review. Int J Environ Res Public Health. 2021 Aug 26;18(17):8990. doi:10.3390/ijerph18178990 PubMed PMID: 34501578; PubMed Central PMCID: PMC8431639.

94. Colombo SM, Rodgers TFM, Diamond ML, Bazinet RP, Arts MT. Projected declines in global DHA availability for human consumption as a result of global warming. Ambio. 2020 Apr;49(4):865–80. doi:10.1007/s13280-019-01234-6 PubMed PMID: 31512173; PubMed Central PMCID: PMC7028814.

95. Coley EJL, Hsiao EY. Malnutrition and the microbiome as modifiers of early neurodevelopment. Trends Neurosci. 2021 Sep 1;44(9):753–64. doi:10.1016/j.tins.2021.06.004 PubMed PMID: 34303552.

References

96. Rogers GB, Keating DJ, Young RL, Wong ML, Licinio J, Wesselingh S. From gut dysbiosis to altered brain function and mental illness: mechanisms and pathways. Mol Psychiatry. 2016 Jun;21(6):738–48. doi:10.1038/mp.2016.50

97. Shennon I, Wilson BC, Behling AH, Portlock T, Haque R, Forrester T, et al. The infant gut microbiome and cognitive development in malnutrition. Clin Nutr. 2024 May 1;43(5):1181–9. doi:10.1016/j.clnu.2024.03.029

98. Ma CS, Zhang W, Peng Y, Zhao F, Chang XQ, Xing K, et al. Climate warming promotes pesticide resistance through expanding overwintering range of a global pest. Nat Commun. 2021 Sep 9;12(1):5351. doi:10.1038/s41467-021-25505-7 PubMed PMID: 34504063; PubMed Central PMCID: PMC8429752.

99. Carvalho FP. Pesticides, environment, and food safety. Food Energy Secur. 2017;6(2):48–60. doi:10.1002/fes3.108

100. Ben-Shlomo Y, Darweesh S, Llibre-Guerra J, Marras C, San Luciano M, Tanner C. The epidemiology of Parkinson's disease. Lancet Lond Engl. 2024 Jan 20;403(10423):283–92. doi:10.1016/S0140-6736(23)01419-8 PubMed PMID: 38245248; PubMed Central PMCID: PMC11123577.

101. Grandjean P, Landrigan PJ. Developmental neurotoxicity of industrial chemicals. The Lancet. 2006 Dec 16;368(9553):2167–78. doi:10.1016/S0140-6736(06)69665-7 PubMed PMID: 17174709.

102. Clarkson TW, Magos L, Myers GJ. The toxicology of mercury--current exposures and clinical manifestations. N Engl J Med. 2003 Oct 30;349(18):1731–7. doi:10.1056/NEJMra022471 PubMed PMID: 14585942.

103. Bolan S, Padhye LP, Jasemizad T, Govarthanan M, Karmegam N, Wijesekara H, et al. Impacts of climate change on the fate of contaminants through extreme weather events. Sci Total Environ. 2024 Jan 20;909:168388. doi:10.1016/j.scitotenv.2023.168388

104. Chapra SC, Boehlert B, Fant C, Bierman VJ, Henderson J, Mills D, et al. Climate Change Impacts on Harmful Algal Blooms in U.S. Freshwaters: A Screening-Level Assessment. Environ Sci Technol. 2017 Aug 15;51(16):8933–43. doi:10.1021/acs.est.7b01498 PubMed PMID: 28650153.

105. McKibben SM, Peterson W, Wood AM, Trainer VL, Hunter M, White AE. Climatic regulation of the neurotoxin domoic acid. Proc Natl Acad Sci. 2017 Jan 10;114(2):239–44. doi:10.1073/pnas.1606798114

106. Costa LG, Giordano G, Faustman EM. Domoic acid as a developmental neurotoxin. NeuroToxicology. 2010 Sep 1;Gene-Environment Interactions in Neurotoxicology: The 12th Biennial Meeting of the International Neurotoxicology Association31(5):409–23. doi:10.1016/j.neuro.2010.05.003

107. Balbus JM, Boxall ABA, Fenske RA, McKone TE, Zeise L. Implications of global climate change for the assessment and management of human health risks of chemicals in the natural environment. Environ Toxicol Chem. 2013 Jan;32(1):62–78. doi:10.1002/etc.2046 PubMed PMID: 23147420; PubMed Central PMCID: PMC3601433.

108. Rafa N, Ahmed B, Zohora F, Bakya J, Ahmed S, Ahmed SF, et al. Microplastics as carriers of toxic pollutants: Source, transport, and toxicological effects. Environ Pollut. 2024 Feb 15;343:123190. doi:10.1016/j.envpol.2023.123190

109. Nihart AJ, Garcia MA, El Hayek E, Liu R, Olewine M, Kingston JD, et al. Bioaccumulation of microplastics in decedent human brains. Nat Med. 2025 Apr;31(4):1114–9. doi:10.1038/s41591-024-03453-1

110. Ross SM, McManus IC, Harrison V, Mason O. Neurobehavioral problems following low-level exposure to organophosphate pesticides: a systematic and meta-analytic review. Crit Rev Toxicol. 2013 Jan;43(1):21–44. doi:10.3109/10408444.2012.738645 PubMed PMID: 23163581.

References

111. Sánchez-Santed F, Colomina MT, Herrero Hernández E. Organophosphate pesticide exposure and neurodegeneration. Cortex J Devoted Study Nerv Syst Behav. 2016 Jan;74:417–26. doi:10.1016/j.cortex.2015.10.003 PubMed PMID: 26687930.

112. Ferguson G, Gleeson T. Vulnerability of coastal aquifers to groundwater use and climate change. Nat Clim Change. 2012 May;2(5):342–5. doi:10.1038/nclimate1413

113. Suarez-Lopez JR, Hood N, Suárez-Torres J, Gahagan S, Gunnar MR, López-Paredes D. Associations of acetylcholinesterase activity with depression and anxiety symptoms among adolescents growing up near pesticide spray sites. Int J Hyg Environ Health. 2019 Aug;222(7):981–90. doi:10.1016/j.ijheh.2019.06.001 PubMed PMID: 31202795; PubMed Central PMCID: PMC6679983.

114. Reuben A, Schaefer JD, Moffitt TE, Broadbent J, Harrington H, Houts RM, et al. Association of Childhood Lead Exposure With Adult Personality Traits and Lifelong Mental Health. JAMA Psychiatry. 2019 Apr;76(4):418–25. doi:10.1001/jamapsychiatry.2018.4192 PubMed PMID: 30673063; PubMed Central PMCID: PMC6450277.

115. Ma J, Guo Y, Gao J, Tang H, Xu K, Liu Q, et al. Climate Change Drives the Transmission and Spread of Vector-Borne Diseases: An Ecological Perspective. Biology. 2022 Nov 7;11(11):1628. doi:10.3390/biology11111628 PubMed PMID: 36358329; PubMed Central PMCID: PMC9687606.

116. Caminade C, McIntyre KM, Jones AE. Impact of recent and future climate change on vector-borne diseases. Ann N Y Acad Sci. 2019 Jan;1436(1):157–73. doi:10.1111/nyas.13950 PubMed PMID: 30120891; PubMed Central PMCID: PMC6378404.

117. Ebi KL, Nealon J. Dengue in a changing climate. Environ Res. 2016 Nov 1;151:115–23. doi:10.1016/j.envres.2016.07.026

118. de Souza WM, Weaver SC. Effects of climate change and human activities on vector-borne diseases. Nat Rev Microbiol. 2024 Aug;22(8):476–91. doi:10.1038/s41579-024-01026-0

119. Carod-Artal FJ, Wichmann O, Farrar J, Gascón J. Neurological complications of dengue virus infection. Lancet Neurol. 2013 Sep 1;12(9):906–19. doi:10.1016/S1474-4422(13)70150-9 PubMed PMID: 23948177.

120. Russo FB, Beltrão-Braga PCB. The impact of Zika virus in the brain. Biochem Biophys Res Commun. 2017 Oct 28;492(4):603–7. doi:10.1016/j.bbrc.2017.01.074 PubMed PMID: 28108286.

121. Kleinschmidt-DeMasters BK, Beckham JD. West Nile Virus Encephalitis 16 Years Later. Brain Pathol Zurich Switz. 2015 Sep;25(5):625–33. doi:10.1111/bpa.12280 PubMed PMID: 26276026; PubMed Central PMCID: PMC8029043.

122. Hora R, Kapoor P, Thind KK, Mishra PC. Cerebral malaria--clinical manifestations and pathogenesis. Metab Brain Dis. 2016 Apr;31(2):225–37. doi:10.1007/s11011-015-9787-5 PubMed PMID: 26746434.

123. Caminade C, Kovats S, Rocklov J, Tompkins AM, Morse AP, Colón-González FJ, et al. Impact of climate change on global malaria distribution. Proc Natl Acad Sci. 2014 Mar 4;111(9):3286–91. doi:10.1073/pnas.1302089111

124. Mattsson N, Bremell D, Anckarsäter R, Blennow K, Anckarsäter H, Zetterberg H, et al. Neuroinflammation in Lyme neuroborreliosis affects amyloid metabolism. BMC Neurol. 2010 Dec;10(1):1. doi:10.1186/1471-2377-10-51

125. Fallon BA, Madsen T, Erlangsen A, Benros ME. Lyme Borreliosis and Associations With Mental Disorders and Suicidal Behavior: A Nationwide Danish Cohort Study. Am J Psychiatry. 2021 Oct 1;178(10):921–31. doi:10.1176/appi.ajp.2021.20091347 PubMed PMID: 34315282.

References

126. Westervelt HJ, McCaffrey RJ. Neuropsychological Functioning in Chronic Lyme Disease. Neuropsychol Rev. 2002 Sep 1;12(3):153–77. doi:10.1023/A:1020381913563

127. Ebi KL, Hess JJ. Health Risks Due To Climate Change: Inequity In Causes And Consequences. Health Aff (Millwood). 2020 Dec;39(12):2056–62. doi:10.1377/hlthaff.2020.01125

128. Pearson AR, White KE, Nogueira LM, Lewis NA, Green DJ, Schuldt JP, et al. Climate change and health equity: A research agenda for psychological science. Am Psychol. 2023;78(2):244–58. doi:10.1037/amp0001074 PubMed PMID: 37011173.

129. Ibanez A, Melloni L, Świeboda P, Hynes W, Ikiz B, Ayadi R, et al. Neuroecological links of the exposome and One Health. Neuron. 2024 Jun 19;112(12):1905–10. doi:10.1016/j.neuron.2024.04.016 PubMed PMID: 38723637; PubMed Central PMCID: PMC11189719.

130. Silveira S, Kornbluh M, Withers MC, Grennan G, Ramanathan V, Mishra J. Chronic Mental Health Sequelae of Climate Change Extremes: A Case Study of the Deadliest Californian Wildfire. Int J Environ Res Public Health. 2021 Jan;18(4):4. doi:10.3390/ijerph18041487

131. Ngcamu BS. Climate change effects on vulnerable populations in the Global South: a systematic review. Nat Hazards. 2023 Sep 1;118(2):977–91. doi:10.1007/s11069-023-06070-2

132. Perera F, Nadeau K. Climate Change, Fossil-Fuel Pollution, and Children's Health. N Engl J Med. 2022 Jun 16;386(24):2303–14. doi:10.1056/NEJMra2117706 PubMed PMID: 35704482.

133. Adalat S, Hajat S, Ikiz B. Climate change has serious implications for children's brain health. BMJ. 2024 Jul 22;386:q1588. doi:10.1136/bmj.q1588 PubMed PMID: 39038838.

134. Diep L, Godfrey S, Tunhuma F, Campos LC, Lakhanpaul M, Parikh P. Cascading impacts of climate change on child survival and health in Africa. Nat Clim Change. 2025 Mar;15(3):254–61. doi:10.1038/s41558-024-02197-7

135. Turek-Hankins LL, Coughlan de Perez E, Scarpa G, Ruiz-Diaz R, Schwerdtle PN, Joe ET, et al. Climate change adaptation to extreme heat: a global systematic review of implemented action. Oxf Open Clim Change. 2021 Jan 1;1(1):kgab005. doi:10.1093/oxfclm/kgab005

136. UNICEF Data. Climate mobility and childhood: Examining the risks, closing the data and evidence gaps for children on the move [Internet]. 2024. Available from: https://data.unicef.org/resources/climate-mobility-and-childhood-report/

137. Smith GS, Anjum E, Francis C, Deanes L, Acey C. Climate Change, Environmental Disasters, and Health Inequities: The Underlying Role of Structural Inequalities. Curr Environ Health Rep. 2022 Mar 1;9(1):80–9. doi:10.1007/s40572-022-00336-w

138. Wilson B. Urban Heat Management and the Legacy of Redlining. J Am Plann Assoc. 2020 Oct 1;86(4):443–57. doi:10.1080/01944363.2020.1759127

139. Hsu A, Sheriff G, Chakraborty T, Manya D. Disproportionate exposure to urban heat island intensity across major US cities. Nat Commun. 2021 May 25;12(1):2721. doi:10.1038/s41467-021-22799-5

140. Crosland P, Ho N, Nguyen KH, Tran K, Hosseini SH, Vacher C, et al. Modeled estimates of the health outcomes and economic value of improving the social determinants of mental health. Nat Ment Health. 2025 Jul 24;1–14. doi:10.1038/s44220-025-00459-7

References

141. Crandon TJ, Vivian ER, Jach M, Rantanen LM, Quek H, Lupton MK, et al. Wildfires, brain health and mental health: A narrative review on the physiological and psychological interplay. Sci Total Environ. 2026 May 1;1028:181731. doi:10.1016/j.scitotenv.2026.181731

142. Wettstein ZS, Vaidyanathan A. Psychotropic Medication Prescriptions and Large California Wildfires. JAMA Netw Open. 2024 Feb 26;7(2):e2356466. doi:10.1001/jamanetworkopen.2023.56466

143. Mishra J, Han H, Ramanathan V. A mental health focus to amplify climate resilience actions. Npj Clim Action. 2025 Jun 12;4(1):55. doi:10.1038/s44168-025-00263-0

144. Chen H, Tong H, Xu Y. Wildfire Smoke and Its Neurological Impact. JAMA Neurol. 2024 Jun 1;81(6):575–6. doi:10.1001/jamaneurol.2024.0058

145. Breuer A, Ikiz B. The International Neuro Climate Working Group: A Global, Transdisciplinary Model for Advancing Planetary Health Through Brain Health. Challenges. 2026 Sep;17(3):27. doi:10.3390/challe17030027

146. El Omrani O, Meinsma N, Massazza A, Wyns A, Mejia A, van Daalen KR, et al. The need and opportunities for mental health integration into global climate negotiations. Nat Ment Health. 2024 Dec;2(12):1435–41. doi:10.1038/s44220-024-00358-3

147. 2023 WHO review of health in Nationally Determined Contributions and long-term strategies: health at the heart of the Paris Agreement. Geneva: World Health Organization; 2023.

148. Eissa M, Newberry Le Vay J, Jennings N, Lawrance EL, Massazza A. Integrating Mental Health into Climate Change Adaptation Policies [Internet]. United for Global Mental Health; 2025. Available from: https://unitedgmh.org/app/uploads/2025/07/Integrating-Mental-Health-into-Climate-Change-Adaptation-Policies-Final.pdf

149. Stewart-Ruano A, Spriggs R, Lawrance EL, Massazza A, Czerniewska A, Reale AS, et al. A Critical Gap in Addressing Mental Health in Heat-Health Action Plans Worldwide. Curr Environ Health Rep. 2025 May 26;12(1):23. doi:10.1007/s40572-025-00486-7

150. Arias D, Saxena S, Verguet S. Quantifying the global burden of mental disorders and their economic value. eClinicalMedicine. 2022 Dec 1;54. doi:10.1016/j.eclinm.2022.101675 PubMed PMID: 36193171.

151. Legaz A, Moguilner S, Barttfeld P, Cuadros Castro J, Galván Rial DS, Migeot J, et al. The exposome of brain aging across 34 countries. Nat Med. 2026 May;32(5):1838–51. doi:10.1038/s41591-026-04302-z

152. World Bank. The Cost of Inaction: Quantifying the Impact of Climate Change on Health in Low- and Middle-Income Countries [Internet]. Washington, DC: World Bank; 2024 [cited 2026 Jun 18]. Available from: https://hdl.handle.net/10986/42419 doi:10.1596/42419

153. Lawrance E, Thompson R, Fontana G, Jennings N. The impact of climate change on mental health and emotional wellbeing: current evidence and implications for policy and practice. Grantham Inst Brief Pap. 2021;36:1–36.

154. Ji JS. China's health national adaptation plan for climate change: action framework 2024–2030. Lancet Reg Health – West Pac. 2024 Nov 1;52. doi:10.1016/j.lanwpc.2024.101227 PubMed PMID: 39498402.

155. Zhang P, Carleton T, Lin L, Zhou M. Estimating the role of air quality improvements in the decline of suicide rates in China. Nat Sustain. 2024 Mar;7(3):260–9. doi:10.1038/s41893-024-01281-2

156. European Environment Agency. Harm to human health from air pollution in Europe [Internet]. LU: Publications Office of the European Union; 2025 [cited 2026 Aug 13]. (EEA briefing). Available from: https://data.europa.eu/doi/10.2800/8961999 doi:10.2800/8961999