

# Convergence of environmental determinants and clinical toxicology: The challenge of the exposome in a changing climate

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**ABSTRACT.** Climate change is increasingly recognized as a major determinant of human health and a powerful modifier of environmental exposures. The exposome, which encompasses the cumulative environmental, chemical, physical, and biological exposures experienced throughout life, provides a valuable framework for understanding how environmental change influences toxicologic risk. Emerging evidence indicates that climate-related changes influence a broad range of toxicologic conditions, including substance use disorders, medication-related toxicity, envenomation, environmental exposures, and mental health outcomes. This mini-review examines the intersection between climate change, the exposome, and clinical toxicology. Integrating climate-related determinants and exposome-based perspectives into risk assessment, surveillance, prevention, and patient care may improve the recognition of emerging hazards and strengthen responses to the evolving toxicologic challenges of a changing world.

**Keywords:** *Exposome; Poisoning; Toxicology; Climate change; Environmental health.*

Contemporary public health is confronting a multi-dimensional crisis in which climate change functions as a powerful amplifier of systemic risks.<sup>1</sup> In this evolving landscape, clinical toxicology must broaden its scope and embrace an integrated framework that incorporates two interconnected concepts: climate change and the exposome.

Climate change refers to long-term alterations in temperature and weather patterns driven by both natural processes and human activities that modify the composition of the atmosphere. Although often viewed primarily through the lens of global warming, its consequences extend far beyond rising temperatures and include prolonged droughts, water scarcity, large-scale wildfires, sea-level rise, flooding, polar ice loss, extreme weather events, and accelerating biodiversity loss.<sup>1,2</sup>

The exposome encompasses the cumulative environmental, chemical, physical, and biological exposures experienced throughout an individual's lifetime.<sup>3</sup> It provides a

framework for understanding how changing climatic conditions reshape patterns of exposure. As climate-related hazards intensify, they alter the distribution, magnitude, and duration of environmental exposures, amplifying both human vulnerability and the health effects of toxic agents.<sup>3,4</sup>

This mini-review examines the intersection between climate change and clinical toxicology through the concept of the exposome, synthesizing current evidence on how environmental change shapes exposure profiles, modifies toxicological hazards, and influences both individual and population health outcomes. Fig. 1 provides a graphical overview of the key concepts discussed in this article.

## DISCUSSION

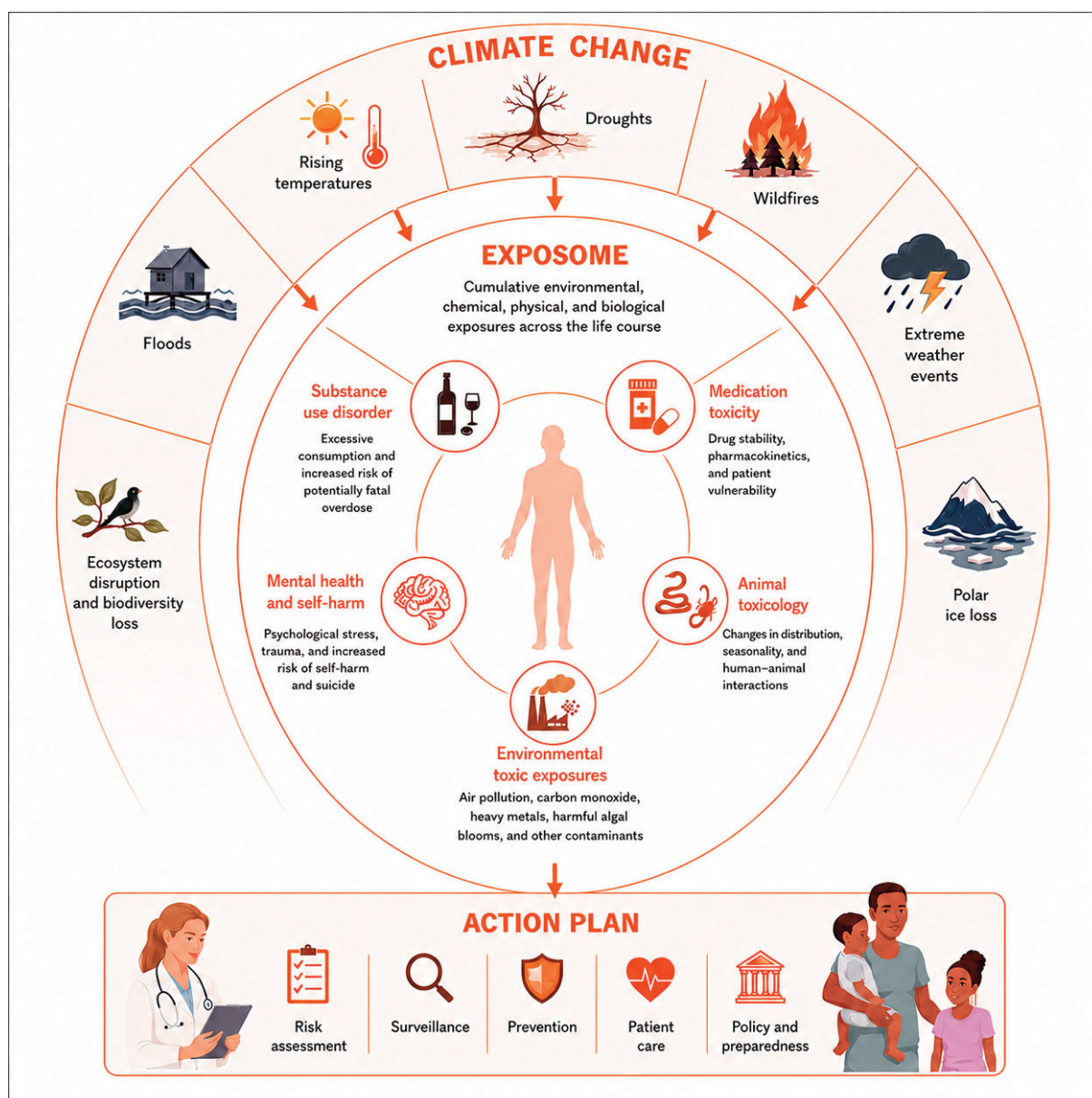
### *Climate change and clinical toxicology*

The relationship between climate change and toxicology has traditionally been examined through the lens of envi-

ronmental toxicology, with particular attention to increases in biotoxins and to changes in air and water pollution that promote higher concentrations of hydrocarbons and heavy metals. However, the implications of climate change extend well beyond environmental contamination and increasingly affect many toxic exposures encountered in everyday clinical practice. Accordingly, strategies for the prevention, diagnosis, and management of poisoning and toxicologic disorders must account for the environmental transformations that are reshaping patterns of exposure worldwide.

**Substance use disorders**

In the field of addiction medicine, growing evidence indicates that higher ambient temperatures are associated with an increased incidence of acute substance-related events requiring hospital care. Heat waves have been linked to a rise in emergency department visits related to alcohol, cannabis, cocaine, and opioid use.<sup>5</sup> Proposed mechanisms include increased impulsivity and a reduced subjective perception of drug effects, both of which may promote excessive consumption and increase the risk of potentially fatal overdose.<sup>6,7</sup>



**Figure 1.** Relationship between climate change, the exposome, and clinical toxicology, highlighting their impacts and the actions needed to address these challenges (AI-assisted figure).

In addition, extreme weather events represent major psychosocial stressors that can increase the likelihood of relapse and substance misuse. Displacement, loss of property, and disruption of livelihoods may further contribute to substance use as a maladaptive coping strategy in the aftermath of climate-related disasters.<sup>3,8</sup>

### **Drug toxicity**

Medication-related toxicity is also profoundly influenced by heat stress, which affects both drug stability and patient physiology. Elevated temperatures have been shown to compromise the effectiveness of medications critical for emergency care, including insulin and epinephrine autoinjectors.<sup>9,10</sup> In addition, commonly prescribed drugs such as diuretics, angiotensin-converting enzyme inhibitors, and angiotensin II receptor blockers may impair thermoregulation and fluid balance, thereby increasing the risk of dehydration and acute kidney injury during periods of extreme heat.<sup>11,12</sup> Dehydration may further alter the pharmacokinetics of drugs with a narrow therapeutic index, including lithium and digoxin, predisposing patients to severe toxicity through increases in serum drug concentrations.<sup>12</sup>

### **Venomous animals**

In animal toxicology, the climate crisis is reshaping the geographic distribution of numerous medically important species. Rising temperatures are facilitating the expansion of venomous animals, including snakes and scorpions of the genus *Tityus*, into regions previously considered free of these species. Many of these organisms also exhibit remarkable ecological plasticity and a high capacity to adapt to urban environments, increasing opportunities for human contact.<sup>13-15</sup> Periods of drought may further increase the incidence of envenomation, as venomous animals seek shelter, food, or water sources in residential and peri-urban areas.<sup>15,16</sup>

### **Environmental toxic exposures**

Environmental exposures to carbon monoxide (CO) and heavy metals provide another example of the indirect effects of climate change on human health. Wildfires, which have become increasingly frequent and severe as a result of prolonged drought and rising temperatures, release substantial amounts of CO and fine particulate matter (PM<sub>2.5</sub>), pollutants associated with neurologic injury, cardiovascular dysfunction, and systemic inflammation.<sup>6,17</sup>

At the same time, drought conditions reduce water levels in rivers, lakes, and other freshwater systems, increasing the concentration of chemical contaminants and heavy metals such as arsenic, mercury, and lead. This process enhances

their bioavailability and may increase the risk of chronic exposure among populations that rely on these water sources.<sup>17</sup>

### **Mental health**

The effects of climate change on mental health and self-harming behaviors represent some of its most concerning consequences. A growing body of evidence has linked temperature anomalies to increased suicide mortality and higher rates of hospitalization for mental disorders.<sup>6,8,18</sup> Prolonged exposure to environmental degradation has given rise to emerging psychological constructs such as eco-anxiety (persistent anxiety related to environmental threats) and solastalgia (distress caused by environmental change in one's home environment). These conditions may act as chronic stressors, impair emotional well-being, and exacerbate pre-existing psychiatric disorders.<sup>3,8,19,20</sup>

### **Future directions**

Clinical toxicology must evolve toward a preventive, interdisciplinary, and adaptive model of care. Integrating climate-related determinants into individual risk assessment, epidemiologic surveillance, and therapeutic decision-making is no longer optional but essential. A deeper understanding of the exposome in the setting of environmental change may help anticipate emerging threats and inform more effective prevention and response strategies. Ultimately, contemporary patients are exposed not only to toxic agents but also to the complex interplay among human biology, environmental exposures, and a rapidly changing climate.<sup>1,18</sup>

## **CONCLUSIONS**

Climate change is emerging as a major determinant of toxic exposures across a broad spectrum of clinical conditions. By reshaping environmental, behavioral, and biologic risk factors, it influences substance use disorders, medication-related toxicity, envenomation, environmental exposures, and mental health outcomes. The exposome provides a valuable framework for understanding how these interconnected factors affect human health throughout the life course. Integrating a climate-based perspective into risk assessment, health surveillance, prevention, and patient care methodologies will be essential to address known toxicological challenges as well as emerging and yet unforeseen threats in a continuously evolving environment.

### **Conflicts of interest**

The author declares no conflicts of interest.

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