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Editorial

Integrated Forecasting–Response to Climate-Related Public Health Emergencies and Disasters in India

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Introduction

Climate-related public health emergencies and disasters such as floods, droughts, cyclones, avalanches, heatwaves and cold waves are becoming a major cause of morbidity and mortality. A disaster is defined as "a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man-made cause, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area". [1] The COVID-19 pandemic, demonstrated that public health emergencies can be more destructive than conventional disasters and demand holistic integrated management. Most recently a comprehensive approach termed Public Health Emergency and Disaster Management (PHEDM) has been proposed and well recognized. [2]

A recent evaluation of panchayat-led PHEDM in Uttarakhand demonstrated substantial and measurable improvements in community preparedness, villagers prepared their own disasters management plans, implementing risk-informed micro-planning, and progressively built capacity, community trust and ownership. These gains can be further strengthened through periodic refresher training in digital and predictive technologies, such as artificial intelligence (AI) and machine learning (ML). [3]

The Hyogo Framework for Action (HFA) adopted at the World Conference on Disaster Reduction in Kobe, Japan in 2005.[4] Identified the imperative to identify, assess and monitor disaster risks and enhance early warning as one of its priority areas for action. Its successor the Sendai Framework for Disaster Risk Reduction 2015-2030, reinforced investment in the risk knowledge and multi-hazard early-warning systems.[5] Satellite remote sensing and modern information technology have since revolutionized disaster warning systems.

Forecasting disease outbreaks and public health

Satellite-based surveillance can be far more proactive than conventional systems, which detect disease introductions and outbreaks only after they have occurred. Recent advances in information management, including geographic information systems (GIS), should likewise be harnessed for emergency and disaster management so that the best possible information is available for effective decision-making.

Through pattern recognition that links disease trends to climatic indices, prospective satellite-based systems can anticipate where and how the next outbreak is most likely to occur although operationalising such prediction remains a challenge. For the control Schistosomiasis in endemic high-risk areas, prediction tools is particularly useful for facilitating early interventions before the wet season, such as mass drug administration, vector control, and community-awareness campaigns.[6] In Vietnam, researchers funded by the UK Space Agency have developed an early warning system that forecast the probability of dengue outbreaks up to six months in advance.[7] Integrating AI algorithms into existing surveillance enables rapid processing of vast datasets and improves the accuracy of outbreak detection.[8] The application of AI to predict climate-driven vector-borne diseases outbreaks nevertheless remains at an early stage.[9] Digital and technological-innovation may soon enable widespread and continuous collection and collation of climate health data. [10]

A growing ecosystem of tools and initiatives now supports outbreak forecasting including the U.S. CDC's Center for Forecasting and Outbreak Analytics, ensemble ML models, epidemic intelligence systems, and predictive health-information platforms. Since the COVID-19 pandemic, these methods have been applied to influenza, dengue and several non-communicable diseases and to the design of preventive strategy. The relevance to India developed an ML model that predicts dengue outbreaks up to two months ahead from meteorological and case data, projecting that, without intervention, rising temperatures and fluctuating monsoon rainfall could increase dengue-related deaths in India by about 13% by 2030 and 23–40% by 2050.[11]. The scale of the threat is sobering more than 14 million dengue cases were reported globally in 2024, against roughly 6 million in 2023. Internationally, geospatial platforms such as the Disease Incidence and Resource Estimator (DIRE) now translate ensemble dengue and malaria forecasts into actionable resource-allocation guidance for decision-makers.[12]

Heatwaves and forecasting their health impact

The human body maintains a core temperature around 37°C. Its principal physiological cooling mechanism in heat is sweating and evaporation from the skin, surface blood vessels dilate to release heat, and the metabolic rate may slow to reduce internal heat production. Radiation, conduction, and convection also contribute to heat loss, but these mechanisms become less effective when air temperature approaches or exceeds skin temperature or when high humidity limits sweat evaporation and cooling efficiency. Prolonged heat exposure can cause dehydration through fluid and electrolyte loss, producing fatigue, dizziness, light-headedness, nausea, and headache, and may progress to heat syncope, heat exhaustion and potentially fatal heatstroke. Heat exposure also impairs sleep, cognition and mental health, raising the risk of accidents and stress-related disorders, and it exacerbates pre-existing conditions such as diabetes, heart disease, and asthma. Although all age and sex groups are affected, infants, pregnant women, older people and those with comorbidities are most vulnerable. As mean temperature continues to rise heat related disorders alongside cascading effects on animals, vectors, plants, and the built environment will become an ever-greater concern.

El Nino conditions influence weather and climate patterns globally raising the risk of extreme heat and heat-related illness and vector-borne disease. Environmental degradation and climate change are intensifying extreme weather events, including floods, landslides, cyclones, wildfires, droughts, and heatwaves, all of which threaten human and planetary health.[13] In 2024, the global mean temperature exceeded 1.5°C above pre-industrial levels for the first time in a calendar year.[14].The World Health Organization estimates that between 2030 and 2050 climate change will cause approximately 250,000 additional deaths annually from heat, malnutrition, and malaria) with economic losses in $2–4 billion, a concern reaffirmed in the climate -and-health discussion at COP-28 (Dubai, 2023).[15]

The human toll of extreme heat is now being measured directly, the 2025 Lancet Countdown reports that annual heat-related deaths have risen by about 63% since the 1990s, reaching an estimated 546,000 per year (2012–2021); that in 2024 — the hottest year on record — the average person experienced 16 additional days of health-threatening heat attributable to climate change; and that heat exposure caused an estimated 640 billion lost labour hours, equivalent to roughly US$1.09 trillion in productivity losses.[13] Earlier landmark events include 2003 European heatwave, linked to about 77,000 excess deaths, 2010 Russian heatwave, which was estimated at about 55,000 premature deaths.[16,17] Every 1^0C rise in mean temperature may increase mortality risk by 0.2-5.5%, modelling suggests that if warning exceeds 2 °C above pre-industrial levels, around one billion people could face heat stress by 2100.[18]

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India's rapid industrialization and urbanization are contributing to more frequent, prolonged and intense heatwaves. The India Meteorological Department (IMD) confirmed 2024 as the country's warmest year since records began in 1901, with 37 cities crossing 45^{0}C and Churu (Rajasthan reaching 50.5^{0}C, the highest in India for eight years. [19] A heatwave is typically declared when the maximum temperature at a location exceeds 45 °C for at least for 2 days, however, there is no acceptable cut off limit as heatwave, hazardous heat and heat stress differ in its impact from area to area; [20] whereas heatwave affected nine states in 2015, they affected 23 states in 2020, and the 2024 pre-monsoon season brought 54 heatwave days. Official tallies placed India's heat-related deaths in 2024 at roughly 45-730, with more than 40,000 heatstroke cases, although independent analyses suggest subsequently higher tolls; by estimate, a quarter of global heatwave-related excess deaths since 1990 have occurred in India.[21] The exceptionally early 2025 heatwave caused hundred further deaths. Excess all-cause mortality during Ahmedabad in May 2010 when temperatures reached 46.8 °C was estimated to increase the deaths by 43% (1344 excess deaths) compared to May 2009–2011 averages.[22]

Existing Indian studies have several important limitations, a focus on specific regions rather than pan-India coverage, reliance on coarse global climate models unable to capture local heat dynamics, the use of divergent emissions scenarios that produces wide-ranging outcomes, and a frequent emphasis on temperature alone, without accounting for humidity.[23-25]

Indian states have institutionalized Heat Action Plans (HAPs), beginning with Ahmedabad in 2013; by 2023, 23 states were developing state-district or city-level HAP. Typical measures include early warning systems, heat-health awareness programs, capacity building of health professionals, and reducing heat exposure for vulnerable groups.[26] Recent advances have strengthened this architecture. Since 2022-23 the IMD has issued advisories covering both hot days and hot nights, with short -and medium-range forecasts, and has piloted an experimental heat index and "heat exposure score" (1-10); heatwaves can now be predicted a week ahead with color coded public warnings. Nationally, the NDMA and the Ministry of Health introduced a National Action Plan on Heat-Related Illnesses (2024), and heat-related illness and death surveillance has run on the Integrated Health Information Platform (IHIP) since 2023, expanded to all states and conducted year-round from the primary-health-centre level upward, while Heat Stroke Management Units are being established at secondary and tertiary hospitals. [27,28] HAP must, however, move beyond forecasting heatwaves alone to modelling the fluctuation and trends of climate sensitive diseases. This is achievable if, for example, IHIP under data under integrated disease surveillance program data are linked with climate data for disease prediction, a step consistent with the National Programme on Climate Change and Human Health (NPCCHH), which is being integrated with non-communicable-disease, vector-borne-disease, IMD, NDMA and environment-ministry activities.

India still lacks a fully comprehensive evidenced-based strategy to mitigate the health impacts of climate change, particularly heatwaves and related illnesses. Many HAPs lack scientific rigor, dedicated financing and locally calibrated thresholds. Strengthened early warning dissemination across multiple communication channels can enhance lead time for proactive heat mitigation among vulnerable groups. National initiatives 'Swachh Bharat Abhiyan', the National Clean Air Program (NCAP)', 'National Action Plan on Climate Change (NAPCC)', 'Nagar Van (urban forest) Scheme' and India Cooling Action Plan aim to reduce greenhouse gases and other air pollutants, and the NDMA's National Disaster Management Plan provides frameworks for heatwave mitigation through early warnings, awareness generation, and inter-agency coordination among agencies for emergency response.[20] A 2024 World Bank cost-benefit analysis nevertheless warns that, without further mitigation, heat- related deaths in major Indian cities could rise by about a third, and labour-productivity losses could reach 2–4% of city economic output, by 2050.[30]

When a new field develops, the development depends upon several area. These may include creation of shared identity, deepening research evidence, collaborating with other fields, development of leaders and pursuing integrative work as the priority, many of which are often contained in workforce development. For meaningful collaboration and opportunities for effective leadership certain structures are required in a field like resilience.[31]

Internationally, COP30 in Belém (2025) marked a shift toward implementation, launching the Belém Health Action Plan — the first international climate-adaptation framework dedicated specifically to health — with 60 action items spanning surveillance systems, evidence-based policy and health innovation, although dedicated finance remains uncertain.[32] Globally, the urgency is realized and the core elements of the heat health action plan are also expanding from governance, identifying at risk population, warning system, communication, health system resilience, surveillance, reducing heat exposure and monitoring and evaluation.[20] These global and national initiatives address climate change largely through response, preparedness and to some extent health adaptation. In the absence of robust evidence-based response, predictive models lack strength their suggested strategies; more research is needed in the area of prediction and evidence must be created whatever sustainable approaches have been trailed. Ultimately, we must accept that until we commit to building a sustainable earth for planetary health, adverse climatic change will not revert back.

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