



International Journal of Environment and Climate Change

Volume 14, Issue 11, Page 650-663, 2024; Article no.IJECC.125602

ISSN: 2581-8627

(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231-4784)

Climate Change and Heatwaves in India: Review of Impacts on Public Health, Livelihoods, and Policy

Sujata Saunik ^{a*} and Rajib Shaw ^a

^a Graduate School of Media and Governance, Keio University, Japan.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/ijecc/2024/v14i114575>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/125602>

Review Article

Received: 27/08/2024

Accepted: 29/10/2024

Published: 11/11/2024

ABSTRACT

This paper presents a literature review studying the impacts of climate change and heatwaves on public health and livelihoods, with a focus on India. As global climate change accelerates, heatwaves are becoming more frequent and intense, necessitating new approaches to mitigate their effects on vulnerable populations, especially in urban areas. The review draws on recent studies (2021-2024) that explore the intersections of climate change, heatwaves, public health, livelihoods, policy interventions, and Heat Action Plans. The main findings reveal that heatwaves in India have significant public health impacts, such as increased mortality and morbidity, and disproportionately affect livelihoods, especially in agriculture and informal labor sectors. Vulnerable populations, including urban dwellers and informal workers, face heightened risks, further exacerbated by inadequate infrastructure and policy gaps. The purpose of this review is to synthesize current research to highlight these vulnerabilities and identify gaps in knowledge and policy response. A comprehensive, localized approach combining detailed risk assessments, nature-based solutions,

*Corresponding author: E-mail: ssaunik@gmail.com, sujati@sfc.keio.ac.jp;

Cite as: Saunik, Sujata, and Rajib Shaw. 2024. "Climate Change and Heatwaves in India: Review of Impacts on Public Health, Livelihoods, and Policy". *International Journal of Environment and Climate Change* 14 (11):650-63. <https://doi.org/10.9734/ijecc/2024/v14i114575>.

technological innovations, and strengthened governance is essential for effective heatwave management in India. The findings underscore the urgent need for continued research focused on local spaces and comprehensive policy interventions to address the escalating risks posed by climate-induced heatwaves, setting the groundwork for future research and effective heatwave management strategies.

Keywords: Climate change; heatwaves; India; public health; livelihood; policy interventions; heat action plans.

1. INTRODUCTION

Climate change refers to significant and lasting changes in Earth's climate patterns over an extended period. Global Warming of 1.5°C (2018): an IPCC Special Report (Lee and Romero, 2023), highlights "The impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways". Further, this report shows an increase in global temperatures over different terrains, "Global surface temperature was 1.09 [0.95 to 1.20]°C higher in 2011–2020 than 1850–19006, with larger increases over land (1.59 [1.34 to 1.83]°C) than over the ocean (0.88 [0.68 to 1.01]°C)." and attributes the cause of rising global temperatures to human activities, "Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850-1900 in 2011-2020."

"Heat wave refers to a long duration of excessive heat particularly all along the summer season." as defined in (Preeti et al., 2021), which also states that, "Heat waves account approximately 90% of the total extreme temperature events related fatalities" and "In recent years, a rise in their occurrence, duration and intensity has been observed as a result of global warming." (p-1593). Moreover, research outlined in (Srivastava et al., 2022) has underscored the gravity of heatwaves by emphasizing, "Heat waves are often termed as the silent killer and have become even more important as recent studies suggest that the heat wave has become the second most devastating extreme weather event in terms of human deaths and losses."

Within the Indian context, the study underscores the magnitude of heatwaves in the country, "India is a tropical country and frequently experiences severe heat wave conditions owing to its unique geographical and climatic set-up." and the study also states that, "India is the most severely affected country by heat waves in the world" (Preeti et al., 2021). The authors referenced in

(Srivastava et al., 2022) discuss the prospective implications of heat impact in India, "Heat waves in India are expected to intensify and cause an increase in heat stress." However, the study in (de Bont et al., 2024) indicates insufficient evidence-based research, "Heatwaves are expected to increase with climate change, posing a significant threat to population health. In India, with the world's largest population, heatwaves occur annually but have not been comprehensively studied."

This study conducts a review of recent literature to explore the effects of heatwaves on human health and livelihood. Additionally, it evaluates the efficacy of existing policies and Heat Action Plans, while aiming to identify recurring themes in addressing heat waves across various papers. To achieve this objective, relevant papers were retrieved from the database and analyzed using common keywords. This paper serves as a foundational investigation for a forthcoming action research project focusing on the impact of heatwaves. Notably, one of the authors holds a policymaking position in India, a region increasingly susceptible to heatwaves. The action research will be carried out in India.

2. METHODS

The aim of this study is to investigate the key impacts of climate change and heatwaves on public health and livelihood cities across India. To achieve this, a comprehensive research methodology was employed, combining both systematic literature review and empirical research methods. The present review employed the methodological framework introduced by (Vom et al., 2009) in their investigation highlighting the significance of precision in documenting the literature search procedure. They presented a comprehensive five-phase methodological model for this process, comprising (1) delineating the scope of the review; (2) conceptualizing the topic; (3) conducting the literature search; (4) analyzing and synthesizing the literature; and (5)

establishing a research agenda. The subsequent sections provide a detailed description of this framework.

2.1 Review Scope Definition

To define the scope of the literature review, an established taxonomy for literature reviews as outlined by (Cooper, 1988) was employed.

- (a) **Focus:** This research aims to comprehend the current scenario and challenges associated with the impacts of heatwaves on health and livelihood in urban areas.
- (b) **Goal:** The primary objective is to pinpoint the central issues concerning the repercussions of heatwaves on health and livelihood, with a specific emphasis on commonalities across diverse aspects in the two urban areas of India.
- (c) **Perspective:** This study is conducted to investigate how the existing literature, with a significant focus on heat waves, addresses the intersection of "health impacts" and "livelihood effects" in the contexts of urban centers. The emphasis is on understanding overarching patterns rather than individual article objectives.
- (d) **Coverage:** Various facets related to the impacts of heatwaves on health and livelihood in different geographies were explored. The intent is to discern common

issues that transcend specific themes in these urban environments.

2.2 Conceptualization of the Topic

This research focuses on examining the significant effects of climate change-induced heatwaves on public health and livelihood. Key themes include understanding citizen vulnerabilities, assessing the broader impact on diverse populations, and exploring community participation and engagement for effective adaptation. The following keywords were used in understanding the main theme of the subject.

2.3 The Literature Search

The procedure depicted in Fig. 1 was adhered to for the literature search, utilizing the methodological model outlined in (Vom et al., 2009). The steps involved selecting the database source, specifying source types (such as books, dissertations, articles), determining keywords and search criteria, and evaluating the chosen sources.

- Database: Web of Science (2024)
- Keywords: "Climate change" AND "Heatwaves" AND "India" OR "Indian Cities" AND "Public Health" AND "Livelihood" AND "Policy Interventions" OR "Heat Action Plans"
- Filters: Publication date 2021 onwards, Open Access articles
- Initial Results: 6,731 articles

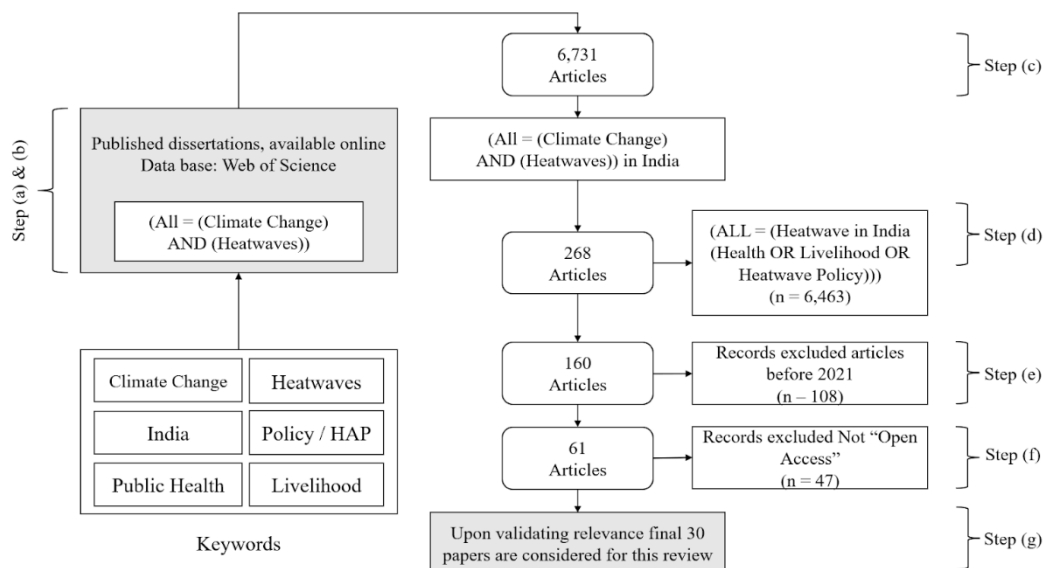


Fig. 1. Steps of the literature search process

Table 1. List of the papers

Sl. No.	Year	Name	Author	Abstract
1	2023	Climate Change 2023 Synthesis Report	Hoesung Lee et al.	The IPCC AR6 Synthesis Report compiles the latest insights on climate change, its impacts, risks, and mitigation/adaptation efforts from Working Groups 1, 2, and 3, along with Special Reports. Its Summary for Policymakers (SPM) addresses Current Status and Trends, Future Climate Change and Responses, and Near-Term Responses, highlighting the interconnectedness of climate, ecosystems, biodiversity, and human well-being. Key findings, expressed in IPCC-approved language, are grounded in scientific evidence.
2	2021	Heat wave fatalities over India: 1978–2014	Preeti Malik et al.	This study examines heat wave fatalities in India from 1978 to 2014 using 'Disastrous Weather Events' reports. Analysis of 660 events reveals 12,273 fatalities, with Andhra Pradesh reporting an average of 104 fatalities per event. The study informs disaster management guidelines for extreme temperature events, which have intensified due to global warming, resulting in thousands of fatalities globally and highlighting the urgent need for effective mitigation strategies.
3	2022	Hot weather hazard analysis over India	Akhil Srivastava et al.	Heat waves, now recognized as the second most devastating extreme weather events, are aggravated not only by high temperatures but also by various meteorological factors. This study aims to quantify the impact of different meteorological parameters on heat waves across India's regions during March to June. Using 30 years of data from 300 stations, it identifies individual and cumulative effects, laying the groundwork for nationwide heat hazard analysis and mitigation strategies, and providing thresholds for early warning services and timely actions by disaster managers and forecasters.
4	2024	Impact of heatwaves on all-cause mortality in India: A comprehensive multi-city study	de Bont, Jeroen et al.	This multi-city study across India reveals strong evidence of heatwaves impacting daily mortality, with longer and more intense heat waves associated with increased mortality risk. Shorter and less extreme heat waves also contribute to higher heat wave-related deaths. With temperatures surpassing the 97th percentile for two consecutive days, there was a 14.7% increase in daily mortality. Alternative definitions of heatwaves, such as higher percentiles and longer durations, show stronger relative risks. Heatwave intensity also influences mortality associations. Annually, an estimated 1116 deaths are attributed to heatwaves.
5	2023	Likely impacts of the 2022 heatwave on India's wheat production	Sidhu et al.	The 2022 Indian heatwave significantly affected key wheat production areas in northwestern and central India during the crop's harvest season, likely resulting in a notable decrease in national wheat production. Using statistical relationships derived from historical climate and wheat yield data, we offer spatially disaggregated estimates of the expected impact on wheat yield. The analysis demonstrates the feasibility of using current and forecasted weather data to estimate real-time impacts of short-term weather variability on end-of-season crop yields, even during the crop season.

6	2022	Extreme heat leads to short- and long-term food insecurity with serious consequences for health	Carolyn Kroeger et al.	India is grappling with an unprecedented heatwave, driving May temperatures to their highest levels in 121 years and threatening food access. Heatwaves not only damage agricultural yields but also disrupt short-term income generation, exacerbating food insecurity and health risks. Medical professionals play a crucial role in addressing heat-related food insecurity risks. Addressing these challenges requires interdisciplinary research and policies that consider climate impacts on food supply, demand, health, and livelihoods, as climate change intensifies globally.
7	2023	Indian heatwaves in a future climate with varying hazard thresholds	Rao, K Koteswara et al.	This study investigates the characteristics of summertime (March–June) heatwaves in both present and future climates. Analysis of India Meteorological Department observational data from 1951 to 2020 reveals escalating trends in heatwave features, primarily in northwest, central, and south peninsular regions. Utilizing statistically downscaled and bias-corrected climate model data from the CMIP6 project, this research assesses future alterations in heatwave attributes using varying hazard thresholds. Findings indicate a notable rise in mean summertime heat waves across much of India, with the most significant increases projected in the far future.
8	2023	Extreme heat, gender, and access to preparedness measures	Ainsley Trahan et al.	India, notably vulnerable, initiated South Asia's first Heat Action Plan (HAP) in 2013, focusing on Ahmedabad. This study examines Ahmedabad's HAP, emphasizing its Early Warning Systems (EWS) and assessing social vulnerability among female outdoor laborers. Findings reveal gender-related disparities in EWS access, influenced by occupation, income, and education. Ahmedabad's HAP highlights the importance of inclusive EWS approaches, urging further exploration of gender's impact on heat vulnerability for effective EWS design globally.
9	2021	Prediction of Heatwave 2013 over Andhra Pradesh and Telangana, India using WRF Model	N. Naveena et al.	Heatwaves, significant meteorological disasters, increasingly impact lives. This study examines 2013's heatwave in Andhra Pradesh and Telangana, where 1216 fatalities occurred. Rising heat wave frequency and intensity are observed nationwide, especially in coastal regions. The Weather Research and Forecasting (WRF) model accurately predicts temperatures 72 hours in advance. Atmospheric circulation patterns contributing to the heatwave are discussed. WRF forecasts effectively anticipate heatwaves in AP and Telangana with a 72-hour lead time.
10	2022	Strong influence of north Pacific Ocean variability on Indian summer heatwaves	Vittal Hari et al.	Using observations and climate model experiments, the study shows that a strong positive phase of PMM correlates with intensified and prolonged heat waves over North Central India (NCI), a high-risk region. Climate models project even higher heat wave intensities in the future, potentially increasing mortality rates by approximately 150%. These findings underscore the need for effective mitigation and adaptation strategies.
11	2023	Projected changes in heatwaves and its	Pyarimohan Maharana et al.	This study examines heatwave frequency and duration in India under two climate scenarios. It predicts that over 90% of India will experience warm nights by the century's end, with the

		impact on human discomfort over India due to global warming under the CORDEX-CORE framework.		western region and states like Odisha and Chhattisgarh most affected. Implementing stringent population stabilization policies, improving adaptive capacities, and mitigating greenhouse gas emissions are crucial to reduce heat stress exposure. Mitigation-focused development could potentially decrease heatwave days, spells, and warm nights, benefiting millions by the century's end.
12	2021	Changes in regional wet heat wave in Eurasia during summer (1979–2017)	Shuang Yu et al.	Wet heat waves, often overlooked, significantly impact human health compared to dry heatwaves. Wet heat waves, defined as three-day periods with T (w) above the 90th percentile, exhibit maximum amplitudes near 31°C in specific regions. Climatological relative humidity (RH) strongly influences T (w) changes, impacting arid regions more significantly. Temperature dominates T (w) increases during wet heatwaves in Europe, Tibet, India, East Asia, and the Arabian Peninsula, while Russia's increases are mainly temperature-driven.
13	2023	Lethal heatwaves are challenging India's sustainable development	Debnath, Ramit et al.	Climate change-induced heatwaves in India jeopardize public health, agriculture, and socio-economic systems, hindering sustainable development goals (SDGs). Relying solely on India's Climate Vulnerability Index (CVI) underestimates heat wave impacts. Analysis combining Heat Index (HI) with CVI reveals over 90% of India faces extreme caution or danger levels, affecting livelihoods, food production, disease spread, and urban sustainability.
14	2022	Heatwaves in South Asia: Characterization, Consequences on Human Health, and Adaptation Strategies	Ayushi Sharma et al.	This study conducts a comprehensive review of heatwaves across South Asian countries, highlighting increased heat-related deaths and rising temperatures. It identifies limited functional heatwave management plans and emphasizes the need for community and residential preparedness. The study recommends adaptation strategies like blue-green spaces and indoor cooling but stresses the importance of collaborative efforts for heatwave-resilient cities.
15	2021	Understanding the hot season dynamics and variability across India	Aditya Dubey et al.	This study delves into India's hot season dynamics across five temperature homogeneous regions using Canonical Correlation Analysis. While all regions exhibit a positive trend with minimal interannual variability, the Gangetic plains stand out. Global teleconnections, including anomalous low pressure over Europe and subtropical/polar jet streams, sustain anticyclonic blocks over North India. Southern India experiences heating from northwest air intrusions, culminating in reduced humidity along coastal regions due to moisture blocking, further amplifying temperature anomalies.
16	2022	Build back better: Why Indian construction must grapple with extreme heat	Kamala Thiagarajan	South Asia is suffering some of its worst heat waves in a century. The public health implications are being made worse by a building infrastructure that is not designed to cope.
17	2023	Climate change and informal workers:	David Dodman et al.	The informal economy sustains urban functions globally, offering primary income for many workers, yet informal laborers face heightened vulnerability to climate change. Research

		Towards an agenda for research and practice		across Indore, Harare, and Masvingo reveals informal workers' susceptibility across sectors due to climate impacts compounded by poor living conditions and inadequate Occupational Health and Safety provisions.
18	2021	Nature-Based Solutions for Co-mitigation of Air Pollution and Urban Heat in Indian Cities	Jyothi S Menon et al.	Nature-Based Solutions (NbS) emerge as cost-effective remedies, offering multiple benefits such as reduced energy and health costs, biodiversity conservation, and improved public health by curbing air pollution and urban heat. This review underscores the dynamic interplay between urban heat and air pollution and advocates for an integrated approach in urban planning, proposing a framework for the implementation of NbS in Indian cities to address these dual challenges effectively.
19	2023	The diurnal variation of wet bulb temperatures and exceedance of physiological thresholds relevant to human health in South Asia	Jenix Justine et al.	Diurnal analysis of South Asian station data reveals that peak wet bulb temperatures lag several hours behind peak dry bulb temperatures. Physiological thresholds for heat stress were surpassed, even in the evenings, totaling over 300 hours of exposure to un-compensable heat stress in South Asia from 1995 to 2020. This highlights the importance of considering physiological thresholds for robust health impact assessments, emphasizing that wet bulb temperature alone is insufficient as a heat hazard indicator.
20	2021	Mental health in mine workers: a literature review	José Matamala Pizarro et al.	The mining environment poses mental health risks for workers, including anxiety and depression. A recent scoping review highlighted four main themes: Psychological problems & personal factors (38.2%), Psychosocial problems & health-related factors (23.6%), Well-being (21.1%), and Physical problems & organization factors (17.1%). Issues such as job strain, safety concerns, poor sleep quality, and substance abuse were identified. The findings emphasize the need for international policies and intervention programs to address mental health challenges in the mining industry.
21	2021	Hot weather and heat extremes: health risks	Kristie L Ebi et al.	High temperatures and heat stress pose serious health risks, including mortality, pregnancy complications, and mental health issues, while also reducing work capacity and productivity. Over 1 billion workers globally are exposed to heat episodes, with a third experiencing adverse health effects. Preventative measures like heat action plans can mitigate risks, but climate change is expected to increase heat-related health problems, particularly in urban areas. Without investment in research and risk management, heat-related morbidity and mortality will likely rise further in the future.
22	2023	The Health Effects of Climate Change on Children: Pediatricians Must Be Part of the	Ruth A. Etzel et al.	Climate change profoundly affects Indian children, leading to respiratory illnesses, heat-related issues, malnutrition, and mental health disorders like post-traumatic stress disorder. Advocacy by professional pediatric associations with government agencies is crucial to urge immediate reduction of greenhouse gas emissions. Indian pediatricians must declare

		Solution		climate change as a child health emergency and take proactive measures to address its impacts.
23	2022	Dynamics and characteristics of dry and moist heat waves over East Asia	Kyung Ja Ha et al.	Increasing heat waves in East Asia (EA) impact agriculture, water management, and livelihoods. Dry heat waves feature amplified anticyclonic circulation driven by wave activity flux convergence, leading to surface warming via adiabatic processes. Moist heat waves result from locally generated anticyclonic anomalies, with surface warming amplified by cloud and water vapor feedback. Model simulations predict intensified dry heatwaves and more moist heat wave days due to rising greenhouse gas concentrations.
24	2021	The driving processes of concurrent hot and dry extreme events in China	Fangxing Tian et al.	Subseasonal heatwave-driven concurrent hot and dry extreme events (HDEs) pose significant threats to crops and livelihoods. These events are characterized by positive temperature and evapotranspiration anomalies and negative soil moisture anomalies, often associated with large-scale subsidence anomalies.
25	2023	Impact of climate change and heat stress on workers' health and productivity: A scoping review	Mustapha Amodu et al.	This scoping review maps evidence on occupational heat stress risk factors, health impacts, and adaptation measures. Risk factors include gender, age, dehydration, payment methods, inadequate protective gear, physically demanding work, and high temperatures. Vulnerable groups include migrants, pregnant women, and children. Adaptation measures include fluid intake, shade rest, altered work hours, and electrolyte intake. Improved work conditions and social support are crucial for ensuring safe working environments amidst climate change.
26	2023	Assessing the Cooling Effect of Blue-Green Spaces: Implications for Urban Heat Island Mitigation	Pritipadmaja et al.	The Urban Heat Island (UHI) effect poses a significant challenge in rapidly urbanizing cities, amplifying the impact of heatwaves on urban livelihoods and environmental well-being. This study in Bhubaneswar, India, assesses the cooling effect of blue-green spaces and their potential to mitigate UHI effects. Utilizing Google Earth Engine (GEE), satellite images were analyzed to determine land surface temperatures (LST) in blue-green spaces. Correlation analysis underscores the influence of urbanization on local climate dynamics, particularly through built-up indices (NDBI). The study highlights the efficacy of blue-green spaces in reducing surface temperatures and mitigating UHI effects.
27	2023	Climate science to inform adaptation policy: Heat waves over India in the 1.5°C and 2°C warmer worlds. Climatic change	Arulalan T et al.	This study analyzes future heat waves in India using observations and model simulations. It predicts increased heat wave probabilities during June and July, posing higher health risks due to humidity. While maximum temperatures may not rise significantly, heat wave duration and area are expected to increase, creating new heat-prone zones. The study suggests a threefold to fivefold increase in long-duration and large-area heat wave events in future climates, emphasizing the need for comprehensive adaptation measures beyond current frameworks.
28	2020	A Critical Analysis of the Heat Action Plan	Maryam Nastar	Heat-related policies like Ahmedabad's Heat Action Plan (HAP) aim to mitigate heat wave impacts, but assessing their effectiveness reveals knowledge gaps. This paper highlights the

		in Ahmedabad, India		need to integrate HAP into urban development projects to ensure inclusivity. Current policies, including HAP, overly rely on technology and overlook social and structural issues like spatial inequality in Indian cities, limiting their effectiveness.
29	2023	How is India Adapting to Heatwaves: An Assessment of Heat Action Plans with Insights for Transformative Climate Action	Valiathan Pillai et al.	This report offers the first critical review of heat action plans (HAPs) in India, analyzing 37 plans across different administrative levels and states. It highlights various opportunities to enhance Indian HAPs and documents a wide array of interventions proposed, encompassing 62 distinct types. While most HAPs include both short and long-term actions, their implementation status remains unclear.
30	2022	Climate change: put water at the heart of solutions	Aditi Mukherji et al.	Global efforts to mitigate carbon emissions and adapt to a warming world must address broader issues of injustice and inequity. Rising sea levels, intensified cyclones, and heatwaves in the Indian subcontinent highlight the urgent need for tailored actions. Remedies should focus on reducing emissions, carbon removal, implementing migration plans, and enhancing emergency response services to cope with extreme weather events.

Two levels of screening were done: excluded articles not relevant to the intersection of climate change, heatwaves, health, and/or livelihood in India, followed by full-text screening. Further assessed eligibility based on inclusion criteria, and after screening 291 articles were selected. With further screening of the papers related to India over the last three years, a total of 30 articles were selected and reviewed. To verify the adequacy of the literature review, an assessment of the review process was undertaken, employing the "Important questions to consider in each step of the review" outlined in (Snyder, 2019).

3. REVIEWED LITERATURES

Initially, papers were categorized based on their given keywords and titles, allowing the identification of prevalent research topics in recent years. The methodologies and conclusions of each paper were then compared, and commonalities among categories were analyzed (refer to Table 1). Subsequently, the contextual usage of the term "public health and livelihood" in each paper was analyzed, focusing on trends in each category. This analysis particularly emphasized the impact of "heatwaves" on public health and livelihood.

4. REVIEW RESULTS

4.1 Analysis by Category

Heat wave induced Climate Change: The literature review is primarily aimed to ascertain the volume of studies conducted in recent years on the impacts of heatwaves, particularly those conducted in India. Moreover, each paper focuses either on the health impacts or other social consequences of heatwaves. Several studies [6 out of 30] have highlighted India's susceptibility to heatwaves and their impact on society. "Abstract India has experienced remarkable changes in temperature extremes in recent decades due to rapid global warming leading to extreme heat events with disastrous societal impacts" (Rao et al. 2023), while another study notes, "India is particularly exposed, with recent heat waves demonstrating significant vulnerabilities" (Trahan et al., 2023). Furthermore, "Heatwaves are acknowledged to be a major meteorological disaster, causing a noticeable impact on humans and animals" (Naveena et al., 2021). Additionally, a study observed, "The 2022 Indian heatwave impacted key geographies of wheat production in northwestern and central

India" (Sidhu et al., 2023). Moreover, another study highlighted India's unprecedented heatwave, noting, "India is in the midst of an unprecedented heatwave with the highest May temperatures since records started 121 years ago" (Kroeger et al., 2022). Another study emphasized the occurrence of heatwaves from March to June, stating, "With a population of 1.3 billion, India stands as one of the hot spots experiencing deadly heat waves during May-June, yet the large-scale physical mechanisms and teleconnection patterns driving such events remain poorly understood" (Hari et al., 2022). All the studies suggest that India is highly susceptible to heatwaves, due to its highly vulnerable population. Furthermore, these studies highlight the current conditions and contributing factors that contribute to this vulnerability.

Impact on Public Health: The majority of the classification pertained to articles related to health impacts, comprising 10 out of 30. Across India, heatwaves are no longer fleeting episodes, but a growing public health crisis. To establish the overarching impact of heatwaves, "This has a direct impact on human health, agriculture, water availability, power generation, various ecosystems, and socioeconomic conditions of the exposed population" (Maharana et al., 2023). Considering their magnitude, "Heatwaves are acknowledged to be the major meteorological disaster, causing a noticeable impact on humans and animals" (Naveena et al., 2021). Highlighting the nuances, "Wet heat waves can have more impact on human health than hot dry heat waves. However, changes in these have received little scientific attention" (Yu et al., 2021). In the context of India, "Due to the unprecedented burdens on public health, agriculture, and other socio-economic and cultural systems, climate change-induced heatwaves in India can hinder or reverse" (Debnath et al., 2023). Examining the regional vulnerability, "South Asia, with more than one-fifth of the world's population, is highly vulnerable to heatwaves and associated health consequences" (Sharma et al., 2022). Underlining the broader consequences, "Climate change has a detrimental impact on human health due to increasing temperature extremes" (Dubey et al., 2021). Highlighting the immediate challenges, "South Asia is suffering some of its worst heat waves in a century. The public health implications are being made worse by building infrastructure" (Thiagarajan et al., 2022). Emphasizing the vulnerability of specific groups, "At the same time, informal workers are

extremely vulnerable to the effects of climate change, with higher temperatures and more intense weather events causing direct physical harm and contributing to ill-health" (Dodman et al., 2023). Addressing the urban context, "The urban population is subjected to multiple exposures of air pollution and heat stress and bear severe impacts on their health and well-being in terms of premature deaths and morbidity" (Menon et al., 2021). Recognizing the hazard of extreme heat, "Extreme heat is increasingly being acknowledged as a serious hazard to human health, through a combination of physiological responses to heat, expressed as dry and wet bulb temperatures, and personal factors" (Justine et al., 2023). The prevailing consensus across the reviewed literature emphasizes the high significance of heat on public health. Each examined paper underscores the urgent need for proactive measures to effectively address the rising challenges presented by climate-induced heatwaves.

Mental Health: The section of papers [3 out of 30] underscore the effects of heat stress on mental health. Each study discusses the effects across diverse settings such as the workplace and various health conditions. The study in (Pizarro et al., 2021) addresses heat hazards amongst mine workers, "The mining environment is hazardous for worker's health, with potential impacts on mental health. These include triggering symptoms and diseases like anxiety, job stress, depression, sleep disorders, and mental fatigue." Furthermore, in (Ebi et al., 2021) the author states, "Hot ambient conditions and associated heat stress can increase mortality and morbidity, as well as increase adverse pregnancy outcomes and negatively affect mental health." Additionally, "mental health problems such as post-traumatic stress disorder from weather disasters. There is a need to increase awareness among pediatricians" (Etzel et al., 2023).

Impact on Livelihood: Limited research reflects onto the impacts of heatwaves on livelihoods, especially in the context of India. However, identified existing literature [6 out of 30] strongly emphasizes the effects that heat has had on people's livelihoods. In the context of regional impacts, "The increasing frequency of heatwaves over East Asia (EA) is impacting agriculture, water management, and people's livelihood" (Ha et al., 2022). Furthermore, by drawing attention to concurrent extremes, "Sub-seasonal heat wave-driven concurrent hot and dry extreme

events (HDEs) can cause substantial damage to crops, and hence to lives and livelihoods" (Tian et al., 2021). As the perspective is broadened globally, by the author in (Amodu et al., 2023), "There are indications that heat waves will be intensified in duration, frequency, and magnitude and will pose threats to the livelihoods and health of the global working population." Looking at the specific challenges faced by India, "Due to the unprecedented burdens on public health, agriculture, and other socio-economic and cultural systems, climate change-induced heatwaves in India can hinder or reverse" (Debnath et al., 2023). Shifting the focus to urban environments, "The Urban Heat Island (UHI) effect is a significant concern in today's rapidly urbanizing cities, exacerbating the impact of heatwaves on urban livelihood and environmental well-being" (Pritipadmaja et al., 2023). Finally, addressing the vulnerability of specific groups, "At the same time, informal workers are extremely vulnerable to the effects of climate change, with higher temperatures and more intense weather events causing direct physical harm and contributing to ill-health" (Dodman et al., 2023). This literature provides a comprehensive overview, linking regional impacts to global trends and specific challenges faced by India and urban environments, as well as highlighting the vulnerability of certain populations.

Heatwave Policy & Heat Action Plans: A subset of the papers [5 out of 30] examined the analysis of diverse Heat Action Plans within the state and the implemented measures up to the present. For heatwave management, understanding the policy-relevant knowledge is important, particularly in developing countries like India, as also stated by the author in (Arulalan et al., 2023), "Generating such policy-relevant knowledge may be particularly important for developing countries such as India." Moreover, there is a rising trend towards the adoption of heat-related policies by city authorities, aimed at safeguarding public health and mitigating the unequal impact of heatwaves. "To protect public health, heat-related policies are increasingly being adopted by city authorities to address the unequal impact of heatwaves, as seen in Ahmedabad's Heat Action Plan" (Nastar et al., 2020). This approach underscores the recognition of heatwaves as a critical public health concern. Additional research also exists that examines policies targeting the management of heatwave impacts. "The review explicitly identifies the population's vulnerability to

heatwaves during recent years and examines heatwave management policies in the region” (Sharma et al., 2022). Identified shortcomings in Heat Action Plans, authors in (Valiathan et al., 2023) state, “Based on the analysis, we identify key areas for improvement: Most HAPs are not built for local context and have an oversimplified view of the hazard; nearly all HAPs are poor at identifying and targeting vulnerable groups; HAPs are underfunded; HAPs have weak legal foundations; HAPs are insufficiently transparent; capacity building is sectorally-targeted.” Looking ahead, addressing the complexities of heatwave management requires multifaceted remedies that extend beyond policy formulation, as said by the author in (Mukherji et al., 2022), “Remedies must aim to reduce emissions and remove carbon, develop plans and policies for migration, and enhance emergency services for responding to extreme weather events, including heatwaves.”

5. DISCUSSION

Globally the risk of heat waves and the cost of managing the impact is increasing each year. In India the mean maximum temperature has seen a rise over the last decade. The frequency of heatwave days has also increased significantly in the same period. The Years 2010, 2015 and 2019 have witnessed the highest number of heat wave days. With different factors impacting different regions, it is almost impossible to have a universal approach for management of heatwave events. It is important to study which factors over time contribute to heat stress and what mitigation measures need to be formulated to reduce the worst effects of heatwaves. While the existing heat action plans provide a foundation, crucial aspects require further research, which can be focused as per:

- 1. Detailed understanding of Heat Risks:** The current plans lack a block-level breakdown of the heat risk index, which is important for the development of targeted strategies. Addressing this gap requires a more localized approach, with detailed block-level assessments to understand how heat hazards differ geographically, who is most vulnerable within each block, and the specific vulnerabilities present. This analysis will allow for targeted mitigation strategies, this will ensure that interventions effectively protect vulnerable populations.
- 2. Leveraging Nature-Based Solutions:** The plans should explore the full potential of nature-based solutions like promoting tree

plantation, green spaces, rooftop gardens, and vertical vegetation. These solutions not only cool the environment but also provide environmental benefits. Integrating these alongside heat-resistant paints can provide a more effective and sustainable approach.

- 3. The Role of Technology:** While some plans mention white paint, exploring upcoming technological solutions can assist in developing enhanced heat mitigation plans. This could include installing cool roofs with specialized materials, investing in smart irrigation systems for green spaces, and even exploring innovative urban cooling systems for specific high-risk areas.
- 4. Strengthening Governance and Awareness:** Effective governance is crucial, involving allocating resources, developing and enforcing regulations, and educating citizens about heat risks and protective behaviors. Raising public awareness through targeted campaigns and involving communities in the process can encourage participation.

Existing measures will have to be studied carefully to suggest changes and additions which can help disaster managers take effective action for heatwave management.

6. CONCLUSION

To conclude, local best practices and approaches by city administrations can also be studied to prepare a more systematic governance system that can form the basis of a multi stakeholder approach which can be developed for policy makers as well as incorporate citizen science initiatives for a holistic approach for mitigation of heat wave impact in the future.

This paper has certain limitations because the top 30 most cited papers were included among the papers that corresponded to the search. In addition, we are aware of a larger number of papers on heatwave strategies focused in specific regions and parameters. We plan to additionally review these papers in the course of future research. This paper is positioned as an introductory study, to show the importance of “studying heat wave impacts”. In the future, the analysis will focus more on previous studies on heatwave impacts and mitigation actions and their effectiveness.

Finally, this paper serves as the basis for a process of action research that is planned for the

future. The eventual implication of this study is to identify and devise localized, data-informed strategies to effectively address the various heat risks and vulnerabilities of individual wards, enhancing the plan's overall efficacy in combating heat-related threats. Prior to this research, this paper aimed to identify issues that have been discussed in recent studies on mitigation impacts of heat on public health and livelihood. After conducting research on heat waves impacts in India, the author plans to conduct action research in Mumbai and Nagpur, two key urban areas in Maharashtra state, where the author lives.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- Amoadu, M., Ansah, E. W., Sarfo, J. O., & Hormenu, T. (2023). Impact of climate change and heat stress on workers' health and productivity: A scoping review. *The Journal of Climate Change and Health*, 12, 100249.
- Arulalan, T., AchutaRao, K., & Sagar, A. D. (2023). Climate science to inform adaptation policy: Heat waves over India in the 1.5°C and 2°C warmer worlds. *Climatic Change*, 176(5), 64.
- Cooper, H. M. (1988). Organizing knowledge syntheses: A taxonomy of literature reviews. *Knowledge and Society*, 1, 104.
- de Bont, J., Nori-Sarma, A., Stafoggia, M., Banerjee, T., Ingole, V., Jaganathan, S., ... & Prabhakaran, P. (2024). Impact of heatwaves on all-cause mortality in India: A comprehensive multi-city study. *Environment International*, 184, 108461.
- Debnath, R., Bardhan, R., & Bell, M. L. (2023). Lethal heatwaves are challenging India's sustainable development. *PLoS Climate*, 2(4), e0000156.
- Dodman, D., Sverdluk, A., Agarwal, S., Kadungure, A., Kothiwala, K., Machedmedze, R., & Verma, S. (2023). Climate change and informal workers: Towards an agenda for research and practice. *Urban Climate*, 48, 101401.
- Dubey, A. K., Kumar, P., Saharwardi, M. S., & Javed, A. (2021). Understanding the hot season dynamics and variability across India. *Weather and Climate Extremes*, 32, 100317.
- Ebi, K. L., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., ... & Jay, O. (2021). Hot weather and heat extremes: Health risks. *The Lancet*, 398(10301), 698–708.
- Etzel, R. A., & Bhave, S. Y. (2023). The health effects of climate change on children: Pediatricians must be part of the solution. *Indian Pediatrics*, 60(9), 714–718.
- Ha, K. J., Seo, Y. W., Yeo, J. H., Timmermann, A., Chung, E. S., Franzke, C. L. E., ... & Ting, M. (2022). Dynamics and characteristics of dry and moist heatwaves over East Asia. *NPJ Climate and Atmospheric Science*, 5(1), 1–11.
- Hari, V., Ghosh, S., Zhang, W., & Kumar, R. (2022). Strong influence of North Pacific Ocean variability on Indian summer heatwaves. *Nature Communications*, 13(1), 5349.
- Justine, J., Monteiro, J. M., Shah, H., & Rao, N. (2023). The diurnal variation of wet bulb temperatures and exceedance of physiological thresholds relevant to human health in South Asia. *Communications Earth & Environment*, 4(1), 244.
- Kroeger, C., & Reeves, A. (2022). Extreme heat leads to short- and long-term food insecurity with serious consequences for health. *European Journal of Public Health*, 32(4), 521.
- Lee, H., & Romero, J. (Eds.). (2023). *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*.
- Maharana, P., Kumar, D., Das, S., Tiwari, P. R., Norgate, M., & Raman, V. A. V. (2023). Projected changes in heatwaves and its impact on human discomfort over India due to global warming under the CORDEX-CORE framework. *Theoretical and Applied Climatology*.
- Malik, P., Bhardwaj, P., & Singh, O. (2014). Heat wave fatalities over India: 1978–2014.
- Menon, J. S., & Sharma, R. (2021). Nature-based solutions for co-mitigation of air pollution and urban heat in Indian cities. *Frontiers in Sustainable Cities*, 3.

- Mukherji, A. (2022). Climate change: Put water at the heart of solutions. *Nature*, 605(7909), 195.
- Nastar, M. (2020). Message sent, now what? A critical analysis of the heat action plan in Ahmedabad, India. *Urban Science*, 4(4), 53.
- Naveena, N., Satyanarayana, G. C., Raju, A. D., Umakanth, N., Srinivas, D., Rao, K. S., & Suman, M. (2021). Prediction of Heatwave 2013 over Andhra Pradesh and Telangana, India using WRF Model. *Asian Journal of Atmospheric Environment*, 15(3), 1–12.
- Pizarro, J. M., & Fuenzalida, F. A. (2021). Mental health in mine workers: A literature review. *Industrial Health*, 59(6), 343–370.
- Pritipadmaja, P., Garg, R. D., & Sharma, A. K. (2023). Assessing the cooling effect of blue-green spaces: Implications for urban heat island mitigation. *Water*, 15(16), 2983.
- Rao, K. K., Jyoteeshkumar Reddy, P., & Chowdary, J. S. (2023). Indian heatwaves in a future climate with varying hazard thresholds. *Environmental Research: Climate*, 2(1), 15002.
- Sharma, A., Andhikaputra, G., & Wang, Y. C. (2022). Heatwaves in South Asia: Characterization, consequences on human health, and adaptation strategies. *Atmosphere*, 13(5), 734.
- Sidhu, B. S. (2023). Likely impacts of the 2022 heatwave on India's wheat production. *Environmental Research Letters*, 18(10), 105001.
- Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339.
- Srivastava, A., Mohapatra, M., & Kumar, N. (2022). Hot weather hazard analysis over India. *Scientific Reports*, 12(1), 19768.
- Thiagarajan, K. (2022). Build back better: Why Indian construction must grapple with extreme heat. *BMJ*, 377, o1473.
- Tian, F., Klingaman, N. P., & Dong, B. (2021). The driving processes of concurrent hot and dry extreme events in China. *Journal of Climate*, 34(5), 1809–1824.
- Trahan, A., Walshe, R., & Mehta, V. (2023). Extreme heat, gender, and access to preparedness measures: An analysis of the heatwave early warning system in Ahmedabad, India. *International Journal of Disaster Risk Reduction*, 99, 104080.
- Valiathan Pillai, A., & Dalal, T. (2023). How is India adapting to heatwaves: An assessment of heat action plans with insights for transformative climate action. *Zenodo*.
- Vom Brocke, J., Simons, A., Niehaves, B., Reimer, K., Plattfaut, R., & Cleven, A. (2009). Reconstructing the giant: On the importance of rigor in documenting the literature search process. In *Proceedings of the 17th European Conference on Information Systems (ECIS)*, Verona, Italy.
- Web of Science. (2024). KOSMOS - Keio University Libraries. Retrieved February 15, 2024, from [Web of Science URL].
- Yu, S., Tett, S. F. B., Freychet, N., & Yan, Z. (2021). Changes in regional wet heatwave in Eurasia during summer (1979–2017). *Environmental Research Letters*, 16(6), 64094.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

© Copyright (2024): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/125602>