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Heat Action Plan for Thane City 2024

Making Thane a Heat-resilient Smart City through Reduced Impacts of Heatwaves

Thane Municipal Corporation, Thane

Prepared by: Council on Energy, Environment and Water

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About the Thane City Heat Action Plan 2024

The Heat Action Plan (HAP) of Thane City has been formulated using a combination of climate datasets and climate projections from sources such as the Indian Monsoon Data Assimilation and Analysis (IMDAA) and Regional Climate Models (RCMs) from the Ministry of Earth Sciences (MoES) for the period from 1982 to 2040. It combines these climatic datasets with on-ground socioeconomic data and satellite-derived indices to map Thane City's heat risk.

Thane City's HAP has been prepared as per the guidelines of the National Disaster Management Authority (NDMA), 2019, and formats prescribed by the National Centre for Disease Control (NCDC), NPCCHH (National Program on Climate Change and Human Health and the *National Disaster Management Plan* (NDMP), 2019.

We sincerely acknowledge the substantial contributions of the expert team from the Council on Energy, Environment, and Water (CEEW) and the following authors who played vital roles in developing this HAP: Shravan Prabhu, Dr Vishwas Chitale, Anup Kumar Srivastava, Aman Tiwari, and Ahana Chatterjee. We also acknowledge the contributions and support of Dr Saru Gupta (Jhpiego), Shashank Prakash, Anurag Sahu, Gaurav Sahni, Anushka Maheshwari, and Anushka Goswami.

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We also express our thanks to the National Disaster Management Authority and the National Centre for Disease Control for providing guidelines and frameworks used to develop this plan. We thank the India Meteorological Department, the Indian Institute of Tropical Meteorology, and the Ministry of Earth Sciences for supplying detailed climate data and downscaled climate projections used in the climate risk assessment for this plan.

Lastly, we express gratitude to the India Climate Collaborative (ICC), Rohini Nilekani Philanthropies (RNP), Mirik Gogri, Renil Gogri, and Spectrum Impact for providing funding support to CEEW for undertaking the research and coordination associated with this HAP.

Contents

Executive summary

In 2023, a global temperature record was set, marking it as the hottest year on record. Such intense global warming will breach the critical 1.5°C threshold within the next five years (World Meteorological Organization 2023). The consequences of this heightened warming are already evident in vulnerable and developing countries such as India. In February 2023, the India Meteorological Department (IMD) reported the hottest February since 1901. Subsequently, in May 2023, 10 Indian states faced a prolonged heat wave lasting 2–3 weeks (IMD 2023). Moreover, in its 2024 summer season forecast, IMD has predicted a high probability of above-normal maximum as well as minimum temperatures leading to longer duration of heatwaves in majority parts of India (IMD 2024).

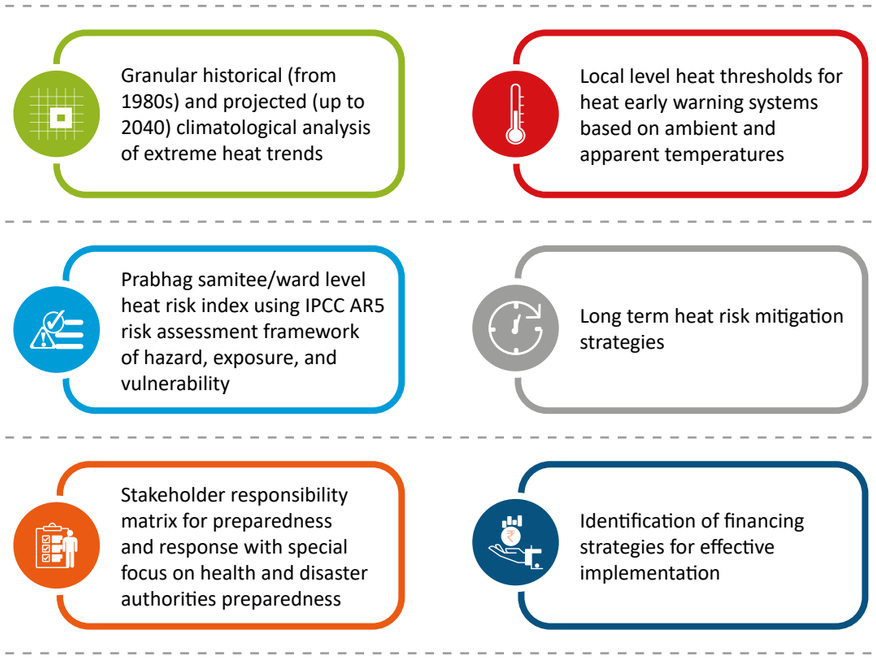
Climatic projections for India indicate that heat extremes are likely to intensify, occur more frequently, last longer, and impact wider geographical areas not previously impacted. Other factors, such as humidity and urban heat islands, particularly in cities, will further exacerbate and compound the risks associated with these extremes. With such record-breaking heat waves already being witnessed nationwide, there is an urgent need to develop and implement heat risk mitigation and adaptation strategies to reduce the impacts of heat waves across various geographical scales.

Currently, India has more than 4,800 urban local bodies (ULBs), representing approximately 35 per cent of the country's population (Ministry of Social Justice and Empowerment 2023). Urban areas face multifaceted challenges associated with both slow-onset events, such as heat waves, and rapid onset events, such as extreme precipitation-induced urban flooding. Cities are also home to a significant number of vulnerable populations, such as senior citizens, children, and individuals with comorbidities and chronic health conditions. This escalates the risks associated with heat stress. Given this context, cities in India must develop comprehensive heat action plans as recommended by the National Disaster Management Authority (NDMA) in their 2019 guidelines, focusing on localised heat risk mapping and developing effective mitigation, preparedness, and response mechanisms.

Coastal cities in India face an additional challenge in the form of compounded risks due to humidity, which can contribute up to an additional 3–4°C when the dry temperature exceeds 30°C and relative humidity surpasses 60 per cent. Consequently, heat action plans for coastal Indian cities such as Thane must factor in the compounded effects of relative humidity. Additionally, the often-overlooked impact of warm nights on health necessitates urgent attention as it significantly contributes to widespread cases of heat strokes and related illnesses as warmer nights do not allow for recovering from daytime heat waves.

Thane City's administration attempted to address these challenges by developing a city-level heat action plan, offering insights into heat risks considering historical trends and projections of dry temperature extremes, humidity, warm nights, and socioeconomic factors at a detailed ward/*Prabhag Samitee* level (Figure ES1). The primary objective was to mitigate the impact of heat stress on human health and establish effective pathways for preparedness and response mechanisms.

Figure ES1: Uniqueness of the Thane City Heat Action Plan



Source: Authors' compilation

Maharashtra's HAP already recognises eastern Maharashtra as a significant heat wave hotspot. However, Thane, situated near the coast, faces additional challenges due to the combination of temperature and humidity. Although not currently labelled as a heat wave hotspot, climatological projections indicate a substantial threefold increase in the frequency of extreme hot days from 2024 to 2040, compared to the period between 1982 and 2024. Consequently, the frequency of warm nights is anticipated to surge nearly fourfold during the same timeframe. Hence, this plan prioritises the mitigation of long-term heat risk and aims to cultivate a culture of preparedness and response to heat waves.

Dedicated to achieving zero mortalities from extreme heat, minimising heat-related illnesses and stress, and reducing economic impacts, the Thane Heat Action Plan adopts a 'when, where, who and how' (3WH) framework for heat action strategies, aligning with the 2019 NDMA *National Guidelines for Preparation of Action Plan: Prevention and Management of Heat Wave* (NDMA 2019).

When to take action: This stage involves establishing city-specific heat thresholds for Thane by analysing bio-meteorological indices, particularly the heat index. Using a long-term (1982–2022) percentile approach, these thresholds map the felt heat based on observed extremes. Though the IMD provides general regional criteria for all coastal areas based on dry maximum temperature for heat wave forecast and declaration, local thresholds for Thane were calculated by considering climatic variables namely maximum temperature and relative humidity. This is crucial for addressing heat stress in a coastal region considering acclimatisation levels in order to enhance the efficiency of heat early warnings. Additionally, similar thresholds based on dry temperature have also been developed, and the plan outlines mechanisms for issuing alerts and early warnings to relevant departments and the population.

Figure ES2: The felt temperature thresholds for colour-coded alerts based on the heat index that indicates the impact of humidity in addition to dry temperature

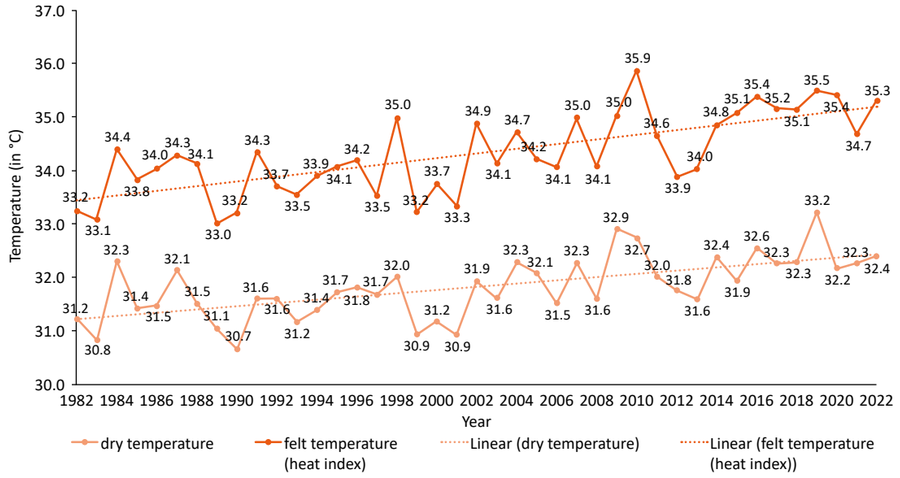
Felt temperature thresholds (in °C)			
Month	**Yellow alert**	**Orange alert**	**Red alert**
March	38	39	41
April	41	42	45
May	42	43	46
June	39	40	43

Source: Authors' analysis

Where to take action: Following the IPCC's risk assessment framework as per its 5th Assessment Report (AR) of 2014, the Thane HAP provides the ranking of all 9 wards in Thane City based on the quantified heat risk. Hazard indicators were quantified using the IMDAA reanalysis climate data (1982–2022) and land surface temperatures from satellites, while a combination of satellite-based indices and socioeconomic data collated by various departments of Thane Municipal Corporation was used for exposure and vulnerability mapping.

An analysis of the heat index, combining temperature and relative humidity (referred to as felt temperature), reveals a substantial increase in both felt and dry maximum temperatures over the last 40 years (1982–2022) during Thane's summer months. The average difference between felt and dry temperatures, indicating rising humidity-related temperatures, has slightly increased in recent years. For instance, in 2022, the average summer maximum felt temperatures were nearly 3°C higher than dry temperatures, emphasising the impact of increased heat stress due to the added humidity factor (Figure ES3).

Figure ES3: The difference between dry temperature and felt temperature (dry temperature + relative humidity) has increased by up to 3°C in Thane City over the past 40 years



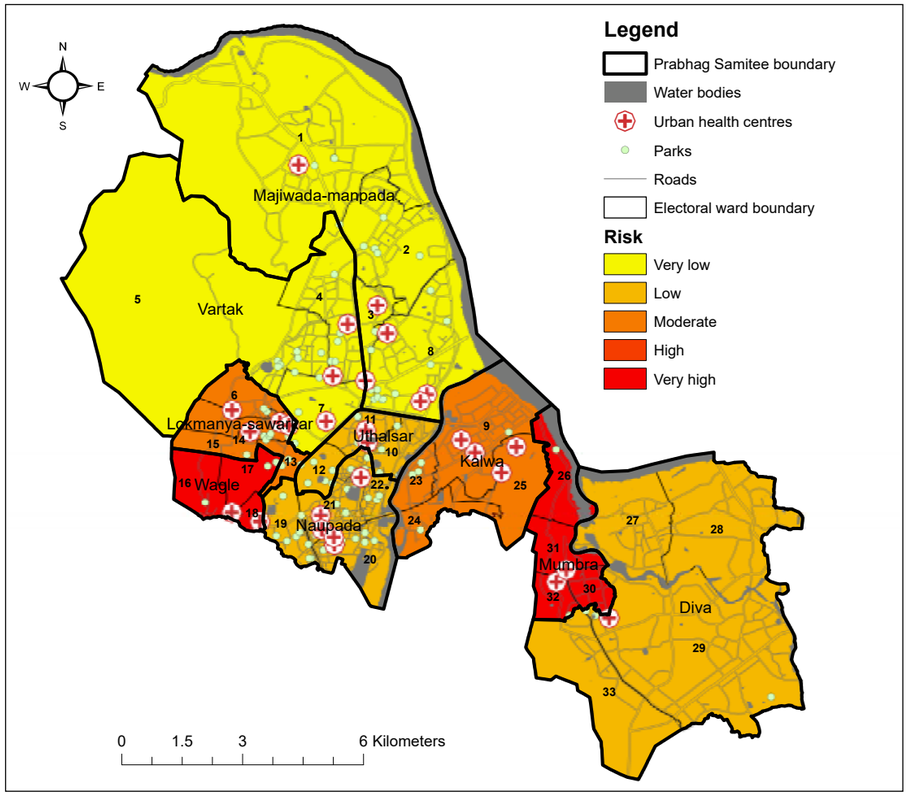
Source: Authors' compilation

As per Thane City's heat risk index seen in Figure ES4, Wagle and Mumbra *Prabhag Samitees* are under the highest risk, followed by Kalwa and Lokmanya Savarkar Nagar *Prabhag Samitees*, which fall in the moderate risk category. They are followed by Diva, Naupada, and Uthalsar, showing low risk and Vartak Nagar and Majiwada-manpada having very low risk.

Who will and how to take action: The responsibilities matrix, outlining mitigation, preparedness, and response strategies, distinctly delineates the roles of relevant departments, the supportive role of the District Disaster Management Authority (DDMA), State Disaster Management Authority (SDMA) and other stakeholders for ensuring effective coordination during plan implementation (See chapters 6 and 7 of this HAP). Thane Municipal Corporation has instituted a Heat Wave Task Force Committee (Refer to annexure 4) that will monitor the execution of the plan and conduct a review after summer season. Documenting lessons learned from this plan will enhance future plan design and implementation. A monitoring and evaluation framework (See chapter 10) tracks and reports progress on each action in the heat action plan. Financial mechanisms for short-term, medium-term, and long-term actions are also identified by each department.

The plan additionally integrates the formats provided by Ministry of Health and Family Welfare (MoHFW) for recording health-related mortalities and illnesses. Information, education, and communication (IEC) strategies are identified to enhance outreach and awareness.

Figure ES4: Heat risk index for Thane City across different Prabhag Samitees as of 2024



Source: Authors' analysis

1. Introduction

With 2023 emerging as the hottest year on record globally, as we inch closer to crossing the 1.5°C global warming threshold earlier than anticipated, the effects of this escalating climate change will manifest itself regionally through climate variabilities and extreme weather events that will disproportionately affect vulnerable populations, particularly in developing and tropical countries such as India (World Meteorological Organization (WMO) 2023).

In addition to other disasters such as floods and droughts, the intensification of heat extremes and resulting heat stress stands out as one of the most direct consequences of climate change. Globally, heat waves have contributed to approximately 166,000 human deaths during 1998–2017 (World Health Organization 2018). Countries such as India, where nearly 80 per cent of the population resides in climate-vulnerable districts, experienced approximately 25,000 heat-related deaths between 1992 and 2015 (Mohanty and Wadhawan 2021, National Disaster Management Authority (NDMA) 2020). Consequently, it is crucial to comprehensively understand extreme weather events through detailed mapping of weather variabilities and events to address the implications of worsening climate change. This needs to be accompanied by designing effective action plans to mitigate and adapt to the adverse effects of events such as heat waves, in addition to response and recovery.

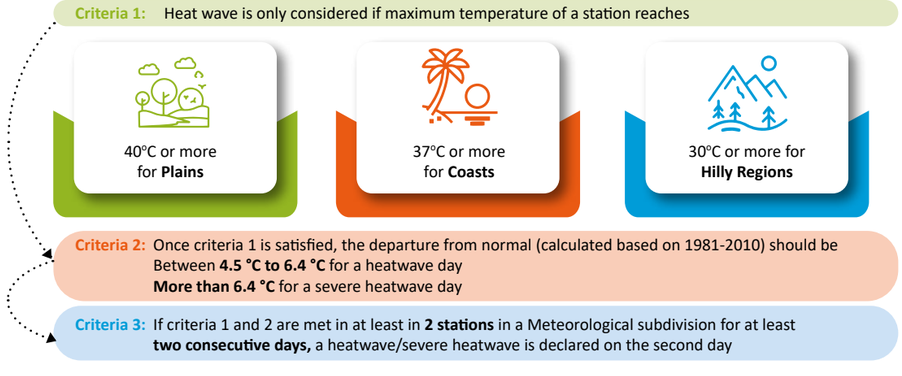
This heat action plan, therefore, emphasises mapping trends and hotspots of heat stress, followed by the formulation of robust mitigation, preparedness, and response strategies to combat heat risk in the Thane Municipal Corporation.

1.1 Understanding heat waves – definitions and terminologies

Heat waves do not have a global definition. The World Meteorological Organization (WMO) characterises a heat wave as "Five or more consecutive days of prolonged heat in which the daily maximum temperature is higher than the average maximum temperature by 5°C (9°F)." However, the definition and criteria for gauging temperature extremes vary significantly worldwide, tailored to local conditions based on climatological and impact criteria specific to each region (WMO 2012; Alexander et al. 2006; Vose et al. 2005).

The US, for example, adopts a complex felt temperature criterion that incorporates humidity with temperature, while Denmark utilises a straightforward daytime maximum temperature threshold of 28°C. On the other hand, countries such as China and Brazil employ a percentile-based approach for measuring heat waves. In India, the India Meteorological Department (IMD) follows layered criteria for measuring heat waves (Figure 1).

Figure 1: Criteria for mapping heat waves in India



Source: India Meteorological Department 2019

1.2 Climate change and escalating heat extremes in India

From 1951 to 2016, India witnessed a significant warming trend, with mean annual temperatures registering a 0.15°C increase per year (Krishnan et al. 2020). This increase in mean temperatures resulted in non-linear risks posed by extreme heat, causing nearly 25,000 deaths between 1992 and 2015, despite known challenges in attributing them to heat mortality (NDMA 2020).

Climatic projections suggest that heat extremes in India will intensify, become more frequent, endure longer, and impact broader geographical areas (Im, Pal, and Eltahir 2017). Daytime and nighttime heat extremes are anticipated to increase twofold and fourfold by 2050, according to the Representative Concentration Pathways (RCPs) 4.5 and 8.5, respectively (Krishnan et al. 2020). The impacts of this will be further compounded by heat stress factors such as humidity and the urban heat island phenomenon, resulting in increased heat-related deaths, challenging working conditions, and a wider spread of vector-borne diseases (Vaghela 2018; Bordoloi and Saharia 2021). These impacts will be felt most acutely in coastal cities such as Thane, Mumbai, Kolkata, and Chennai.

By 2050, as many as 23 cities in India are projected to witness average summertime maximum temperatures of more than 35°C. This will have significant impacts on vulnerable populations such as those living in slums and might require additional resources to deal with extreme events in the face of rapid urbanisation. The International Labour Organization anticipates a 5.8 per cent rise in working hours lost due to heat stress by 2030, equivalent to 34 million hours (International Labour Organization 2019). While cities are generally considered to face the highest risks, recent impacts in India also indicate effects on other critical sectors, such as agriculture and livestock. For instance, the recent 2022 heat wave, which was one of the longest lasting, led to wheat yield reductions of 15–25 per cent in the Indo-Gangetic plain states. Additionally, in the same region, milk yield was reduced by up to 15 per cent in milch animals due to the loss of appetite and higher body temperature (Indian Council on Agriculture Research 2022).

The looming risks posed by increased heat extremes and heat stress will disproportionately affect various sectors and populations, jeopardising progress on achieving the Sustainable Development Goals (SDGs) and the targets of the Sendai framework for disaster risk reduction, and is projected to face risks by up to 4.5 per cent of gross domestic product (GDP) of India by 2030 (Reserve bank of India 2020).

1.3 Heat Action Plans (HAPs) in India

Heat extremes are becoming more frequent and intense, however they can be prevented from escalating into a disaster. The key to preventing them lies in successfully implementing the solutions outlined in the Heat Action Plans (HAPs). HAPs are policy documents prepared by state, district, and city governments. They provide a framework to prepare, respond, recover, and learn from extreme heat. Figure 2 represents the timeline of heat action in India.

In 2016, the National Disaster Management Authority (NDMA) formulated the first set of guidelines for the development of HAPs, with a primary focus on enhancing the preparedness and response capabilities of authorities of health and disaster management department. The overarching goal was to prioritise the limited healthcare, financial, information, and infrastructural resources toward those most at risk of extreme heat within a specific jurisdiction.

In 2019, these guidelines underwent a revision to encompass short-term, medium-term, and long-term heat risk–reduction strategies. The revised guidelines feature an eight-point checklist, emphasising effective inter-agency and stakeholder coordination, mapping vulnerable and at-risk populations, establishing localised heat thresholds for early warnings, formulating a stakeholder responsibility matrix, and delineating strategies for monitoring, evaluation, and plan updating (NDMA 2019).

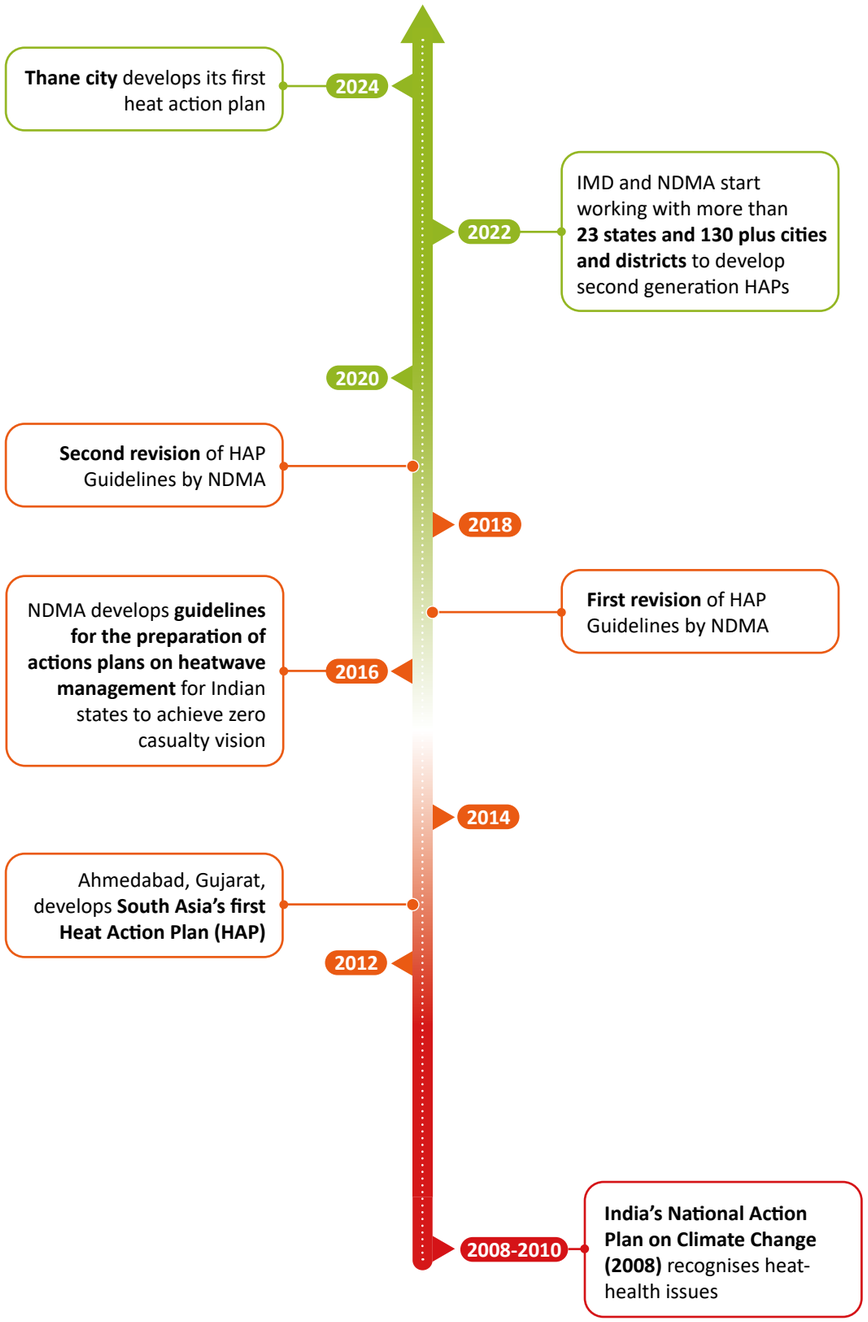
In India, HAPs have demonstrated their efficacy in managing extreme heat, with studies highlighting a substantial reduction in mortalities following their implementation. A noteworthy example is the city of Ahmedabad in Gujarat, which was an early adopter of the HAP in 2013. Studies reveal that the city avoided an estimated 1,000 annual deaths (across all causes) in 2014–15 compared to a baseline of 2007–10, showcasing the tangible positive impact of HAP implementation (Hess et al. 2018).

Box 1: Nodal agencies for HAPs as per guidelines on combating extreme weather events (heat waves) by the Ministry of Home Affairs

1. **National Disaster Management Authority (NDMA)**: At the national level, the NDMA issued the national guidelines for the *Preparation of Action Plan – Prevention and Management of Heat Wave* in 2016. These guidelines serve as a framework for implementing, coordinating, and evaluating activities related to extreme heat waves in India. The NDMA revised the national guidelines on heat waves in 2017 and again in 2019.
2. **India Meteorological Department (IMD)**: In conjunction with the NDMA, the IMD places special emphasis on early warning and impact-based forecasts and alerts for heat wave events, aiding states in implementing appropriate mitigation measures. As of 2024, the IMD is also developing an India-specific heat hazard index that combines temperature, humidity, and wind and the persistence of these factors.
3. **The National Centre for Disease Control (NCDC), NPCCHH (National Program on Climate Change and Human Health)**: The NCDC monitors and compiles data on epidemic-prone diseases weekly, enhances the capacity of medical staff, and provides justification for illness and casualty certificates. It recently released the template for developing the *District Action Plan of Climate Change and Human Health* (DAPCCHH) and the formats for the recording of heat-related illnesses and mortalities.
4. **State governments**: Various state governments have undertaken necessary preparedness and mitigation measures for heat waves. In recent years, several state governments, districts, and cities have formulated HAPs. They are actively implementing them and taking comprehensive measures to prevent mortality resulting from heat waves. The state of Maharashtra developed a state HAP in 2022.

Source: Authors' compilation

Figure 2: Timelines of heat action in India



Source: Authors' compilation

2. Profile and state of heat extremes in Maharashtra and Thane

2.1 Profile of the state, district, and municipal corporation

Maharashtra, the third-largest state in India, stretches from the western coast to the central part of the country. It covers an area of 3.08 lakh sq km and has the fourth-longest coastline, spanning 720 km along the Arabian Sea. The state is divided into 36 districts across 6 divisions and has Mumbai City as its capital. Maharashtra is the second-most populous state, home to 11.237 crore people (Ministry of Home Affairs 2011). Its topography comprises the Deccan Plateau, the Sahyadri range, and the Konkan coastal strip.

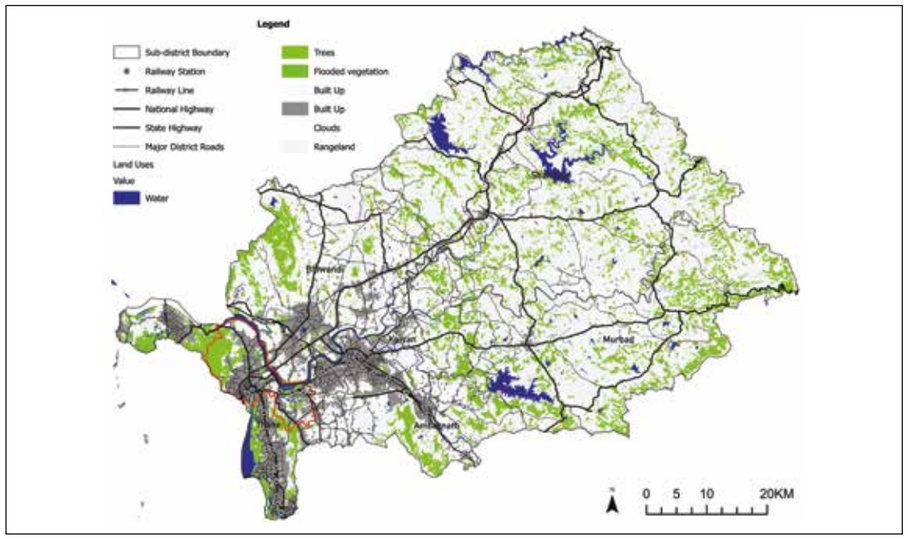
The north-south orientation of the Sahyadri mountain range creates a geographical separation, influencing the climatic conditions of the coastal districts of Thane, Mumbai City, Mumbai Suburban, Raigad, Ratnagiri, and Sindhudurg from the rest of Maharashtra. This has resulted in varying climatic patterns, with the western slopes and coastal districts experiencing heavy monsoon rains due to the intersecting monsoon stream. The Deccan Plateau, in contrast, is a rain shadow region. Traditionally, the state receives rainfall during the southwest monsoon season (June to September), with disparities in precipitation across regions.

The district of Thane, situated in the north Konkan division, was divided into the Palghar and Thane districts in 2014. Covering an area of 4,214 sq km and accounting for 1.37 per cent of the geographical area of Maharashtra, Thane district is the third-most populous in the state according to the 2011 Census. Bound by Nashik, Pune, Ahmednagar, and Palghar districts, Thane is divided into the seven talukas of Thane, Kalyan, Ulhasnagar, Ambernath, Bhiwandi, Shahpur, and Murbad. Thane district is characterised by two main rivers, Varanasi and Ulhas. Figure 3 provides a map of the district and the Thane Municipal Corporation.

Thane City falls within the sub-district of Thane and exercises jurisdiction over Kalwa, Mumbra-Kausa, and the central city of Thane. Covering an area of approximately 128.23 sq km, Thane City is situated between east longitude 72.50° and north latitude 19.10° and is subdivided into 9 *Prabhag Samitees* (administrative wards) and 33 electoral wards. Thane district is bordered by the Sahyadri mountain ranges to the east, the Arabian Sea to the west, the dense forest section of Gujarat to the north, and shares its southern boundary with the economic hub of Mumbai. The population of Thane city, according to the 2011 census, stands at 18,26,649.

The topography of Thane City ranges from 0–7m above mean sea level, featuring black and sand-mixed soil conducive to the cultivation of rice, vegetables, and orchards. The city's topography is defined by submerged marshland along Thane Creek and the Ulhas Riverbank, complemented by high hills on one side.

Figure 3: Thane district and areas under the Thane Municipal Corporation (in red)



Source: Authors' compilation

2.2 State of heat extremes in Maharashtra and Thane

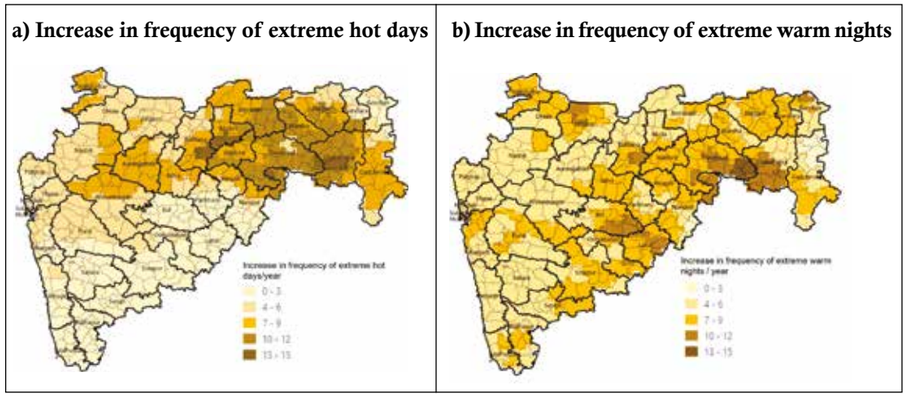
As highlighted in the Maharashtra State Heat Action Plan 2023, heat waves are generally observed in 36 districts during March to June, with April and May witnessing severe heat waves. Initially, approximately seven districts in Vidarbha, Marathwada, and Khandesh were considered under the influence of heat. However, in the last decade, 15 districts, including Akola, Amravati, Bhandara, Buldhana, Chandrapur, Dhule, Gadchiroli, Gondia, Jalgaon, Latur, Nagpur, Nanded, Yavatmal, Wardha, and Washim, have been identified as heat-prone based on temperature and humidity trends (State Disaster Management Authority 2023).

Recognising heat stress as a 'silent disaster' and classifying it as a disaster in a 'local context' as part of its disaster management plans, Maharashtra has developed eight district HAPs and two city HAPs as of 2024 based on information available in the public domain. This includes the cities of Nagpur and Chandrapur and the districts of Gonda, Wardha, Jalgaon, Buldhana, Akola, Washim, Nanded, and Latur.

Figure 4 illustrates the increase in the occurrence of extreme hot days and warm nights over the past decade (2012–22) compared to the climatic baseline (1982–2011). This analysis relies on the 95th percentile threshold using data from the Indian Monsoon Data Assimilation and Analysis (IMDAA) reanalysis at a spatial resolution of 12 km. The results indicate that Maharashtra has witnessed a comparable increase in the frequency of both daytime and nighttime heat extremes, ranging from 1–15 days per year during the summer months of March, April, May, and June.

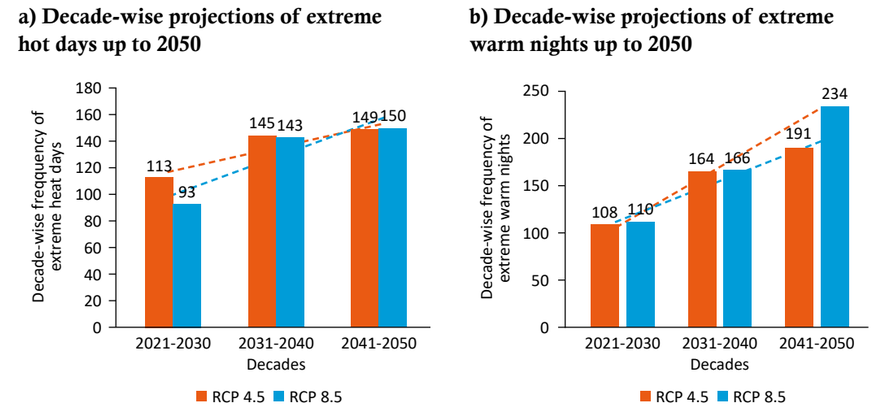
By 2050, Maharashtra is expected to experience a substantial two to five-fold increase in the frequency of daytime and nighttime heat extremes, as shown in Figure 5. According to the projections by the Indian Institute of Tropical Meteorology's RegCM4 models for two Representative Concentration Pathway (RCP) scenarios— RCP 4.5 (mid-emission) and RCP 8.5 (high-emission) — as part of the CORDEX South Asia project, the increase in the frequency of extreme warm nights is projected to surpass that of extreme hot days.

Figure 4: Increase in frequency of heat extremes in Maharashtra in the last decade (2012–22) compared to climatic baseline (1982–2011) in districts and talukas



Source: Authors' analysis

Figure 5: Projections of daytime and nighttime heat extremes over Maharashtra till 2050



Source: Authors' analysis

Though traditionally not designated as hotspots, the coastal districts of Maharashtra have witnessed high numbers of heat-related illnesses and incidences of heat-related fatalities in recent years. This can be directly attributed to the combined effects of heat and humidity. In 2023, for instance, Kharghar, situated in the Panvel municipal corporation, reported at least 14 sunstroke-related deaths and more than 120 heat-related illnesses even though a heat wave was not officially declared during that period in the coastal district of Raigad (PTI 2023).

Given the prevailing context of escalating heat extremes and future projections, it is imperative for all cities and districts in Maharashtra to formulate and implement comprehensive HAPs. This is crucial for enhancing preparedness, response measures, and undertaking long-term mitigation strategies against heat risks. Furthermore, considering the dynamic nature of heat and the compounded impacts of urban heat islands and humidity, coastal regions must specifically address humidity-induced heat stress and the prevalence of warm nights, which have a high correlation with urban heat islands.

3. Rationale, objectives, & approach for Thane HAP development

3.1 Rationale for developing HAPs at the level of urban local bodies

The National Disaster Management Act of 2005 mandates national-, state-, and district-level disaster management plans. While there is no direct mention of preparing sub-divisional or city-level plans, it is implied that the success of district-level plans can only be achieved by more localised analyses and adaptation strategies. Moreover, the Constitution (Seventy-fourth) Amendment Act, 1992 (CAA), which came into effect on 1 June 1993, introduced Part IXA (municipalities). The act provided constitutional status to urban local bodies (ULBs). Article 243W of the CAA authorised the state legislature to enact laws to endow local bodies with powers and authority as may be necessary to enable them to function as institutions of self-governance and make provisions for the devolution of powers and responsibilities.

The Twelfth Schedule of the Constitution enumerated the following 18 specific functions to be devolved to ULBs:

1. Urban planning, including town planning;
2. Regulation of land use and construction of buildings;
3. Planning for economic and social development;
4. Roads and bridges;
5. Water supply for domestic, industrial, and commercial purposes;
6. Public health, sanitation, conservancy, and solid waste management;
7. Fire services;
8. Urban forestry, protection of the environment, and the promotion of ecological aspects;
9. Safeguarding the interests of the weaker sections of society, including the handicapped and differently abled;
10. Slum improvement and upgradation;
11. Urban poverty alleviation;
12. Provision of urban amenities and facilities such as parks, gardens, and playgrounds;
13. Promotion of cultural, educational, and aesthetic aspects;
14. Burials and burial grounds; cremations, cremation grounds, and electric crematoriums;
15. Cattle pounds; prevention of cruelty to animals;
16. Vital statistics, including registration of births and deaths;
17. Public amenities, including street lighting, parking lots, bus stops, and public conveniences;
18. Regulation of slaughterhouses and tanneries.

This empowers ULBs such as the Thane Municipal Corporation to carry out substantial initiatives for disaster risk and vulnerability reduction by focusing on mitigation, preparedness, and response to the increasing frequency of extreme heat waves.

3.2 Objectives of the Thane HAP

The Thane HAP is a unique initiative in India that recognises the dynamic nature of heat extremes and the compounding effects of humidity and urban heat islands. Thane HAP has integrated these factors while devising effective local-level heat action strategies. The HAP maps heat risk at a granular level down to the level of *Prabhag Samitees* and proposes mitigation, preparedness, and response strategies for each stakeholder and department.

The HAP's mission is to achieve zero mortalities from heat extremes in the city, reduce heat-related illnesses and heat stress, and minimise economic impacts across sectors.

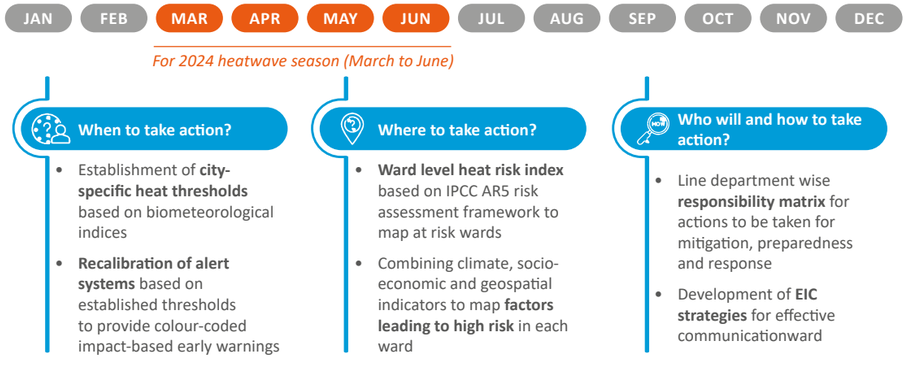
To achieve the desired mission, the HAP has the following objectives:

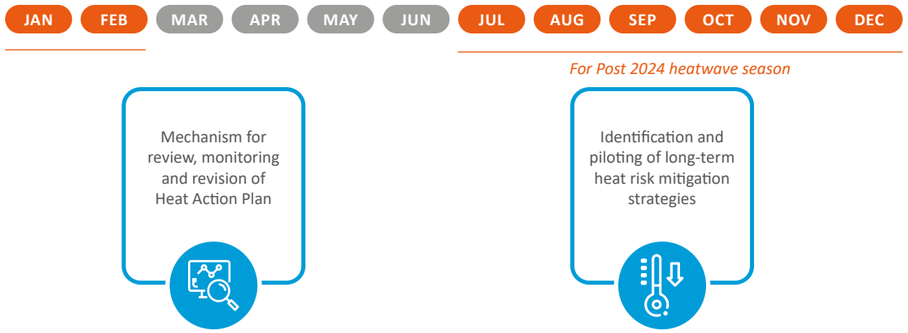
- Granular mapping of heat hazards under various climate change scenarios, establishing local heat-health thresholds for early warnings, and mapping vulnerable populations.
- Designing effective preparedness and response strategies, with a focus on health and disaster management, to ensure zero human mortalities.
- Reducing heat-health risks, heat stress, and heat-related illnesses by implementing robust tracking, surveillance, and innovative cooling solutions.
- Long-term reduction of economic losses in different sectors through region-specific heat risk mitigation strategies.
- Capacity building of relevant stakeholders to prepare for, respond to, and undertake a review of the heat action plan implementation.

3.3 Approach for the development of the Heat Action Plan of Thane City

A multidisciplinary approach was employed, integrating technical tools, scientific analysis, policy evaluation, and stakeholder engagement to formulate Thane City's HAP. Building on the foundation provided by the NDMA guidelines of 2019 for HAPs and the *National Disaster Management Plan 2019*, a comprehensive framework for effective heat action was established. This framework comprises the following three critical components: i) when to take action, ii) where to take action, and iii) who will and how to take action. Figure 6 provides more details of the framework.

Figure 6: Approach for development of the Thane HAP

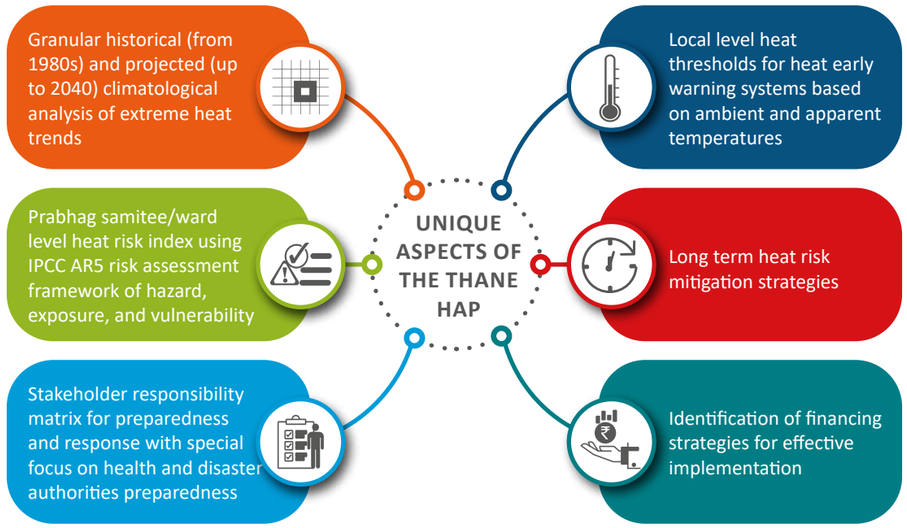




Source: Authors' compilation

Recent studies analysing existing HAPs in India have identified several design gaps in them, including the absence of localised heat hazard and threshold mapping, insufficient vulnerability and heat risk assessments, and a lack of identification of financing mechanisms (Pillai and Dalal 2023). Consequently, to establish the Thane HAP as a second-generation plan and as a template plan for other cities with similar climatic conditions, the approach towards designing the HAP was tailored to address these gaps comprehensively. Figure 7 illustrates the unique aspects incorporated into the city-level HAP.

Figure 7: Unique aspects of the Thane HAP



Source: Authors' compilation

The approach to developing the Thane HAP involved rigorous validation through extensive stakeholder consultations (Figures 8a–8f). Various stakeholders, including line departments, scientific experts, and policymakers crucial to the plan's implementation, actively participated. The consultations centred around presenting climatological analysis, the heat risk index with its indicators, and the locally developed heat thresholds. Further details on these aspects, along with the stakeholder responsibility matrix, are elaborated in subsequent chapters of this HAP.

Figure 8: Snapshots from various consultation-cum-validation workshops and meetings for Thane HAP development

a) Meeting with all line departments chaired by the additional commissioner, Thane Municipal Corporation

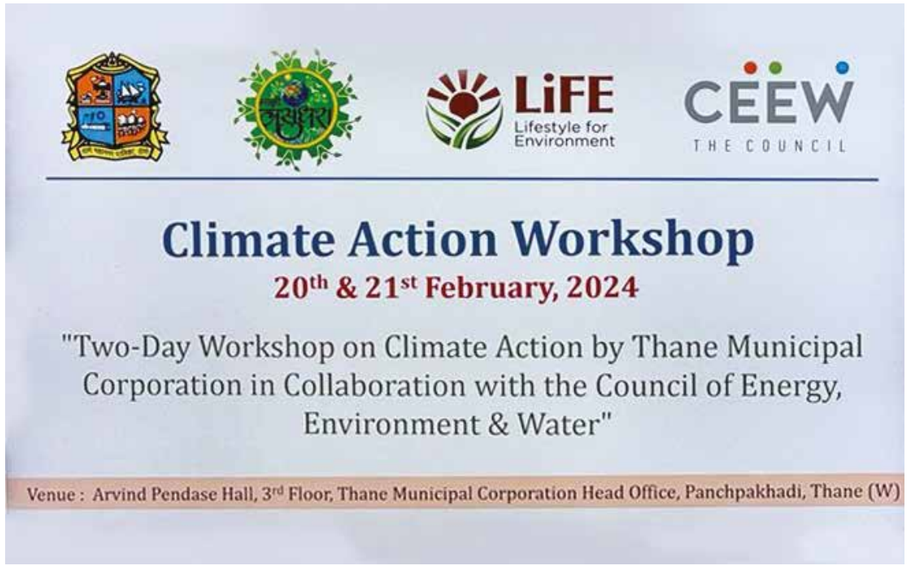
b) A two-day workshop on climate action organised with officials from various line departments in February 2024

Images: CEEW

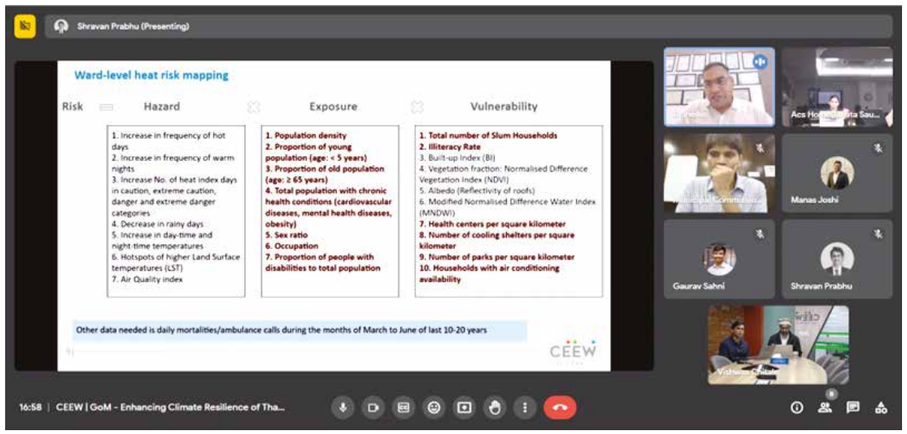
c) CEEW team in discussion with relevant line departments validating the heat risk assessments

Images: CEEW

d) A two-day climate action workshop organised with officials from various line departments on 20–21 February 2024



e) Online consultation meeting with Ms Sujata Saunik, Additional Chief Secretary, Government of Maharashtra; Mr Abhijit Bangar, Municipal Commissioner, Thane Municipal Corporation; and Dr Dnyaneshwar Shelke, Chief Operating Officer, BVG Maharashtra Emergency Medical Services, held on 9 January 2024



Images: CEEW

f) Online consultation meeting with Ms Sujata Saunik, Additional Chief Secretary, Government of Maharashtra; Mr Ashok Shingare, District Collector, Thane District; and Mr Abhijit Bangar, Municipal Commissioner, Thane Municipal Corporation held on 31 August 2023

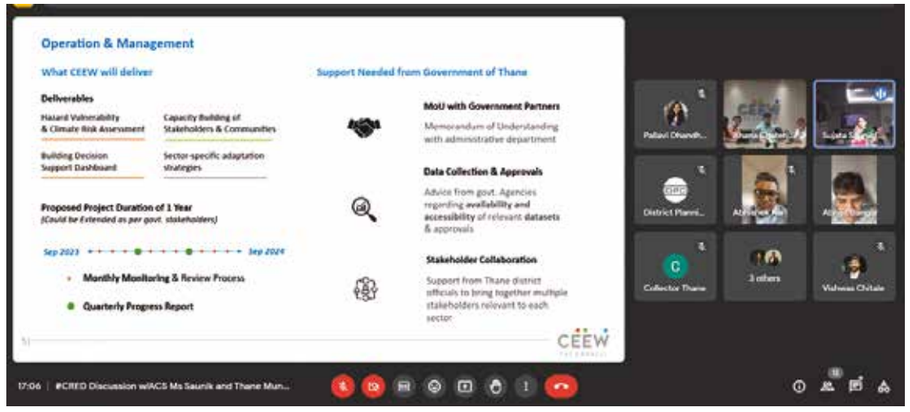


Image: CEEW

4. Hazard, vulnerability, and risk assessment

While there is widespread agreement in climate science that climate change has led to an increase in the frequency, intensity, and duration of extreme heat events, their impacts and risks depend on exposure and vulnerability of the population, which vary significantly across locations, even within a city.

Many city-level HAPs have developed response mechanisms to heat as a hazard by implementing heat-health warning systems. These systems aim to furnish information about the health implications of extreme heat conditions in specific areas, crucial for decision-makers in determining 'when to take action'. However, these warnings are often issued at broad regional scales, and decision-makers require detailed knowledge of variations in vulnerabilities and risks within the city to prioritise their actions. A comprehensive HAP requires an understanding of sub-city-level at-risk populations, a factor missing in almost 95 per cent of Indian HAPs (Pillai and Dalal 2023).

To address this gap and formulate the 'where to take action' element of the Thane HAP, *Prabhag Samitee*-level analysis of heat risk was conducted. This analysis follows the climate risk framework of the Intergovernmental Panel on Climate Change (IPCC), involving a granular examination of observed (1982–2022) and projected (2022–50) heat extremes through historical climatological assessment and climate projections. Additionally, it includes mapping exposure and urban heat islands using satellite imagery, along with official socioeconomic data of vulnerability collated by the various departments of the Thane Municipal Corporation.

4.1 Mapping of heat hazards over Thane

In the context of rapid climate change, it has become imperative to comprehend local-level shifts in climatic variables when formulating an action plan. This section delves into mapping the climatological changes in the city of Thane, spanning both observed (1982–2022) and projected time scales (up to 2050) with respect to heat extremes. The analysis uses the indices recommended by the World Health Organization (WHO), WMO, and the IMD, drawing upon finely detailed climatic data obtained from the Ministry of Earth Sciences (MoES) and climatological models developed by the Indian Institute of Tropical Meteorology (IITM).

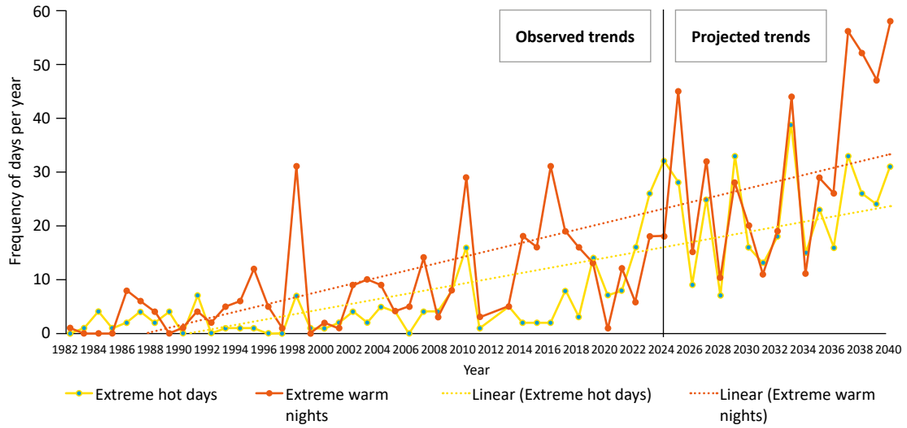
4.1.1 Observed and projected trends in daytime and nighttime heat extremes

To analyse observed and projected trends in both daytime and nighttime heat extremes in Thane city, a combination of data from the IMDAA (Rani et al. 2021) and the Coordinated Regional Downscaling Experiment–South Asia (CORDEX-SA) regionally downscaled models (RegCM4 by the IITM) was utilised. Detailed information on the models, downscaling methodology, bias correction, and data processing is available in Annexure 2 of this report.

The analysis examines the frequency of extreme hot days and extreme warm nights to project changes in Thane city's heat extremes under RCP 4.5, which represents a mid-emission scenario aligning with the net-zero targets of India and Maharashtra.

The extreme hot days and extreme warm nights are calculated based on the 95th percentile threshold of the baseline from 1982–2011 for the individual months between March and June. The number of days exceeding this threshold was calculated for each year from 1982–2040.

Figure 9: By 2040, the increase in the frequency of extreme warm nights is projected to be much more than extreme hot days



Source: Authors' analysis

The trends indicate a nearly threefold increase in the frequency of extreme hot days from 2024–40, compared to the period between 1982 and 2024. Notably, the frequency of warm nights is projected to rise nearly fourfold during the same period. The increased occurrence of warm nights is linked to the urban heat island effect, where building structures and other built-up areas, such as concrete roads, trap the heat and impede the upward movement of ground heat during the daytime, resulting in warmer nighttime temperatures (Parker 2010; Nichol 2005).

This surge in both extreme hot days and warm nights presents substantial challenges for Thane's population. Warmer nights hinder the cooling of human bodies from daytime temperatures, compounded by the augmented heat stress due to increased relative humidity. Addressing these challenges, this HAP outlines long-term strategies for heat risk mitigation in the subsequent sections.

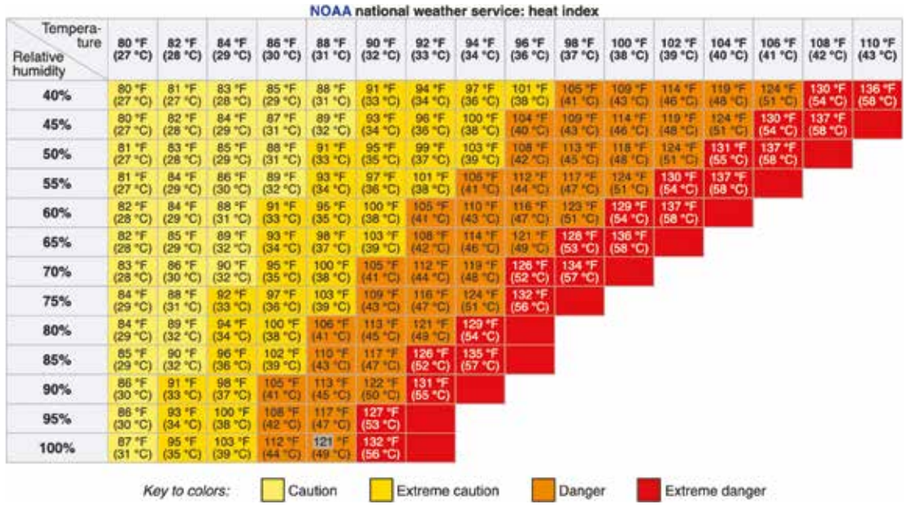
4.1.2 Developing the heat index for mapping felt temperatures

To understand the aggravated impacts of humidity and temperature combined and establish the thresholds for felt temperature – a crucial factor in comprehending heat stress in regions experiencing both high heat and humidity – the heat index developed by Steadman in 1979 and widely utilised by the National Oceanic and Atmospheric Administration (NOAA) was used (Steadman 1979).

The human body typically regulates its temperature through the evaporation of sweat. Elevated relative humidity reduces evaporation and the cooling effect, amplifying discomfort and the potential for heat stress. Individuals may perceive heat differently due to factors such as body shape, metabolism, hydration level, pregnancy, or other physical conditions. The heat index (HI) serves as an indicator that combines air temperature and relative humidity in shaded areas, presenting an

equivalent temperature perceived by humans – essentially, how hot an individual would feel if the humidity were at a different value in the shade. For instance, when the temperature reads 32°C with 70 per cent relative humidity, the heat index is 41°C.

Figure 10: The heat index matrix



Source: National Oceanic and Atmospheric Administration 2022

To compute the HI, the biometeorological formula illustrated in Figure 11, comprising nine constants and three variables, was applied. The inputs for calculating the HI variable included relative humidity in percentage and the dry temperature at 2 metres in Fahrenheit derived from the IMDAA hourly reanalysis data over Thane city from 1982–2022 for the months of March–June. The resulting HI variable was then converted from Fahrenheit to Celsius. The outputs of the HI are referred to as 'felt temperature' for the sake of consistency and ease of interpretation.

Figure 11: Bio-meteorological formula used for developing the heat index

$$HI = c_1 + c_2T + c_3R + c_4TR + c_5T^2 + c_6R^2 + c_7T^2R + c_8TR^2 + c_9T^2R^2$$

where

HI = ambient index (in degrees Fahrenheit)

T = ambient dry-bulb temperature (in degrees Fahrenheit)

R = relative humidity (percentage value between 0 and 100)

$c_1 = 42.379$, $c_2 = 2.049\,015\,23$, $c_3 = 10.143\,331\,27$,

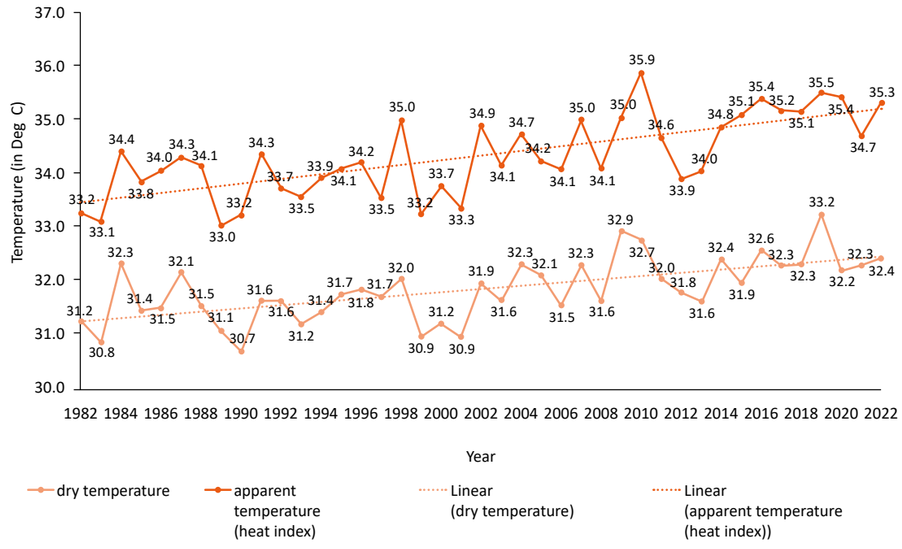
$c_4 = -0.224\,755\,41$, $c_5 = 6.837\,83 \times 10^{-3}$, $c_6 = -5.481\,717 \times 10^{-2}$,

$c_7 = 1.228\,74 \times 10^{-3}$, $c_8 = 8.5282 \times 10^{-4}$, $c_9 = -1.99 \times 10^{-6}$.

Source: Steadman 1979

The HI analysis indicates that Thane City has been witnessing a significant increase in both felt and dry maximum temperatures during the summer months over the last 40 years (1982–2022). However, in recent few years, the difference between the felt and dry temperatures has been increasing, albeit marginally; for instance, in 2022, the felt temperature was higher by almost 3°C than the dry temperature due to the added impact of humidity (Figure 12).

Figure 12: Trends in summer dry and felt temperature over Thane city from 1982–2022



Source: Authors' analysis

4.2 Mapping of urban heat islands using land surface temperatures

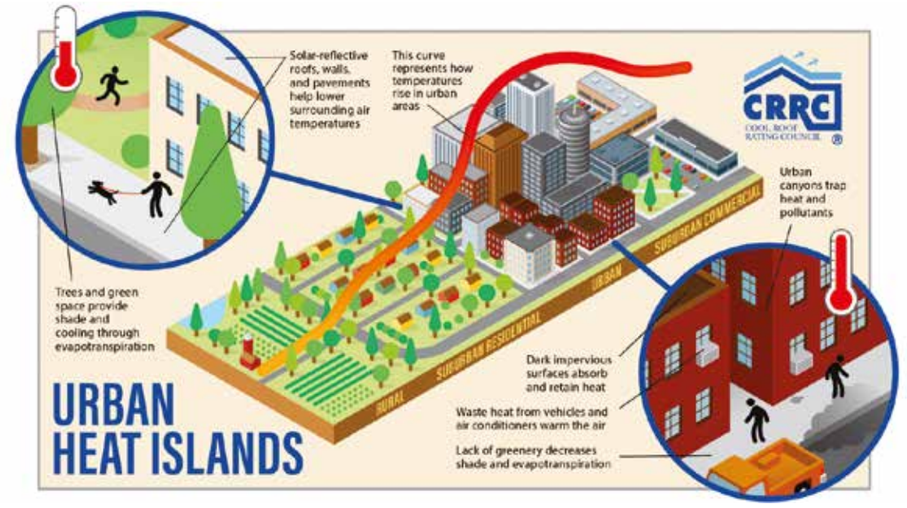
While air temperature provides valuable insights into its potential impacts on human bodies, land surface temperatures (LST) play an equally crucial role in understanding city-level heat extremes, offering key information about urban heat island (UHI) development.

Land surface temperature, which indicates the Earth's surface temperature and can be detected by remote sensing instruments, offers insights into the thermal characteristics of various land covers. Urban heat islands occur when urban areas experience higher temperatures than their rural surroundings due to human activities and alterations to the natural environment. Urban landscapes mostly consist of buildings, roads, and other infrastructure, most of which are made up of cement, steel, and bricks. These absorb a large amount of heat, and due to the lack of green spaces in cities, UHIs are formed, which trap the heat from solar radiation and increase the temperature.

Elevated surface temperatures contribute to higher air temperatures, particularly during the night. Heat islands not only amplify discomfort, illness, and mortality associated with heat but also drive up energy costs and air pollution due to the increased use of air conditioners. The adverse effects of urban heat disproportionately affect marginalised communities (Hsu et al. 2021; Hoffman et al. 2020; Wilson 2020).

Land surface temperature data identifies cool and hot spots within the city. Cool spots, with lower temperatures, may indicate green spaces or bodies of water mitigating UHI effects, while hot spots signal more intense UHI, often linked to high-density development or insufficient green infrastructure. By understanding LST patterns, city planners can formulate targeted strategies, such as green roofs or increased tree canopy cover, to mitigate UHI effects in specific areas.

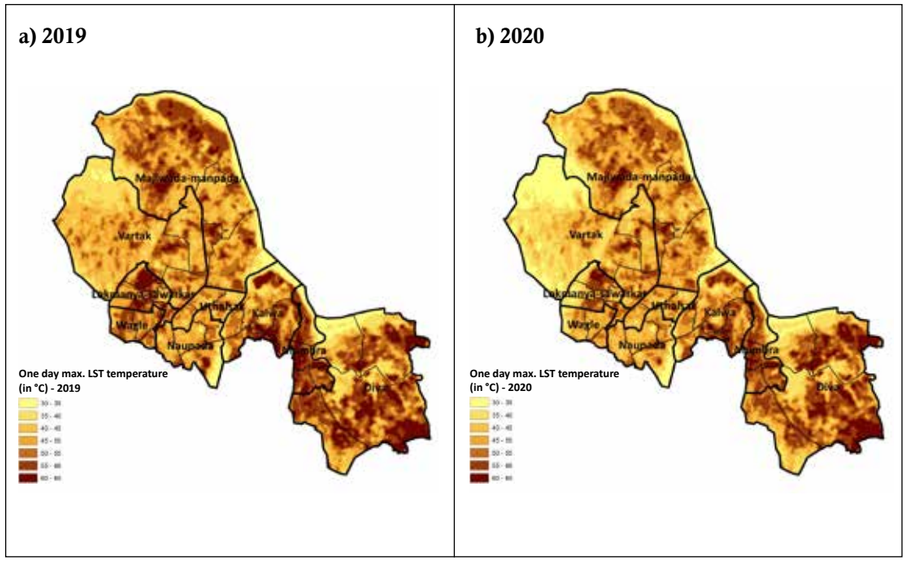
Figure 13: How urban heat islands develop and create heat risk

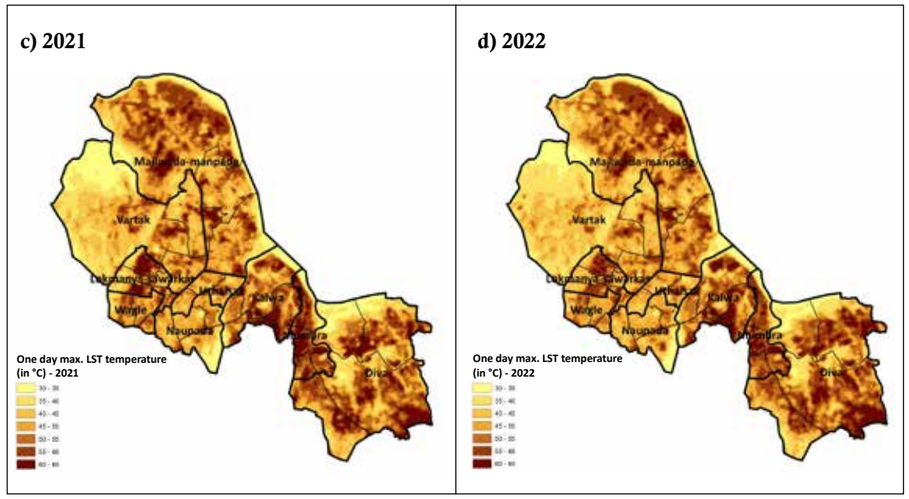


Source: Cool Roof Rating Council 2023

For the Thane HAP, the Landsat 8 satellite imagery at a 30-metre spatial resolution was used to map LST for the period 2019–23. This data is helpful in identifying UHI hotspots, guiding strategies such as cooling shelters, and greening interventions based on spatial and thermal information. Temporal variations in LST highlight areas consistently experiencing elevated temperatures, indicating potential UHI hotspots. The detailed methodology of LST quantification is provided in Annexure 3.

Figure 14: Yearly one-day maximum land surface temperature (LST) from 2019–23 during the months of March–June ranges from 30–65°C





Source: Authors' analysis

4.3 Ward-level heat risk index

To enhance the 'where to take action' aspect of the Thane HAP framework, a ward-level heat risk index was specifically developed for Thane City. The analysis evaluated extreme heat exposure and vulnerability across Thane's *Prabhag Samitees* and wards, assigning risk scores to each.

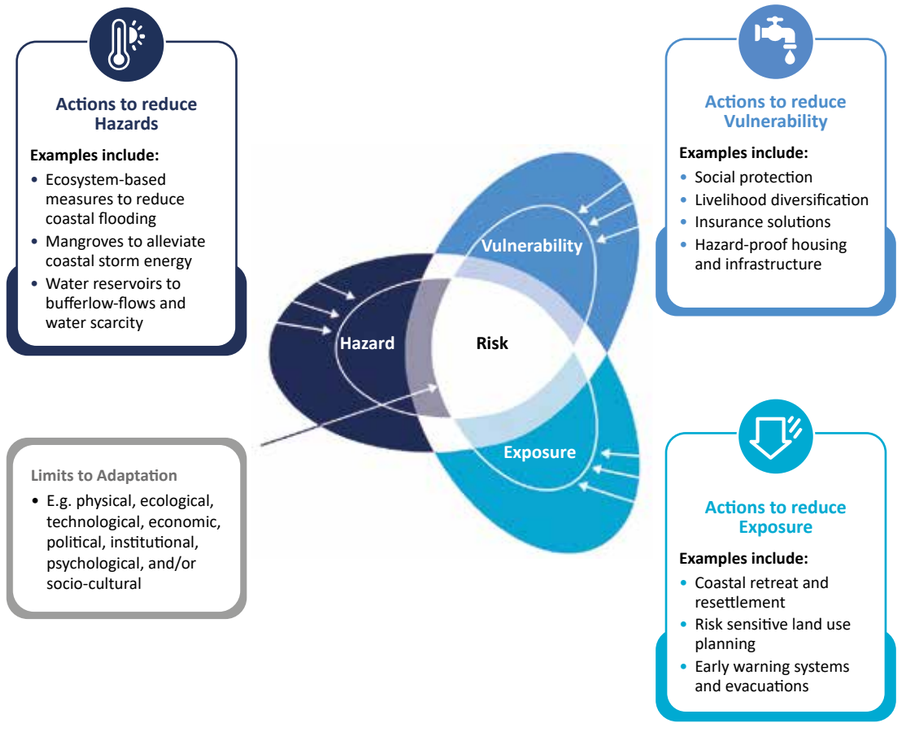
Heat wave risk and vulnerability result from a combination of socioeconomic, physiological, climatological, and behavioural variables. Changes in any of these variables can significantly impact the outcome, either amplifying or attenuating risks. Therefore, a meticulous analysis of factors contributing to risk in each *Prabhag Samitee* was conducted, enabling the identification of appropriate measures to adapt to and mitigate heat-related risks.

4.3.1 Approach and methodology: The risk assessment framework as per the Intergovernmental Panel on Climate Change

The development of the heat risk index in this assessment adhered to the standardised methodology outlined in the IPCC Fifth Assessment Report (AR5) of 2014, which is also endorsed by the Indian Department of Science and Technology (DST) for national-level assessments. This approach, acknowledged by the Ministry of Environment, Forests, and Climate Change (MoEFCC) in India, highlights the 'risk' concept as the outcome of interactions between vulnerability, exposure, and hazard.

The framework defines 'risk' as "the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species" (IPCC 2014).

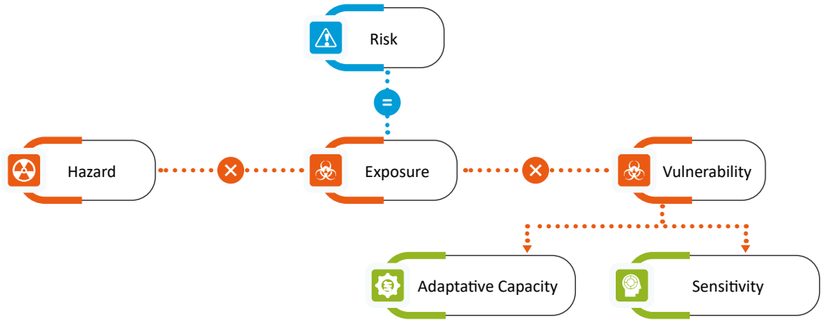
Figure 15: The conceptual framework of the IPCC AR5 risk assessment



Source: IPCC 2014

In its AR5, the IPCC emphasises that the severity of impacts resulting from weather and climate events, whether extreme or non-extreme, is closely tied to the level of vulnerability and exposure to these events. Consequently, comprehending the nature of vulnerability and the extent of exposure becomes imperative to mitigate and adapt to the challenges presented by climate change. The risk is calculated by the equation presented in Figure 16.

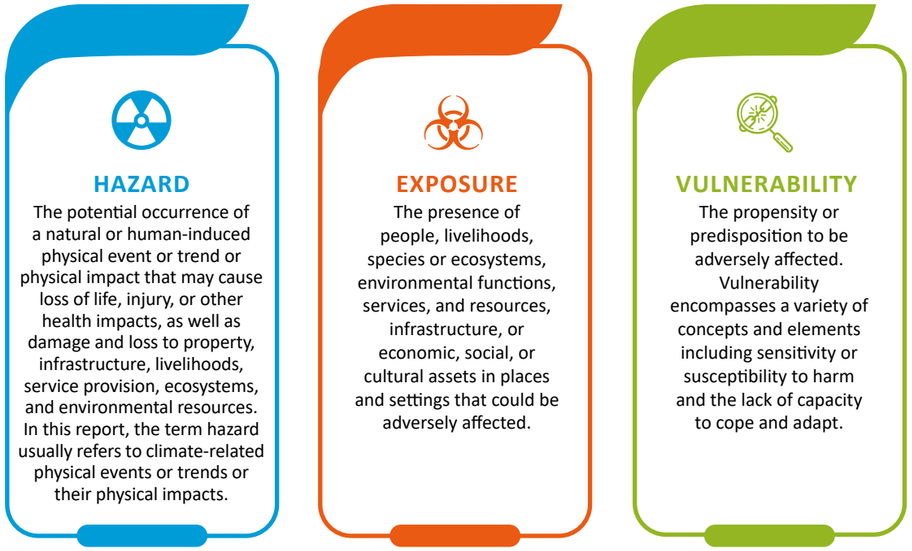
Figure 16: Risk assessment equation



Source: Authors' compilation

The risk assessment framework comprises three components that define the risk to the systems (in this analysis, the *Prabhag Samitees*). The sub-indices are hazards, exposure, and vulnerability (consisting of adaptive capacity and sensitivity), as defined in Figure 17.

Figure 17: Definitions of sub-indices of hazard, exposure, and vulnerability



Source: Authors' compilation

The vulnerability component of the AR5 framework includes the following two sub-indices:

- Sensitivity: refers to the degree to which a system or species is affected, either negatively or positively, by climate variability or change.
- Adaptive capacity: refers to the ability of systems, institutions, humans, and other organisms to adjust to potential damage, seize opportunities, or respond to consequences arising from climatic or anthropogenic causes.

4.3.2 Identification of indicators for hazard, exposure, and vulnerability assessment

Risk assessment is a multistep process that requires establishing clear goals and objectives. These determinations guide the type of risk assessment, scale, tier, indicators, and methods to be employed. The concept of risk can be operationalised in two ways: i) the starting point/contextual approach or ii) the endpoint/outcome approach. In the starting point/contextual approach, risk is considered a pre-existing condition in the anticipation of a hazard. In contrast, the endpoint/outcome approach involves assessing risk before and after exposure to a hazard (Department of Science and Technology 2019; Kelly 2000).

For this action plan, a starting point/contextual approach was adopted, where risk was identified based on pre-existing conditions within the given context. The heat risk assessment considered current climate hazards to provide insights into the existing vulnerabilities of natural or socioeconomic systems and the factors contributing to these vulnerabilities. This information serves as a basis for developing strategies to address identified weaknesses in the system and effectively respond or adapt to these contributing factors.

The first step of the assessment included identifying indicators for each component (viz., hazard, exposure, and vulnerability). Indicators are variables closely linked to the intended phenomenon or concept to be measured but are often challenging to quantify directly. The values of these indicators, whether examined individually or as an aggregate index, help understand the relative position of a system or unit of interest compared to others in relation to the associated phenomenon. Therefore, indicators or the use of indicator methods are particularly valuable in planning development interventions. When tracked over time, indicators can also serve as a useful tool for monitoring and evaluating programmes, as highlighted by Crane et al. (2017) in the case of vulnerability and risk assessment.

In this risk assessment, indicators reflecting the three dimensions of risk – hazard, exposure, and vulnerability – were selected based on a review of relevant literature, considering theoretical aspects underlying different risk determinants, data availability at a sub-city level, and stakeholder consultations. The detailed list of indicators, along with their data sources and rationale, is provided in Tables 1–3.

Table 1: Hazard indicators

Indicator	Description	Relation to heat risk	Data source
Increase in frequency of very hot days	An increase in the frequency of daytime and nighttime extremes and felt temperatures will directly lead to higher risk. These indicators have been calculated as an increase in the indicator in the last decade (2012–22) compared to the climatic baseline (1982–2011).	Direct	CEEW analysis based on IMDAA reanalysis data at 12 km resolution from 1982–2022.
Increase in frequency of very warm nights		Direct	
Increase in heat index		Direct	
Decrease in rainy days	A decrease in the number of rainy days will lead to compounding impacts on increasing heat extremes.	Direct	
Land surface temperatures	LST aids in pinpointing hotspots in specific areas prone to elevated heat conditions, primarily attributed to the urban heat island phenomenon.	Direct	CEEW analysis based on Landsat 8 data at 30 m resolution.

Source: Authors' compilation

Table 2: Exposure indicators

Indicator	Description	Relation to heat risk	Data source
Population density	Dense urban areas with high population density often face heightened vulnerability due to inadequate infrastructure, limited access to cooling resources, and higher socioeconomic disparities, worsening the impact of extreme heat events on health.	Direct	Thane Municipal Corporation, UHC-wise data, 2023.
Percentage of built-up area to total geographical area	Areas with high levels of impervious surfaces such as roads and buildings may experience higher temperatures due to the urban heat island effect and the trapping of heat.	Direct	CEEW analysis based on Land Use Land Cover Analysis from Sentinel 2A at 10 m resolution, 2022.
Building density	High building density exacerbates heat exposure by intensifying the urban heat island effect, trapping and radiating heat, and elevating temperatures.	Direct	CEEW analysis based on Google building footprint data, 2023.

Source: Authors' compilation

Table 3: Vulnerability indicators

Indicator	Description	Relation to heat risk	Data source
Sex ratio	Women often face greater vulnerability to disasters, particularly in developing nations. Social and economic factors can magnify the impact of extreme heat on women, including gender-based inequalities in healthcare, education, and economic opportunities.	Direct	Health Department, Thane Municipal Corporation, 2023.
Proportion of population with disabilities to total population	Disabled populations face higher vulnerability to heat risk due to mobility challenges, difficulties in accessing information, and limited adaptive capacity.	Direct	
Total slum population	Slum populations are particularly vulnerable to elevated temperatures due to factors such as inadequate nutrition, poor housing quality, and substandard living conditions. Additionally, the lack of access to basic amenities such as clean water and sanitation exacerbates the impacts of extreme heat.	Direct	
Illiteracy rate	Individuals with lower literacy rates may be more vulnerable to extreme heat events due to reduced awareness of potential dangers and limited access to heat alerts.	Direct	
Number of health centres per sq. km.	Urban health centres play a pivotal role by being first responders in medical care and disseminating information on staying safe. Accessible health services empower individuals and communities to cope with extreme heat and alleviate its health impacts.	Inverse	

Indicator	Description	Relation to heat risk	Data source
Number of parks per sq. km,	The presence of parks plays a pivotal role in alleviating the impact of high temperatures by mitigating the urban heat island effect, resulting in a more temperate and comfortable environment for residents.	Inverse	Garden Department, Thane Municipal Corporation, 2023.
Normalised Difference Vegetation Index (NDVI)	NDVI is a remote sensing index employed to evaluate the health of vegetation. Higher NDVI values represent dense and healthy vegetation, which can be used as an indicator to identify green spaces that provide a cooling effect.	Inverse	CEEW analysis based on Landsat8 imagery, 2023.
Proportion of young population to total population (below 6 years)	It is widely acknowledged, in addition to the WHO and NDMA guidelines, that young and old populations are more vulnerable to extreme heat due physiological factors and pre-existing health conditions. Limited adaptive capacity, behavioural considerations, and the UHI effect further exacerbate this vulnerability.	Direct	Health Department, Thane Municipal Corporation, 2023.
Proportion of old population to total population (above 60 years)			
Proportion of population with chronic health conditions	Heat can lead to severe dehydration and acute cerebrovascular accidents and contribute to thrombogenesis (blood clots). Those with chronic diseases on daily medications face an elevated risk of complications and death during heat waves, along with older individuals and children (WHO 2018; Koppe et al. 2004).	Direct	
Access to water sources	Access to water sources is crucial in dealing with extreme heat. Water sources additionally reduce heat risk by moderating temperatures through evaporation and creating localised cooling.	Inverse	CEEW analysis based on Modified Normalised Difference Water Index (MNDWI), 2023 from Landsat8 satellite imagery.
Access to road network	Increased road density implies improved accessibility and mobility, facilitating access to vital services and resources, such as medical care, water, and cooling centres during extreme heat events.	Inverse	Town planning department, Thane Municipal Corporation, 2023.
Number of automatic weather stations (AWS) per sq. km.	A higher number of AWS facilitates the recording of localised meteorological data, enabling timely alerts for extreme heat. Moreover, it contributes to the enhancing of long-term forecasting systems.	Inverse	Thane Municipal Corporation, 2023.

Source: Authors' compilation

Data availability significantly influenced indicator selection while developing the heat risk index at the granular level of wards. A comprehensive review of national and global literature, along with insights from recent heat action plans in Indian cities such as the Jodhpur HAP 2023 and Ahmedabad HAP 2019 (Qureshi and Rachid 2022; Wu et al. 2022; Liu et al. 2020; Adnan et al. 2022; Xiang et al. 2022; Sidiqui et al. 2022; Zuhra et al 2019.; Estoque et al. 2020; Zhang et al. 2018; Abrar et al. 2022; Cai et al. 2019; Inostroza, Palme, and De La Barrera 2016; Conlon et al. 2020; Rathi et al. 2022; Leal Filho et al. 2018; Nanda et al. 2022; Johnson et al. 2012, Angel et al. 2021), guided the selection process. The indicators were finalised based on stakeholder consultations with staff from all the line departments involved in this HAP.

The indicators included direct associations with heat risk and inverse relationships, where an increase in certain indicators mitigated heat risk. For instance, a rise in the slum population indicated higher vulnerability and, consequently, increased heat risk. On the other hand, a higher number of health centres per sq km reduced vulnerability and, hence, reduced heat risk.

The indicators were normalised by bringing all the indicators to a common scale. Further, to make them unit-free, the min-max normalisation technique was used for indicators related to exposure, vulnerability, and hazard. Normalisation is based on the indicators' functional relationship with vulnerability. For positively related indicators, i.e., where risk increases with an increase in the value of the indicator, the following formula was used:

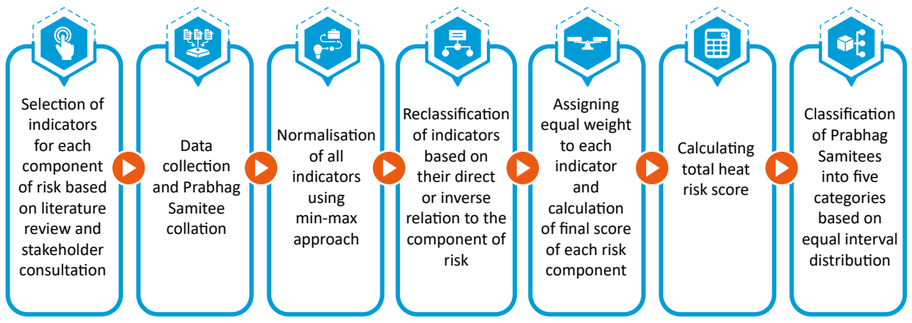
$$X^{P}_{ij} = \frac{Xij - Min_i\{Xij\}}{Max_i\{Xij\} - Min_i\{Xij\}}$$

For negatively related indicators, i.e., where vulnerability decreases with an increase in the value of the indicator, the following formula was used:

$$X^{N}_{ij} = \frac{Max_i\{Xij\} - Xij}{Max_i\{Xij\} - Min_i\{Xij\}}$$

Normalised values of an indicator range between 0–1, where 1 corresponds to a *Prabhag Samitee* with maximum risk, and 0 corresponds to a *Prabhag Samitee* with minimum vulnerability with respect to a particular indicator. Due to a lack of information on indicator weightages contributing to heat risk in the Indian context and the absence of these weightages in existing Indian HAPs and literature, an equal weightage approach has been used when calculating scores for each risk component.

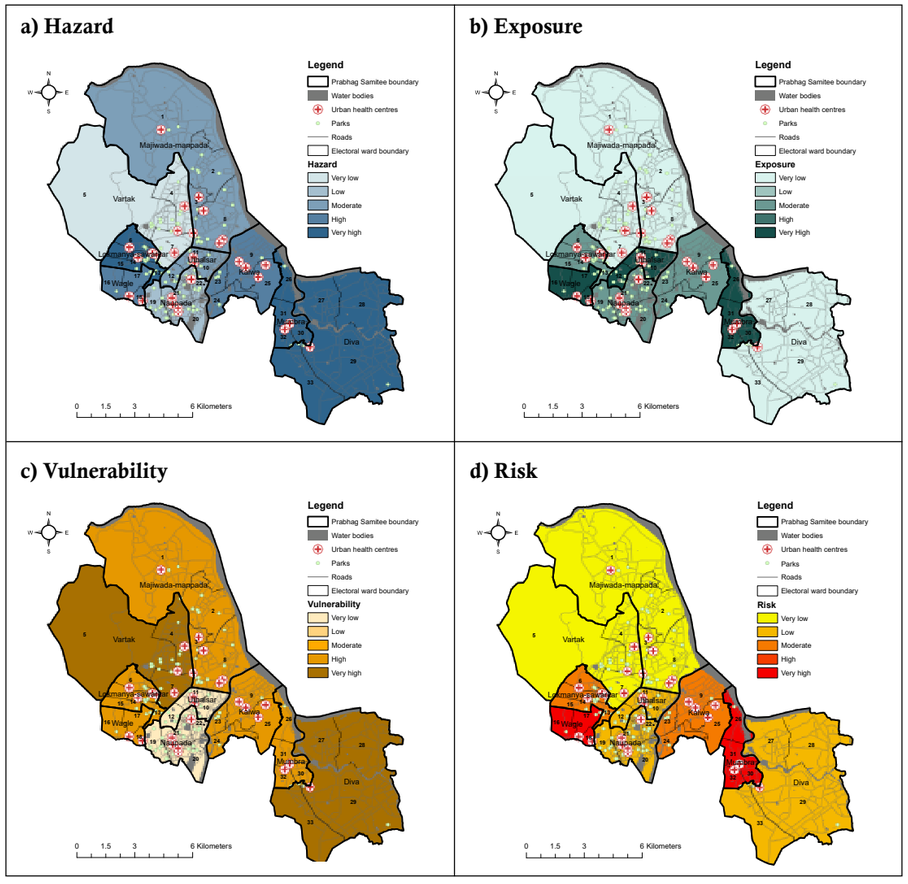
Figure 18: Schematic representation of the stepwise approach to compute the heat risk index



Source: Authors' compilation

4.3.3 Results of the heat risk index

Figure 19: Findings from the heat risk index for Thane City: a) hazard, b) exposure, c) vulnerability, and d) risk.



Source: Authors' analysis

Table 4: Prabhag Samitees in the high and very high categories for each component of heat risk

Component	*Prabhag Samitees* in the very high category	*Prabhag Samitees* in the high category
Hazard	1. Mumbra 2. Lokmanya-sawarkar 3. Diva	1. Wagle 2. Kalwa
Exposure	1. Wagle 2. Mumbra 3. Uthalsar	
Vulnerability	1. Diva 2. Vartak	1. Kalwa 2. Wagle 3. Lokmanya-sawarkar 4. Mumbra 5. Majiwada-manpada
Risk	1. Mumbra 2. Wagle	1. Lokmanya-sawarkar 2. Kalwa

Source: Authors' analysis

4.3.4 Identification of factors leading to heat risk in each *Prabhag Samitee*

The indicators for each component of hazard, exposure, and vulnerability with a very high score (equal to or more than 8 out of 10) that were identified are detailed in Table 5. This information offers government stakeholders the necessary details to address potential causes of heat risks in specific *Prabhag Samitees* and take targeted actions for enhancing heat resilience.

Table 5: Factors contributing to heat risk in each Prabhag Samitee

Factors of risk		Name of *Prabhag Samitee* (From left to right represents high to low heat risk)									Relation to risk
Component	**Indicator**	**Mumbra**	**Wagle**	**Lokmanya-sawarkar**	**Kalwa**	**Uthalsar**	**Diva**	**Naupada**	**Majiwada-manpada**	**Vartak**	
Hazard	Land surface temperature										Direct
Exposure	Percentage of built up area to total geographical area										Direct
	Population density										Direct
	Building density										Direct
Vulnerability	Sex ratio										Direct
	Proportion of population with disabilities to total population										Direct
	Total slum population										Direct
	Illiteracy rate										Direct
	Number of health centres per sq km										Inverse
	Number of parks per sq km										Inverse
	Normalised Difference Vegetation Index										Inverse
	Proportion of young population to total population (below 6 years)										Direct
	Proportion of old population to total population (above 60 years)										Direct
	Proportion of population with chronic health conditions										Direct
	Percentage of water bodies to total geographical area										Inverse
	Access to road network										Inverse
	Number of automatic weather stations per sq km										Inverse

Source: Authors' analysis

As part of the implementation strategy of the Thane HAP, a ward-wise questionnaire based framework of mapping vulnerability and risk will be applied to understand hyperlocal risks and take appropriate actions (Refer annexure 5).

5. Establishing local-level heat thresholds for early warning systems

In the preceding section, a heat risk index was quantified to determine 'where to take action'. An equally critical aspect for planning mitigating measures is comprehending 'when to take action'. Given the gradual and impending impacts of heat waves on human health, distinct from the hard and rapid effects of other hazards such as floods or cyclones, it is imperative to understand the threshold at which temperatures become hazardous and necessitate responsive measures tailored to the specific context of Thane City. This section elaborates on the formulation and implementation of localised heat thresholds for Thane City to provide precise early warnings and alerts for heat waves.

5.1 Approach for establishing local heat-health thresholds

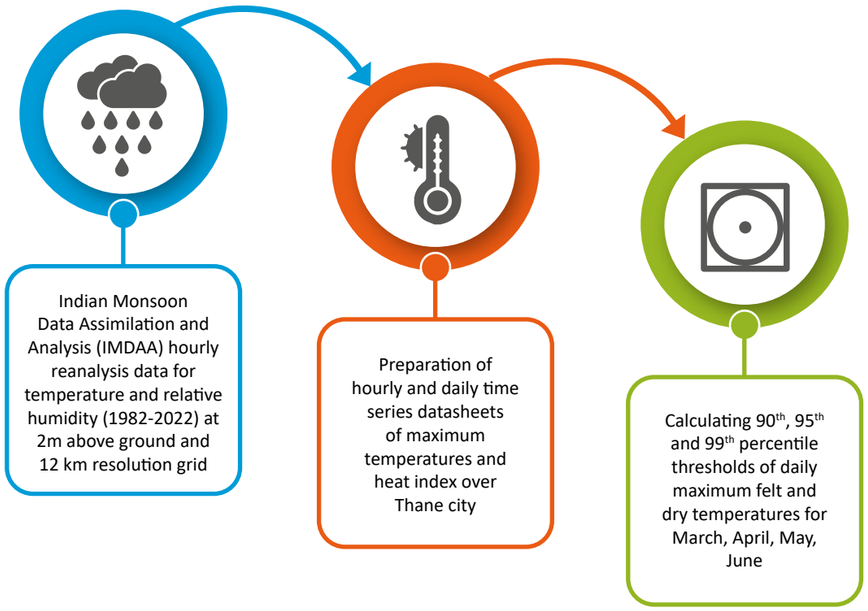
While the criteria for heat waves offer insights into when weather conditions are conducive to an extreme heat event, heat-health thresholds primarily aim to examine the impacts of this extreme heat on the human body. In 2015, the WMO and the WHO collaboratively formulated and published guidance on heat-health warning systems (HHWS). The report emphasised the necessity and the process of developing a heat-health action plan (HHAP) and outlined various parameters to be considered during the plan's development. Forecasting and issuing warnings to the target group constitute integral components of any early warning system. Heat thresholds are established through two primary methods.

1. **Biostatistical analysis:** This method involves establishing a relationship between an extreme temperature variable and a health outcome variable. Numerous studies have utilised various health variables, including all-cause daily mortality count data, cause-specific daily mortality count data, hospital daily admissions count data, and emergency ambulance (108) services daily call count. All-cause mortality, often adjusted to a baseline or standardised to account for within-season variability, is the most widely used variable in available literature (Sheridan and Kalkstein 2004; Pascal et al. 2006; Ahmedabad Municipal Corporation 2019). Similarly, the mortality of people aged 65 and older (Kent et al. 2002) and non-accidental cause mortality (Michelozzi et al. 2005) have also been employed. Regarding meteorological variables, thresholds to trigger early warnings are determined using single parameters such as maximum temperature (T.Max) or a combination of multiple parameters such as the heat index. The choice of the parameter is typically based on factors such as geographical conditions, the availability of historical health data, and temperature data (WHO and WMO 2015; NDMA 2019).
2. **Biometeorological indices:** According to the WHO–WMO guidance, "In situations where there is basic meteorological information but no health data, a percentile-based threshold (90th, 95th) could be contemplated as a warning trigger value." Therefore, many studies have employed the development of long-term time-series temperature data and calculated percentiles to establish these thresholds.

In India, a hybrid approach combining both methodologies has been employed. For instance, the Ahmedabad HAP established thresholds by developing a dose-response relationship between the daily maximum temperature during summer and the corresponding daily all-cause mortality. Expanding on this HAP, in 2019, the NDMA conducted a comprehensive study to establish these thresholds for 103 cities in India. This involved a time-series analysis of temperature and mortality for five cities, determining thresholds based on published research for two cities, and establishing seasonal and monthly maximum temperature thresholds using the 75th, 85th, and 95th percentile values for 96 cities (Srivastava et al. 2019).

The local heat thresholds for Thane city were developed by leveraging the latest fine-resolution IMDAA reanalysis data, available at a 12-km spatial grid. The approach went beyond daytime extreme dry temperatures to incorporate felt temperatures, utilising the heat index – a composite of relative humidity and temperature outlined in the previous sections. Figure 20 provides a detailed methodology for the computation of heat thresholds for Thane City. For this plan, the 90th, 95th, and 99th percentiles have been used to compute yellow, orange, and red colour-coded alert thresholds, respectively.

Figure 20: Schematic representation of methodology for developing Thane City–specific local heat thresholds



Source: Authors' compilation

5.2 Thane City-specific heat thresholds for early warning systems

This section provides the month-wise local thresholds for Thane City. Figures 21 and 22 represent these thresholds. The analysis suggests that the thresholds were nearly similar for dry and felt heat during the month of March, but the felt heat thresholds started getting higher in April. Consequently, both dry and felt temperature thresholds were computed. The dry thresholds are applicable for use in the month of March, while the felt thresholds are suitable for the months of April–June, specifically when both temperatures and relative humidity significantly escalate.

Figure 21: Felt heat thresholds for Thane City

Felt temperature thresholds (in °C)			
Month	**Yellow alert**	**Orange alert**	**Red alert**
March	38	39	41
April	41	42	45
May	42	43	46
June	39	40	43

Source: Authors' analysis

Figure 22: Dry heat thresholds for Thane city

Dry heat thresholds daytime (in °C)			
Month	**Yellow alert**	**Orange alert**	**Red alert**
March	38	39	40
April	39	40	41
May	38	39	41
June	36	37	40

Source: Authors' analysis

6. Long-term heat risk mitigation

Based on the analysis presented earlier in this report, it is evident that both the frequency of extreme hot days and extreme warm nights are expected to increase significantly, nearly three to four times, by the year 2040. Moreover, there has been an observed rise in felt temperatures over the last four decades (1982–2022), compounding challenges, particularly for the vulnerable populations in Thane City. In light of this scenario, it becomes imperative to devise heat risk mitigation strategies aimed at enhancing the resilience of Thane's populations and sectors, ultimately reducing mortality, heat-related illnesses, and economic losses across various sectors. This chapter outlines these strategies through a stakeholder responsibility matrix and presents innovative cooling solutions for the city of Thane.

6.1 Stakeholder responsibility matrix for heat risk mitigation

Themes		Task/Activities	Municipal corporation (Main)			District authority (Secondary)		State (Support)	
			Responsibility	Division		Responsibility	Department	Responsibility	Department
Understanding vulnerability and risk									
Hazard risk vulnerability capacity assessment	**1**	Hazard risk vulnerability assessment	Conduct heat wave vulnerability and risk assessment at ward level by considering hazard, exposure, sensitivity, and adaptive capacity in slums, individual households, and communities. Identify and map heat risk hot spot areas for designing appropriate response measures.	External expert agency		Coordinate with state and State Remote Sensing Centre (SRMC) for heat wave hot spot mapping for the identification of vulnerable areas and population.	District Emergency Operation Centre (DEOC) /District Disaster Manage-ment Authority (DDMA)	Identify heat wave vulnerable populations at the state and district level and coordinate with National Remote Sensing Centre (NRSC) for heat wave hot spot mapping to help in designing appropriate response.	State Emergency Operation Centre (SEOC)/State Disaster Manage-ment Authority (SDMA)/ Commi-ssioner of Relief (COR)
			Map out the physical vulnerability due to age, chronic illness, morbidities, outdoor vendors/workers, type of housing, occupation, etc. by using available resources and robust scientific methods.			Adopt uniform process for physical vulnerability and risk assessment at district level.	DEOC/DDMA Health	Formulate a standard risk assessment process to be followed by all district and MC.	SEOC/SDMA/COR
	2	Risk assessment	Generate a heat wave risk index through assessment and prepare a ward-wise atlas for mitigation and adaptation measures.	External expert agency		Identify hot spot area mapping for appropriate mitigation measures and intervention.	DEOC/DDMA	Prepare HRVA with district as a unit to identify and prioritise most prone districts and provide necessary support.	SEOC/SDMA/COR
			Identify high risk wards, settlements, industries, and vulnerable groups, particularly homeless and aged individuals, households, communities, people with morbidities, outdoor vendors/workers, traffic police, etc., to concentrate on mitigation measures at a specific area on priority basis.			Coordinate and provide support for identification of local NGOs and corporate houses to provide shelters, drinking water, medical supplies, and temporary homes during heat wave season.	DEOC/DDMA		
	3	Estimation of local temperature threshold	Estimate ward-wise or city-wise thresholds, including thermal variables such as temperature and humidity and health variables such as mortality and morbidity.	External expert agency		Provide mortality and met-data to MC and support developing the thresholds.	DC/District hospital	Provide meteorological data/ information	RMCs/Health department
Inter-agency coordination									
Heat wave risk reduction	**4**	Heat wave management cell	Set up a heat wave management cell. Understand and use all the heat wave-related information from various agencies of district/state and central agencies.	Municipal commissioner					
	5	Nodal officer as mentioned in response matrix	Appoint a nodal officer to head the heat wave cell, manage coordination, and monitor all the activities of the heat wave cell.			The DDMA may appoint a district nodal officer to coordinate preparedness, response, and mitigation measures at the district level.	DEOC/DDMA	The SDMA may appoint a State Nodal Officer to coordinate preparedness and response measures at the state level.	SEOC/SDMA/COR
			Coordinate among ward members and review mitigation measures.	Additional municipal commissioner					
			Ensure coherence and mutual reinforcement of heat wave risk reduction, climate change adaptation, and development.			Ensure coherence and mutual reinforcement of heat wave risk reduction, climate change adaptation, and development.	DC/DDMA	Ensure coherence and mutual reinforcement of heat wave risk reduction, climate change adaptation, and development.	COR/SDMA
	6	Mainstreaming and upscaling	Coordinate for mainstreaming heat wave risk reduction activities with relevant departments, local NGOs/CSOs, and ward leaders.	Additional municipal commissioner		Coordinate for mainstreaming heat wave risk reduction with relevant departments, institutions, and NGOs at the district level.	DEOC/DDMA	Coordinate for mainstreaming heat wave risk reduction with relevant departments, institutions, and NGOs at the state level.	SEOC/SDMA/COR
			Identify convergence with heat wave activities in various programmes/ schemes run by different departments NGOs, for heat wave risk reduction.			Identify convergence with various programmes/ schemes run by different departments for heat wave risk reduction activities.	DEOC/DDMA DC	Identify convergence of various programmes/schemes run by different departments for heat wave risk reduction activities.	SEOC/SDMA/COR
Investing in heat wave risk reduction: Non-structural mitigation measures									
Mitigation of heat wave risk	**7**	Municipal administration and urban development	Sprinkling of water on the road to reduce heat and improve air quality with a priority in identified at risk wards in the heat risk assessment.	Public works department		The nodal officer could coordinate mitigation measures with relevant departments. Organise district-level meetings with line departments and plan and implement mitigation measures. Create large-scale cooling shelters and green spaces during heat waves.	DEOC/DDMA DC	1. State nodal officers may coordinate mitigation measures with relevant departments. 2. Issue advisory for open park/shaded space during the daytime in heat wave season. 3. Support the construction of shelters/sheds at public places and provide access to public parks during heat waves.	SEOC/SDMA/COR/ Urban Dev.
	8	Techno-legal rimes – Increase green cover	Implementation of laws/rules and regulations. Improve green cover through plantation to enhance water ponds, fountains, and increase green parks. Promote heat-resistant building materials to reduce heat island effects in urban areas such as cool roofs and thermal insulation.	Deputy city engineer		Provide guidance and support to law regulation and enforcement. Improve green cover through plantation to enhance water ponds. Promote use of heat-resilient building materials to reduce heat island effects in urban areas.	SEOC/SDMA/ COR/UD/Forest.	Provide advisory/policy for law and regulation Improve green cover through plantation to enhance water ponds. Promote the use of heat resilient building materials to reduce heat island effect in urban areas.	SEOC/SDMA/COR/ UD/Forest.

Themes		Task/Activities	Municipal corporation (Main)			District authority (Secondary)		State (Support)	
			Responsibility	Division		Responsibility	Department	Responsibility	Department
	9	Public health intervention	Issue health advisories for different vulnerable population and create displays on ambulances to build public awareness during the summer season. Organise camps for health check-up in slum areas. Procure adequate quantity of life-saving medicines, IV fluids, ORS, etc., in all health centres under municipal corporation areas.	Medical officer of health		Ensure 24×7 heat- health facilities with adequate provision of basic medicine. Ensure separate beds/seperate wards in PHCs, district hospitals, medical colleges, and private hospitals for the treatment of heat stroke patients during the heat wave period.	DEOC/DDMA DC/UD Health	Issue healthcare advisories for all vulnerable groups. Ensure that all government hospital (PHCs/CHCs) have plans in place. Ensure sufficient supply/procurement and stock of adequate quantities of life-saving medicines, IV fluids, ORS, etc.	SEOC/SDMA/COR/ Health
	10	Water supply	Maintain portability of water quality Ensure availability of drinking water supply at all wards during the summer season, especially in vulnerable places. Ensure clean drinking water facilities at common places such as bus stands, labour hubs, markets, and parks. Open water kiosks at identified hot spots. Frequently repair/maintain mechanical/electrical faults in water supply before season.	Deputy city engineer Water Supply		Ensure availability of sufficient drinking water supply at all vulnerable places. Open water kiosks at identified hot spot areas. Repair/maintain mechanical/electrical fault of water supply on priority basis to ensure water storage and smooth supply.	DEOC/DDMA DC/ PHED Health	Issue advisories for water supply during the heat wave season. Make suitable arrangements for drinking water supply and promptly respond to water scarcity. Repair/Maintain mechanical/electrical fault of water supply on priority basis to ensure water storage and smooth supply.	SEOC/SDMA/COR/ PHED
	11	Road transport	Encourage the use of public transport, electric vehicles, and bicycles to reduce vehicle emissions and traffic congestion for a safe environment. Ensure shelter/sheds at bus stops. Plant trees on roadside or create green dividers.	TMT manager		Encourage the use of public transport and electric vehicles to reduce vehicle emissions and traffic congestion and ensure a clean environment. Ensure shelter/sheds at bus stops and frequency of public transport. Plant trees on roadside or create green dividers with the help of the forest departments.	DEOC/DDMA DC/ DTO	Promote the use of public transport and electric vehicles to reduce vehicle emissions and traffic congestion and ensure a clean environment. Ensure shelter/sheds at bus stops on state/national highways and ensure frequency of transport, and drinking water facilities on the highways. Plant trees on roadside or create green dividers for all SH and connecting roads.	SEOC/SDMA/COR/ RTO
	12	Rail transport	Coordinate with local railway stations in charge of repair/maintenance of mechanical, electrical faults and ensure sheds, shelter, temperature cooling equipment, and water supply at public waiting areas during the heat wave season.	Additional municipal commissioner		Coordinate with railways to ensure sheds, shelters, temperature cooling equipment, and water supply at public waiting areas during the heat wave season.	DDMA/Railways	Coordinate with the divisional railway manager (DRM) to ensure sheds, shelters, temperature cooling equipment, and water are provided at public waiting areas during the heat wave season.	
	13	Electricity and power	Coordinate with the electricity department for uninterrupted electric supply in higher risk areas and wards. Promote energy efficiency and use of renewable energy for cooling and electricity needs. Promote the use of renewable energy such as solar energy for cooling and electricity needs.	Deputy city engineer Electrical Department		Undertake repair and maintenance work for uninterrupted electricity supply before and during the summer season. Re-schedule load shedding if required. Promote the use of renewable energy such as solar energy for cooling and electricity needs.	DEOC/DDMA DC/agency responsible for power/electricity	Manage peak demand without power cut. Undertake repair and maintenance work for un-interrupted electricity supply before and during the summer season. Promote the use of renewable energy such as solar and wind for cooling and electricity needs.	SEOC/SDMA/COR/ Department of Energy and Power
	14	Education	Reschedule MC schools and institutions timing as per heat wave situation and alerts. Ensure all schools and institutions have cooling equipment in working condition and ensure adequate water facilities. Ensure the students avoid outdoor games and physical activities during heat waves.	DMC Education		Ensure all schools and institutions have cooling equipment in working condition and availability of drinking water. Ensure that the students avoid outdoor physical activities during heat waves.	DEOC/DDMA DC/ CEO/DEO	Issue directions for re-scheduling school timing and vacation as per heat wave situation. Issue directions to all schools and institutions to have cooling equipment and its working condition and ensure availability of drinking water.	SEOC/SDMA/COR/ Education departments
	15	Labour	Ensure heat illness orientation for factory officers, staff, and general practitioners through IEC materials. Conduct awareness campaigns regularly, particularly during high-risk days. Coordinate rescheduling of working hours for workers and labourers across different sectors within the municipal area. Provide drinking water at work sites and use of temperature control measures such as fans and coolers.	Medical officer of health		Ensure adjusting work schedules to avoid the hottest part of the day, by starting work earlier. Coordinate with the health department and ensure regular health check-up of the workers. Ensure that industries provide emergency ice-pack and heat illness prevention materials to workers.	DEOC/DDMA DC/ labour	Issue advisories to adjust work schedules and avoid the hottest part of the day by starting work shifts earlier. Consider extended afternoon breaks or alternate working hours for workers.	SEOC/SDMA/COR/ Labour and Employment
	16	Livestock	Ensure adequate sheds and shelters for livestock in high-risk wards. Have publicity drives on protective measures to save livestock and poultry during heat waves. Ensure adequate stock of medicines and fluids in all veterinary hospitals. Ensure additional mobile hospitals ready to reach vulnerable areas.	Veterinary doctor		Issue and implement advisories to ensure protective measures are taken to save livestock and poultry during heat waves. Prepare handouts for veterinary paramedical staff about heat illness. Ensure the visit of veterinary staff in vulnerable areas during heat waves.	DEOC/DDMA DC/ AH	Issue advisories on protective measures to save livestock and poultry during heat waves. Prepare handouts for doctors and veterinary paramedical staff about heat illness. Ensure sufficient supply and stock of life saving veterinary medicines.	SEOC/SDMA/COR/ AH

Themes		Task/Activities	Municipal corporation (Main)			District authority (Secondary)		State (Support)	
			Responsibility	Division		Responsibility	Department	Responsibility	Department
	17	Parks and garden	Ensure that all parks have sitting and resting sites for the public during heat waves. Conduct promotional campaigns for green roof and cool roof buildings, increasing ventilation, and setting up green spaces. Ensure construction of green buildings. Increase green coverage through individuals, households, communities, resident welfare associations (RWAs), institutions, etc.	DMC Garden		Promote the use of green roofs and cool roofs in buildings, increasing ventilation, and setting up green spaces. Encourage planting of trees and improve vegetation in neighbourhoods to create a cooler and more pleasant environment.	DEOC/DDMA DC/ Forest	Issue directions for the construction of green buildings following energy conservation building codes (ECBC) related to heat wave risk mitigation. Increase forest coverage and green areas. Promote forestation and mass tree plantation.	SEOC/SDMA/COR/ Forest.
	18	Fire	To be in a state of preparedness and ready to face any fire emergency. Ensure adequate supply of water and foam to fight fires. List designated point of contact for each ward in case of fire.	Chief officer Fire & Bridge Department		Coordinate with fire brigades and MCs in the district for any emergency situation. Check the state of readiness of vehicles and fire-fighting equipment to face any fire emergency. Ensure adequate supply of water and foam to fight fires. Provide additional equipment, vehicles and manpower if needed in case of major fires.	DEOC/DDMA DC/	Ensure availability of adequately trained staff, vehicles, and fire-fighting equipment for managing any emergency situation arising during heat waves. Ensure adequate quantity of foam to fight fires. Provide training and capacity building for fire staff and officials.	SEOC/SDMA/COR/ Home department
Investing in heat wave risk reduction: Structural mitigation measures (climate change and long term)									
Regulation of building construction	**19**	Heat-resilient infrastructure	Create public cooling centres green spaces and parks for people to cool off and avoid heat-related illnesses and deaths. Have heat risk–informed urban planning for mitigating future heat risk. Mandate all construction to include heat wave–resilient features and standards. Ensure heat-resistant building features such as cool roofs and thermal insulation to reduce the indoor temperature. Promote greater use of permeable materials in civic infrastructure and residential construction to reduce the urban heat island effect.	Chief environment officer		Promote heat wave–resilient buildings and infrastructure.	SEOC/SDMA/ COR/UD/Forest	Issue policies, guidelines, and schemes for heat wave–resilient construction of buildings and infrastructure.	SEOC/SDMA/COR/ UD/Forest
	20	Social housing schemes and urban greenery	Increase urban greenery tree plantation drives. Ensure that social housing schemes have heat wave–resilient features and use reflective materials on buildings and ventilated cooling spaces.	Dy city engineer PWD		Increase urban greenery through tree plantation, enhance blue spaces (water bodies), and use reflective materials on buildings, and ventilated cooling spaces. Expand wetlands and restore ponds and lakes.	DEOC/DDMA DC/UD Forest	Increase urban greenery through tree plantation, enhance blue spaces (water bodies), and promote the use of reflective materials on buildings and ventilated cooling space. Prepare heat wave–resilient building designs for beneficiaries to use in social housing schemes.	SEOC/SDMA/COR/ UD/Forest
Climate change adaptation	**21**	Rooftop solar energy	Promote rooftop solar panels to help cooling inside buildings. This will also help climate change adaptation.	Dy city engineer Electrical Department		Promote rooftop solar panels to help cooling inside buildings. This will also help climate change adaptation.	DEOC/DDMA DC/ Forest	Promote rooftop solar panels to help cooling inside buildings. This will also help climate change adaptation.	SEOC/SDMA/COR/ MNRE/Forest.
	22	Renewable energy	Promote the use of renewable energy sources such as solar and wind for cooling and electricity needs. Install solar-powered appliances such as fans and air conditioners to stay cool and comfortable.			Promote the use of renewable energy sources such as solar and wind for cooling and electricity needs. Promote the installation of solar-power appliances such as fans and air conditioners to stay cool and comfortable during heat waves.	DEOC DDMA DC/ Power	Promote the use of renewable energy sources such as solar and wind for cooling and electricity needs. Promote the installation of solar-powered appliances such as fans and air conditioners to stay cool and comfortable during heat waves.	SEOC/SDMA/COR/ MNRE/Power
	23	Ensure open spaces to reduce pollution and heat island effects	Maintain/Create open spaces, open areas in the city to reduce pollution and heat island effects.	Chief environment officer		Maintain/Create open spaces/areas in the city to reduce pollution and heat island effects.	DEOC DDMA DC/ Forest DTO	Implement policy to maintain/create open spaces/areas in the city to reduce pollution and heat island effects.	SEOC/SDMA/COR/ Forest/RTO/
	24	Solid waste management	Reduce the size of landfills and waste segregation. Sound solid waste management at the source can reduce methane production and fires that exacerbate urban heat.	DMC SWM					

6.2 Development of innovative cooling solutions for Thane City

A hackathon could be announced after the launch of the HAP to invite ideas on innovative solutions for affordable cooling. This will help gather interesting ideas from academia, NGOs, CSOs, and other stakeholders, which can be documented and made open for other cities to access. An expert panel of jury could be identified for selecting the best three solutions, which could be shared with the Ministry of Urban and Housing Affairs (MoHUA) for knowledge sharing and uptake in other cities of India.

7. Preparedness and response plan

While heat risk mitigation is a critical component to make cities heat resilient in the long term, severe and prolonged heat waves in the immediate periods can disrupt general, social, and economic services. Government agencies, with support from CSOs, have a crucial role to play in preparing for and responding to heat waves at the municipal, ward, and local levels. This requires the strengthening and close collaboration of the health and disaster management departments with other relevant departments to ensure effective intra- and inter-departmental coordination.

Successful heat wave planning and action depend on the convergence of initiatives by the departments and other stakeholders, including private entities and civil society. Effective and timely early warning systems are vital to ensure the seamless flow of critical information to stakeholders. It is essential to prepare, enhance, and strengthen the capabilities and resources of regional and local bodies and wards for local-level preparedness. Moreover, assessing the impact of actions taken after each summer heat season and continually reviewing and updating heat action plans on a timely basis are important measures to enhance effectiveness.

This section details the stakeholder responsibility matrix for preparedness and response, the Municipal Heat Wave Task Force for coordination and implementation, and the information, education, and communication (IEC) strategies.

7.1 Stakeholder responsibility matrix for preparedness and response to heat waves

Themes		Task/Activities	Municipal corporation (Main)			District authority (Secondary)		State (Supportive role)	
			Responsibility	Division		Responsibility	Department	Responsibility	Department
Preparation of heat action plan and standard operating procedures									
Planning for heat action	1	Preparation of action plan and implementation	Coordinate with stakeholders and experts for preparing the heat action plan and its implementation.	Heat wave task force committee in the TMC		Preparing/Updating of HAP based on NDMA guidelines/State Heat Action Plan. Support to MC for integration of district and city HAP.	DEOC/DDMA	Preparing/Updating of state HAP based on NDMA guidelines and provide technical support to DC/MC for the preparation/updating of HAP.	SEOC/COR
	2	Standard operating procedure (SoP)	Prepare a standard operating procedure (SoP) for heat wave risk mitigation, preparedness, and response with clearly defined roles and responsibilities of different departments in MC with timelines. Issue necessary orders and coordinate with all stakeholders.	Heat wave task force committee in the TMC		Coordination with vertical and horizontal agencies for directions.	DEOC/DDMA	Coordination with vertical and horizontal agencies for directions.	SEOC/COR
Inter-agency coordination									
Early warning and forecast/alert	**3**	Early warning and coordination	Coordinate with weather forecasting and warning institutions before the summer season (March to June).	Nodal officer, Regional Disaster Management Cell (RDMC) in charge		Coordination with IMD before the summer season and share early warning information to MC.	SEOC/DDMA	Strengthening of early warning system and timely alert to districts by coordinating with IMD for forecast and early warning.	RMC/IMD
			Analyse all weather updates received from the IMD, district, state and other research institutions.	Nodal officer, RDMC in charge					
			Modify or customise the received forecasts based on local thresholds for heat wave warning and alerts as well as based on the target groups.	Nodal office, RDMC in charge					
	4	Impact-based early warning dissemination	Disseminate colour-coded impact-based early warning to all wards. Ensure early warnings reach to the most vulnerable populations identified in the HAP.	Nodal officer, RDMC in charge					
			Partner with city-level institutions, NGOs, state institutions and experts.	Nodal officer, education officer, chief environment officer					
Heat wave preparedness and response	**5**	Formation of a heat wave management cell	Form a heat wave management cell. Appoint ward-wise heat wave in-charge officer. Develop a clearly defined area-specific mitigation, preparedness, and response plan. Coordinate with district and state agencies. Monitor the HAP implementation on a daily basis during the heat wave season (March to June). Organise meetings for immediate response, whenever required.	Municipal commissioner; additional municipal commissioner Medical officer of health					
	6	Appointment of a nodal officer	Appoint a nodal officer to coordinate preparedness, response, and mitigation measures with all relevant stakeholders, agencies from division, district, and state, NGOs, etc.	Municipal commissioner		The DDMA may appoint a district nodal officer to coordinate preparedness, response, and mitigation measures.	DEOC/DDMA	The SDMA may appoint a state nodal officer to coordinate preparedness and response measures.	SEOC/SDMA/COR
			Implement regulatory orders related to heat waves. Govern the flexible timing of schools, markets, and offices under the municipal area during heat wave alert.	Municipal commissioner		Issue necessary regulatory orders.	DC DEOC/DDMA	Issue necessary regulatory orders.	Department of Home SEOC/SDMA/COR
	7	Expert groups/ committee	Constitute city-level technical advisory groups comprising experts, academicians, NGOs, and other stakeholders.	Municipal commissioner		The DDMA may constitute a district-level advisory group and issue advisories.	DEOC/DDMA	The state government may constitute a state-level expert advisory group and issue advisories.	SEOC/SDMA/COR
			Constitute ward-level committees including local NGOs, CSOs, and RWAs to coordinate preparedness and response actions in their wards and for sharing information effectively.	Assistant municipal commissioner					

Themes		Task/Activities	Municipal corporation (Main)			District authority (Secondary)		State (Supportive role)	
			Responsibility	Division		Responsibility	Department	Responsibility	Department
	8	Restricted public gathering/ permission	Deny permissions for public gathering during heat wave periods. If permitted under extraordinary circumstances, ensure compliance to a checklist of necessary requirements such as facilities for drinking water, sheds, ambulances, etc., by the organisers at the place of gathering. Avoid outdoor games/sports activities and regulate use of swimming pools during daytime.	Municipal commissioner					
	9	Protecting traffic personnel				Ensure shade for traffic police as they are more exposed to heat wave and ensure the distribution of cooling jacket for traffic personnel.	Superintendent of Police	Ensure shade for traffic police as they are more exposed to heat wave and ensure the distribution of cooling jacket for traffic personnel.	Department of Home
	10	During elections	Ensure polling booth–wise specific precaution measures for providing sheds, drinking water, and medical facilities during the voting hours.	Additional municipal commissioner		Ensure polling booth–wise specific precaution measures for providing sheds, drinking water, and medical facilities during the voting hours.	District Election Officer	Ensure polling booth–wise specific precaution measures for providing sheds, drinking water, and medical facilities during the voting hours.	Chief Electoral Officer of the State
	11	Hospital preparedness	Prepare a hospital plan for heat wave–related illnesses. Procure adequate quantities of life saving medicines, IV fluids, ORS etc., in all MC healthcare centres. Establish first-aid and medical-aid facilities in key risk locations as identified in this plan. Ensure special health facilities for people with pulmonary illness, renal, psychiatric problems, etc. Establish first-aid and medical-aid facilities on priority basis in key locations as per the vulnerable and risk assessment.	Medical officer of health		District-level hospital preparedness and preparedness of the healthcare staff.	DDMA/District Health Officer	State-level hospital preparedness and preparedness of the health department and healthcare staff.	SDMA and Health Department
			Ensure daily reporting on heat waves mortality and morbidity from all relevant departments/units of the healthcare facilities. Collect heat wave mortality and morbidity data ward-wise and analyse for better policy and implementation of measures related to heat wave response and mitigation.	Medical officer of health		Collection of data at the district level and analysis for better policy and implementation of measures related to response and mitigation.		Collection of data at the state levels and analysis for better policy and implementation of measures related to response and mitigation.	
	12	Water supply	Ensure supply of drinking water at all identified vulnerable points and worksites on a priority basis.	Deputy city engineer Water Supply					
	13	Livestock	Ensure that livestock have sufficient shade and water at the most vulnerable wards during heat wave alerts.	Veterinary					
Relief measures	**14**	Ex-gratia payment	As heat waves have been declared as a state-specific disaster and are covered for relief from SDRF, issue necessary certificates.	Municipal commissioner		Necessary process for ex-gratia payment to families of deceased persons after verification of cause of death and payment of ex-gratia.		State may notify the ex-gratia amount to families of deceased persons.	
Capacity building, training, public awareness, and community outreach									
Capacity building and training	**15**	Training	Conduct training programmes for different stakeholders such as health professionals, ASHA, ANM, MC school teachers, and relevant NGOs/CSOs for activities to be undertaken during pre-, during, and post- heat wave season.	Education officer and medical officer of health		Develop training modules and conduct training programmes for different stakeholders. Provide a resource person for conducting the training programmes.	DEOC/DDMA and all relevant departments.	Develop training modules for different stakeholders such as health professionals, ASHA, ANM, teachers and relevant departments, NGOs Provide a resource person for conducting the training programmes.	SDMA/COR YASHDA (ATI), and all relevant departments.
			Conduct trainings for CD, RWAs, community, volunteer health workers, and rapid response teams. Conduct training for creating and maintaining heat wave–resilient infrastructure.	Medical officer of health		Train all health staff and workers for heat and health–related disasters.	DEOC/DDMA	Conduct professional master training of district and MC officials for heat wave risk reduction.	SEOC/SDMA/COR
			Conduct training programmes for identified vulnerable groups.	Medical officer of health					
	16	Mock drills and exercises	Joint execution of emergency mock drills with local administration/staff to address heat wave emergencies.	RDMC in charge and medical officer of health					
	17	Empowering women	Incorporate gender-sensitive and equitable approaches in capacity development for coping with heat waves.	Nodal officer MOH		Promote gender sensitive and equitable approaches.		Promote gender sensitive and equitable approaches.	

Themes		Task/Activities	Municipal corporation (Main)			District authority (Secondary)		State (Supportive role)	
			Responsibility	Division		Responsibility	Department	Responsibility	Department
Public awareness, community outreach	**18**	Public awareness and community outreach	Sensitise public through print and electronic media and through other social media channels. Create awareness on the use of swimming pools during heat waves. Share forecasts and alerts as bulk messages on mobile phones, and to the media for wider broadcast.	RDMC in charge and medical officer of health		Sensitise public through print and electronic media and through other social media channels.	DEOC/DDMA DEOC/DDMA	The state could consider developing a website and a mobile app that provides heat alerts and also helps users locate, via maps, heat shelters and drinking water sources along with access to roads throughout the state.	SEOC/SDMA RMCs/SEOC/SDMA
	19	IEC campaigns	Develop and organise IEC campaigns to create awareness at individual, community, and RWA levels and for the public through various posters, pamphlets, public advertisements, etc.	Nodal officer, medical officer of health		Develop and organise IEC campaigns to create awareness through print, electronic and social media.	DEOC/DDMA	Generate IEC materials for creating awareness and share them with the district offices and municipal corporation.	SEOC/SDMA
	20	Dos and don'ts	Display dos and don'ts in public areas, hospitals, parks, and schools, including RWAs in local languages.	Nodal officer MOH		Follow national/state advisories and disseminate to public.	DEOC/DDMA	Issue advisories on dos and don'ts.	SEOC/SDMA
	21	Play short TV commercials in public spaces	Play short TV commercials in public places periodically to make the public aware of the precautions to be taken against heat waves.	Nodal officer AMC advertisement department		Advertise TV commercials in all movie theatres, before and during interval time.	DEOC/DDMA DC	Prepare short TV commercials about precautions to be taken to safeguard oneself against heat waves and share them to the district offices and municipal corporation.	SEOC/SDMA/COR
			Establish electronic screens at traffic intersections and marketplaces and display heat wave information.	AMC Advertisement department		Establish electronic screens at busy traffic intersections and marketplaces.	DEOC/DDMA		SEOC/SDMA
	22	Quiz and competitions	Organise heat wave awareness quizzes and competitions including essay-writing and poster-making, lectures, and puppet shows for students.	Education officer			DEOC/DDMA		
Research and development for climate change adaptation and heat wave risk reduction									
Research and development	**23**	Climate change adaptation (CCA) and heat wave risk reduction	Develop innovative local solutions for climate change adaptation and heat wave risk mitigation. Promote NGOs/CSOs for community-based field research.			Provide support for field research on CCA and mitigation measures for heat wave risk reduction.	SEOC/SDMA Forest NGOs/CSOs	Undertake research on climate change adaptation and mitigation measures for heat wave risk reduction.	SEOC/SDMA
	24	Heat-health impact research	Undertake heat-health impact research.			Undertake heat-health impact research at the district level.	DDMA, Health	Undertake heat-health impact research at the state level.	SDMA/Health Department
	25	Field research	Undertake research studies at individual, community, or at workplace level to identify the most vulnerable populations and their risk factors.			Promote local research study for heat wave risk reduction.	DEOC/DDMA	Undertake research study for heat wave risk reduction and long-term impact on infrastructure due to heat waves.	SEOC/SDMA
Monitoring and evaluation: Data collection, documentation, and plan update									
Monitoring and Evaluation	**26**	Monitoring and evaluation	The Thane heat wave monitoring cell could monitor HAP implementation regularly. It could scale up its monitoring to a daily basis during the heat wave season. It should use different types of tools such as GIS and artificial Intelligence.			The district monitoring cell could monitor HAP implementation on a regular basis, and scale it up to a daily basis during heat waves.	DEOC/DDMA	The state monitoring cell could monitor HAP implementation regularly, and scale it up to a weekly basis during the heat wave season.	SEOC/SDMA
			Monitoring and evaluation of Thane HAP activities and the impact of heat waves on mortality and morbidity.						
	27	Reviews	The Heat wave task force committee nodal officer should monitor and review preparedness and response activities on a weekly basis.			The head of the institution should monitor and review preparedness and response activities on a weekly basis.	DEOC/DDMA	The head of the institution should monitor and review preparedness and response activities on a weekly basis.	SEOC/SDMA/All relevant departments
	28	Data collection, documentation, and updating of HAP	Collect segregated data on all-cause mortality from all wards, hospitals, and maintain a database at the Thane Municipal Corporation Area.			Nodal officer to collect all-cause mortality data and heat wave–related data from local bodies and *talukas*, and maintain a database at the district level.	DEOC/DDMA/ Health	Heat wave nodal officer to collect all-cause mortality data and heat wave–related data from all districts, and maintain records at the state level.	SEOC/SDMA/Health
			Follow standard protocol in all MC hospitals for illness and death investigations as per the prescribed format in this HAP/or as issued by the state government.			Follow standard protocol for illness and death investigations as per the prescribed format by the state government.	DEOC/DDMA/ Health	Provide standard protocol and format for illness and death investigations to all relevant district and local bodies.	SEOC/SDMA/Health
	29	Documentation	Adapt a uniform process for the registration of casualties/ deaths due to heat wave based on post-mortem reports, death count, type of disease, temperature, time, and duration.			Adapt a uniform process for the registration of casualties/deaths in local bodies due to heat wave at the state level.	DEOC/DDMA	Adapt a uniform process for the registration of casualties/deaths due to heat wave at the state level.	SEOC/SDMA/Health

7.2 Heat Wave Task Force Committee in Thane Municipal Corporation

To ensure inter-departmental and inter-agency coordination for successfully implementing the strategies outlined in the previous two chapters, a Heat Wave Task Force Committee was established in the Thane Municipal Corporation under the Thane municipal commissioner.

Table 6: The Heat Wave Task Force members

Designation	Role
Additional Commissioner	Chairman
City Engineer, PWD	Member
Medical Officer of Health, Health Department	Member
RDMC Chief	Member
Deputy Commissioner, Education Department	Member
Deputy Commissioner, Garden Department	Member
Deputy City Engineer, Town Planning Department	Member
Members of external expert agency	As needed
Public Relation Officer	Member
Chief Environmental Officer	Member Secretary

Source: Order issued by the Thane Municipal Corporation on 27 February 2024

7.3 Early warning system and alert mechanism

The India Meteorological Department, MoES, is the nodal agency that provides weather information, including forecasts and current warnings for all weather-related hazards for optimum operation of weather-sensitive activities. It provides a warning against severe weather phenomena, such as tropical cyclones, squally winds, heavy rainfall/snow, thunder squalls, hailstorms, dust storms, heat waves, warm nights, fogs, cold waves, cold nights, and ground frost. It also provides real-time data and weather prediction of maximum temperatures, heat wave warnings, extreme temperatures, and heat alerts for vulnerable cities and rural areas.

The IMD issues forecasts and warnings for all weather-related hazards in the short to medium range (valid for the next five days) every day as a part of its multi-hazard early warning system. These warnings, updated four times a day, are available on their website at <http://www.imd.gov.in/pages/allindiawxfcbulletin.php>.

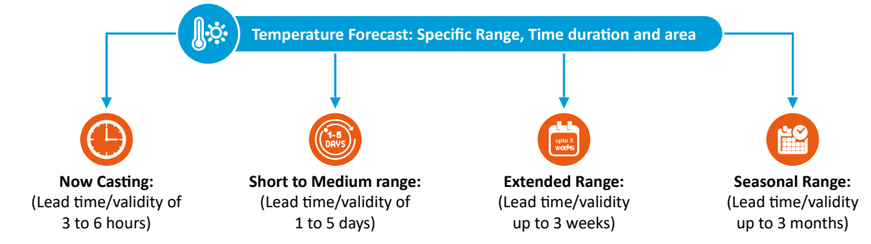
A new system of exclusively heat-related warnings has been introduced with effect from 3 April 2017. These warnings, valid for the next four days, are issued at 1600 hours IST daily and are provided to all relevant authorities (departments of health, disaster management, Indian Red Cross, Indian Medical Association, NDMA, etc.) for taking suitable action at their end. A bulletin in extended range with an outlook for two weeks (for all hazards, including heat waves) is issued every Thursday and available on their website at <http://www.imd.gov.in/pages/extended.php>.

In addition to the above, climate forecast system-based forecast maps of daily maximum temperatures and their departures from normal for the next 21 days (issued every Thursday) are also available on the IMD website at <http://nwp.imd.gov.in/cfs_all.php?param=tmax> and <http://nwp.imd.gov.in/cfs_all.php?param=tmaxa>.

The IMD also issues seasonal temperature outlooks for three months, valid from March to May, and a second one for April to June every year. These seasonal outlooks are issued in the form of a press release on the IMD website and disseminated through electronic and print media. These are

also provided to all chief secretaries, disaster managers, and the health sector through the Indian Medical Association (IMA).

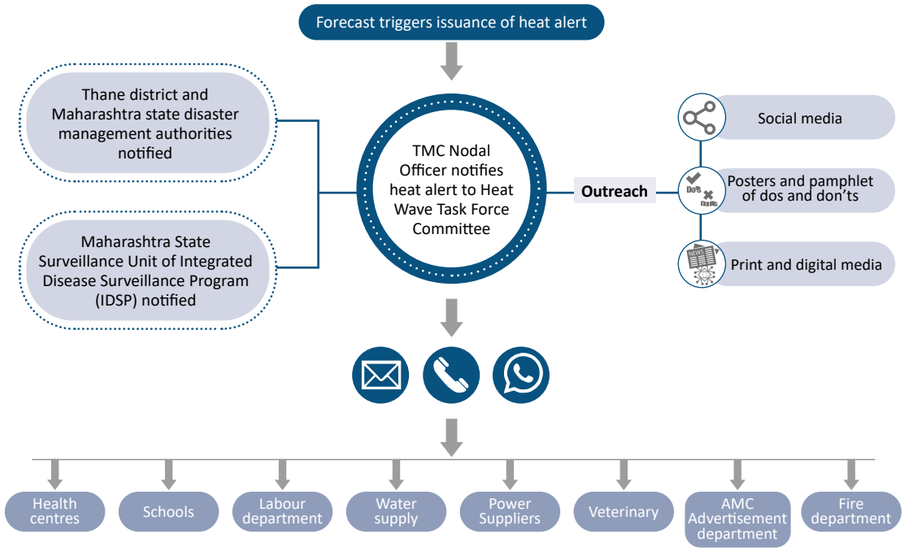
Figure 23: The operational system of weather forecasts and warnings



Source: IMD 2023

The district disaster management authority receives forecasts from the IMD regional meteorological centre in Mumbai and relays them to the nodal officer of the Thane Municipal Corporation for the HAP. Analysing meteorological variables such as temperature and relative humidity based on the heat thresholds developed in this plan, the nodal officer will issue colour-coded heat alerts to the Heat Wave Task Force Committee for further dissemination to line departments and vulnerable populations. Figure 24 illustrates the communication flow for disseminating the alerts.

Figure 24: Communication flow for sending out heat alerts



Source: Authors' compilation

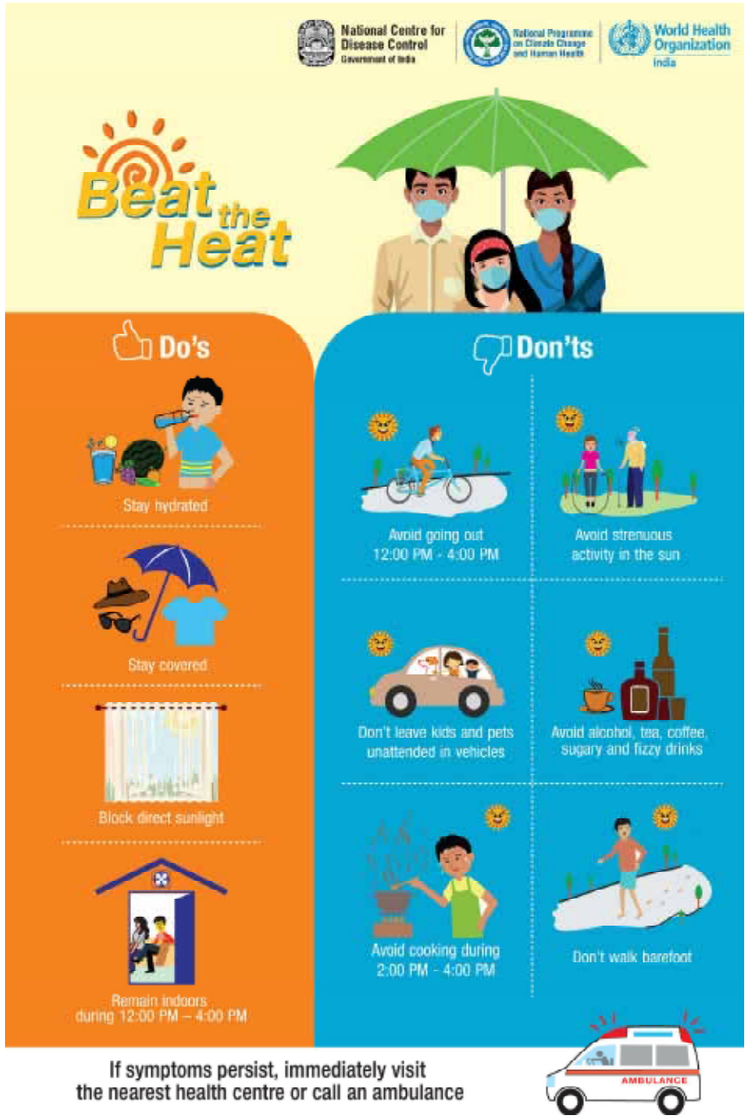
The outreach materials in the form of IEC presented in the next chapter will be utilised by the Heat Wave Task Force Committee in collaboration with the TMC advertisement department and social media influencers to raise awareness among vulnerable populations. The focus will be on communicating essential dos and don'ts, with priority actions emphasised in identified at-risk and vulnerable wards.

7.4 Information, education, and communication strategies

The IEC material for preparing alerts for vulnerable populations and other outreach has been made available in this section. This material has been integrated directly from the National Centre for Disease Control (NCDC), NPCCHH (National Program on Climate Change and Human Health) as there is a dedicated cell for Climate change in NCDC, the Maharashtra State Heat Action Plan, and the Maharashtra Governance Department of Public Health.

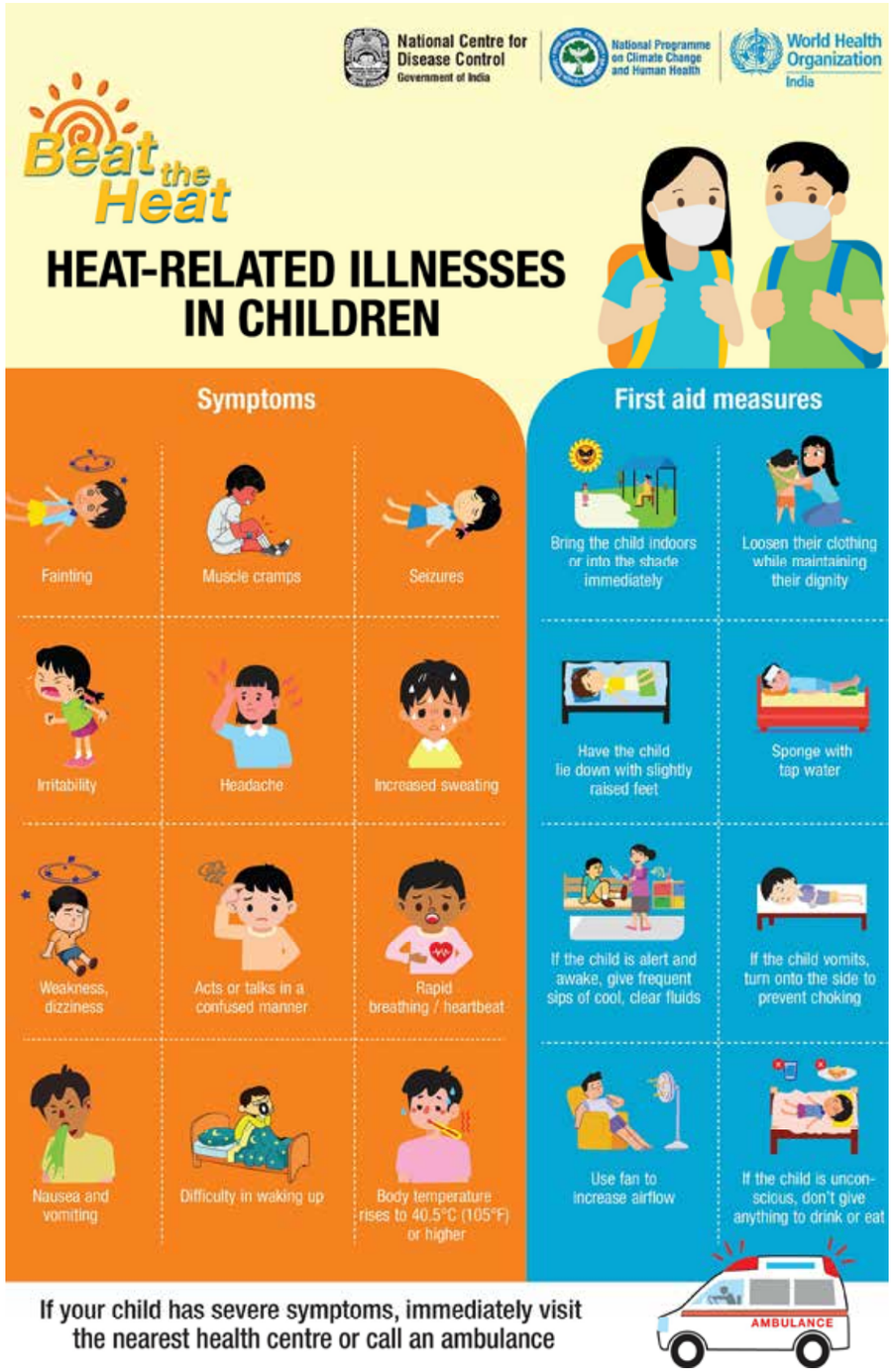
Figure 25: IEC material in English

a) Dos and don'ts



Source: National Centre for Disease Control 2021

b) Heat-related illnesses in children



Source: National Centre for Disease Control 2021

c) First-aid measures

Source: National Centre for Disease Control 2021

d) Safeguarding workers from the heat

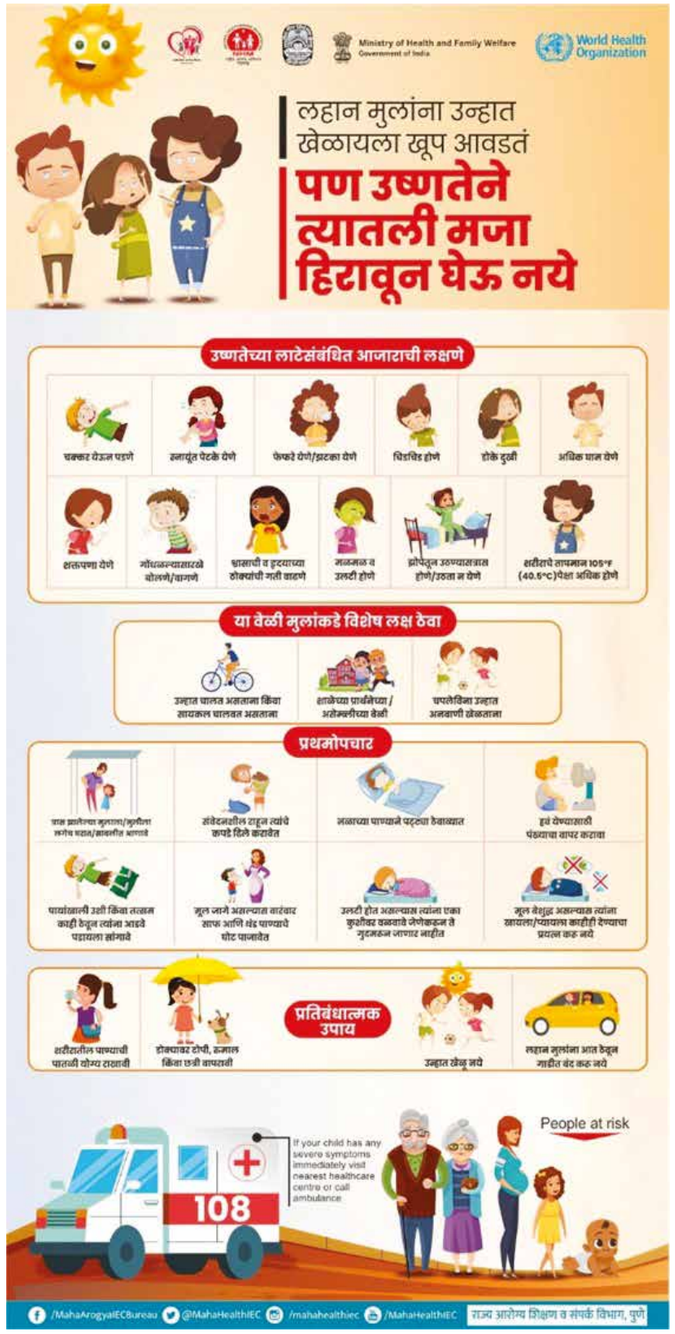
Source: National Centre for Disease Control 2021

e) Safeguarding oneself from the heat

Source: National Centre for Disease Control 2021

Figure 26: IEC material in Marathi

a) At-risk populations

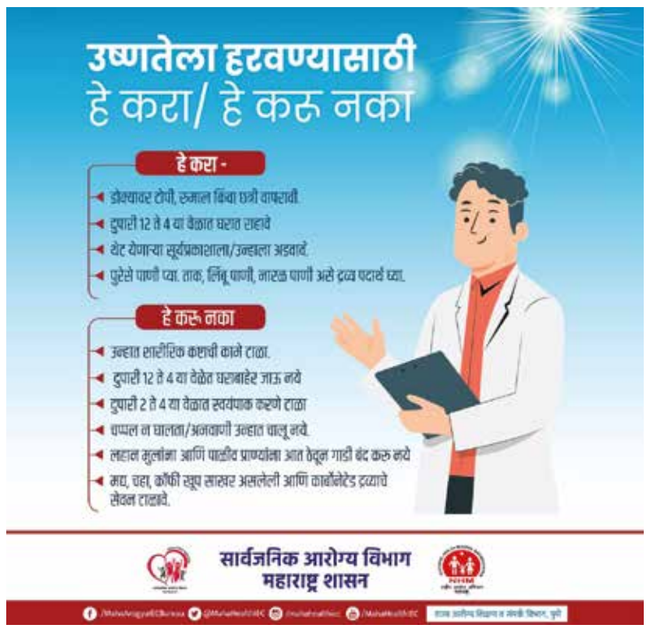


Source: Maharashtra Governance Department of Public Health 2022

b) Prevention measures for children

Source: Maharashtra Governance Department of Public Health 2022

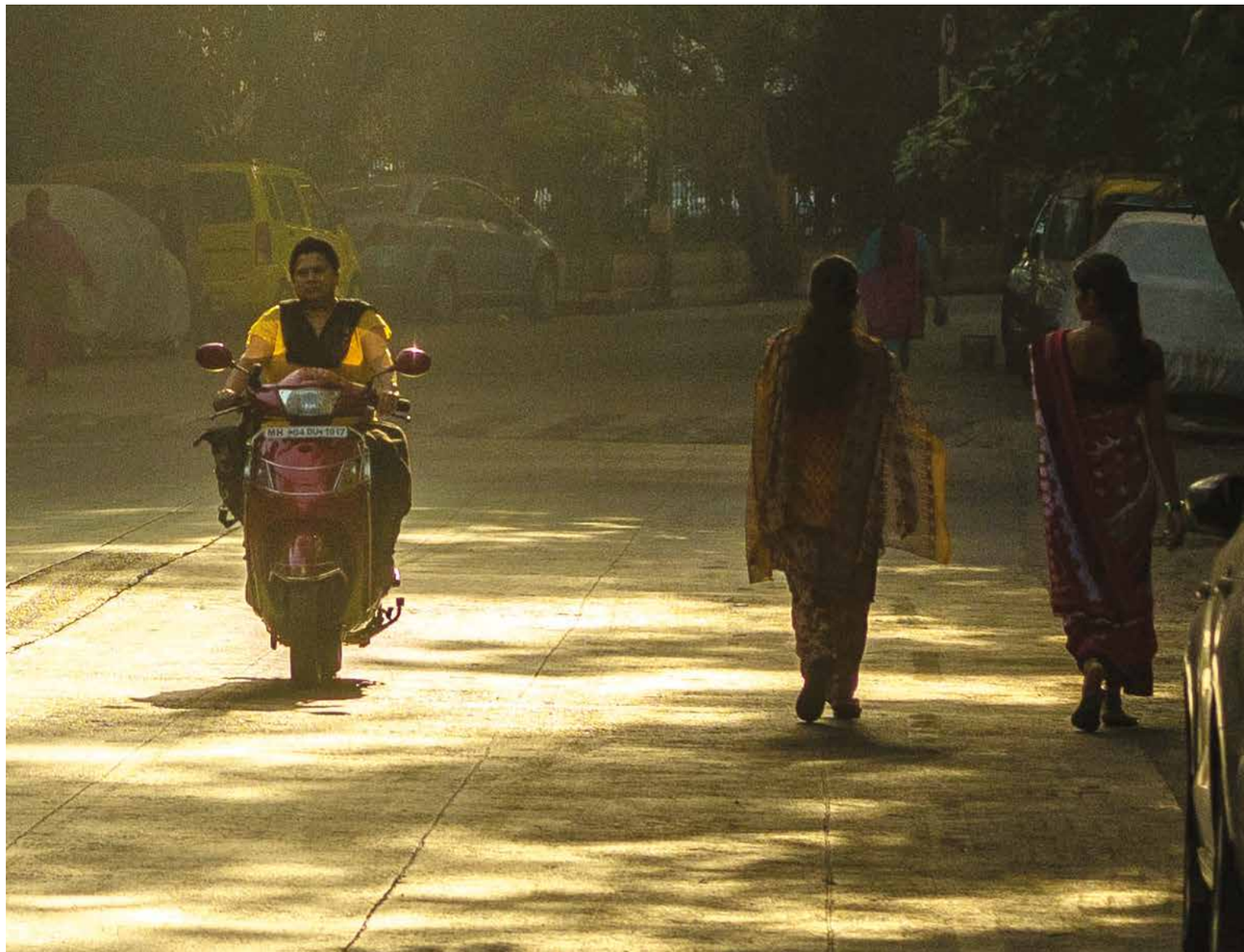
c) Dos and don'ts



Source: Maharashtra Governance Department of Public Health 2022

8. Budgeting and financing the implementation of HAP strategies

A Heat Wave Task Force has been formed under the chairmanship of the additional municipal commissioner of Thane Municipal Corporation, which comprises of officials from all relevant departments for effective coordination and communication. The budgetary and financing mechanisms will be identified from existing budgets from various departments of TMC to implement the identified actions under this HAP. For additional budgetary requirements, the TMC will seek support from the district-, state-, and national-level disaster management agencies.



9. Maintaining, monitoring, and updating the HAP

While this HAP has tried to integrate all the aspects necessary for it to be effective, the implementation of the plan is equally important. To ensure success, it is essential to monitor, evaluate, and revise the plan consistently. Evaluation is necessary for ensuring that activities are having the intended effects (effectiveness), determining whether activities are cost-effective (efficiency); establishing whether activities are acceptable to the target population (social acceptability), and ensuring that evaluation features at all stages of the planning, development, implementation, and review of programmes (WHO 2008).

To ensure effective and timely implementation of this HAP, the process and outcome of the plan must be monitored at designated intervals. Monitoring of short-term strategies through quantitative performance-based indicators would strengthen the level of preparedness of officials and stakeholders, as well as the awareness and capacity of vulnerable groups. Following the heat wave season, the analysis of the plan outcome and impact level would help assess the plan's effectiveness, remaining gaps, and future needs.

9.1 Monitoring and evaluation framework for Thane HAP implementation

Key performance indicators (KPIs) in alignment with each outlined strategy, i.e., for preparedness and response (in the short term) and heat risk mitigation (in the long term), would facilitate the quantitative evaluation of plan performance. The KPIs associated with each strategic theme, as outlined in Chapters 6 and 7, have been listed in the form of an actionable framework (Table 7). The relevant authority responsible for implementing the sub-theme would also be responsible for data collection, mapping, and the estimation of measurable KPIs against set minimum performance standards to track their progress towards the larger goal.

Table 7: Actionable framework of KPIs for Thane HAP

Process evaluation						
Code	**KPI type**	**Description of measurable KPI**	**Short term**	**Long term**	**Assessment period**	**Responsible authority**
6.1	**Evaluation of stakeholders' understanding of heat risk**	No. of expert consultations for understanding of heat risk			End of March	Heat Wave Task Force Committee, TMC
6.2		No. of questionnaire-based interviews with Heat Wave Cell for understanding SOP				
6.2		No. of stakeholders participating in training programmes				
6.3		No. of consultations with RDMC before summer season				
6.4	**Evaluation of vulnerable communities' awareness of heat risk and preparedness**	No. of wards that received colour-coded impact-based early warning				
6.4		No. of focus group discussions conducted with identified vulnerable communities in each at risk ward				
6.4		No. of questionnaire-based surveys with heat vulnerable households				
6.4		No. of emergency mock drills conducted with vulnerable communities				
6.4		No. of IEC materials distributed				
6.5	**Evaluation of preparedness against heat wave-related illnesses**	No. of wards with appointed heat wave incharge			Mid-April	Municipal Commissioner
6.5		No. of nodal officers for coordinating preparedness				
6.11		No. of wards with identified population identified at risk from heat-related illnesses				Medical Officer of Health
6.11		No. of workshops in hospitals to implement hospital preparedness plan				
6.15		No. of trainings conducted for health professionals				
6.11		No. of wards with data collection plan				
6.12		No. of wards with identified population identified at risk from heat related illnesses				

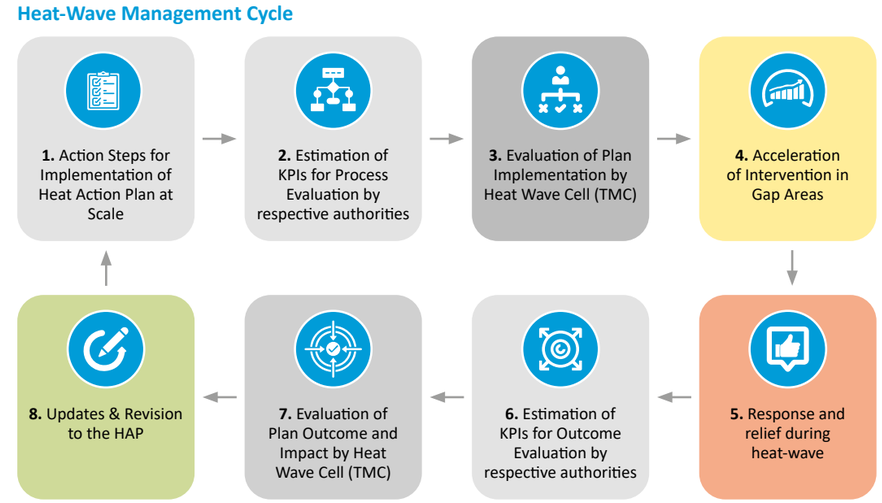
Process evaluation						
6.12	**KPI type**	No. of water supply stations added in vulnerable wards			Assessment Period	
6.7	**Evaluation of preparedness and response of relevant authorities**	No. of ward-level committees to coordinate preparedness and response actions				
6.7		No. of meetings organised to prepare for emergency response and relief				Deputy City Engineer Water Supply
Output Evaluation						
Code	**KPI type**	Description of Measurable KPI	Short Term	Long Term	Assessment Period	Responsible Authority
7.2	**Monitoring of heat-related socioeconomic parameters**	No. of reported heat related illnesses (ward-wise)			July	Medical Health Officer
7.2		No. of heat induced mortality cases (ward-wise)				
7.2		No. of wards with reported water shortage				
7.8	**Monitoring of mitigation and adaptation measures**	Ward-wise change in green space per person			December	Municipal Commissioner and Chief Environment Officer
7.10		No. of wards with improved water access				
7.10		No. of wards with improved water quality				
7.11		Change in modal share of electric vehicles				
7.11		Change in share of renewable energy use				
7.11		No. of roads with green divider introduced				
7.13		Change in share of renewable energy use				
7.21		No. of rooftop solar panels installed (ward-wise)				
7.17		No. of promotional campaigns for innovative cooling solutions				
7.19		No. of ward-wise cooling shelters installed				
7.9		No. of health check-up camps organised in slum areas				
7.23	**Monitoring of heat-related environmental parameters**	Change in ward-wise land surface temperature			January	Heat wave task force committee

Source: Authors' compilation

9.2 Revising the HAP

Considering the evolving and projected heat extremes in Thane City and being the inaugural edition of the heat action plan for the city, it is imperative to revisit this HAP following the 2024 heat wave season. This revision should be informed by the successes and challenges observed during the 2024 heat wave season. The heat wave management cycle, depicted in Figure 27, seamlessly integrates monitoring, evaluation, and plan updating into the year-round implementation plan. This cyclical approach ensures continuous refinement and adaptability to address emerging heat-related challenges effectively in Thane City.

Figure 27: Heat wave management cycle for Thane Heat Action Plan



Source: Authors' compilation

Furthermore, certain key considerations should shape the forthcoming iteration of Thane City's HAP.

- **Establishment of heat-health thresholds**: While the current version has set local-level thresholds using biometeorological indices, it is advisable to enhance this by correlating data on mortalities and heat illnesses collected through the formats outlined in Chapter 10 with observed felt and dry temperatures. Bio-statistical analysis techniques should be employed to establish more accurate heat-health thresholds.
- **Incorporation of wind speeds and meteorological persistence**: The current plan utilises the heat index based on daytime and nighttime relative humidity and temperature variables. The upcoming version should consider integrating India-specific heat index data being developed by the IMD, ensuring a comprehensive analysis and incorporation of this information.
- **Development of ward-level heat risk index**: While the current plan has devised a heat risk index at the sub-city level (*Prabhag Samitees*), there is a necessity to refine this further to the electoral-ward level. This entails leveraging socioeconomic data obtained through on-field surveys to pinpoint heat risk at an even more localised level, enabling authorities to prioritise actions effectively.

These considerations aim to enhance the precision and effectiveness of Thane City's future HAPs.

10. Documenting the heat-related mortality and morbidity data

To mitigate the risks associated with the projected heat extremes in Thane, resilient health systems will need to serve as primary responders for heat-related mortalities and illnesses. For this, the availability of detailed, granular data on health-related factors associated with mortalities and illnesses caused by heat waves is very important. High-quality heat-tagged data will help reinforce heat-health early warning systems and also enhance the localised heat risk assessments in future revisions of this action plan.

This chapter provides the formats and guidelines for recording and documenting this data, which are based on the national-level formats provided by the Ministry of Health and Family Welfare and the National Disaster Management Authority guidelines. In 2015, the MoHFW issued *Guidelines on the Prevention and Management of Heat-Related Illnesses* (MoHFW 2015). Building on this, the *National Action Plan on Heat-Related Illness, July 2021* (MoHFW 2021) was developed, which incorporated chapters on paediatric age groups, hospital preparedness plans, new surveillance formats, standard operating procedures, and guidelines for investigating suspected heat-related illness (HRI) deaths.

Since 2015, the *Integrated Disease Surveillance Programme* (IDSP) under the NCDC, MoHFW has collected and compiled HRI and related death data annually from 17 heat-vulnerable states (23 states since 2019) of Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Gujarat, Haryana, Jharkhand, Karnataka, Maharashtra, Madhya Pradesh, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Kerala, Goa, Uttarakhand, Jammu and Kashmir, West Bengal, Arunachal Pradesh, and Himachal Pradesh. The surveillance formats were subsequently revised in 2021 to capture heat stroke cases, deaths due to suspected/confirmed heatstroke, deaths due to cardiovascular diseases, and all-cause deaths.

These guidelines and formats have been developed by an internal MoHFW committee at the National Centre for Disease Control and an expert group compromising medicine and paediatric departments from central government hospitals, NDMA, NIDM, IMD, WHO, Emergency Medical Relief, IDSP, Indian Institute of Public Health, Gandhinagar, and the Public Health Foundation of India.

This section integrates these formats into the Thane HAP to ensure effective data collection on heat-related illnesses and mortalities. These formats will also be incorporated into the Thane District Action Plan on Climate Change Human Health (DAPCCHH), ensuring cohesive data collection at various administrative levels. The detailed formats and the report on the *National Action Plan on Heat-Related Illnesses* can be accessed at <https://ncdc.gov.in/WriteReadData/linkimages/NationActionplanonHeatRelatedIllnesses.pdf>.

10.1 Guidelines for the investigation of suspected heat-related illness death

Unique ID:

Respondent's Name: Relationship of respondent with deceased:

Residential address of respondent:

Section A: Deceased's identifier details

A.1. Name of deceased:	A.2. Age (in completed years & months)	Y	Y	M	M
A.3. Sex: Male/Female/Transgender:	A.4. Father's/Mother's/Spouse's name:				
A.5. Residential Address of deceased					
A.5.1 State:	A.5.2. District:				
A.5.3. Block/Taluka:	A.5.4. Ward/village:				
A.6. Does the deceased have the following socioeconomic card	i. BPL ii. Antayodya iii. Annapurna iv. Other or equivalent (mention)..... v. None				
A.7. What was the last occupation of the deceased:					

Section B: Death detail

No.	Questions	Coding categories	If no, Skip to
B.1	Was the deceased found unconscious or dead?	Yes.....1 No.....2 I don't Know.....3	B.3
B.2	Place where deceased was found unconscious or dead?	Athome.....1 At workplace.....2 At social gathering.....3 On-road.....4 Other (specify).....	
B.3	Location where deceased was found unconscious or dead		
	B.3.1 State:	B.3.2. District:	
	B.3.3. Block/Taluka:	B.3.4. Ward/village:	
B.4	Name of hospital and address where deceased was brought dead or died:		

B.5	Date and time of the death: (from medical record)	**DD**	**MM**	**YYYY**	**HH**	**MM**

Section C: Clinical history in past 24 hr before death (from medical record followed by respondent)

C.1. Symptoms at the time of onset of illness:						
C.1.1. Was the skin hot and dry? (a. From Medical Record b. From Respondent c. both)	Yes.....1 No.....2 I don't know.....3					
C.1.2 Was the deceased in altered mental sensorium? (a. From Medical Record b. From Respondent c. both)	Yes.....1 No.....2 I don't know.....3					
C.1.3. What was the core body temperature? (from medical record only):						
C.1.4. What was the deceased's vitals? (from medical record only): a. Pulse rate: b. Respiratory rate: c. Blood pressure:						
C.2. Date and time of onset of the first symptom of heat illness:	DD	MM	YYYY	HH	MM	
C.3. Place of onset of first symptom:	At home.....1 At workplace.....2 At social gathering.....3 On-road.....4 School/college.....5 Other specify.....					
C.4. Location of onset of symptoms						
C.4.1 State:	C.4.2. District:					
C.4.3. Block/Taluka:	C.4.4. Ward/village:					
C.5. Did the deceased have an alcoholic beverage within a day of onset of illness?	Yes.....1 No.....2 I don't know.....3					

Section D: Outdoor activities just before the onset of illness

No.	Questions	Coding categories	If no, Skip to
D.1	Just before the onset of illness, was the deceased present outdoors?	Yes.....1 No.....2 I don't Know.....3	E.1
D.2	Was the deceased engaged in outdoor occupational activities?	Yes.....1 No.....2 I don't Know.....3	D.3
D.3	Was the deceased working under direct sunlight?	Yes.....1 No.....2 I don't Know.....3	
D.4	Was the deceased working in peak hours of the day, i.e. 11 AM to 4 PM?	Yes.....1 No.....2 I don't Know.....3	
D.5	Was the deceased working near heat sources.e., hot furnace, stove, gas fire, wood fire, steam, hot engines/ machines?	Yes.....1 No.....2 I don't Know.....3	D.7

D.6	If yes to D.5, the type of heat source was:	Fire (hot furnace, stove, gas fire, hot engines).....1 Steam.....2	
D.7	Was the deceased doing any physical exertional activity?	Yes.....1 No.....2 I don't Know.....3	D.8
D.8	Was the deceased sitting in a vehicle?	Yes.....1 No.....2 I don't Know.....3	D.12
D.9	If yes to D.8, was the vehicle parked in a shaded area?	Yes.....1 No.....2 I don't Know.....3	
D.10	If yes to D.8, what was the approx. duration of sitting in vehicle?	0-1 hr.....1 >1 hr.....2	
D.11	If yes to D.8, was the air-conditioner working in vehicle?	Yes.....1 No.....2 I don't Know.....3	
D.12	Remarks on outdoor activity, if any:		

Section E: Indoor conditions just before the onset of illness

E.1	Was the deceased INDOORS?	Yes.....1 No.....2 I don't know.....3	F1
E.2	If yes to E.1, were the following items, i.e., ceiling fan, desert cooler, air conditioner present?	Yes.....1 No.....2 I don't know.....3	
E.3	If yes to E.2, describe the item, its working condition and whether it was switched on or not? Description:		
E.4	Type of house/Room where decease was found	Pucca house (house-made with high- quality materials throughout, including the floor, roof and exterior walls).....1 Katcha house (house made from mud, thatch, or other low-quality materials).....2	
E.5	Windows in rooms	Yes.....1 No.....2 I don't know.....3	
E.6	If there were windows in the room, were they open at the time of onset of symptoms	Yes.....1 No.....2 I don't know.....3	

Section F: Medical conditions recorded at first medical contact (as per medical record)

No.	Questions	Coding categories	If no, Skip to
F.1	Was the deceased suffering from any chronic medical condition?	Yes.....1 No.....2 I don't Know.....3	
F.2	Was the deceased suffering from any acute medical conditions before the onset of the current illness?	Yes.....1 No.....2 I don't Know.....3	F.4
F.3	If yes to F.2, list the illness and duration of suffering-		
F.4	Was the deceased taking any medications before the onset of current illness?	Yes.....1 No.....2 I don't Know.....3	Section-G
F.5	If yes to F.4, list the medication and duration since taking-		

Section G: Weather data from the India Meteorological Department

No.	Questions and Filters	Coding categories/Response	If no, Skip to
G.1	What was the maximum temperature (Tmax) of the day in the area at/ around the onset of illness/death (if onset unknown)?		
G.2	What was the maximum temperature (Tmax) for each day of the past 3 days from the date of patient death?:	a. One day back: b. Two days back: c. Three days back:	
G.3	Was there a heatwave affecting the area/ region on the date of onset of illness?	Yes.....1 No.....2 I don't know.....3	
G.4	Was there a heatwave in the previous 3 days in the area where the onset of illness occurred?	Yes.....1 No.....2 I don't know.....3	
G.5	What was the relative humidity of the area at/around the onset of illness (or at time of death if onset unknown)?:		
G.6	What was the relative humidity for each day of the past 3 days from the patient's date of death?:	a. One day back: b. Two days back: c. Three days back:	

Form filled by:

Name: ..... Signature:

Designation: ..... Date:

10.2 Surveillance of heat-related illnesses (formats with standard operating procedures)

FORMAT 1 (A): HEALTH FACILITY FORMAT

Daily line List of Suspected Heatstroke CASES# at Health Facility

(From Medicine, Paediatrics and Casualty/Emergency department)
(To be kept at health facility for record)

Name of health facility: _____ Block: _____ District _____	Date of reporting: _._/_._/_._
Type of health facility (Circle the applicable): 1. PHC 2. CHC 3. Taluka/Rural Hospital/Block Hospital 4. Sub-district 5. District Hospital/Civil Hospital 6. Medical College & Hospital 7. Private hospitals with emergency facility 8. Other.....	
(A). Total no. of patients in department (Casualty/Emergency of Medicine + Paediatrics):	

Daily line List of Suspected Heatstroke CASES# at Health Facility

S. No.	Hospital Registration No.	Name	Age*	Sex (M/F)	Address		Outcome within date of reporting (tick the box)				Remarks
					Block	District	Admitted	Died	Referred	Recovered	
Total											

**Age in completed years*

Name of person filling the form: Name of Facility In-Charge:

Designation: Signature of Facility In-Charge:

Signature: Date:

#**Suspected Heatstroke:** Altered mental status (including disorientation, delirium, seizure, obtundation) **with elevated core body temperature ≥ 40 °C/≥104 °F,** without signs of stroke, history of infection, or signs of medication overdose **OR** Altered mental status (including disorientation, delirium, seizure, obtundation) with hot and dry skin and deranged vitals, i.e., tachycardia, tachypnoea and wide pulse pressure without signs of stroke, history of infection, or signs of medication overdose. *(definition is applicable during heatwave season, i.e., March to July)*

Standard Operating Procedures: Format 1(A)

1. **Format 1 (A)** is a daily line list format of **suspected heatstroke cases** to be filled at health facility.
2. It will be kept at health facility for record purpose.
3. It will be **used to compile line list Format 1(B) and daily reporting Format 2.**
4. **Suspected heatstroke (Case definition):** Altered mental status (including disorientation, delirium, seizure, obtundation) **with elevated core body temperature ≥ 40 °C/≥104 °F,** without signs of stroke, history of infection, or signs of medication overdose **OR** Altered mental status

(including disorientation, delirium, seizure, obtundation) with hot and dry skin and deranged vitals i.e., tachycardia, tachypnoea and wide pulse pressure without signs of stroke, history of infection, or signs of medication overdose. *(definition is applicable during Heatwave season i.e., March to July)*

5. **Institute and department who will compile suspected heatstroke cases:**
   a. All public hospitals with casualty/emergency.
   b. All private hospitals with casualty/emergency.
   c. Reporting Departments will be casualty/emergency of medicine and paediatrics.
6. **Data collection period:** In standard it will be from **01st March to 31st July, every year**. Further direction will be communicated at the start of the year if required.
7. **Case identification:**
   a. **Person who will diagnose:** A qualified medical doctor will diagnose HRI case as per case definition.
   b. **Where will the data be recorded:** A qualified medical practitioner will write the provisional diagnosis in the casualty/emergency register as suspected heatstroke.
   c. **Data collecting person:** Pharmacist, multipurpose health worker-male (MPHW-M), staff nurse -either of the employee will collect the data of suspected heatstroke cases that were diagnosed on previous day from emergency/casualty of medicine and paediatrics departments every day.
8. **Day of diagnosis and recording:** The date of diagnosis will be considered as day zero. Cases diagnosed on day Zero should be recorded on the following day, i.e., day One in FORMAT 1 (A). Example: Cases diagnosed on Sunday (Day Zero) will be recorded on Monday (Day One).
9. **Data compilation:** A hard copy of each completed and signed **Format 1(A)** should be stored in a file **daily** in a proper order. A soft copy of the line list should be maintained as a single excel sheet which should be updated **weekly** to include all Heatstroke cases. It should be ready to be submitted to DSU or SSU as per request.
10. **Reporting after a holiday:** A report which should have been prepared on holiday (e.g. Sunday or gazetted holiday) must be compiled and filed on the next working day. For example, cases diagnosed on Saturday (Day Zero) must be recorded on **Format 1 (A)** on Monday (Day Two) along with a separate daily **Format 1 (A)** report of cases diagnosed on Sunday (Day One).
11. **Nil reporting is mandatory in the prescribed format.** No columns will be left blank; in case of nil reporting, "0" should be written.

FORMAT 1 (B): HEALTH FACILITY FORMAT

Daily line List of Suspected Heatstroke DEATHS# and Confirmed CVD DEATHS*

(From Medicine, Paediatrics and Casualty/Emergency department)
(To be kept at health facility for record)

Name of health facility: _____ Block: _____ District: _____	Date of reporting: _._/_._/_._

Type of health facility (Circle the applicable): 1. PHC 2. CHC 3. Taluka/Rural Hospital/Block Hospital 4. Sub-district 5. District Hospital/Civil Hospital 6. Medical College & Hospital 7. Private hospitals with emergency facility 8. Other.....

(A). Total no. of all-cause deaths in health facility (Casualty/emergency of Medicine and Paediatrics):

Daily line List of Suspected Heatstroke DEATHS and Confirmed CVD DEATHS

S. No.	Registration number	Name	Age	Sex (M/F)	Address		Deaths (tick the box)	
					Block	District	Suspected Heatstroke death##	Confirmed CVD death
Total								

Name of person filling the form: Name of Facility In-Charge:

Designation: Signature of Facility In-Charge:

Signature: Date:

#**Suspected Heatstroke:** Altered mental status (including disorientation, delirium, seizure, obtundation) **with elevated core body temperature ≥ 40°C/≥104 °F,** without signs of stroke, history of infection, or signs of medication overdose **OR** Altered mental status (including disorientation, delirium, seizure, obtundation) with hot and dry skin and deranged vitals, i.e., tachycardia, tachypnoea and wide pulse pressure without signs of stroke, history of infection, or signs of medication overdose. *(definition is applicable during Heatwave season, i.e., March to July)*

##**Suspected Heatstroke Death:** This is a death on account of suspected heatstroke patient.

***Cardiovascular death** includes death resulting from an acute myocardial infarction (MI) or sudden cardiac arrest or heart failure (HF) or cardiovascular (CV) procedures or CV haemorrhage or death due to other CV causes.

Standard Operating Procedures: Format 1 (B)

1. **Format 1 (B)** is a daily line list of **suspected heatstroke deaths** and **confirmed cardiovascular disease (CVD) deaths.**
2. The total number of all-cause deaths in a health facility (casualty/emergency of medicine and paediatrics) should also be recorded.

3. **Institute and department who will report suspected heatstroke cases:**
   a. All public hospitals with OPDs & casualty/emergency.
   b. All private hospitals are having casualty/emergency.
   c. Reporting departments will be casualty/emergency of medicine and paediatrics.
4. **Date of death and recording:** Date of death will be considered as day zero. Cases that died on day Zero should be recorded on the following day, i.e., day One in FORMAT 1 (B). Example: Cases diagnosed on Sunday (Day Zero) will be recorded on Monday (Day One).
5. **Data compilation:** A hard copy of each completed and signed **Format 1 (B)** should be stored in a file **daily** in a proper order. A soft copy of the line list should be maintained as a single excel sheet which should be updated **weekly** to include all suspected heatstroke deaths and confirmed CVD deaths. It should be ready to be submitted to the district or state nodal unit as per request.
6. **Nil reporting is mandatory in the prescribed format.** No columns will be left blank; in case of nil reporting, **"0"** should be written.

FORMAT 2: HEALTH FACILITY FORMAT FOR SENDING TO DISTRICT

Daily numbers of Suspected Heatstroke CASES# and All cause DEATHS*

(Compilation of Format 1, A & B)
(To be sent to District Nodal Unit daily)

Name of health facility: _____ Block: _____ District: _____	Date of reporting: _._/_._/_._
Type of health facility (Circle the applicable): 1. PHC 2. CHC 3. Taluka/Rural Hospital/Block Hospital 4. Sub-district 5. District Hospital/Civil Hospital 6. Medical College & Hospital 7. Private hospitals with emergency facility 8. Other	
Department (Circle the applicable): 1. Emergency Medicine 2. Emergency Paediatrics 3. Casualty	

Date	**Total patients in the department**	**New Suspected Heatstroke Cases Suspected Heatstroke Cases (A)**	**Total Suspected Heatstroke cases since 1st March 2020 (B)**	**All-cause deaths****			
				Suspected Heatstroke deaths## (a)	**Confirmed CVD deaths (b)**	**Others including unknown (c)**	**Total deaths (a+b+c)**
01-03-20							
02-03-20							

Form filled by (Name): Name of Facility In-Charge:

Designation: Signature of Facility In-Charge:

Signature: Date:

****All-cause death:** All of the deaths in casualty/emergency medicine plus paediatrics, regardless of cause.

#**Suspected Heatstroke:** Altered mental status (including disorientation, delirium, seizure, obtundation) **with elevated core body temperature ≥ 40 °C/≥104 °F,** without signs of stroke, history of infection, or signs of medication overdose **OR** Altered mental status (including

disorientation, delirium, seizure, obtundation) with hot and dry skin and deranged vitals, i.e., tachycardia, tachypnoea and wide pulse pressure without signs of stroke, history of infection, or signs of medication overdose. *(definition is applicable during heatwave season, i.e., March to July)*

##**Suspected Heatstroke Death:** This is a death on account of suspected heatstroke patient.

***Cardiovascular death** includes death resulting from an acute myocardial infarction (MI) or sudden cardiac arrest or heart failure (HF) or cardiovascular (CV) procedures or CV haemorrhage or death due to other CV causes.

Standard Operating Procedures: Format 2

(Health facility format for sending to DISTRICT)

1. **Format 2** will be compiled from data of **Format 1 (A)** and **Format 1 (B)** by the nodal person at the health facility daily.
2. **Institute and department who will report HRI:**
   a. All public hospitals with casualty/emergency.
   b. All private hospitals are having casualty/emergency.
   c. Reporting Departments will be medicine, paediatrics and casualty/emergency.
3. **Time of reporting to district nodal unit: Format 2 compiled from Format 1 (A) should be reported to District nodal unit on the following day (day one) by 12.00 hr (i.e. noon).**
4. **Reporting person:** A nodal person identified for the health facility will prepare the report.
5. **Data compilation:** A soft copy in the form of an excel sheet shall be e-mailed **daily** to the district nodal unit through a proper channel. In places where the internet facility is not available, the report can be communicated by any possible means. A hard copy of each **Format 2** should be kept in a designated file daily at the institutions/health facility.
6. **Data collection period:** In standard, it will be from **01st March to 31st July every year.** Further direction will be communicated during the start of the year if required.
7. **Nil reporting is mandatory in the prescribed format.** No columns will be left blank; in case of nil reporting, "0" should be written.
8. **If not submitted on time:** Late report must be submitted within 48 hrs.

FORMAT 3 (A): DISTRICT FORMAT FOR DAILY COMPILATION

Daily numbers of Suspected Heatstroke CASES# and All cause DEATHS*

(Compiled from Format 2)
(To be kept at District for record)

Cases and deaths due to HRI- *District name* 2020									Date of reporting: _._/_._/_._
S. No.	**Name & type of Health Facility**	**Total patients of the day (Emergency Medicine + Emergency Paediatrics + Casualty)**	**New Suspected Heatstroke cases (A)**	**Total Suspected Heatstroke cases since 1st March, 2020 (B)**	**All-cause deaths****				**Re-marks**
					Suspected Heats-troke deaths## (a)	**Con-firmed CVD deaths (b)**	**Others including unknown (c)**	**Total deaths (a+b +c)**	
	PHC1								
	PHC2								
	CHC								
	CH/DH								
	PVT1								
	PVT2								
	PVT3								
Total for District 1									

Total number of New Confirmed Heatstroke Deaths* in the District on _._/_._/_._**

Total number of Confirmed Heatstroke Deaths in the District since 1st March 2020:

[confirmed by death committee (heat death committee/three men committee)]

Name of person filling the form: Name of nodal officer:

Designation: Signature of nodal officer:

Signature: Date:

****All-cause death:** All of the deaths in casualty/emergency medicine plus paediatrics, regardless of cause.

#**Suspected Heatstroke:** Altered mental status (including disorientation, delirium, seizure, obtundation) **with elevated core body temperature ≥ 40°C/≥104 °F,** without signs of stroke, history of infection, or signs of medication overdose **OR** Altered mental status (including disorientation, delirium, seizure, obtundation) with hot and dry skin and deranged vitals, i.e., tachycardia, tachypnoea and wide pulse pressure without signs of stroke, history of infection, or signs of medication overdose. *(definition is applicable during heatwave season, i.e., March to July)*

##**Suspected Heatstroke Death:** This is a death on account of a suspected heatstroke patient.

***Cardiovascular death** includes death resulting from an acute myocardial infarction (MI) or sudden cardiac arrest or heart failure (HF) or cardiovascular (CV) procedures or CV haemorrhage or death due to other CV causes.

****Confirmed Heatstroke Death:** A suspected heatstroke death confirmed by the death committee (heat death investigation committee/three-person committee) at the district level.

Standard Operating Procedures: Format 3 (A)

(District format for compilation from health facility)

1. **Format 3 (A)** will be compiled by a nodal officer **daily** at District nodal unit.
2. **Format 3 (A)** will be compiled from **Format 2** from all health facility.
3. **Format 3 (A) adaptation:** Modify relevant fields (in grey italic fonts) in given Format 3 (A) to add the name of your district, to list **all** the government facilities and private reporting units in a proper order- from the primary health centre (PHC), Community Health Centre (CHC), District Hospital (DH), Civil Hospital (CH) to Private. This will be the **standard Format 3(A)** for your district for daily data compilation during the whole reporting period of a year.
4. **Total patient of the day:** Against each health facility, write the total patient of the day from emergency medicine, emergency paediatrics and casualty.
5. **Data compilation:** District nodal unit should receive Format 2 from health facilities by **12.00 hr (i.e. 12.00 noon) daily.** Format 3 (A) should be compiled daily from all submitted Format 2 reports. A date-wise soft copy of each daily Format 3 (A) report should be maintained digitally in a designated folder. A hard copy of the same should be printed and filed daily at the district level.
6. **Data collection period:** In standard, it will be from **01st March to 31st July every year.** Further direction will be communicated during the start of the year if required.
7. No reporting by health facility:
   a. If a health facility report **(Format 2)** is not received on time, write "delayed" in the row for that facility.
   b. If the facility reports to the district after the deadline of 12:00 noon, **Format 3 (A)** should be updated to reflect the change. Format 3 (A) for the given reporting period can be updated till 48 hrs and should show the updated date of reporting, if applicable.
   c. If the health facility does not submit **Format 2 at all or** submits it after 48 hrs of reporting deadline, Format 3 of that reporting period should be updated; "delayed" should be changed to "not available".
8. **Reporting after a holiday: Format 3 (A)** which should have been prepared on holiday (e.g. Sunday) must be compiled and prepared on the next working day. For example, facility reports (Format 2) submitted to the district on Saturday must be compiled on **Format 3**(A) on Monday, along with a separate **Format 3**(A) for facility reports submitted to the district on Sunday.
9. **Nil reporting is mandatory in the prescribed format.** No columns will be left blank; in case of nil reporting, "0" should be written.
10. **Confirmed heatstroke death:** A suspected heatstroke death is to be reported as and when the death is confirmed by the death investigation committee (heat death committee/three men committee) at the district level.

FORMAT 3 (B): DISTRICT FORMAT FOR SENDING TO STATE

Daily numbers of Suspected Heatstroke CASES# and All-cause DEATHS*

(Compiled from Format 3 A)

(To be sent to State Nodal Unit daily while keeping a copy for record)

Cases and deaths due to heatstroke - *District name* 20 _____								Date of reporting: _._/_._/_._	
Date	**Total patients of the day (Emergency Medicine + Emergency Paediatrics + Casualty)**	**New Suspected Heat-stroke Cases (A)**	**Total Suspected Heat-stroke cases since 1st March, 20 (B)**	**All-cause deaths****				**New Confirmed Heat-stroke Deaths*****	**Total Confirmed Heat Deaths since Ist March 20__**
				Suspected Heat-stroke deaths## (a)	**Confirmed CVD deaths (b)**	**Others including unknown (c)**	**Total deaths (a+b +c)**		
01-03-2020									
02-03-2020									

Name of person filling the form: Name of nodal officer:

Designation: Signature of nodal officer:

Signature: Date:

****All-cause death:** All of the deaths in casualty/emergency medicine plus paediatrics, regardless of cause.

#Suspected Heatstroke: Altered mental status (including disorientation, delirium, seizure, obtundation) **with elevated core body temperature ≥ 40°C/≥104 °F,** without signs of stroke, history of infection, or signs of medication overdose OR Altered mental status (including disorientation, delirium, seizure, obtundation) with hot and dry skin and deranged vitals i.e., tachycardia, tachypnoea and wide pulse pressure without signs of stroke, history of infection, or signs of medication overdose. *(definition is applicable during heatwave season, i.e., March to July)*

##Suspected Heatstroke Death: This is a death on account of suspected heatstroke patient.

***Cardiovascular death** includes death resulting from an acute myocardial infarction (MI) or sudden cardiac arrest or heart failure (HF) or cardiovascular (CV) procedures or CV hemorrhage or death due to other CV causes.

*****Confirmed Heatstroke Death:** A suspected heatstroke death confirmed by the death investigation committee (heat death committee/three men committee) at the district level.

Standard Operating Procedures: Format 3 (B)

(District format for sending to State)

1. **Format 3 (B)** will be compiled by a nodal officer **daily** at District nodal unit.
2. **Format 3 (B)** will be compiled from the end row of **Format 3 (A).**
3. **Time of reporting to state nodal unit:** Format 3 (B) compiled from Format 3 (A) should be reported to the state nodal unit on the following day **(day one) by 04.00 PM.**
4. **Reporting after a holiday: Format 3 (B)** which should have been prepared on holiday (e.g. Sunday) must be compiled and prepared on the next working day. For example, facility reports (Format 2) submitted to the district on Saturday must be compiled on **Format 3**(B) on Monday, along with a separate **Format 3**(B) for facility reports submitted to the district on Sunday.
5. **Nil reporting is mandatory in the prescribed format.** No columns shall be left blank; in case of nil reporting, "0" should be written.
6. **Confirmed heatstroke death:** a suspected heatstroke death is to be reported as and when the death is confirmed by the death committee (heat death committee/three-man committee) at the district level.

FORMAT 4 (A): STATE FORMAT FOR DAILY COMPILATION (district wise)

Daily numbers of Suspected Heatstroke CASES# and all-cause DEATHS*

(To be sent to Central Nodal Unit daily while keeping a copy for record)

Cases and deaths due to Heatstroke - State name 2020									Date of reporting: _._/_._/_._	
S. No.	**Name of District**	**Total patients of the day (Medicine + Paediatrics + Casualty/ Emergency)**	**New cases of Heat-stroke (A)**	**Cumulative total of Heats-troke cases since 1st March 2020 (B)**	**All-cause deaths****				**New Confirmed Heat-stroke Deaths*****	**Total Confirmed Heats-troke Deaths since 1st March 2020**
					Suspected Heats-troke deaths## (a)	**Confirmed CVD deaths* (b)**	**Others including unknown (c)**	**Total deaths (a+b +c)**		
1	District 1									
2	District 2									
3	District 3									
	Total									

Name of person filling the form: Name of nodal officer:

Designation: Signature of nodal officer:

Signature: Date:

****All-cause death:** All of the deaths in casualty/emergency medicine plus paediatrics, regardless of cause.

#Suspected Heatstroke: Altered mental status (including disorientation, delirium, seizure, obtundation) **with elevated core body temperature ≥ 40°C/≥104 °F,** without signs of stroke, history of infection, or signs of medication overdose **OR** Altered mental status (including disorientation, delirium, seizure, obtundation) with hot and dry skin and deranged vitals, i.e., tachycardia, tachypnoea and wide pulse pressure without signs of stroke, history of infection, or signs of medication overdose. *(definition is applicable during heatwave season, i.e., March to July)*

##Suspected Heatstroke Death: This is a death on account of a suspected heatstroke.

***Cardiovascular death** includes death resulting from an acute myocardial infarction (MI) or sudden cardiac arrest or heart failure (HF) or cardiovascular (CV) procedures or CV haemorrhage or death due to other CV causes.

*****Confirmed Heatstroke Death:** A suspected heatstroke death confirmed by the death committee (heat death investigation committee/three-person committee) at the district level.

Standard Operating Procedures: Format 4 (A)

(State format for sending to centre)

1. **Format 4** will be compiled from data reported by all districts by nodal officer at the state nodal unit daily.
2. **Districts** will report health facility-wise aggregate number of cases due to suspected heatstroke. Also, the aggregate number of all-cause deaths with segregation of suspected heatstroke deaths confirmed CVD deaths and others.
3. **Time of reporting:**
   a. Health facility to district nodal unit: **Cases diagnosed on day zero** (from 00.01 hr to 24.00 hr of a day) at health facilities to be reported to district nodal unit on day 1 (i.e. next day) at 12:00 noon **in Format 2.** The daily compiled report from the district nodal unit **(Format 3)** should be submitted to Integrated Disease Surveillance Programme (IDSP) at the district Surveillance unit (DSU) through the proper channel by **01:00 PM** on day 1 (i.e. next day).
   b. District to State: by **04:00 PM** the **day 1**.
   c. State to centre: by **05:00 PM** the **day 1**.
4. **Data compilation:** A soft copy of **Format 4** in the form of an excel sheet shall be e-mailed **daily** to the Central unit through the proper channel. A date-wise soft copy of each daily **Format 4** report should be maintained digitally in a designated folder. A hard copy of **Format 4** should be kept daily in a designated file at the state level.
5. **Data collection period:** In standard, it will be from **01st March to 31st July every year.** Further direction will be communicated during the start of the year if required.
6. No report by a district:
   a. If a **Format 3** from a district is not received on time, write **"delayed"** in the row for that district.
   b. If the district reports to the state State after the deadline of 4.00 PM, **Format 4** should be updated to reflect the change. **Format 4** for the given reporting period can be updated till 48 hrs and should show an updated date of reporting, if applicable.
   c. If a district does not submit **Format 3 at all or** submit it after 48 hrs of reporting deadline, **Format 4** of that reporting period should be updated, i.e., "delayed" should be changed to **"not available"** for that district.
7. **Changing a filed report:** A submitted **Format 4** can be changed only if an update is generated by a health facility and communicated to the District within 48 hrs of reporting deadline. Updated **Format 4** for that reporting period should be submitted again to the Central unit with a new date of reporting if applicable.
8. **Reporting after a holiday:** A **Format 4,** which should have been prepared on holiday (e.g. Sunday), must be compiled and submitted on the next working day. For example, Format 4 for Saturday must be compiled on Monday along with a separate **Format 4** for Sunday.
9. **Nil reporting is mandatory in the prescribed format.** No columns shall be left blank; in case of nil reporting, "0" should be written.
10. **If not submitted on time:** Late report must be filed within 48 hrs with the correct date of reporting.
11. **Analysis:** Analysis of the data should be done every week according to the guidelines provided here.

FORMAT 4 (B): STATE FORMAT FOR DAILY COMPILATION (day wise)

Daily numbers of Suspected Heatstroke CASES# and all-cause DEATHS*

(To be kept at State for record)

Cases and deaths due to Heatstroke - State name 2020								Date of reporting: _._/_._/_._	
Date	**Total patients of the day (Medicine + Paediatrics + Casualty/ Emergency)**	**New cases of Heat-stroke (A)**	**Cumula-tive total of Heat-stroke cases since 1st March, 2020 (B)**	**All-cause deaths****				**New Con-firmed Heat-stroke Deaths*****	**Total Con-firmed Heat-stroke Deaths since 1st March 2020**
				Suspected Heatstroke deaths## (a)	**Con-firmed CVD deaths* (b)**	**Others including unknown (c)**	**Total deaths (a+b+c)**		
01-03-2020									
02-03-2020									
Total									

Name of person filling the form:

Designation:

Signature:

Name of nodal officer:

Signature of nodal officer:

Date:

****All-cause death:** All of the deaths in casualty/emergency medicine plus paediatrics, regardless of cause.

#Suspected Heatstroke: Altered mental status (including disorientation, delirium, seizure, obtundation) **with elevated core body temperature ≥ 40°C/≥104 °F,** without signs of stroke, history of infection, or signs of medication overdose **OR** Altered mental status (including disorientation, delirium, seizure, obtundation) with hot and dry skin and deranged vitals, i.e., tachycardia, tachypnoea and wide pulse pressure without signs of stroke, history of infection, or signs of medication overdose. *(definition is applicable during heatwave season, i.e., March to July)*

##Suspected Heatstroke Death: This is a death on account of a suspected heatstroke.

***Cardiovascular death** includes death resulting from an acute myocardial infarction (MI) or sudden cardiac arrest or heart failure (HF) or cardiovascular (CV) procedures or CV haemorrhage or death due to other CV causes.

*****Confirmed Heatstroke Death:** A suspected heatstroke death confirmed by the death investigation committee (heat death committee/three-man committee) at the district level.

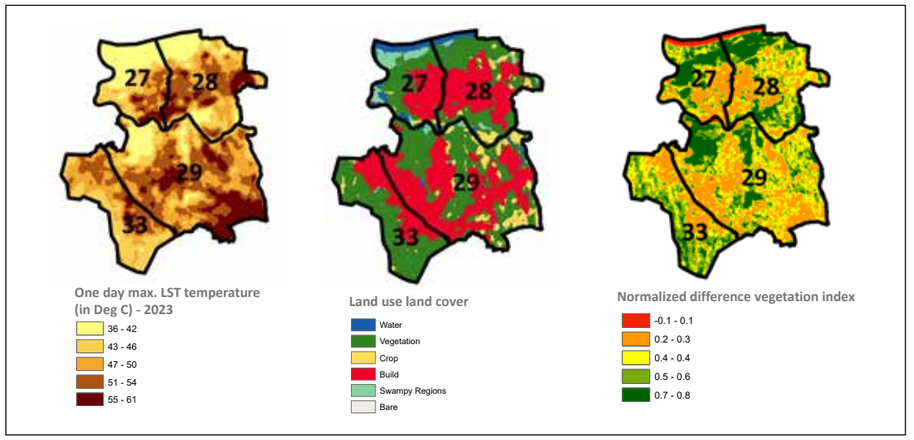
Annexures

Annexure 1: *Prabhag Samitee*–wise maps of urban heat island analysis through land surface temperatures, normalised difference vegetation index (NDVI) and land use land cover (LULC)

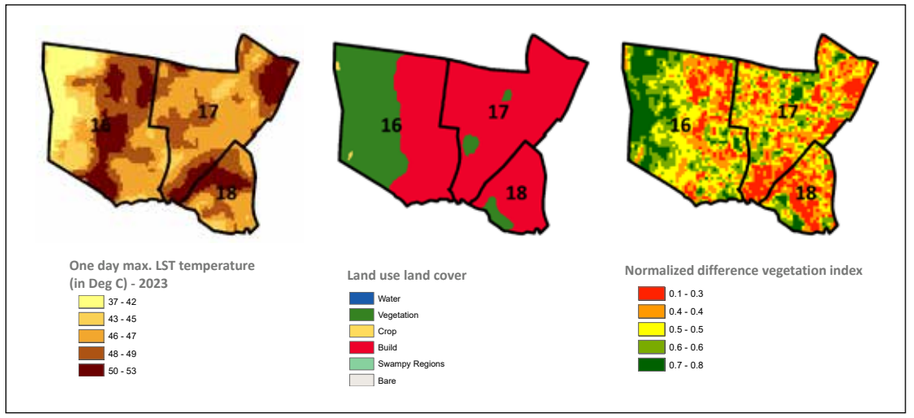
Figure A1: Prabhag Samitee–wise urban heat island maps

a) Locator map for understanding spatial distribution of *Prabhag Samitees* in Thane

b) Diva



c) Wagle



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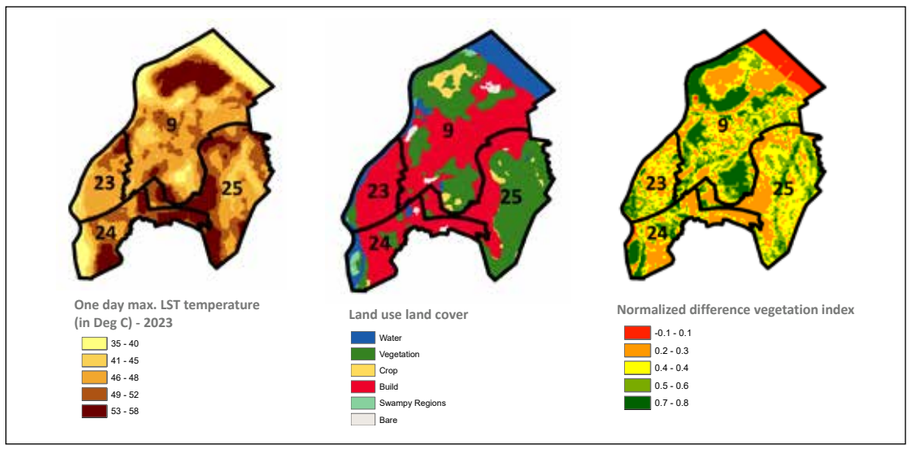

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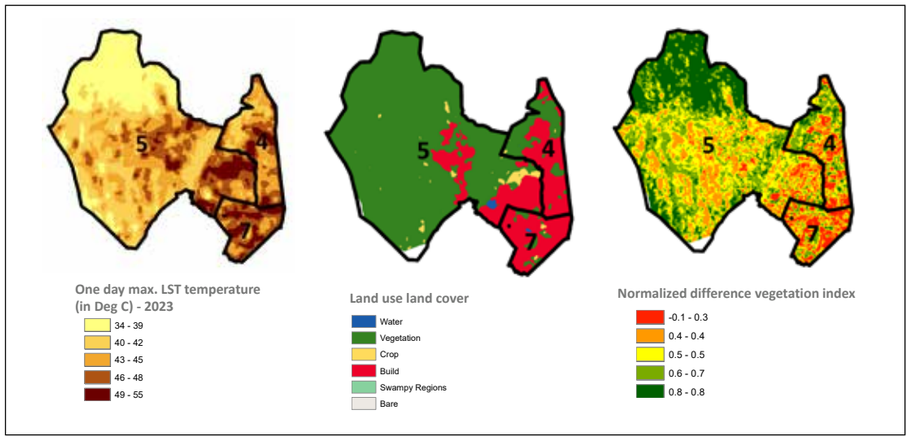
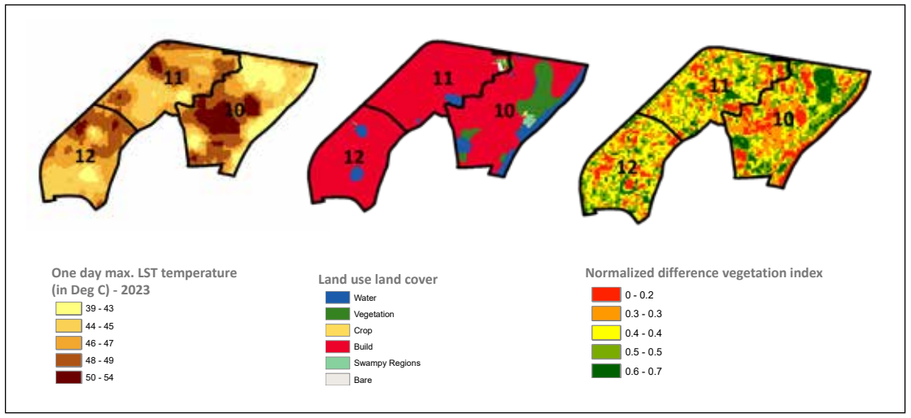
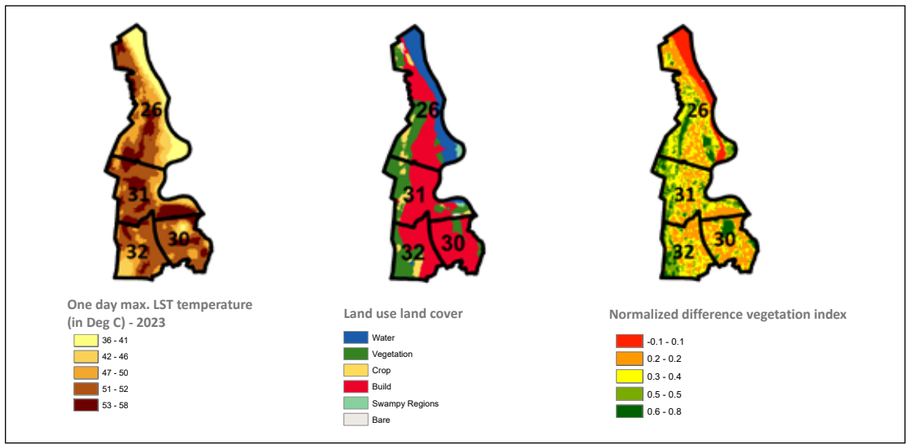


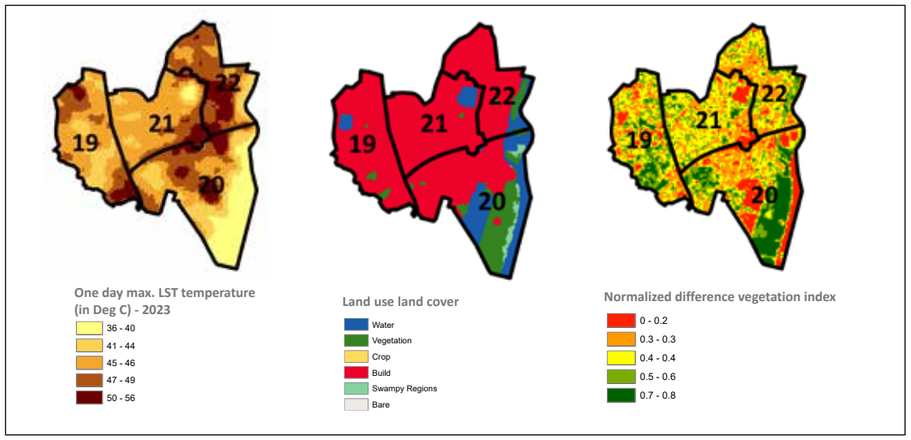
f) Uthalsar



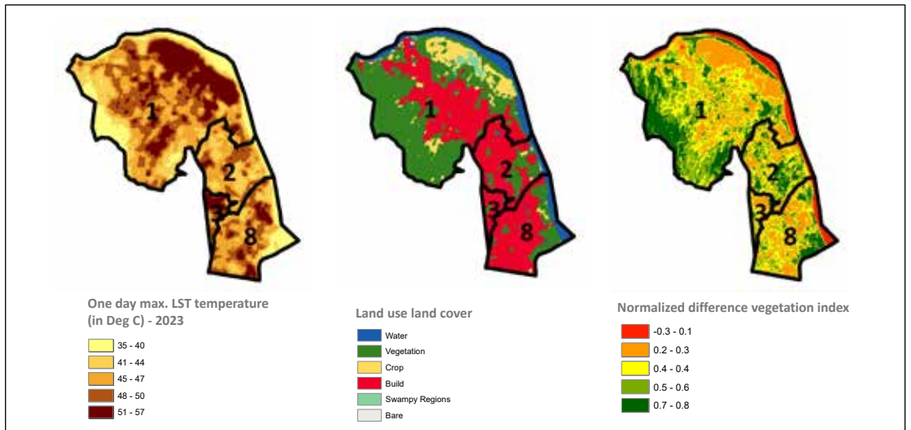
g) Mumbra



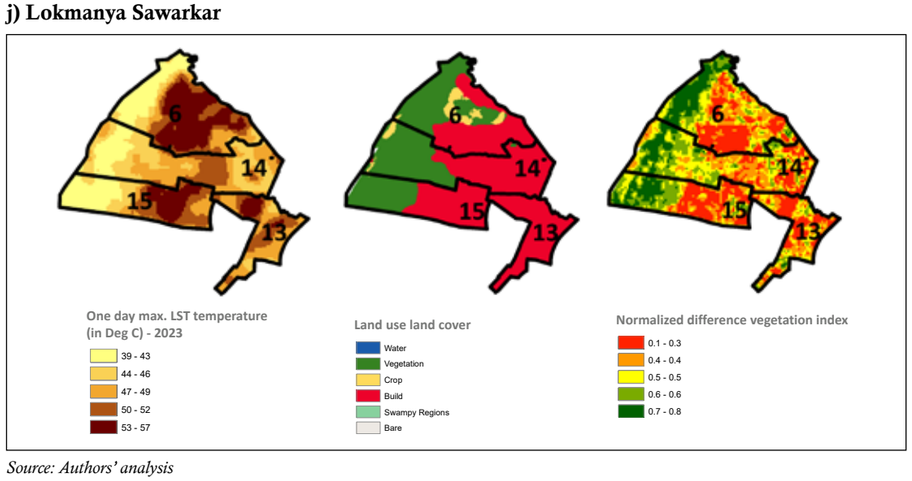
h) Naupada



i) Majiwada



j) Lokmanya Sawarkar

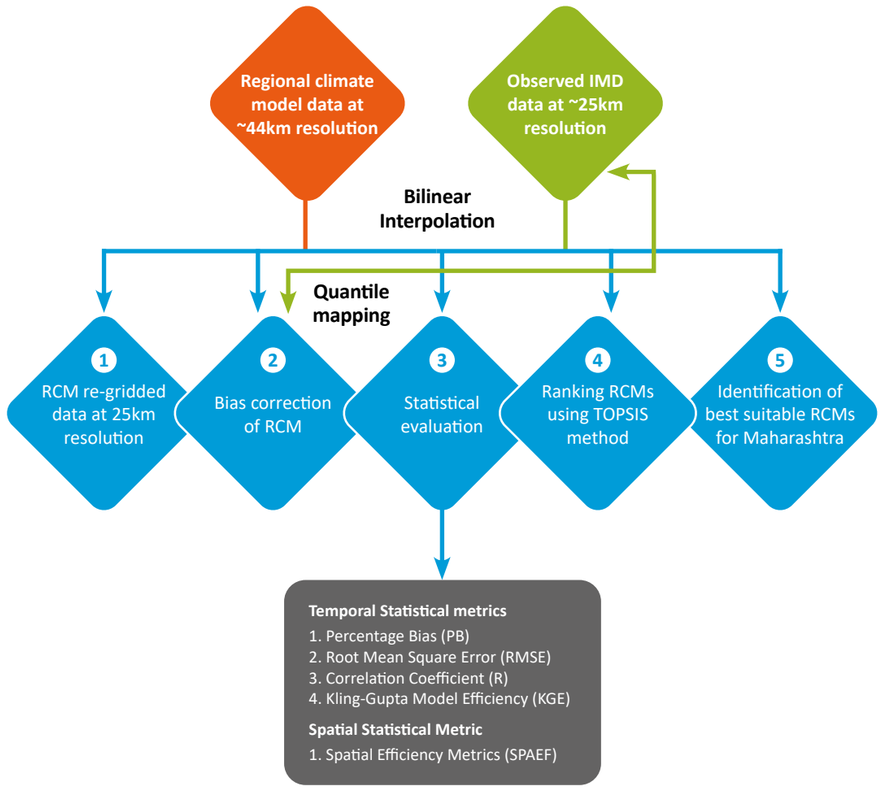


Source: Authors' analysis

Annexure 2: Detailed methodology for undertaking climatological projections over Thane City

To grasp future climatic patterns, the detailed downscaled projections from the Coordinated Regional Climate Downscaling Experiment (CORDEX) South Asia programme, overseen by the Centre for Climate Change Research (CCCR) at the Indian Institute of Tropical Meteorology (IITM), Pune, were used in this plan. These projections stem from the CMIP5 (Coupled Model Intercomparison Projects, 5th generation) climate models, a collaborative platform showcased in the IPCC's fifth assessment report (AR5). Under CORDEX, regional models driven by CMIP5 data portray scenarios for Representative Concentration Pathways (RCPs) – specifically, RCP 4.5 (mid-range emissions) and RCP 8.5 (high-end emissions). These scenarios depict a time series of emissions, concentrations of greenhouse gases, aerosols, and land-use changes. While temperature projections are considered with high or moderate confidence, rainfall projections bear lower confidence, prompting the use of robust statistical methods for model selection and bias correction. Despite such corrections, the inherent variability in the Indian climate and coarse model resolution introduces some level of uncertainty. Evaluating the bias-corrected Regional Climate Model (RCM) outputs involved temporal and spatial metrics, ultimately leading to the ensemble of top-performing models, specifically the CanESM2 and CSIRO-Mk3.6 for temperature.

Figure A2: Methodology for developing climatic projections



Source: Authors' analysis

Table A1: List of models chosen for projection analysis

Driving CMIP5 GCM	Contributing CMIP5 modelling centre
CCCma-CanESM2	Canadian Centre for Climate Modelling and Analysis (CCCma), Canada
NOAA-GFDL-GFDL ESM2M	National Oceanic and Atmospheric Administration (NOAA), Geophysical Fluid Dynamics Laboratory (GFDL), USA
CNRM-CM5	Centre National de Recherches Me´te´orologiques (CNRM), France
MPI-ESM-MR	Max Planck Institute for Meteorology (MPI-M), Germany
IPSL-CM5A-LR	Institut Pierre-Simon Laplace (IPSL), France
CSIRO-Mk3.6	Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Source: Authors' compilation

Annexure 3: Detailed methodology for calculating satellite-based indices

Calculating satellite-derived indices: For mapping urban heat islands and various other landscape indicators, a combination of satellite-based data obtained from Landsat-8 and Sentinel 2 was used. Landsat-8 data is particularly useful for calculating various indices, such as the normalised difference vegetation index and modified normalised difference water index. These indices utilise the spectral information captured by Landsat-8 to derive meaningful insights about land cover, vegetation health, and water bodies.

1. **Normalised difference vegetation index (NDVI):** The NDVI is a widely used vegetation index calculated from remotely sensed data, in this case, from Landsat-8. It quantifies the presence and health of vegetation by measuring the difference between near-infrared (NIR) and red (RED) bands of the electromagnetic spectrum (Huang et al. 2020). The formula for NDVI is:

$$NDVI = \frac{NIR - Red}{NIR - Red}$$

   NDVI values range from –1 to 1, where higher values indicate healthier vegetation and lower values indicate sparse or stressed vegetation. It provides insights into vegetation density, distribution, and health over large spatial scales.

2. **Modified normalised difference water index (MNDWI):** The MNDWI is designed to detect the presence of water bodies in remotely sensed imagery. It is particularly effective at distinguishing between water and non-water features, such as built-up areas or vegetation. MNDWI is calculated using the green (Green) and shortwave infrared (SWIR) bands of the electromagnetic spectrum (Chang et al. 2022). The formula for MNDWI is:

$$MNDWI = \frac{Green - SWIR}{Green + SWIR}$$

   MNDWI values typically range from –1 to 1, where higher values indicate the presence of water and lower values correspond to non-water features.

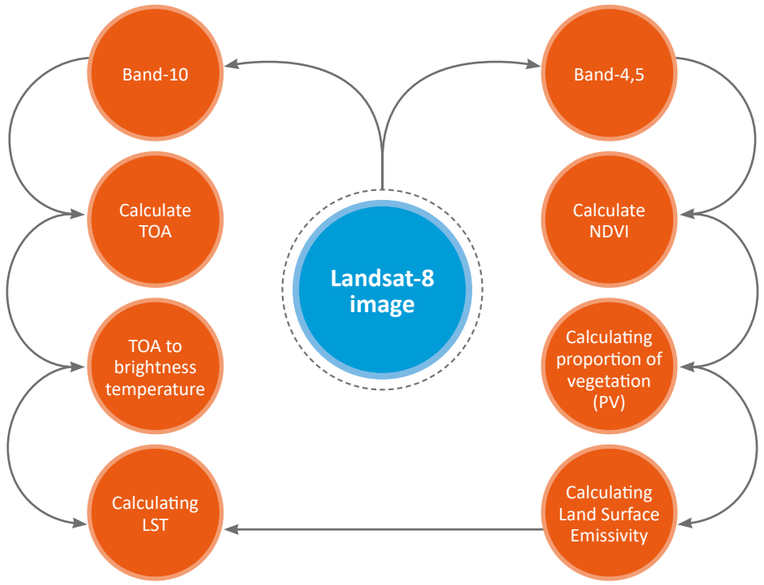
3. **Normalised difference built-up index (NDBI):** The NDBI is used to detect built-up or urban areas in remotely sensed imagery. It helps differentiate between impervious surfaces, such as buildings and roads, and natural features, such as vegetation or soil. NDBI is calculated using the near-infrared (NIR) and shortwave infrared (SWIR) bands of the electromagnetic spectrum (Malik 2019). The formula for NDBI is:

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR}$$

NDBI values typically range from –1 to 1, where higher values indicate the presence of built-up areas and lower values correspond to non-built-up areas.

4. **Land surface temperature (LST):** LST refers to the temperature of the Earth's surface as measured from a satellite or other remote-sensing platform. It is a crucial parameter which provides insights into surface energy fluxes, urban heat island effects, and land–atmosphere interactions. Landsat-8 is equipped with the Thermal Infrared Sensor (TIRS), which enables the estimation of land surface temperature (Ridho 2023; Anandababu et al. 2018).

Figure A3: Methodology for computing LST from Landsat-8



Source: Authors' analysis

5. **Land use land cover:** The LULC data was taken as the direct product of Sentinel 2A derived indices from the ESRI's Living Atlas as a raster data of the year 2022 (most recent available data at the time of analysis). This data underwent initial categorisation into various classes, subsequently refined into six distinct categories tailored for our specific analysis. These categories were water, vegetation, crop, build, swampy region, and bare.

6. **Building density:** Utilising Google's Open Building dataset, an assessment of building density was conducted through the creation of 500m square grids. These grids were generated using the fishnet tool within ArcGIS Pro, ensuring a systematic and comprehensive coverage of the study area. Following this, a spatial join operation was executed, integrating the building data with the generated grids. As a result, each grid acquired a count of total buildings within its boundaries, facilitating the calculation of building density across the analysed region. This methodological approach ensures a detailed understanding of the spatial distribution and concentration of buildings within the study area.

Annexure 4: Department wise responsibility matrix of both heat risk mitigation and preparedness and response

To enhance accessibility and streamline information, the responsibility matrices outlined in the preceding chapters have been consolidated into a unified matrix. This comprehensive matrix encompasses both heat risk mitigation and preparedness/response measures that each department is tasked with. It serves as a convenient tool to identify department-specific activities and tasks for effective implementation.

Name of the Department	Mitigation Strategies		Name of the Department	Preparedness and Response Strategies	
Division	Task/Activity	Responsibility	Division	Task/Activity	Responsibility
External Expert agency	Hazard Risk Vulnerability Assessment	1. Conduct Heat wave vulnerability and risk assessment at ward level by considering hazard, Exposure, Sensitivity, and Adaptive Capacity in Slums, individuals, House Holds, and communities 2. Identify and map heat risk hot spot areas for designing appropriate response measures	Heat wave Cell in the TMC	Preparation of Action Plan and implementation	• Coordinate with stakeholders and experts for preparing the Heat Action Plan and its implementation
External Expert agency	Hazard Risk Vulnerability Assessment	Map out the physical vulnerability due to age, chronic illness, morbidities, outdoor vendors/workers, type of housing, occupation, etc. by using available resources and robust scientific methods.	Heat wave Cell in the TMC	Standard operating Procedure (SoP)	• Prepare Standard Operating Procedure (SoP) for heat wave response with clearly defined roles and responsibilities of different dept. in MC with a timeline • Issued necessary orders and Coordinate with all stakeholders
External Expert agency	Risk assessment	Generate a heat wave risk index through assessment and prepare ward wise atlas for mitigation and adaptation measures.	Nodal officer RDMC Incharge	Early warning and Coordination	• Coordination with weather forecasting and warning institutions before the summer season (March to June)

Name of the Department	Mitigation Strategies		Name of the Department	Preparedness and Response Strategies	
Division	Task/Activity	Responsibility	Division	Task/Activity	Responsibility
External Expert agency	Risk assessment	Identify High risk wards, settlements, industries and vulnerable groups particularly homeless, aged, individuals, House Holds, communities, people with morbidities, outdoor vendors/workers, traffic police, etc. to concentrate on mitigation measures at a specific area on priority basis	Nodal officer RDMC Incharge	Early warning and Coordination	Analyse all weather updates received from IMD, District, State and other research institutions.
External Expert agency	Estimation of local temperature threshold	Estimate ward wise or city-wise threshold including thermal variables like temperature, humidity and health variables like mortality	Nodal officer RDMC Incharge	Early warning and Coordination	• Modify or customise the received forecasts based on local thresholds for heat wave warnings and alerts as well as based on the target groups.
Add. Municipal Commissioner	Nodal officer as mentioned in response matrix	Coordination among ward members and review mitigation measures	Nodal Officer RDMC Incharge	Impact Based Early warning dissemination	• Disseminate Colour Coded impact based Early warning to all wards. • Ensure early warning reach to the most vulnerable populations identified in the HAP
Add. Municipal Commissioner	Nodal officer as mentioned in response matrix Climate Change Adaptation and development	Ensuring coherence and mutual reinforcement of Heat wave Risk Reduction	Nodal Officer & MOH	Do's and Don'ts	• Display Do's and Don'ts in public area, hospitals, parks, schools including RWAs in local language
Add. Municipal Commissioner	Mainstreaming and up-scaling	Coordinate for mainstreaming heat wave risk reduction activities with all concerned Depts., local NGOs/CSOs, Ward leaders	Nodal Officer & MOH	IEC Campaign	Develop and conduct IEC Campaigns to create awareness at individual, community, RWA levels and for public at large through various– poster, pamphlets, public advertisements etc.
Add. Municipal Commissioner	Mainstreaming and up- scaling	Identify Convergence with heat wave activities in various programs/schemes run by different dept. NGOs, for heat wave risk reduction.	Nodal Officer AMC Advertisement department	Playing Short TVCs in public spaces	Play short TVCs in public places from time to time make the public aware about precautions to be taken against heat waves
Add. Municipal Commissioner	Rail transport	Coordinate with local railway station in charge for repair/ maintenance of mechanical, electrical fault and ensure sheds, shelter, temperature cooling equipment, and water supply at public waiting areas during heat wave season.	Thane Municipal Commissioner Add. MC 1& 2 and Medical Officer of Health	Formation a Heat wave Management Cell	Formation a heat wave Management cell • Appoint ward wise heat wave in charge officer • Develop a clearly defined area specific response plan • Coordination with district and state agencies. • Monitor the Heat Action Plan implementation on daily basis during heat wave season (March to June). • Organise meetings for the immediate response, Whenever required.
Public Work Department	Municipal Administration and urban development	1. Sprinkling of water on road to reduce heat and improve air quality.	Thane Municipal Commissioner Add.MC 1& 2 Medical Officer of Health Nodal officer Education Officer / Chief Environment Officer	Formation a Heat wave Management Cell	Formation a heat wave Management cell • Appoint ward wise heat wave in charge officer • Develop a clearly defined area specific response plan • Coordination with district and state agencies. • Monitor the Heat Action Plan implementation on daily basis during heat wave season (March to June). • Organise meetings for the immediate response, Whenever required.

Name of the Department	Mitigation Strategies		Name of the Department	Preparedness and Response Strategies	
Division	Task/Activity	Responsibility	Division	Task/Activity	Responsibility
Dy. City Engineer TDO	Techno-legal crimes - Increase green cover	• Implementation of law/rules and regulation • Improving green cover through plantation to enhances water ponds, fountains, increase green parks • Promote heat-resistant building materials to reduce heat island effects in urban areas such as cool roofs and thermal insulation.	Thane Municipal Commissioner	Appoint Nodal officer	• Appoint a Nodal officer to coordinate preparedness, response and mitigation measures with all concerned stakeholders/ division and district/state agencies, NGOs etc
Dy. City engineer Electrical dept.	Electricity & Power	• Coordinate with electricity department for un-interrupted electric supply on higher risk area/ ward • Promote energy efficiency and use of renewable energy for cooling and electricity needs • Promote the use of renewable energy sources such as solar energy for cooling and electricity needs.	Thane Municipal Commissioner	Appoint Nodal officer	• Implements regulatory orders related to heat waves • Governing and flexible timing of Schools, markets and offices under Municipal Areas during heat wave alert
TDMC. Education	Road Transport	• Encourage the use of public transport, Electric Vehicles, and bicycles to reduce vehicle emissions and reduce traffic congestion for a safe environment • Ensure shelter/ sheds at bus stops • Tree plantation of roadside or create green divider.	Thane Municipal Commissioner	Expert groups/ committee	• Constitute city level technical advisory groups comprising experts, academicians, NGOs, and other stakeholders.
DMC. Education	Education	• Ensure rescheduling of MC schools/ institutions timing as per heat wave situation and alerts. • Ensure all schools and institutions have cooling equipment which are in working condition and ensure adequate water facilities • Ensure the students avoid outdoor games / physical activities during heat wave	Thane Assistant Municipal Commissioner	Expert groups/ committee	• Constitute Ward level Committee including local NGOs, CSOs, RWAs to coordinate preparedness and response actions in their wards and for sharing information effectively
Veterinary doctor	Livestock	• Ensure adequate sheds and shelters to livestock in high-risk wards • Publicity of protective measures to save livestock and poultry during heat wave season. • Ensure adequate stock of medicines and fluids in all veterinary hospitals. • Ensure additional mobile hospital ready to reach vulnerable areas	Thane Municipal Commissioner	Restricted public gathering / permission	• Avoid giving permission for public gathering during heat wave time. If it is must, then have a check list, which has necessary requirement such as facilities of drinking water, sheds, etc at place of gathering by the organizers • Avoid outdoor games/sports activities and regulate use of swimming pools during day time.
DMC Garden	Parks and Garden	• Ensure that all parks have sitting/resting sites available for public during the heat wave. • Conduct promotional campaigns for green roof and cool roof buildings, increasing ventilation, and setting up green spaces.	Thane Municipal Commissioner	Ex-Gratia payment	• As “Heatwave” has been declared as a State Specific disaster and is covered for relief from SDRF, issue necessary certificate

Name of the Department	Mitigation Strategies		Name of the Department	Preparedness and Response Strategies	
Division	Task/Activity	Responsibility	Division	Task/Activity	Responsibility
		• Ensure construction of green buildings. • Increase green coverage through individuals, HH, communities, RWAs, institutions etc.			
Chief officer Fire & Bridge dept.	Fire	• To be in a state of preparedness and ready to face any fire emergency. • Ensure adequate supply of water and foam to fight fires. • List designated point of contact for each ward in case of f fire	Assistant Municipal Commis-sioner	During Election	• Ensure polling booth wise specific precaution measures for providing sheds, drinking water, medical facilities during the election voting periods
Chief Environment Officer	Heat resilience infrastructure	• Create public cooling centres and green spaces, /parks where people can go to cool off and avoid heat-related illnesses / deaths • Heat risk informed Urban planning for mitigation future heat risk • All construction must include heat wave resilient features and standards. • Ensure heat-resistant building features such as cool roofs and thermal insulation to reduce the indoor temperature of their homes • Greater usage of permeable materials in civic infrastructure and residential construction can reduce the urban heat island effect.	Dy. City Engineer Water Supply	Water supply	Ensure drinking water supply at all identified vulnerable points and worksites on a priority basis
Chief Environment Officer	Ensure Open spaces to reduce pollution and heat island effects	Maintain/create open spaces, open areas in the city to reduce pollution and heat island effects	Veterinary	Livestock	Ensure that the live-stock has sufficient shade and water at most vulnerable wards during heat wave alerts
Dy. City Engineer PWD	Social Housing Schemes and Urban greenery	• Increasing Urban greenery through plantation of trees • Ensure that Social Housing Schemes have heat wave resilient features and use reflective materials on buildings, ventilated cooling spaces incorporated	Education officer & Medical Officer of Health	Training	• Conduct training programs for different stakehold-ers such as health professionals, ASHA, • ANM, MC school teachers and concerned NGOs/ CSOs for activities to be undertaken during pre, during and post heat wave season.
Dy. City Engineer Electrical Dept.	Roof top solar energy	• Promote roof top solar panels to help cooling inside building. This will also help climate change adaptation	RDMC Incharge & Medical officer of Health	Mock-drills / Exercise	• Joint execution of emergency mock drills with local administration/ staff to address heat wave emergencies
Dy. City Engineer Electrical Dept.	Renewable energy	• Promoting the use of renewable energy sources such as solar and wind energy for cooling and electricity needs. • Installing solar-powered appliances such as fans and AC to stay cool and comfortable.	RDMC Incharge & Medical officer of Health	Mock-drills / Exercise	Joint execution of emergency mock drills with local administration/ staff to address heat wave emergencies
DMC SWM	Solid West Management	• Reducing the size of landfills, waste segregation, and sound solid waste management at the source can reduce methane production and fires that exacerbate urban heat	RDMC Incharge & Medical Officer of Health	Public awareness, community outreach	• Sensitise general public through print and electronic and through other social media channels • Awareness regarding use of swimming pools during heat wave • Sending forecasts and alerts as bulk messages on mobile phones, and to the media for wider broadcast.

Name of the Department	Mitigation Strategies		Name of the Department	Preparedness and Response Strategies	
Division	Task/Activity	Responsibility	Division	Task/Activity	Responsibility
Medical Officer of Health	Public Health Intervention	• Issue health advisories for different vulnerable people and create displays on ambulances to build public awareness during the summer season • Organise camps for health check-up in slums areas • Procurement of adequate quantity of life saving medicines, IV fluids, ORS, etc. in all health centres under Municipal corporation areas	AMC Advertisement department	Playing Short TVCs in public spaces	Establish electronic screens at traffic intersections and market places and display heat wave information
Medical Officer of Health	Labour	• Heat illness orientation for factory officers, staff and general practitioners through IEC materials • Conduct awareness campaigns regularly and more importantly during high-risk days • Coordination for rescheduling of working hours for workers and labourers across different sectors under municipal area. • Provide drinking water at work sites and use of temperature control measures like Fan, Cooler, etc.	Education Officer	Quiz and competition	• Organize Heat wave awareness quiz, competition – essay, poster, lecture, puppet shows for students
Dy. City Engineer Water Supply	Water supply	• Maintain portability of water quality • Ensure availability of drinking water supply at all wards during the summer season especially in vulnerable places • Ensure clean drinking water facilities at common places such as bus stands, labour hub's, markets, parks, etc. • Open water kiosk at identified hot spot area/ place • Frequently repair /maintenance of mechanical / electrical faults in water supply before season.	Medical Officer of Health	Training	• Conduct trainings for CD, RWAs, Community, volunteers' health workers and rapid response teams • Conduct training for creating and maintaining heat wave resilient infrastructure
Thane Municipal Commissioner	Heat wave Management cell	Set up a Heat wave Management cell • understand and use all the Heat wave-related information from various agencies of district/ state and central agencies	Medical Officer of Health	Hospital preparedness	• Prepare a hospital plan for heat wave related illness • Procure adequate quantities of life saving medicines, IV fluids, ORS etc. in all MC health care center • Establish First Aid/ Medical Aid facilities in key risk locations as identified in this plan. • Ensure special health facilities for people with pulmonary illness, renal, psychiatric problems etc. • Establishing First Aid/ Medical Aid facilities in priority basis of key locations as per vulnerable & risk assessment

Name of the Department	Mitigation Strategies		Name of the Department	Preparedness and Response Strategies	
Division	Task/Activity	Responsibility	Division	Task/Activity	Responsibility
Thane Municipal Commissioner	Nodal officer	• Appoint a Nodal officer to head the Heat wave cell and manage coordination and monitor all the activities of the heat wave cell.	Medical Officer of Health	Hospital preparedness	• Ensure daily reporting on heat waves mortality and morbidity from all concerned dept/ units of the health facilities • Collection of the above data ward wise and analysis for better policy and implementation measures for response and mitigation
			Medical Officer of Health	Training	• Conduct training programs for different stakeholders such as health professionals, ASHA, ANM, • MC school teachers and concerned NGOs/CSOs for activities to be undertaken during pre, during and post heat wave season.
			Medical Officer of Health	Field Research	• Undertake Research studies at individual, community or at workplace level to identify the most vulnerable population and their risk factors
			Medical Officer of Health	Monitoring & Evaluation	• Thane heat wave monitoring cell could monitor HAP implementation regularly and on daily basis during heat wave season. It should use different Iot tools like GIS, Artificial Intelligence
			Medical Officer of Health	Monitoring & Evaluation	Monitoring and evaluation of Thane HAP activities, and the impact on heat waves on mortality and morbidity
			Medical Officer of Health	Data collection, documentation, updating	Collect segregated data on all cause mortality from all wards, hospitals, and maintain a database at Thane Municipal Corporation Area
			Medical Officer of Health	Data collection, documentation, updating	Follow Standard protocol in all MC Hospital for illness and death investigation as per prescribed format in this HAP/or as issued by the state government
			Medical Officer of Health	Documentation	Adapt a uniform process for registration of casualties / deaths due to heat wave based on post mortem reports, death count, type of disease, temperature, time, and duration.
			Thane Municipal Commissioner and Add. Municipal Commissioner	Reviews	Head of the institution should monitor, and review preparedness, and response activities on weekly basis

Annexure 4: Signed order of the Thane Municipal Commissioner for formation of Heat wave Task Force Committee

जा.क्र.ठामपा/प्रनिक/ ९४३/२३-२४
ठाणे शहराचे Heat Action Plan साठी Task Force Committee गठीत करणेबाबत.
दिनांक : २७.०२.२०२४

आदेश

सद्यस्थितीत नागरीकरणामुळे शहरांमध्ये हरित वायुंचे प्रमाण वाढत असून, तापमानामध्ये वाढ होत आहे. समुद्र, खाडी किनाऱ्यांच्या शहरांमध्ये आद्रतेचे प्रमाणे जास्त असते त्यामुळे उन्हाचा त्रास जास्त जाणवतो, त्या दृष्टीने सर्व सामान्य नागरीक, शालेय विद्यार्थी, कामगार यांना उन्हाचा त्रास दैनंदिन कामकाजा निमित्त मोठ्या प्रमाणत जाणवतो. उन्हाच्या त्रासामुळे घश्याला कोरड पडणे, चक्कर येणे, हिट स्ट्रोक येथे यामुळे माणूस दगावू हि शकतो. सध्याच्या वातावरण बदलामुळे याचा परिणाम वाढत असून त्यादृष्टीने उपाययोजना करणे अनिवार्य आहे. त्याअनुषंगाने शासनाच्या निर्देशानुसार ठाणे शहरासाठी Heat Action Plan तयार करण्यात येत आहे.

Council on Energy Environment and Water या संस्थेची नेमणूक शासन स्तरावर झालेली असून सदर संस्थेने ठाणे शहरातील Heat Action Plan तयार केलेला आहे. सदर कृती आराखड्यामध्ये Heat Wave Mitigation आणि Heat Wave Preparedness and Response हे दोन भाग आहेत. त्या संदर्भात मा.आयुक्त स्तरावर बैठक झाली असून सदर कामासाठी Task Force Committee ची स्थापना करणे आवश्यक आहे. असे संस्थेने नमूद केले. त्यादृष्टीने Heat Wave Action Plan साठी खालील प्रमाणे ठाणे महानगरपालिका आयुक्त यांच्या सनियंत्रणाखाली Task Force Committee गठीत करण्यात येत आहे.

१.	अतिरिक्त आयुक्त	अध्यक्ष
२.	नगर अभियंता, सार्वजनिक बांधकाम विभाग	सदस्य
३.	वैद्यकीय आरोग्य अधिकारी, आरोग्य विभाग	सदस्य
४.	आपत्कालीन विभाग प्रमुख,	सदस्य
५.	उपआयुक्त, शिक्षण विभाग	सदस्य
६.	उपआयुक्त, उद्यान विभाग	सदस्य
७.	उपनगर अभियंता, शहर विकास विभाग	सदस्य
८.	तज्ञ संस्थेचे अधिकारी	आवश्यकतेप्रमाणे
९.	माहिती व जनसंपर्क अधिकारी, माहिती व जनसंपर्क विभाग	सदस्य
१०.	मुख्य पर्यावरण अधिकारी, प्रदूषण नियंत्रण विभाग	सदस्य सचिव

तरी वरील प्रमाणे Task Force Committee गठीत करण्याबाबत मान्यता असावी. सदर समितीचे कामकाजाचे स्वरूप खालील प्रमाणे राहिल.

१. सदर समिती तज्ञ संस्थांच्या समन्वयाने दरवर्षी Heat Action Plan बाबत आढाव घेईल व प्राप्त प्रतिसादर प्रमाणे बदल सुचविणे.
२. प्रभाग समिती स्तरावर समन्वय साधणे व तेथील Heat Wave Action Plan बाबत केलेल्याकामाचा आढाव घेईल.

३. सदर समिती स्थानिक NGO/CSO प्रभागातील कार्यकर्ते यांच्या समवेत परस्पर संवाद (Interaction) करेल.
४. सदर समिती Heat Wave Action Plan च्या अनुषंगाने आवश्यक असणाऱ्या कामांची पडताळणी करेल, जागा निश्चिती करेल तद्नंतर प्रस्ताव मा.आयुक्त सो. यांचेकडे सादर करण्यात येईल.
५. सदर समिती शासनाने दिलेल्या मार्गदर्शक तत्वांची Heat Wave Action Plan बाबत अंमलबजावणी होईल हे सनिश्चित करेल.
६. संबंधित विभागाकडून Heat Wave Action Plan बाबत कामांची अंमलबजावणी प्रभावीपणे होत असल्याचे दक्षता घेईल.
७. सदर समिती Heat Wave बाबत आपत्कालीन परिस्थिती निर्माण झाल्यास जलद गतीने व प्रभावी पणे माहितीचे प्रसारण (Communication) होईल. याबाबत दक्षता घेईल.
८. सदर समिती देखरेखीसाठी व अंमलबजावणीसाठी जबाबदार राहील व वेळोवेळी आयुक्त कार्यालयात अहवाल सादर करेल.

(अभिजीत बांगर)
आयुक्त तथा प्रशासक
ठाणे महानगरपालिका, ठाणे

Annexure 5: Mapping hyperlocal vulnerabilities and risks through a resilience index and 5x5 matrix as part of the implementation strategy

To map the heat risk and vulnerabilities at a more granular level beyond wards to inform hyper-local decision making and heat action, a 5x5 matrix of indicators based on the framework provided by the Climate Disaster Resilience Index (CDRI) will be used as part of the Thane HAP implementation strategy (Joerin and Shaw 2011). The framework has already been piloted in cities globally, including in Manila.

The CDRI framework employs a structured questionnaire with five dimensions—physical, social, economic, institutional, and natural. Each dimension encompasses a set of questions designed to gauge the city's resilience to climate-related hazards, notably heatwaves. The framework, having undergone successful piloting in various cities, contributes to a more detailed and effective understanding of local vulnerabilities.

Table A2: List of dimensions and parameters of CDRI

Physical	Social	Economic	Institutional	Natural
Electricity	Population	Income	Mainstreaming of disaster risk reduction and climate change adaptation	Intensity/ severity of natural hazards
Water	Health	Employment	Effectiveness of city's crisis management framework	Frequency of natural hazards
Sanitation and solid waste disposal	Education and awareness	Household assets	Effectiveness of city's institutions to respond to a disaster	Vulnerability of ecosystem services
Accessibility of roads	Social capital	Finance and savings	Institutional collaboration with other organisations and stakeholders	Land-use in natural terms
Housing and land-use	Social cohesion and community preparedness during a disaster	Budget and subsidy	Good governance	Environmental policies and food security

Source: Joerin and Shaw 2011

Each dimension comprises five parameters, with five corresponding questions or variables. Each variable is rated on a scale from 1 (poor, not available/existent) to 5 (good, fully sufficient). Subsequently, within each parameter, variables are ranked against one another. The weighting of variables, ranging from 1 (not important) to 5 (very important), is determined based on their significance within the context of the city or ward. This approach empowers the questionnaire respondent, whether an individual or group, to assign appropriate importance to each variable.

This hyperlocal analysis, guided by the framework and drawing insights from the implementation of similar frameworks in Indian cities like Delhi and Chennai, will facilitate the precise execution of Thane HAP strategies at the hyper-local level (Joerin and Shaw 2011; Joerin et al. 2012b; Prashar, Shaw, and Takeuchi 2013; Joerin et al. 2012a). It will enable the identification of vulnerabilities and the formulation of targeted heat risk mitigation measures which are tailored to the specific characteristics and risks of Thane's wards.

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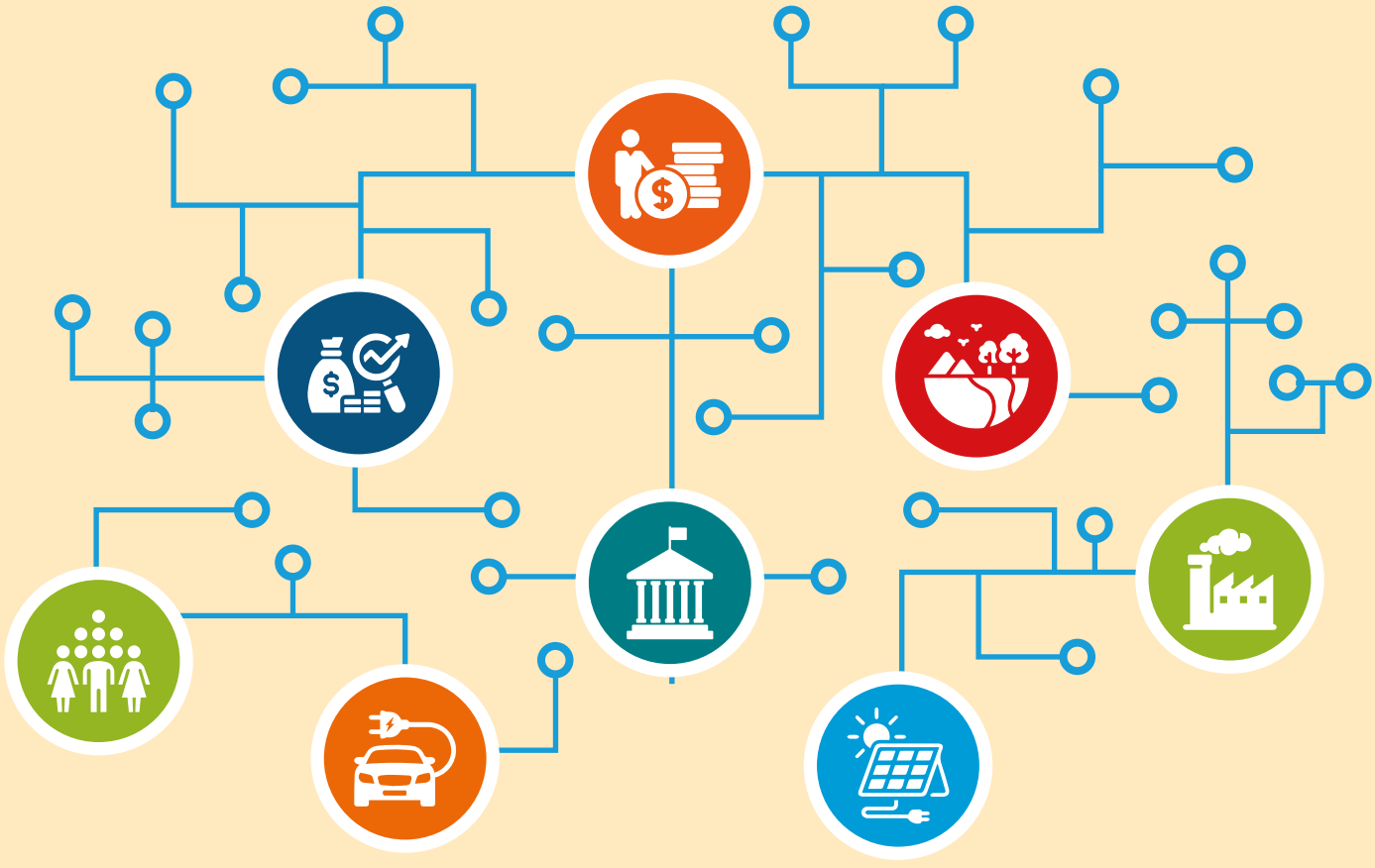
Acronyms

AR	Assessment Report
CAA	Constitution Amendment Act
CCCma	Canadian Centre for Climate Modelling and Analysis
CCCR	Centre for Climate Change Research
CEEW	Council on Energy, Environment and Water
CNRM-CM	Centre National de Recherches Me´te´orologiques
COR	Commissioner of Relief
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRIDA	Central Research Institute for Dryland Agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAPCCHH	District Action Plan on Climate Change Human Health
DDMA	District Disaster Management Authority
DEOC	District Emergency Operation Centre
DMC	Destination management company
DTO	Distric Transport Office
ERA	European Environment Agency
FSI	Forest Survey of India
GDP	Gross domestic product
GFDL	Geophysical Fluid Dynamics Laboratory
HAP	Heat Action Plan
HI	Heat index
HRI	Heat-related illness
HHAP	Heat-health action plan
HHWS	Heat-health warning systems
IAS	Indian Administrative Service
ICAR	Indian Council of Agricultural Research
ICC	India Climate Collaborative
IDSP	Integrated Disease Surveillance Program
IEC	Information, education, and communication
IITM	Indian Institute of Tropical Meteorology
ILO	International Labour Organization
IMD	India Meteorological Department
IMDAA	Indian Monsoon Data Assimilation and Analysis
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
IPSL	Institut Pierre-Simon Laplace

ISO	Intra-seasonal oscillations
ITCZ	Inter-tropical convergence zone
JJAS	June, July, August, September
KPI	Key performance indicators
LPA	long-period average
LST	Land surface temperatures
LULC	Land use land cover
MNDWI	Modified normalized difference water index
MoEFCC	Ministry of Environment, Forests, and Climate Change
MoES	Ministry of Earth Sciences
MoHFW	Ministry of Health and Family Welfare
MOHUA	Ministry of Urban and Housing Affairs
MPI	Max Planck Institute for Meteorology
NCDC	National Centre for Disease Control
NCMRWF	National Centre for Medium Range Weather Forecasting
NDBI	Normalized difference built-up index
NDMA	National Disaster Management Authority
NDMP	*National Disaster Management Plan*
NDVI	Normalized Difference Vegetation Index
NRSC	National Remote Sensing Centre
NOAA	National Oceanic and Atmospheric Administration
OND	October, November, December
PIB	Press Information Bureau
PTI	Press Trust India
RBI	Reserve bank of India
RCM	Regional climate model
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
RDMC	Regional Disaster Management Cell
RNP	Rohini Nilekani Philanthropies
RTO	Regional Transport Office
SAPCC	State action plan on climate change
SDG	Sustainable Development Goals
SDMA	State Disaster Management Authority
SEOC	State Emergency Operation Centre
SOP	Standard operating Procedure
SRMC	State Remote Sensing Centre
SWM	Solid Wast Management
TMC	Thane Municipal Corporation
UHI	Urban Heat Island
UK	United Kingdom
ULB	Urban local Bodies
USD	United States Dollar
WHO	World Health Organization

Notes



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