Jodhpur Heat Action Plan 2023

NRDC India

म्हारो जोधपुर
नगर निगम उत्तर

MAHILA HOUSING SEWA TRUST
Dignified Home, Dignified Work, Dignified Life

Contents

Executive Summary

Climate change is known to have significant impacts globally on the frequency, duration, and intensity of extreme weather events, including heat waves.[1] More specifically, the Indian subcontinent is experiencing higher temperatures that arrive earlier and stay for longer, and will likely continue to experience more frequent heat waves in the coming decades.[2]

In April 2022, India was plunged into the grip of a punishing early spring heat wave that brought the country to a standstill, with temperatures in the capital, New Delhi, topping 46°C.[3] Heat wave-like conditions prevailed in 16 states of India from March 11 to April 24, 2022.[4] By April 29, 2022, almost 70% of India was affected by extreme heat.[5] The India Meteorological Department (IMD) reported that in April 2022, Rajasthan's Ganganagar exceeded 45°C six times, three of which were consecutively on April 28, 29 and 30. The unusual early season April heat wave caused some stations to break their all-time maximum temperature records.[6] In particular, Jodhpur, located in the semi-arid climate of the State of Rajasthan, consistently experiences high daytime temperatures from March-June every year. On May 19, 2016, the village of Phalodi in Jodhpur recorded a daytime temperature of 51°C, ranking as the highest temperature recorded in India.[7]

Extreme heat fueled by human-caused climate change is adversely affecting the ecology, economy, and health of people from all walks of life and all of parts of the world. Extreme heat takes a substantial toll of lives in India. India's Ministry of Earth Sciences points out that the mortality rates per million for heat waves have increased by 62.2% during the last four decades.[8] According to the National Disaster Management Authority (NDMA) and IMD, India registered 1743 deaths between 2016-2021 due to the impact of extreme weather events including heat waves.[9] In addition to mortalities, extreme heat adds to the difficulties of many poor and marginalized communities—who are living in inadequately ventilated, hot, and crowded homes—to maintain thermal comfort due to the high costs of cooling.[10]

Extreme heat threatens the health and livelihood of millions of occupationally exposed people in India. According to the World Bank, India may account for 34 million of the projected 80 million global job losses from heat stress associated with productivity decline.[11] Lost labor from rising heat and humidity could result in loss up to 4.5% of India's Gross Domestic Product (GDP) (equivalent to approximately US$150-$250 billion) by the end of this decade.[12] Further, according to IMD in its Statement on Climate of India in 2022, anomalously high temperatures and heat waves reduced crop yields, especially wheat.[13] In these many ways, heat wave conditions are likely to have continuing, deadly consequences for human health, making the role of adaptation strategies and mitigating heat risks very critical. It is important to develop zero tolerance towards heat wave-related deaths.

As heat risks intensify, city leaders in Jodhpur are taking steps to develop a local Heat Action Plan (HAP), following the steps of Ahmedabad, which implemented South Asia's first HAP that has helped avoid more than 1,100 deaths a year since its launch.[14] Ahmedabad's groundbreaking work is informing discussions in Jodhpur on ways to adapt to extreme heat hazards in an equitable and durable way.[15]

Essentially, a local Heat Action Plan aims to implement the following key strategies:

- Vulnerability Assessment
- Establish Early Warning System and inter-agency coordination
- Preparedness at the local/primary level for health and education department
- Health system capacity building
- Public awareness and community outreach
- Colloboration with non-government organisations and civil society
- Evaluating the impact (solicit feedback for reviewing and updating the plan)

1. Introduction

1.1 Climate Change and Extreme Heat in India

Extreme heat is of concern all over the world for causing human deaths of ~166,000 globally during 1998–2017.[16] India has been substantially affected by deadly heat waves, which are being fueled by the warming climate, and pose serious risks to India's increasing population.[17]

There is not one consistently applied global heat wave definition. The World Meteorological Organization (WMO) defines a heat wave as "a marked warming of the air, or the invasion of very warm air, over a large area; it usually lasts from a few days to a few weeks." The India Meteorological Department (IMD) monitors heat waves using station data and uses maximum temperature and threshold of anomalies to declare a heat wave. The heat waves over India have also been examined for the impact of El Niño Southern Oscillation (ENSO) and showed that years preceding and succeeding El-Nino events experienced warmer than average temperatures.[18]

Heat waves occupy a crucial class of climate-related hazards, with numerous studies exploring the connection between health outcomes and thermal stress.[19] While there have been many impact studies related to heat waves in the developed world, the population most prone to risk of death and conspicuous harm caused by extreme heat is under-represented. In India, heat waves have an impact on many critical sectors including health, agriculture, ecosystems, and national economy.[20]

Severe heat waves that resulted in thousands of deaths to humans and livestock were reported around Odisha (eastern India) in 1998, Andhra Pradesh in 2003, and Ahmedabad and other parts of Gujarat (western India) in 2010.[21] The 2015 heat wave is considered one of the deadliest heat waves that India experienced and affected the south-eastern part of India which claimed more than 2500 lives.[22]

Most of the heat waves over India occur in the period from March to June, before the establishment of the southwest monsoon.[23] Figure 1 shows the time-series of 2m air temperature (T2M in degree Celsius, °C) over India for the months of March, April, May and June. All the months show a significant increasing trend except for the month of June.

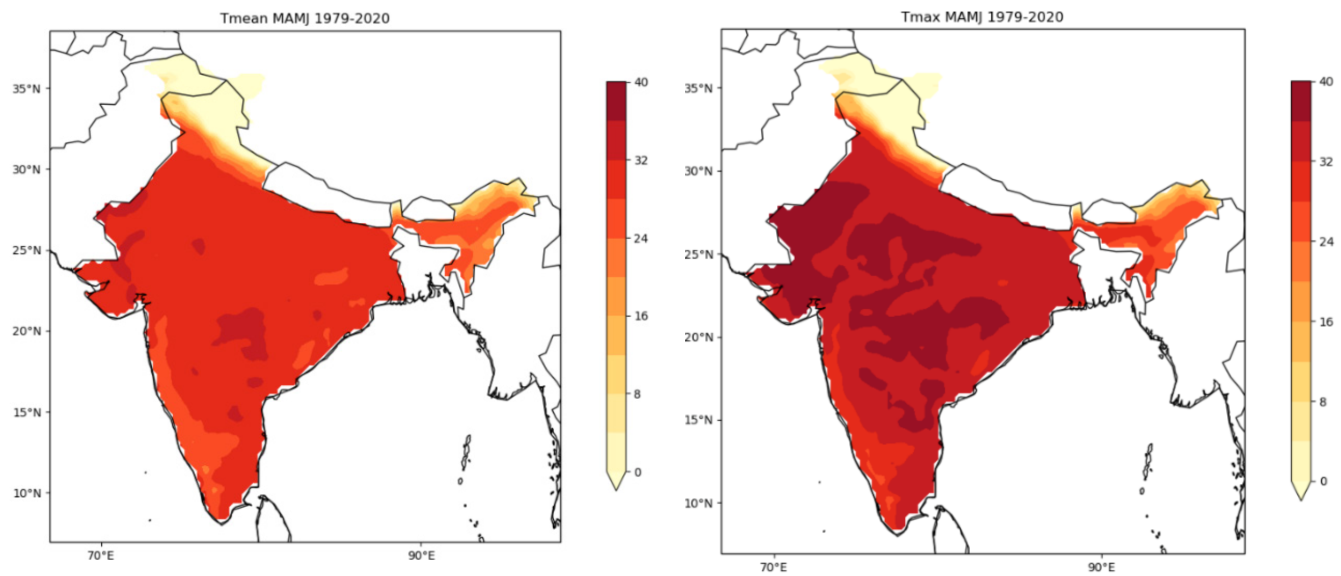


Figure 1: *Time series of Indian mean T2M for 1979-2018 for March, April, May and June over India. Data was extracted from ERA5 reanalysis.[24] The trends are statistically significant at 95% level and were calculated using Mann Kendall test.*

The north-western and central part of India during the March – April – May – June (MAMJ) season experience the highest temperatures (Figure 2).

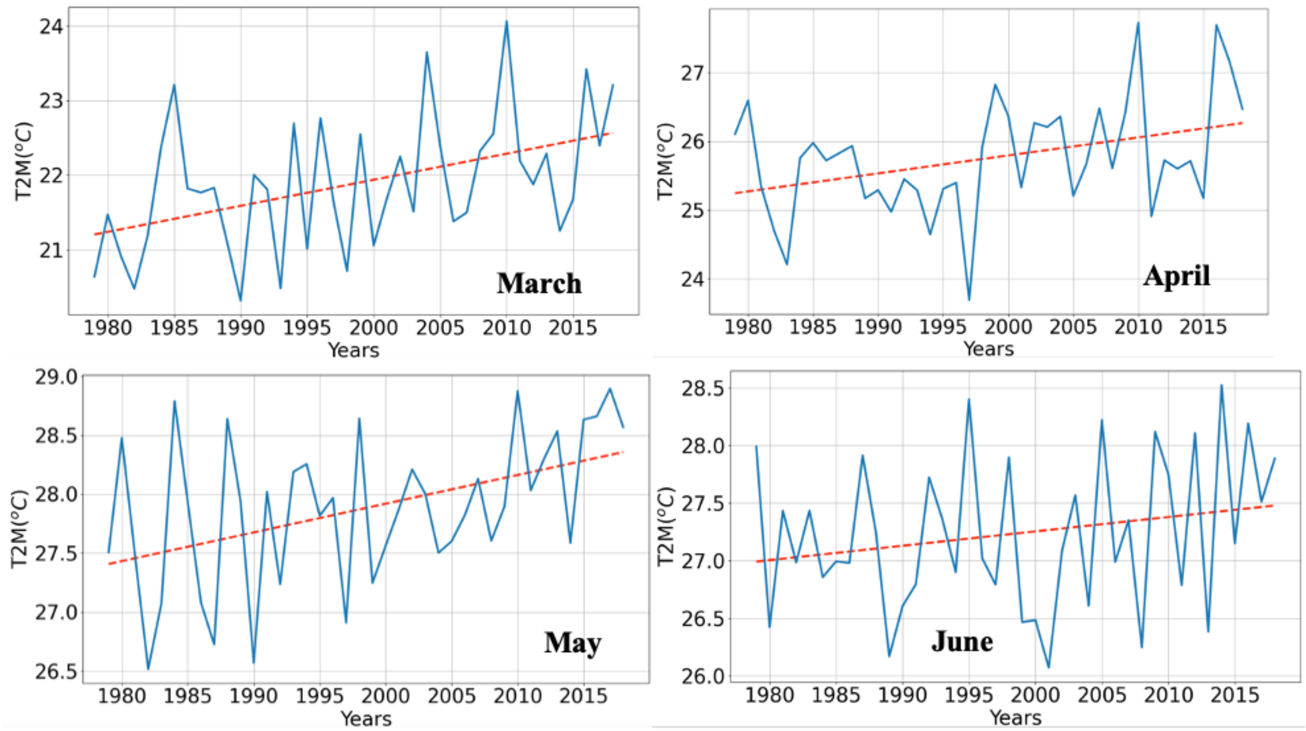


Figure 2: *Seasonal Climatology (March, April, May & June – MAMJ) (a) 2m Mean Temperatures (T2M, °C) and (b) 2m Maximum Temperatures. (Data: ERA5 Reanalysis 1979-2020 – Daily T2M and TMAX).*

1.2 Heat waves In India and Corresponding Risks

Extreme temperature episodes present a challenge for public health since they have significant impacts on wellbeing. The World Health Organization (WHO) also has identified climate change as a global risk factor for health, with heat waves presenting a particularly acute risk. The amount of heat exposure an individual can tolerate depends on an individual, and the tolerance range of an individual narrows with age and or illness. Global evidence indicates that high temperatures cause heat stroke, heat exhaustion, heat syncope (fainting), and heat cramps.[25] Heat waves are also related to increase in emergency hospital admissions, including for kidney and respiratory disease, particularly in the elderly.[26] Other heat risk factors include older and younger age, disability, or external factors like housing and certain behaviors The external factors vary depending on a person's geographic location and their possible adaptations to local heat.

Research linking temperature and health effects in developing countries like India is sparse since data challenges currently make it difficult to estimate deaths attributable to heat waves. India is among one of the world's most heat hazard-prone countries—a study lists India second among the top rank five countries in the world where the total exposure of the population to heat wave days per year is high.[27]

Deaths from heat waves are not inevitable, and, in fact, they can be greatly reduced through the implementation of relatively simple and cost-effective actions. Leaders in India across government, academia, and civil society have been working to strengthen resilience to warming temperatures for years. One key knowledge sharing platform for heat-health adaptation is the NDMA national workshop on heat waves, held annually right before the start of the heat season, to assess heat preparedness among various stakeholders and to support timely implementation of Heat Action Plans (HAPs). The city of Ahmedabad experienced one of the most devastating heat waves in India in 2010, when more than 1300 people were killed in a week in the city alone, prompting the start of efforts to develop coordinated Heat Action Plans.[28]

NDMA supports national implementation of state and city Heat Action Plans, efforts that help to coordinate local heat response interventions through heat-health early warning systems. Since the first plan launched in city of Ahmedabad a decade ago, HAPs have now reached 23 states and over 100 cities and districts, thanks to the collaboration of NDMA, IMD, and partners such as the Indian Institute of Public Health-Gandhinagar and Natural Resources Defense Council (NRDC).[29]

1.3 Heat Risks in Jodhpur

The state of Rajasthan is historically one of the hardest hit by heat in the country, and heat waves are considered a disaster by the state authorities.[30] It is especially characterized by low and inconsistent rainfall, high air and soil temperature, exceptional sun-powered radiation, and high wind speed. The arid and semi-arid regions of the state experience high daily and occasional fluctuations in temperature as a result of proximity to the Thar desert. Midyear (March – July) temperature averages around a range of 26–46°C.

Jodhpur, one of the major cities in the state of Rajasthan, has national significance because of the high influx of international as well as national tourists every year. Positioned near the Thar desert's stark landscape, the city experiences bright and sunny weather throughout the year. On May 19, 2016, the village of Phalodi (a town in the Jodhpur district) logged the highest daytime temperature reading ever recorded in India at 51°C (123.8 °F), which was ranked third highest among global temperatures observed that day. Annual and maximum temperatures in Jodhpur have been increasing for the last few decades. Given these dangerous temperature trends (Figure 3), along with high population density and continuing urbanization, improving heat preparedness is imperative in a "Tier 2" city like Jodhpur. Tier 2 cities have populations ranging from of 50,000-100,000 and are considered "engines of growth" where economic potential is still developing. Therefore, it becomes essential to incorporate the action plans right from the nascent stage in Tier 2 cities, so that the cities are more prepared for and resilient in the future.

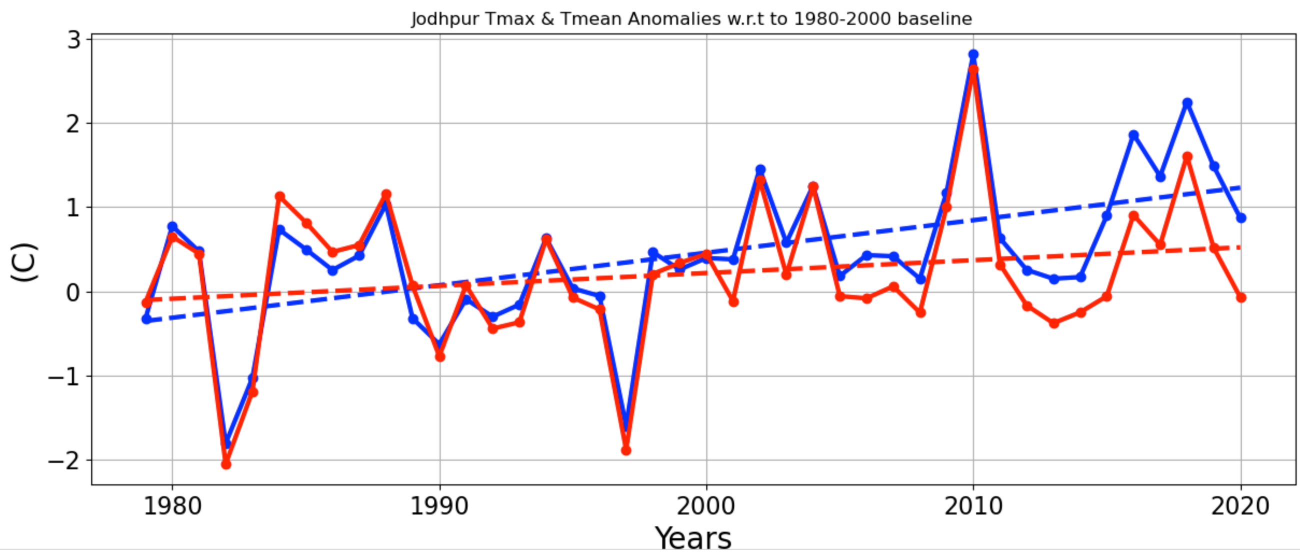


Figure 3: *Annual MAMJ Tmax (red) and Tmean (blue) anomalies with respect to 1980-2000 baseline period for the city of Jodhpur (26.23° N, 73.02° E). Both Tmax and Tmean show an increasing trend.*

In 2023, as India assumes the Presidency of the Group of Twenty nations (G20), it is highlighting a theme of "One Earth-One Family-One Future" and ways for the international community to activate transformative actions that could secure a cleaner and greener future.[31] As part of India's G20 leadership, the country is launching a new working group focused on Disaster Risk Reduction. That effort could not be more urgent: with the 2023 heat season nearly here, forecasters are worried that the effects of El Niño could push temperatures to record-setting levels once again.[32]

With the IMD's 2023 seasonal outlook already pointing towards above normal temperatures and higher heat wave probability for Rajasthan (Figure 4 a and b), action is currently underway in Jodhpur to develop a more coordinated heat response.[33] Last year, in June 2022, NRDC and Mahila Housing Trust (MHT) co-organized a workshop for Jodhpur Nagar Nigam North (JNNN) to initiate a dialogue on the development of a local HAP (Figure 5).

MHT, building on its strong presence in the city, has been working to facilitate and empower women in poor communities to improve their housing and living conditions. Low-income neighbourhoods are more heat-vulnerable because of heightened exposures and limited access to cooling options. In its grassroots program on climate resilience, MHT is installing cool roofs and building heat resilience by enabling legal access to electricity and renewable energy, implementing cooling solutions for thermal discomfort in cities, and extending climate risk insurance to low-income households.

Jodhpur's HAP, slated for launch this heat season, will prioritize an enhanced focus on the needs of particularly vulnerable groups, identified through a risk assessment (RA) that characterizes spatial patterns in heat-sensitive populations, environmental risks, and community assets. Scientific evidence in understanding how the population is affected in different regions is crucial in developing HAPs. The risk score of each ward in the city accounts for local heat exposures, household inhabitants' physical sensitivity to heat, and adaptive capacity to minimize exposures through resources like urban cooling centres, parks, and water distribution nodes. The power of the RA approach is its flexibility to incorporate a range of relevant data sources—spanning from individual biophysical characteristics to population-level demographic, health, economic, and environmental data. The Jodhpur RA will form the basis for the city's Heat Action Plan, as the index provides new spatial information for municipal leaders to identify heat exposure risks and prioritize 'at-risk' areas for targeted local interventions.

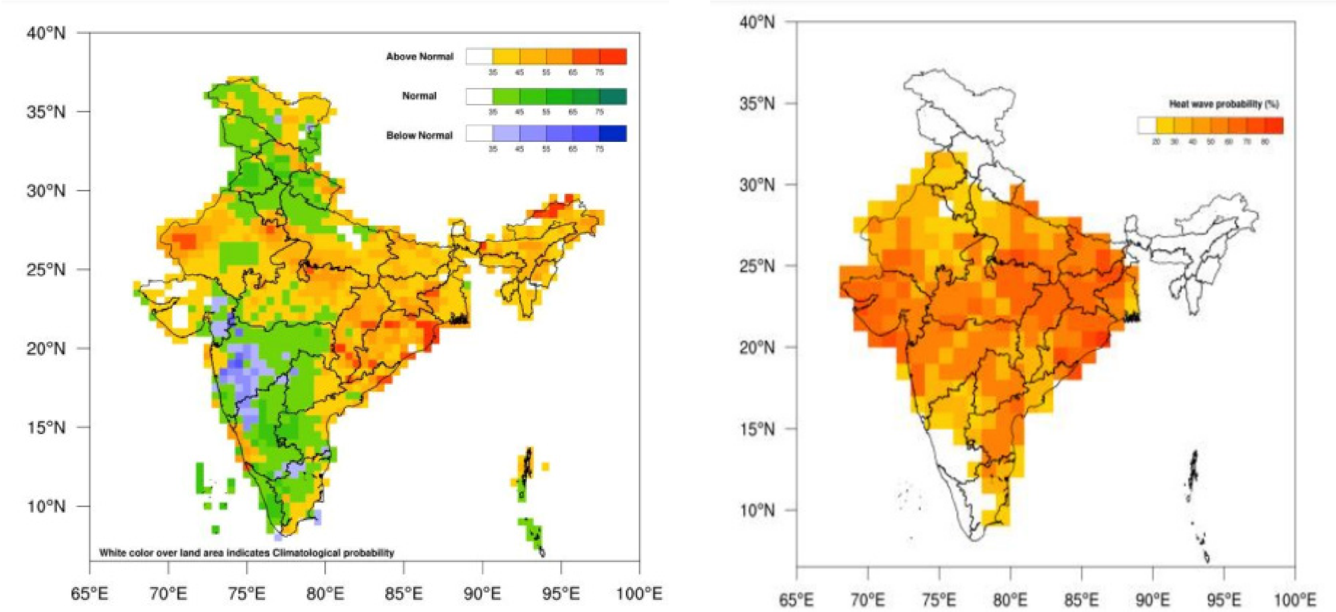


Figure 4: *IMD 2023 Seasonal Outlook (a) Probability Forecast of Maximum Temperature for March to May 2023 (b) Probability Forecast of heat wave for March to May 2023*

Figure 5: *Experts at the MHT-NRDC June 2022 workshop in Jodhpur, Rajasthan on 'Strengthening Preparedness and Response to Extreme Heat through Heat Action Plans and Cool Roofs" (Credit: Mahila Housing Trust)*

2. Preparing Jodhpur's Heat Response

2.1 Background and City Topography

Rajasthan is the largest state in India, encompassing 22,850 sq. km in the northwestern part of the country.[34] Major cities in the state include Jaipur, Jodhpur, Kota, Bikaner, Ajmer, and Udaipur. Jodhpur is a popular tourist destinations and is known as the sun city for the bright and sunny weather it enjoys year-round. The state economy also depends to a large extent on the tourism sector, which accounts for almost 15% of the state's economy.[35] Jodhpur is in an arid zone of Rajasthan and accounts for about 12% of the total arid zone of the state, including the great Thar desert. Extreme heat in the summer and cold in the winter is a major characteristic of this region, where temperatures are extremely high throughout the period from March to October. Only 6,948 hectares, accounting for 0.3% of the total reported area of land use in Jodhpur was covered with forests in 1999-2000.[36] Due to the sandy soil and dry climate of the district, only shrubs and thorny bushes of vegetation are found in the vegetated areas of Jodhpur. The level of groundwater in Jodhpur does not get frequently replenished due to the extremely low levels of rain in the district.[37]

The city of Jodhpur, set on the foothills of the Mehrangarh Fort, is known for its culture and heritage, including the traditional blue color of the houses and the traditional construction techniques followed in building them. In the modern era, the settlement structures and building materials have changed, in some cases causing significant negative impacts on the coping capacity of Jodhpur against high temperatures and heat stress.[38] Uneven distribution of socio-economic and cultural resources across Rajasthan affects various population groups and capacity to respond as well as to adapt to the hazards. Lack of adequate provision of many essential determinants of health such as access to safe drinking water, adequate sanitation systems, diet and nutrition, safe housing and gender equality play a crucial role in establishment of vulnerability among the population. Rural Rajasthan is additionally vulnerable to extreme heat because of its lack of heat-health awareness, poor access to healthcare, and very limited access to cooler places.

2.2 Local and National Governance for Heat Waves and Heat Related Illness

Various government functionaries—including Disaster Management & Relief Department (DMRD), Public Health Department, District and Block Administration, Public Health Engineering and Education Department, Jodhpur Municipal Corporation (Mayor, Ward Councilors, Medical Officer, Nodal Officer, Divisional Commissioner), India Meteorological Department in Jodhpur, Labour Department, School and Education Board, Additional Collector, Electricity Board, Ground Water Department, Tourism Department, Rajasthan Health Department and Chief Medical and Health Officer—are all crucial in developing and implementing various adaptation and mitigation strategies to combat extreme heat and its consequences. In fact, the Royal Family of Jodhpur, which has an unconventional bearing on the city, could also play a key role in making Jodhpur resilient to extreme heat.

Because heat waves increase the incidences of illness and death, the Government of India through the Ministry of Health and Family Welfare (MoHFW) issued 'Guidelines on Prevention and

Management of Heat-Related Illnesses (HRI)" and "National Action Plan on HRI" in July 2021. Since 2015, the Integrated Disease Surveillance Programme (IDSP) at the National Centre for Disease Control (NCDC) under MoHFW is collecting and compiling data on HRI, and deaths due to HRI, during March to July every year from 17 vulnerable states including Rajasthan.

Prior to 2015, heat waves were being dealt with exclusively by the States (including Rajasthan, which formally recognizes heat waves as a local disaster) in a response-centric manner. From 2016, NDMA steered the path towards heat-wave risk reduction measures through national guidelines issued in 2016 (revised in 2019) that include short-term, medium term and long-term solutions for heat-wave risk reduction.

At the national level, the National Disaster Management Authority (NDMA) issued the National Guidelines for 'Preparation of Action Plan – Prevention and Management of Heat Wave' in 2016, to provide a framework for implementation, coordination, and evaluation of extreme heat wave-related activities in India. Further, NDMA revised the National Guidelines on Heat Waves in 2017 and again in 2019.

Along with NDMA, India Meteorological Department (IMD) provides a special focus on early warning and impact-based forecast/alerts of heat wave events over a particular area, which helps the States in taking appropriate measures in mitigating the adverse impacts. National Centre for Disease Control (NCDC) monitors and collects data on epidemic-prone diseases on weekly basis, builds capacity of medical staff, provides justification of illness and casualty certificates etc.

The concerned State Governments have taken necessary preparedness and mitigation measures for heat waves. During the last few years, multiple State Governments, Districts, and Cities have prepared Heat Action Plans (HAP) and are now implementing them. Based on these Action Plans, the State Governments and District administration take all possible measures to prevent mortality due to heat waves.

Text Box: *State Institutions for Combating Extreme Weather Event – Heat Waves (Ministry of Home Affairs, Government of India)*[39]

2.3 Stakeholders Workshop

Figure 6: *Letter of Intent signing among Jodhpur Nagar Nigam North (JNNN), NRDC, and MHT at the stakeholder workshop held in March 2023 for Jodhpur Heat Action Plan (HAP) (Credit: NRDC/MHT)*

On March 20-21, 2023, JNNN, MHT, and NRDC organized a stakeholder workshop to gather input on the draft heat action plan. This workshop was organized with the objective to seek support and input from various key stakeholders on the Heat Action Plan for Jodhpur. The workshop convened experts in climate, health, heat waves and public policy to share how heat preparedness and response measures can be both strategic and quickly effective in reducing vulnerability to extreme heat. Specifically, attendees included early warning and forecasting agencies, local government departments, academic research institutions and community members working on improving local heat preparedness.

The workshop also informed the participating stakeholders on the actions taken by MHT and NRDC to mitigate the effects of heat stress and roles, and the responsibilities of key stakeholders in implementing a Heat Action plan. Related discussion topics included:

- Informing the stakeholders on the Vulnerability Assessment conducted for the North zone of Jodhpur.
- Sharing the existing measures adopted to strengthen resilience to extreme heat in North of
- Jodhpur bringing in the aspects of low-capacity adaptive passive cooling solutions.
- Mapping the early warning system and inter-agency coordination strategies for the heat action plan.
- Planning the local public awareness, community outreach, and community heat adaptation strategies.

Workshop participants identified additional city-specific short-, medium-, and long-term heat mitigation and adaptation measures to improve local resilience to intense heat, with particular focus on urban poor and other vulnerable groups. These suggestions are being incorporated into the city's draft Standard Operating Procedures (SOPs) for HAP implementation.

***Figure 7:** Ongoing discussions with various attendees at the stakeholder workshop in March 2023 for Jodhpur Heat Action Plan (HAP) (Credit: NRDC/MHT)*

3. Vulnerability Assessment of Heat Risks in Jodhpur

3.1 Context

Extreme heat events, both within and outside of India, typically lead to an overall increase in mortality and illness. However, the impact of extreme heat depends upon the vulnerability of the population. According to the Fourth Assessment Report of the IPCC, vulnerability is defined as "the propensity or predisposition to be adversely affected. It encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt."[40] A common approach to characterization of vulnerability and its subsequent mapping has been the development of vulnerability indices. Vulnerability indices are critical in hazard mitigation planning as they provide concrete risk scores.[41] The purpose of these indices is to highlight areas with elevated scores so that specific mitigation and adaptation strategies can be designed to reduce the likelihood of an event-related impact such as death, illness, loss of livelihood or damage to property and infrastructure. Furthermore, if heat and health are placed in a climate risk management framework, then information on vulnerability to heat at spatial resolutions finer than the regional or city scale is required to assist decision makers with the allocation of resources in the preparation for and response to extreme heat events. Therefore, identifying risk (at sufficient spatial resolution) is the first step to building cities that embrace heat-resilient pathways.

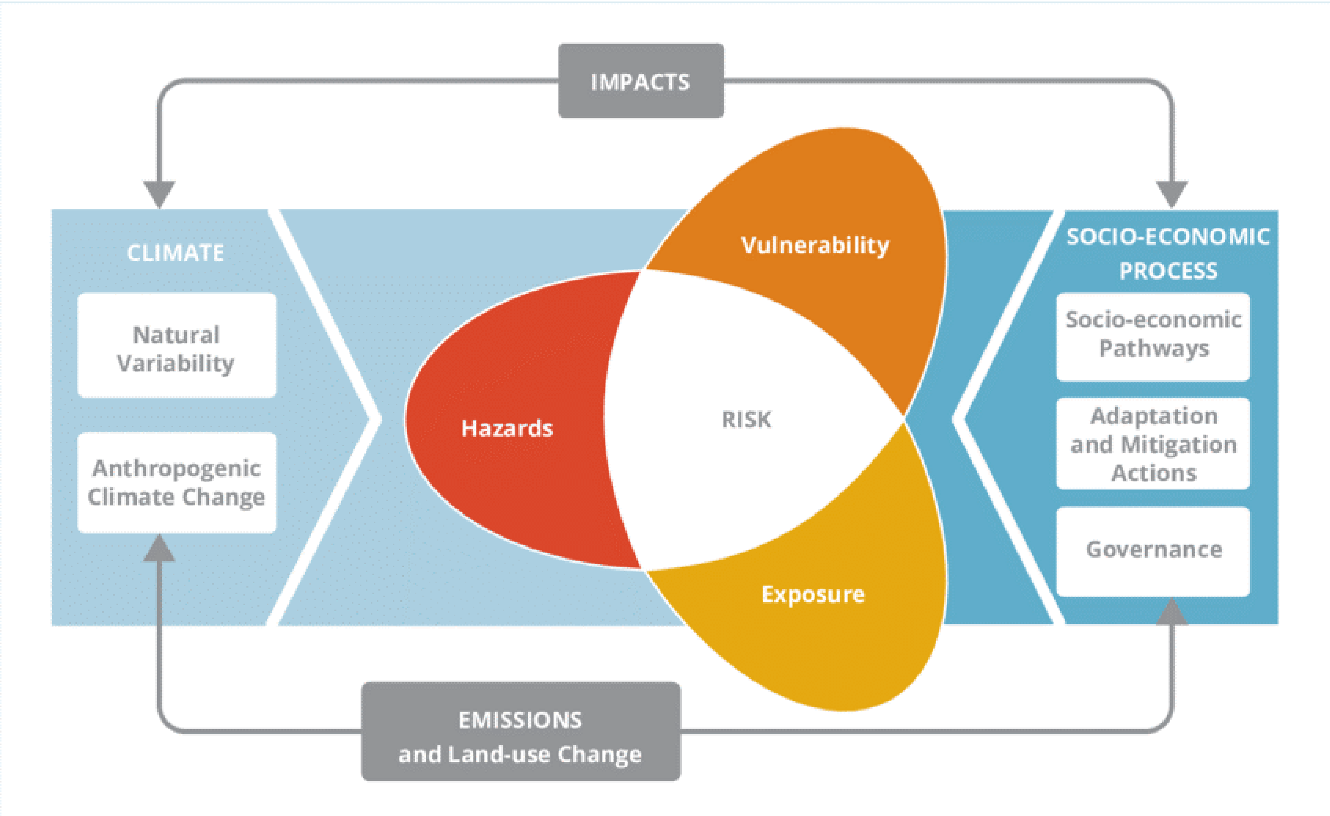


***Figure 8:** Illustration of the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) framework for components risk and vulnerability (Source: IPCC, 2014)*

3.2 Heat Vulnerability Assessment

One adaptation response to heat as a hazard in cities has been the development of heat health warning systems.[42] The purpose of these warning systems is to provide information on the health implications of hot weather conditions in a particular area. However, these warnings are often given at very broad regional scales. Heat Action Plans that provide detailed, sub-city scale warnings, and that incorporate key population risk factors, are the most useful for planning response actions. To aid this effort, our analysis assesses the preliminary extreme heat vulnerability for Jodhpur city and assigns risk scores to each of its 80 municipal wards.

Vulnerability to heat waves is a combined result of the socio-economic, physiological, climatological, as well as behavioral variables. Any change in one of these variables can lead to a minor or major change in the state of the system, which can either amplify or attenuate vulnerability. These variables can often be classified into **exposure, sensitivity, and adaptive capacity** (Figure 7). While an increase in exposure and sensitivity leads to an increase in vulnerability, an increase in adaptive capacity leads to a decrease in overall vulnerability.[43]

Exposure

The presence of people, livelihoods,species or ecosystems, environmental functions,services, and resources, infrastructure, or economic,social, or cultural assets in places and settings that could be adversely affected.

Sensitivity

The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Adaptive Capacity

The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Figure 9: *Diagrammatic representation of IPCC's Assessment Report 5 (AR5) categorization for three components of vulnerability: Exposure, Sensitivity and Adaptive Capacity (Source, IPCC 2014).*

3.2.1 Data Sources and Methodology

For the preliminary analysis, vulnerability to heat is conceptualized as a function of exposure to heat and the sensitivity of people. We selected fourteen physical, land use, land surface temperature, and socio-economic-related parameters (indicators) from different sources. Except for satellite-derived parameters, all other parameters were directly obtained from Census or local sources. These fourteen indicators (Table 1) were used to construct a ward vulnerability index.

Category	Indicators	Unit/Resolution/Data Format	Data Source and Time-Period
Exposure	Land Surface Temperature (LST	°C, 30 m, Raster	LANDSAT 8, USGS, 2013- 2022
	Population Density	No. of persons per square km, Vector	Jodhpur Nagar Nigam based on 2011 Census
Sensitivity	Slum Households	No. of slums per square km, Vector	Jodhpur Nagar Nigam North (JNNN), 2011
	Female Population	No. of females per square km, Vector	Census 2011
	Illiteracy Rate	No. of illiterate people per square km, Vector	Census 2011
	Normalized Differ-ence	Zonal Pixel Ratio, 30m, Raster	LANDSAT 8, USGS, 2022
	Built-Up Index (NDBI)	Km2, Vector	Primary Survey by MHT, February 2023
	Sites of Labor Chowks	-	Jodhpur Devel-opment Plan, 2013
	Land use	No. of health centers per km2, Vector	Chief Medical and Health Offi-cer (CMHO), 2022
Adaptive Capacity	Access to Urban Health Centers	No. of parks per km2, Vector	Jodhpur Devel-opment Plan, 2013
	Access to Parks	Zonal Pixel Ratio, 30m, Raster	LANDSAT 8, USGS, 2022
	Normalized Differ-ence Vegetation Index (NDVI)	No. of Baoris per km2, Vector	Primary Survey by MHT, February 2023
	Access to Baoris Normalized Differ-ence Water Index (NDWI)	Zonal Pixel Ratio, 30m, Raster	LANDSAT 8, USGS, 2022
	Access to Road	Km ratio, 30m, Raster	LANDSAT 8, USGS, 2022

Table 1: *Description of Variables used for Heat Vulnerability Assessment*

Rationale for selection of the variables:

3.2.2 Exposure

- Land Surface Temperature (LST): LST as a parameter for exposure helps to identify areas where heat conditions are more likely to occur.
- Population Density: High population concentration in India can be associated with poverty and a low standard of living (including poor quality housing) which contributes to heat exposure.

3.2.3 Sensitivity

- Number of Slum Households: Slum populations are often sensitive to higher temperatures due to poor nutrition, poor housing quality and inadequate housing conditions. Additionally, they may lack access to basic amenities such as clean water and sanitation, which can exacerbate the impacts of extreme heat.
- Female Population: Females are generally more sensitive to heat-related health impacts than males especially in developing countries.[44] Additionally, social and economic factors can exacerbate the impacts of extreme heat on females, such as gender-based inequalities in access to healthcare, education, and economic opportunities.
- Illiteracy Rate: People with lower literacy rate could be more sensitive to extreme heat events, as they are less aware of these events' potential danger or have less access to heat alerts.
- Normalized Difference Built-up Index (NDBI): It is a remote sensing index that captures the degree of Built up (development) in an area by measuring the difference between the reflectance of near-infrared and shortwave infrared spectral bands. The low values represent non-built-up areas such as vegetation, water bodies, and bare soil; and positive values represent built-up areas such as buildings, roads, and pavements. The built-up area can be more associated with heat wave risk, as these areas retain the heat longer than the surrounding environment, which contributes to the increase in overall temperature of the city.
- Labor Chowks: These are places where the informal workers come together and spend considerable amount of time looking for work. These chowks do not provide adequate shelter or other measures of protection from extreme heat. More generally, workers in informal sectors often have limited access to protective measures and healthcare services, and they may work in open spaces or poorly ventilated areas, which can increase their sensitivity to heat. Therefore, including sites of informal work as a parameter for sensitivity helps to identify sensitive populations that may require targeted interventions to reduce their risk to heat-related health impacts.
- Land use: Areas with high levels of industrial activity or mining may have a higher concentration of informal workers who may be at increased risk of heat-related health impacts due to their working conditions. Areas with high levels of impervious surfaces such as roads and buildings may experience higher temperatures due to the urban heat island effect. Areas with sparse or no vegetation, such as barren land or cremation grounds, may also be more prone to high temperatures.

3.2.4 Adaptive Capacity

- Access to Urban Health Centers: Urban health centers can play a crucial role in reducing the health impacts of extreme heat by providing medical treatment, counseling, and information about how to stay safe during periods of high heat. Having adequate good access to health services can help individuals and communities to better cope with the effects of extreme heat and reduce the severity of health impacts.
- Access to Parks: Communities with better access to parks and open spaces have higher adaptive capacity to cope with extreme heat. These areas can provide relief from high temperatures by reducing the urban heat island effect, leading to a cooler and more comfortable environment for residents.
- Normalized Difference Vegetation Index: NDVI is a remote sensing index used to measure the amount and health of vegetation in a given area. NDVI is calculated from the reflectance values of near-infrared and visible light bands captured by satellite remote sensing. High NDVI values, usually indicate dense and healthy vegetation, while low NDVI values, indicate sparse or non-vegetated areas, such as deserts or urban areas.
- Access to Baoris: (subterranean 'stepwells') Baoris can provide a source of cooling and drinking water during heat waves and can also serve as a social gathering place for the community.
- Normalized Difference Water Index (NDWI): NDWI uses near-infrared and shortwave infrared bands of electromagnetic radiation to distinguish between bodies of water and areas with low water content (such as soil, vegetation, or built-up areas). NDWI is an important parameter for assessing adaptive capacity to extreme heat, particularly in arid or semi-arid regions.
- Access to Roads: The indicator of Road density is associated with adequacy of road infrastructure. High road density means better accessibility and mobility, which can enable people to access essential services and resources during extreme heat events, such as medical care, water, and cooling centers.

3.2.5 Methodology

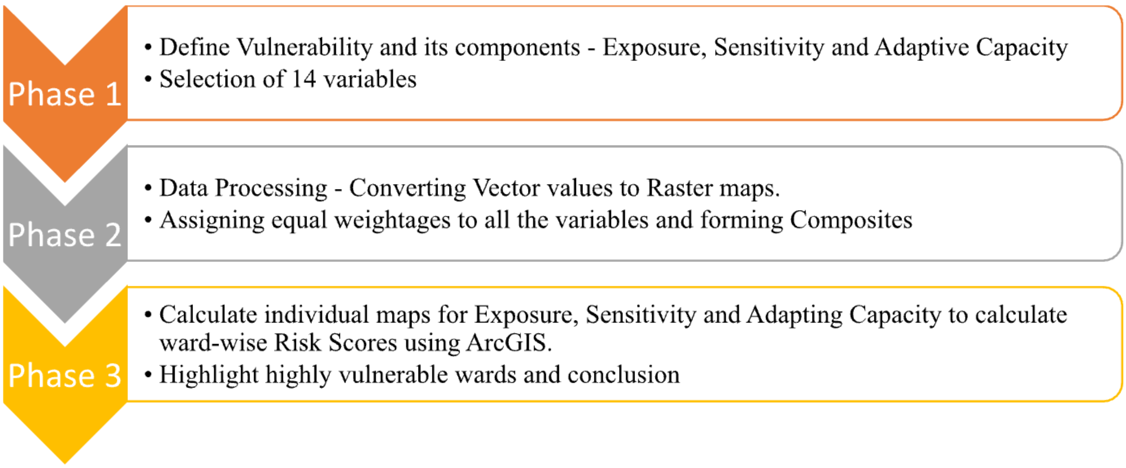


Figure 10: *Flowchart of Methodology to calculate ward-wise risk score for North Jodhpur*

ArcGIS 10.8.2 software developed by the Environmental Systems Research Institute was used to carry out the composite analysis. All the variables were assigned equal weights in this a preliminary analysis to identify highly heat-vulnerable wards in Jodhpur; other recent research applies the same approach to indicator weighting.[45] In future analyses, differential weighting of exposure, sensitivity, and adaptive capacity variables may be warranted based on their relative importance in determining population-level risks to extreme heat.

3.3 Results and Conclusions

The Risk Score for each ward was obtained by first calculating the Vulnerability which is a function of Exposure, Sensitivity and Adaptive Capacity (Figure 9).

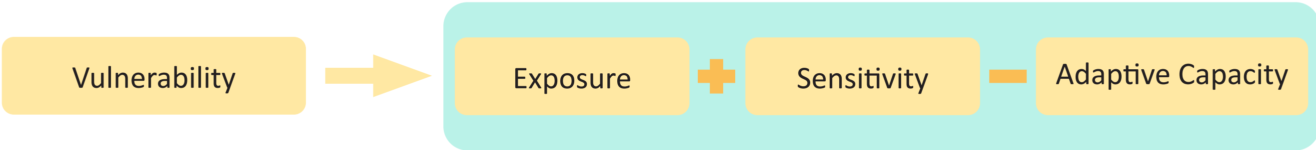


Figure 11: *Diagrammatic Representation of Vulnerability Function*

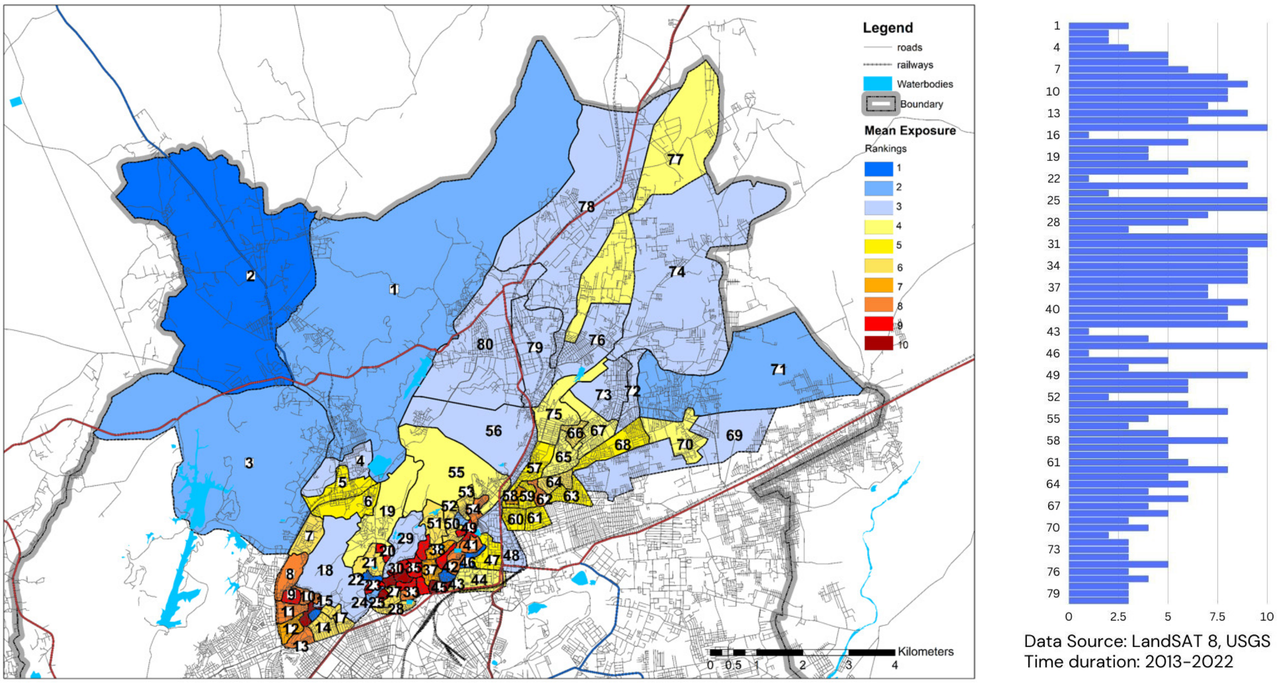


Figure 12: *Exposure composite (dark blue – 1 (lowest) to dark red –10 (highest) (a) GIS Representation (b) Ward wise score bar plots*

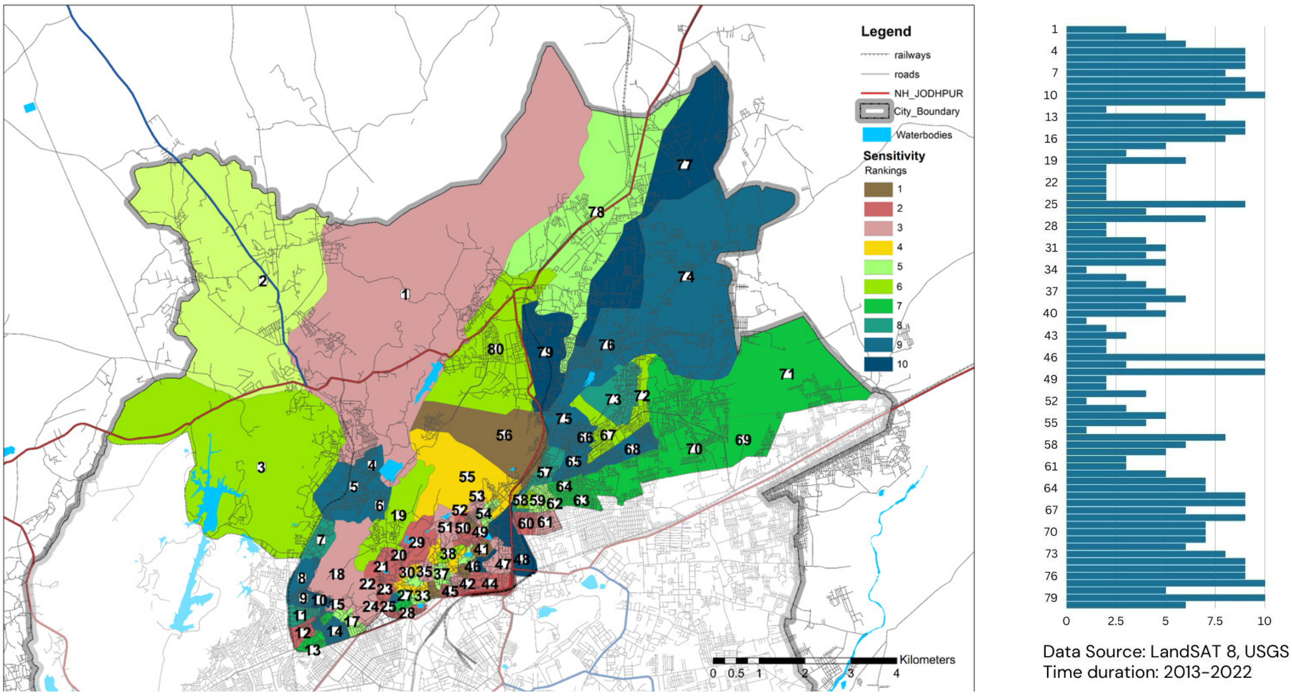


Figure 13: *Sensitivity composite (brown – 1 (lowest) to dark blue –10 (highest) (a) GIS Representation (b) Ward wise score bar plots*

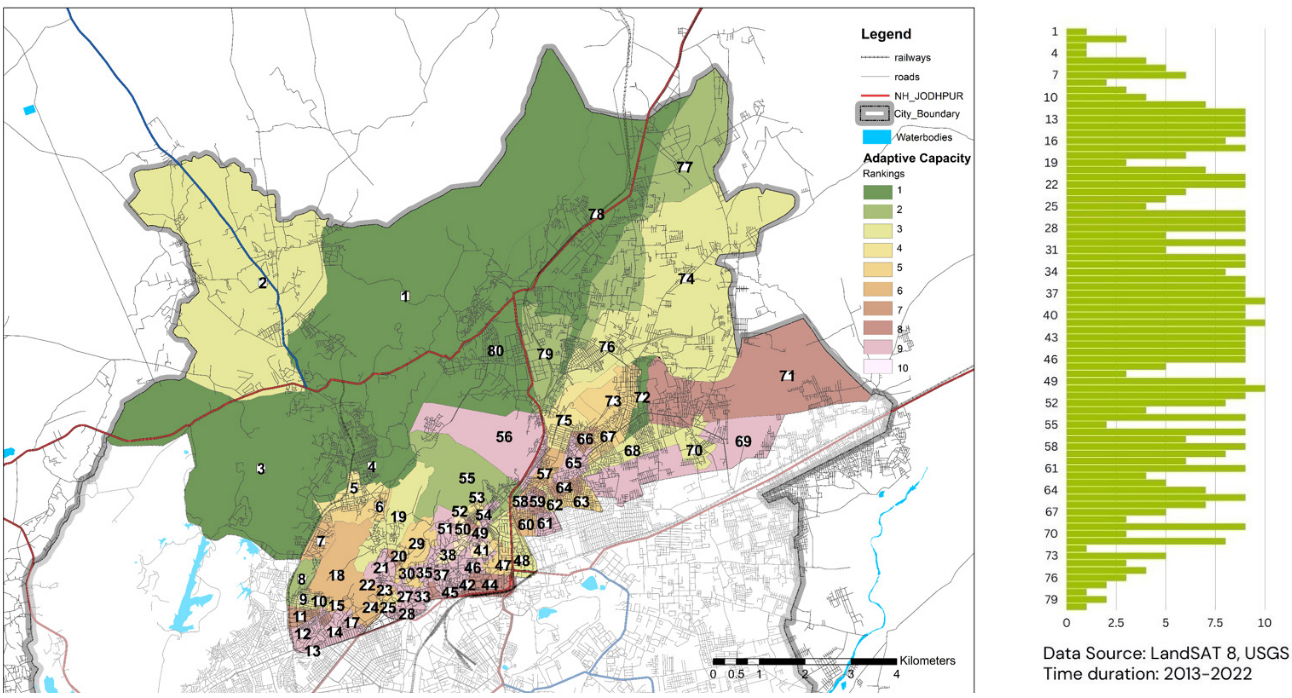


Figure 14: *Adaptive Capacity composite (green – 1 (lowest) to light mauve –10 (highest) (a) GIS Representation (b) Ward wise risk bar plots*

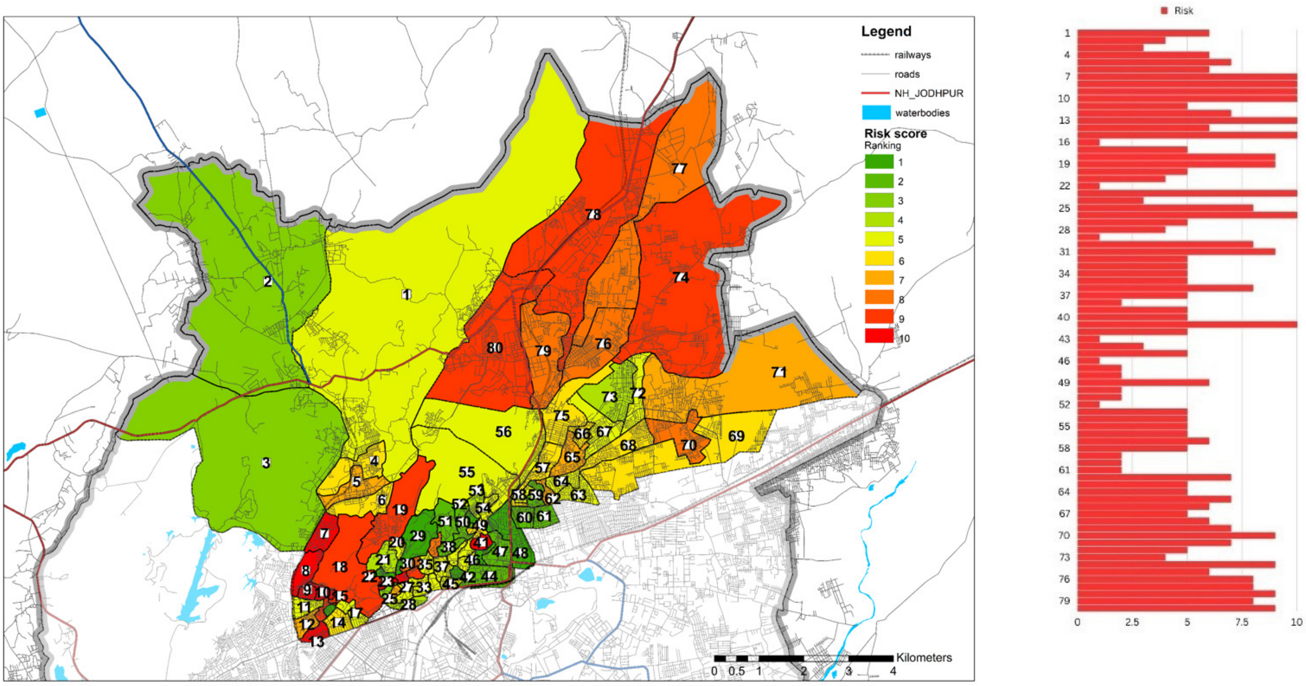


Figure 15: *Overall Risk Score composite (dark green – 1 (lowest) to dark red –10 (highest) (a) GIS Representation (b) Ward wise risk score bar plots*

Of the 80 wards in the risk map (Figure 13 a), they can be categorized as follows:

Category	Risk Score	Total No. of Wards	Percentage (%)
High	8 – 10	22	27.5
Moderate	5 – 7	37	46.25
Low	1 – 4	21	26.25

Table 2: *Categorization of Risk categories for Heat Vulnerability Assessment*

Most of the wards are present in the Moderate category, followed by high and then low risk wards.

High Risk Wards

Wards number 7, 8, 9, 10, 13, 15, 18, 19, 22, 23, 30, 41, 70, 74, 76, 77, 78, 79 and 80 are among the highlighted zones for bearing the brunt of extreme heat.

- In terms of exposure, these wards have moderate to extremely high LST and moderate to high population density.
- In terms of sensitivity, the wards that have dense population, more towards the periphery of South Jodhpur have higher female population (7, 8, 9, 10, 13, 18, 22, 70, 76, 78, 79 & 80), while some wards exhibit the lowest literacy rates.
- Presence of slum population in the northern part of the city makes certain wards (70, 74, 76, 77, 78, 79, 80) exceptionally more sensitive to heat events and coping capacity challenges.
- High NDBI is also a feature of wards 70, 74, 76, 77, 78, 79, 80 which adds to the effects of heat due to the development of urban heat islands (UHI) in the city.
- Adaptive Capacity (other than 'access to roads') in these wards is low most exposure and sensitivity variables are high. Thus, these wards need special attention, policy interventions and inter-agency coordination in future.

Moderate Risk Wards

Wards number 1, 4, 5, 6, 11, 14, 17, 55, 56, 58, 59, 63, 66, 67, 68, 72, 73, 75 experience moderate heat-health risk.

- These wards exhibit lower LST and have moderate population density (4, 5, 6, 7, 55, 56, 69, 72, 73, 75) which results in moderate exposure.
- In terms of sensitivity, high population density is not a problem in these wards, but the female population and is high and low literacy rates are comparable to high-risk wards.
- The NDBI for these wards is higher which denotes a high density of pavements, buildings and roads.
- These wards have labor chowks where daily wage workers (informal) work in open spaces and are directly sensitive to extreme heat.
- Some of the Urban Health Centres and green spaces are concentrated in these wards (4, 5, 6, 11, 55, 56, 58, 59, 63, 66, 67) which increases adaptive capacity and thus helps offset the high exposure and sensitivity.
- These wards exhibit high NDVI which indicates dense and healthy vegetation. Along with high NDVI in these areas, NDWI is also high which helps in mitigating the effects of extreme heat.
- Access to Roads is another important factor that improves adaptive capacity for wards in this category.

Low Risk Wards

Wards number 2, 3, 5, 20, 21, 23, 29, 38, 41, 42, 44, 46, 47, 50, 51, 52, 54, 59 experience lower exposure and sensitivity and have better coping capacity than rest of the wards. Despite the fact that some of these wards have high population density that increases the exposure and have low to moderate sensitivity that increases the risk for certain populations, high adaptive capacity is what sets these wards apart. Presence of Urban Health Centres, access to parks and green spaces, presence of Baoris, and high NDVI/NDWI outweighs other parameters. The examples of adaptive capacity in these wards can serve as preliminary models for reducing heat risk in high and moderate risk wards.

The methodology and maps developed in this analysis can serve as a powerful tool for assessing the effect of extreme heat and can be used for risk communication purposes giving residents and local stakeholders access to visualizations of risk to extreme heat. It can also be influential in decisions to target resources for vulnerable populations to develop adaptation responses that promote resilience.

Risk Category	Ward Number	Conclusion
High	7, 8, 9, 10, 13, 15, 18, 19, 22, 23, 30, 41, 70, 74, 76, 77, 78, 79 and 80	High Exposure and Sensitivity Low Adaptive Capacity
Moderate	1, 4, 5, 6, 11, 14, 17, 55, 56, 58, 59, 63, 66, 67, 68, 72, 73, 75	Low to Medium Exposure and Sensitivity Medium to High Adaptive Capacity
Low	2, 3, 5, 20, 21, 23, 29, 38, 41, 42, 44, 46, 47, 50, 51, 52, 54, 59	Low Exposure and Sensitivity High Adaptive Capacity

Table 3: *Categorization of wards based on the Risk Score*

3.4 Derivatives from Risk Assessment

This preliminary research sheds light on the following solutions that can help citizens to combat heat episodes:

- Availability of risk visualizations can be powerful tools for risk communication, inspiring mitigation, preparedness, and adaptation.
- Investigate how the presence of old water structures (indicated through Baoris and NDWI) could aid short-term mitigation measures as well as long-term adaptation measures.
- Strengthen risk governance mechanisms by informing the responsible stakeholders of the risks associated with each ward, which could lead to targeted attention.
- Enhance preparedness, implementation of immediate mitigative measures, and proactive adaptive practices informed through the developed risk maps based on risk scores (with an emphasis on ‘high risk’ areas--say, where risk score is above 7)
- Regular monitoring during the summer season in the city and setting city-based thresholds for temperature-triggered response actions.

4. Municipal Coordination and Response Plan

4.1 Heat wave Plan Implementation

Severe and prolonged heat waves can cause disruption to general, social, and economic services. Government agencies and private stakeholders including non-governmental organizations will all have to play important roles in preparing and responding to heat waves at the municipal/ward/local level, working closely with the health and other related departments on both long-term and short-term strategic plans.

Heat wave planning and action can be effective only if there is convergence between departments and other stakeholders, including private entities and civil societies. Effective and timely early warning systems can ensure seamless passage of critical information to stakeholders. It is important to prepare, improve and strengthen the capabilities and resources of regional/local bodies/wards for preparedness at the local level. It is also important to assess post-summer the impact of actions taken each summer heat season, and to keep reviewing and updating heat action plans on a timely basis.

Some critical steps for recognizing and addressing the severity of heat waves in Rajasthan include:

- Collaborating among various government agencies as well as civil societies.
- Indian Meteorology Department (IMD) forecasting of extreme heat events, along with observations of heat wave frequency and intensity (which can build upon automated weather stations already installed across Rajasthan).
- Ensuring immediate notification about alerts and warnings to the public and other stakeholders
- Conducting mapping exercises of the concerned areas
- Issuing heat wave alerts at the grassroots level through various forms of media
- Coordinating action efforts among government departments, health care professionals, emergency medical staffs, hospital staffs and community groups

4.2 Plan Implementation Committee at Municipal Level

The following members will constitute the Heat wave Plan Implementation Committee.

Jodhpur Municipal Commissioner	Member & Convenor
Jodhpur (North) MLA	Member
Jodhpur Additional Mayor	Member
Medical Officer, JMC	Member
Nodal Officer, Heat Action Plan, JMC	Member
Additional Chief Engineer, JMC	Member
Ward Councillor (High Risk Ward)	Member
Ward Councillor (High Risk Ward)	Member
Divisional Commissioner (North)	Member
Doctor (AIIMS)	Member
Additional District Officer (Women and Child Development Board)	Member

Chief Conservator of Forests (Forest Department)	Member
Joint Labour Commissioner (Labour Department)	Member
Secretary, IMO (Jodhpur)	Member
Additional Joint Director, School, and Education Board	Member
Managing Director, Electricity Board	Member
Fire Department	Member
District Nodal Officer, NPCCHH, Jodhpur	Member
Secretary, Jodhpur Transport Bhawan	Member
	Member

Jodhpur Heat Action Plan aims to provide guidelines to the Urban Local Bodies, Local Government and other essential government functionaries to minimize the impact of heat waves. The primary objective is to -

- ensure zero mortality amongst the at-risk population
- reduce heat-related illness
- reduce the cascading impacts of heat wave on different sectors

Jodhpur Municipal Corporation headed by the Municipal Commissioner is coordinating the heat wave preparedness and mitigation activities. Initial Municipal level consultations were held with important stakeholders. Jodhpur Municipal Corporation is working along with key stakeholders like IMOD Jodhpur, DMRD, Nodal Officer for HAP, JMC, AIIMS, CMHO, civil societies, private agencies and other essential departments for heat wave preparedness.

4.2.1 Heat Early Warning System

A heat wave is an event where maximum temperature of a station reaches at least 40^0C or more for Plains regions and at least 30^0C or more for Hilly regions. [46]

a) Based on Departure from Normal

Heat Wave	Departure from normal is 4.5ºC to 6.4ºC
Severe Heat Wave	Departure from normal is >6.4ºC

b) Based on Actual Maximum Temperature

Heat Wave	When actual maximum temperature ≥ 45ºC
Severe Heat Wave	When actual maximum temperature ≥ 47ºC

Warm nights are considered only when the maximum temperature remains 400C or more. It is defined on departures or actual minimum temperatures as follows:

Warm Night	Minimum Temperature Departure is 4.5ºC to 6.4ºC
Severe Heat Wave	Minimum Temperature Departure is >6.4ºC

IMD further issues following color code impact-based heat warning jointly with NDMA.

Colour Code	Alert	Warning	Impact	Suggested Actions
Green (No action)	Normal Day	Maximum temperatures are near normal	Comfortable temperature. No cautionary action required	Nil
Yellow Alert (Be Updated)	Heat Alert	Heat wave conditions at isolated pockets which persists on for 2 days	Moderate temperature. Heat is tolerable for the general public but a moderate health concern for vulnerable people e.g., infants, elderly, people with chronic diseases	a) Avoid heat exposure; b) Wear light-coloured, loose, cotton clothes; c) Cover your head; d) Use a cloth, hat, or umbrella
Orange Alert (Be prepared)	Severe Heat Alert for the day	a) Severe Heat wave conditions persist for 2 days b) Though not severe, but Heat wave persists for 4 days or more	High temperature. Increased likelihood of heat illnesses symptoms in people who are either exposed to sun for a prolonged period or doing heavy work. High health concern for vulnerable people e.g., infants, elderly, people with chronic diseases	a) Avoid heat exposure – keep cool, avoid dehydration b) Drink sufficient water – even if not thirsty v) Use ORS, homemade drinks like lassi, torani (rice water), lemon water, butter milk, etc., to keep yourself hydrated
Red Alert (Action Req.)	Extreme Heat Alert for the day	(i) Severe Heat Wave persists for more than 2 days (ii) Total number of heat/severe Heat wave days exceeding 6 days	Very high likelihood of developing heat illnesses and heat stroke in all ages	Extreme care needed for vulnerable people

The JMC appointed Nodal Officer to head the coordination of stakeholders and ensure implementation of the Heat Action Plan. The appointed nodal officer is responsible for coordinating and communicating actions ahead of, and during, extreme heat events, and provides support staff for HAP functions through the Nodal Office as necessary

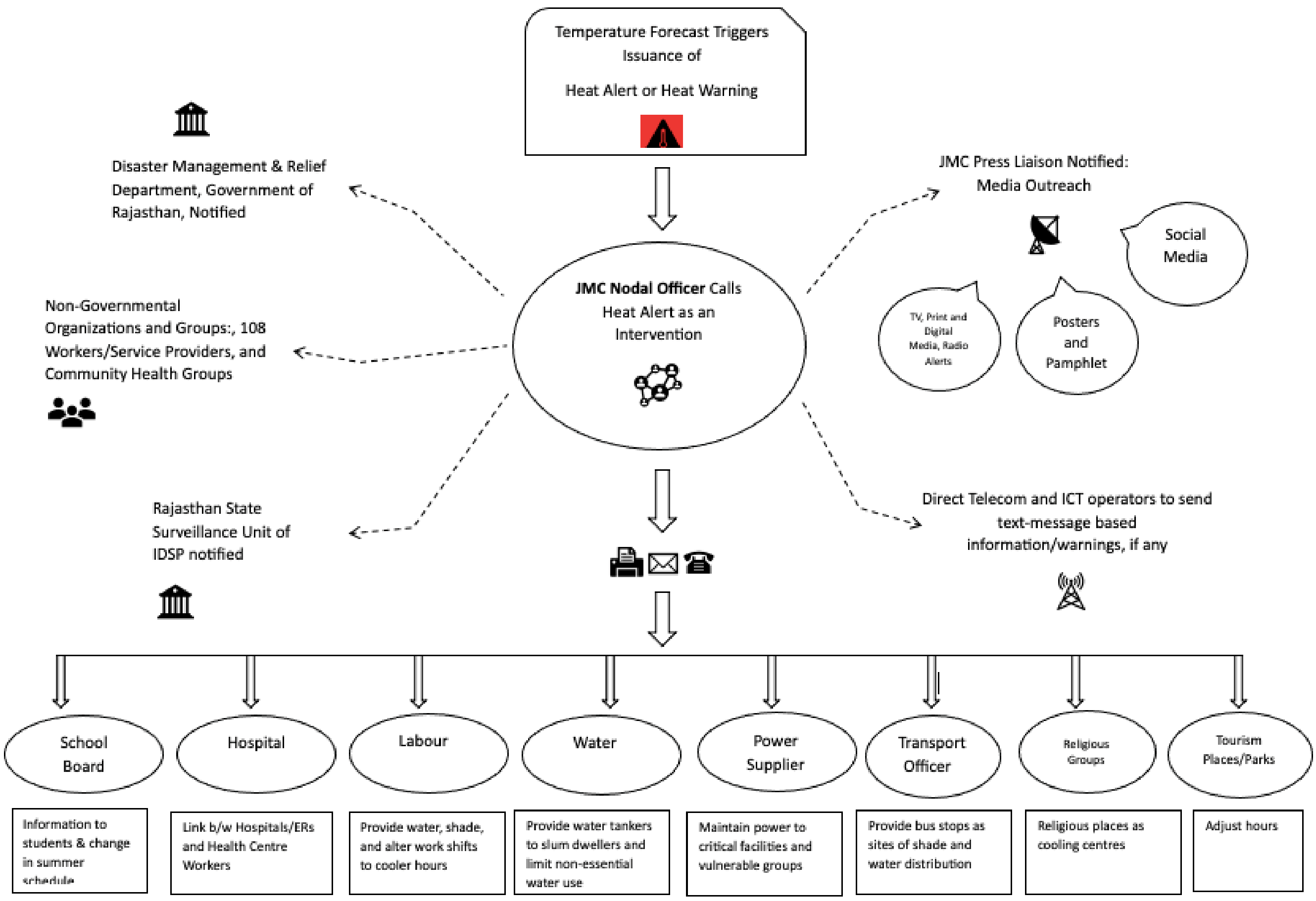


Figure 16: *Interagency Coordination Plan when Jodhpur HAP Nodal Officer Activates Alerts*

4.2.2. Strategies and Activities (Pre-Heat Season)

A - Warning System and Inter-Agency Coordination

- To establish an Early Warning System and Inter-agency coordination
- Identify key agency leaders (DC, CMHO, Civil Societies, etc.), Tourist Boards / Associations, Market Associations, Worker Associations etc.)
- Facilitate internal communication with community groups, local agencies working on environmental health, district officials and the urban local body
- Purchase and distribute reusable soft plastic ice packs in each ward, urban health centres and 108 ambulances
- Publish and disseminate IECs which are suited to the local context and specific to the sector
- "Beat the Heat in Jodhpur with…"
- Adopt heat-focused examination procedures in Urban Health Centres
- Identify and set up public display of temperatures at places in wards with more population density

B - Capacity Building through training programmes for health care professionals

- Organize trainings for healthcare workers, teachers, community members and school children
- Conduct monitoring and supervision of processes or activities related to trainings

C - Sensitization of Public/Communication, Outreach and Awareness Messages

- Distribute pamphlets to schools and community settings (preferably, in local language and using local media/community leaders/influencers)
- Conduct awareness/education sessions in wards
- Banners and posters in high-risk areas

D - Collaborate with NGOs and Civil Societies

- Identify NGOs/CSOs working in each ward or in cluster of wards
- Identify willing community leaders, especially in at-risk wards
- Establish public/private partnerships for mobilization of community members and better outreach/ implementation
- At-community capacity building initiatives for immediate response as well as long term adaptation
    - Capacity building in terms of dos and don'ts based on existing cultural and traditional practices
    - Capacity building in terms of immediate response to HRI at the individual and community levels
- Secure partnerships and support especially in the High-risk wards (as identified)
    - To provide mid-term / long-term solutions like
        - cool roofs,
        - blue walls,
        - water harvesting,
        - early warning of heat waves using advanced meteorological prediction techniques, and restricting outdoor activities on the days of extreme temperatures

4.2.3. Strategies and Activities (Heat Season)

A - Warning System and Inter-Agency Coordination

- Organize an annual Heat Action Plan evaluation meeting with key agency leaders and relevant stakeholders
- Evaluate Heat Action Plan process based on performance and revise periodically
- Revised plan needs to be highlighted on Rajasthan Health Department Website
- Initiate public awareness about the dangers of HRI involving the Nodal Officer via Press Conference
- Communicate halting of all non-essential water utilization (other than drinking, keeping cool)
- Communicate the local utility protocol to prioritize maintain of power to critical facilities
- Circulate bulk warnings to public via centralized email databases during heat alert
- Develop an SMS alert system to send direct messages to the community members, school headmasters, etc. in additional to medical practitioners
- Use local media and radio to disseminate heat protection tips and high temperature warnings to the high-risk wards in urban areas

B - Surveillance, Monitoring & Evaluation and Reforestation and Increase of Shade Cover

- Build on the ‘Green Cover’ activity to establish tree plantation campaign in high-risk zone areas such as roadsides, parks, etc. involvement of school students
- Perform an epidemiological case investigation of heat-related morbidities and mortalities during the summer
- Collect the data from various sources, investigations regarding heat risk factors, illnesses and death based on daily average temperature. Measure the morbidity and mortality rates based on data before and after the plan got implemented
- Incorporate data findings in upcoming Heat Action Plan

C - Collaborate with NGOs and Civil Societies

- Development of cooling centres in public places such as temples, schools, colleges, bus stands, etc. and providing access to water and electricity to vulnerable populations
- Identify and Provide temporary shelters for affected populations and expand access to shaded areas for outdoor workers, slum communities and vulnerable populations
- Distribute fresh drinking water to public and also ensure upkeeping of the traditional water resources

4.2.4. Strategies and Activities (After Heat Season)

A - Warning System and Inter-Agency Coordination

- Activate the heat alert and local response in all wards when extreme temperature is forecasted by notifying the key agency leaders, Collector, Municipal Commissioner, Ward Councillors and DDMA
- Monitor and increase the heat alert level when necessary to match the severity of the forecast
- Conduct frequent calls to discuss reports and breaking developments during heat alerts
- Identify and set up public display of temperatures at places in wards with more population density
- Notify the committee when the heat alert is over
- Initiate public awareness about the dangers of HRI involving the Nodal Officer via Press Conference

B - Sensitization of Public/Communication, Outreach and Awareness Messages

- Communicate halting of all non-essential water utilization (other than drinking, keeping cool)
- Communicate the local utility protocol to prioritize maintain of power to critical facilities
- Circulate bulk warnings to public via centralized email databases during heat alert
- Develop an SMS alert system to send direct messages to the community members, school headmasters, etc. in additional to medical practitioners
- Use local media and radio to disseminate heat protection tips and high temperature warnings to the high-risk wards in urban areas

C - Collaborate with NGOs and Civil Societies

- Development of cooling centres in public places such as temples, schools, colleges, bus stands, etc. and providing access to water and electricity to vulnerable populations
- Provide temporary shelters for affected populations and expand access to shaded areas for outdoor workers, slum communities and vulnerable populations
- Distribute fresh drinking water to public

4.4 Checklist: Pre-Summer and Summer declaration of measures

HAP Nodal Officer

Pre Summer

- Identify areas that are vulnerable
- Check inventories of medical supplies in health centres
- Identify cooling centres and barriers to access cooling centres
- Community involvement for workers' and trainers' education

During Heat Event

- Prepare rapid response team
- Distribute "Dos and Don'ts" to community
- Effectively send a "Don't Panic!" message to community
- Ensure access to Medical Mobile Van in the Red Zone
- Ensure additional medical vans available

Post-summer Evaluation

- Participate in annual evaluation of heat action plan
- Review revised heat action plan

Urban Health Centres

Pre Summer

- Distribute pamphlet and other materials to community
- Sensitize link workers and community leaders
- Develop and execute school health program
- Dissemination of materials in slum communities
- Coordinate outreach efforts with other community groups, non-profits, and higher education

During Heat Event

- Recheck management stock
- Modify worker hours to avoid heat of the day
- Visit at-risk populations for monitoring and prevention
- Communicate information on tertiary care and 108 service

Post-summer Evaluation

- Participate in annual evaluation of heat action plan
- Review revised heat action plan

Public Relations Department

Pre Summer

- Secure commercial airtime slots for public service announcements
- Identify areas to post warnings and information during heat season
- Organize training for health workers and medical professionals
- Activate telephone heat hotline
- Begin placing temperature forecasts in newspapers
- Increase installed LED screens with scrolling temperature data

During Heat Event

- Issue heat warnings on electronic media
- Contact local FM radio and TV stations for announcements
- Use SMS, text and WhatsApp mobile messaging and centralized mobile databases to send warnings
- Contact BRTS and transport department to place warnings on buses

Post-summer Evaluation

- Evaluate reach of advertising to target groups and other means of communication such as social media
- Participate in annual evaluation of heat action plan
- Review revised heat action plan

Labour Department

Pre Summer

- Heat illness orientation for factory medical officers and general practitioners
- Generate list of factory medical officers and contractors to include in heat action communications from Nodal Officer
- Communicate directly about heat season with non-factory workers
- Utilize maps of construction sites to identify more high-risk outdoor workers
- Conduct publicity campaigns during high-risk days in identified high-risk areas

During Heat Event

- Provide water at work sites
- Request use of A/C at factory facilities
- Extended hours at Occupational Health Centres
- Consider extended afternoon break or alternate working hours for workers

Post-summer Evaluation

- Participate in annual evaluation of heat action plan
- Review revised heat action plan
- Pilot project to provide emergency ice packs and heat-illness prevention materials to traffic police, BRTS transit staff and construction workers

Police and Fire Department

Pre Summer

- Organize ward-level review and planning meetings
- Prioritize updation and review of police department SOPs
- Designate point of contact for each ward and zones in heat wave management
- Organize monthly review of activities and situation analysis
- Establish heat illness and mortality tracking system and update datasets
- Give priorities to departments to areas which are at high-risk
- Ensure proper impact mitigation strategies are at place for protecting officials working outdoors, especially at traffic, highways, etc.

During Heat Event

- Ensure updates and communication from each nodal officer
- Announcement of heat wave warning at least 48 hours in advance to all agriculture officers
- Maintain contact with department points of contact for updates on conditions
- Ensure staff presence and availability of supplies
- Communicate locations of emergency facilities and cooling shelters/shaded areas
- Ensure local agriculture officers are issuing guidance to farmers bases on the early warnings issued by IMD and DMRD, Government of Rajasthan
- Monitor heat alert and increase level when severe forecast

Post-summer Evaluation

- Organize annual evaluation of heat plan and same can be reported to DMRD
- Review and revise department heat wave action plan
- staff and construction workers

108 Emergency Service

Pre Summer

- Prepare handouts for paramedics about heat illness
- Create displays on ambulances to build public awareness during major spring events
- Establish Dynamic Strategic Deployment Plan for ambulances
- Ensure adequate supply of IV fluids
- Identify at-risk areas
- Prepare SMS messages to disseminate during emergencies
- Identify media point-of-contact

During Heat Event

- Ready medicine stocks
- Keep accurate records of pre-hospital care
- Send messages to all employees alerting them of heat action plan
- Activate Dynamic Strategic Deployment Plan
- Staff surplus employees and restrict leave

Post-summer Evaluation

- Provide data to key agency leaders
- Participate in annual evaluation of heat action plan
- Review revised heat action plan

Disaster Management and Relief Department

Pre Summer

- Organize district level line department review and planning meeting
- Prioritize updation and review of department SOPs
- Designate point of contact for each department in heat wave management
- Organize monthly review of activities and situation analysis
- Establish heat illness and mortality tracking system and update data sets
- Ensure proper impact mitigation strategies at Education and WCD for uninterrupted education, critical health and nutrition services to women, children, and infants

During Heat Event

- Ensure updates and communications from each line department nodal officers
- Announcement of heat wave warning at least 48 hours in advance
- Maintain contact with department points of contact for updates on conditions
- Communicate locations of emergency facilities and cooling shelters

Post-summer Evaluation

- Participate in annual evaluation of heat action plan
- Review revised heat action plan

Animal Husbandry Department

Pre Summer

- Ensure additional mobile hospital ready at vulnerable villages
- Update surveillance programme and protocol including track daily heat is related to livestock
- Establish more clinical education to communities or families owning livestock
- Continue to train medical and paramedical staff in this period
- Identify areas that are vulnerable for animals
- Prepare handouts for animal paramedical to heat illness
- Ensure medical supply of medicines and fluids
- Capacity building programmes at veterinary hospitals/centres especially for farmers

During Heat Event

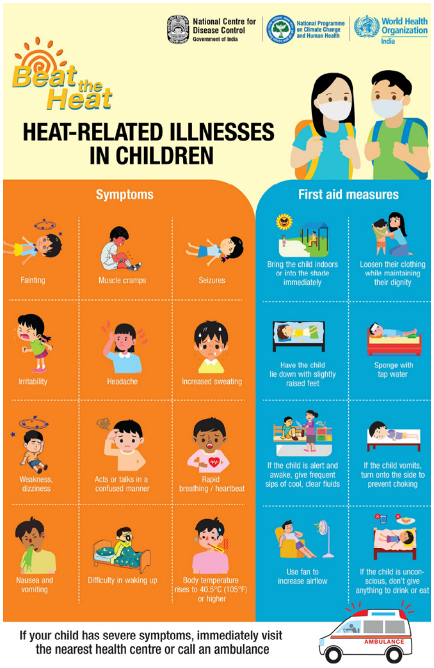
- Adopt heat related illness and prevention protocol
- Deploy all animal husbandry staff on duty during heat wave
- Ready medicine stocks
- Monitor water borne diseases

Post-summer Evaluation

- Provide data to key agency leaders
- Participate in annual evaluation of heat action plan
- Review and revise heat wave action plan

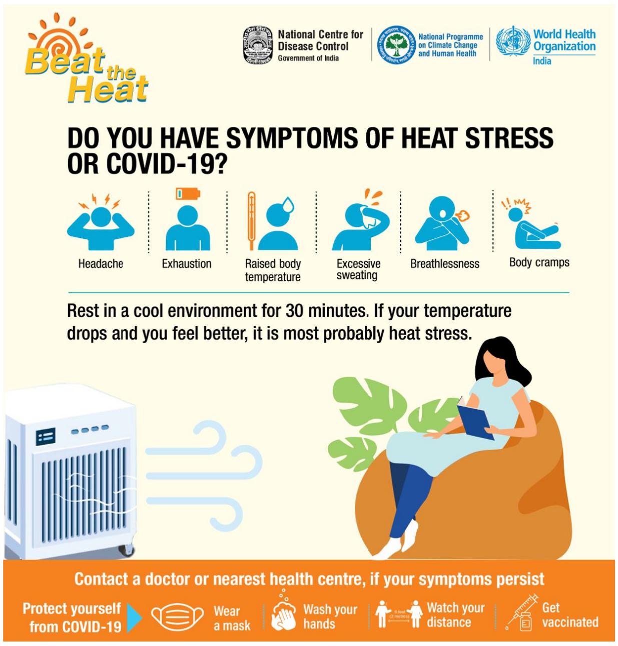
4.5 Heat Information, Education & Communications (IECs)[47]

IEC-Heat related illnesses in Children



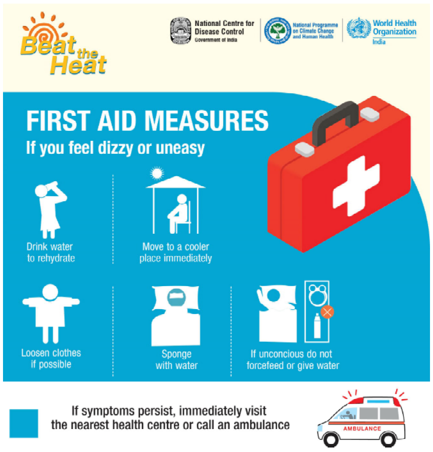
Beat the Heat

Clarifying symptoms of COVID-19 and Heat Stress



Safeguard Workers from the Heat

First Aid Measures



Safeguard yourself from the Heatv

5. Long-Term Strategies

5.1 Cool Roof Deployment by Mahila Housing Trust (MHT)

The term "cool roofs" applies to a broad class of technologies that function to increase surface albedo (reflectance) of buildings to deflect a higher fraction of incoming solar radiation.[48] Because of their relatively low cost and flexible application of reflecting materials (e.g., solar reflective paint or mosaic tiles), cool roofs are potential low-tech solutions to help keep indoor temperatures cooler and reduce cooling demand.[49] Many cities in India for example, including Ahmedabad and Hyderabad) have adopted cool roof strategies because of their simplicity and low cost.[50] Depending on the setting, cool roofs can help moderate indoor temperatures by 2-5°C (3.6-9°F) as compared to traditional roofs.[51] In addition to that, they can help in reducing the cooling demand from the air conditioners and lead to reduction of air pollution through energy savings.[52]

Mahila Housing Trust (MHT) works with communities and cities on building resilience against extreme heat across India. MHT's inputs to Ahmedabad's Heat Action Plan have resulted in a cool roof program targeting the most vulnerable settlements with poor quality homes that trap heat and become dangerously hot. The Trust painted the roofs of selected slum households with solar reflective paint. People living in slums and low-income communities are particularly heat vulnerable—a large percentage of their homes are far from optimal, with few options for cooling. At present, the cool roof initiatives carried out by MHT are in four cities—Jodhpur, Bhopal, Surat, and Ahmedabad.

As a future recommendation for working around extreme heat in Jodhpur, selected households in wards that rank in high on the risk score can be selected based on factors such as the household's electricity bill, having a tin roof, direct sunlight exposure, and number of household members sharing the space. These households can serve as controls for comparison with white painted roofs (cool roofs). MHT has local community workers that train the household to paint their own cool roof. This saves the labor costs and builds the household's capacity by learning the skill.

Through these community-led cool roof initiatives ahead of the upcoming heat season, Jodhpur has time to implement programs and prepare vulnerable wards for extreme heat with inter-agency coordination, save energy and combat climate change. Passive cooling technologies are an important strategy which when embedded within local heat action plans helps in protecting public health from heat risks.

Cool roofs programs can deliver great benefits citywide,[53] and should be tailored to a city's needs and resources. Three emerging models for expanding cool roof implementation exist: 1) small-scale pilot programs - designing and implementation of cool roofs to showcase benefits; 2) municipal, voluntary, and corporate social responsibility (CSR) programs - implementing cool roofs in municipal and government buildings; and 3) building code programs that require cool roof installations - enforcing cool roof provisions through building codes and partner with real estate developers and residents for wider adoption.[54] These models for cool roof programs enable cities to steadily make progress while building community awareness and support. These three models allow city cool roofs program to grow from a single neighborhood to a city-wide effort. Identifying and mobilizing funding sources for each phase is critical to the program's success.

Figure 18: *Houses with cool roof paints deployed to adapt to extreme heat in Jodhpur, India (Credit: Mahila Housing Trust)*

5.2 Threshold Estimation using Temperature and Mortality Data

IMD issues national seasonal forecasts in the form of Extended Range Forecasts and Short to Medium Range Forecasting services every year before the heat season begins. This helps in issuing heat alerts to different cities and regions and should form the basis for developing an early warning system.

The heat wave definition by IMD is based on current climatic zones. Given India's heterogeneous climate and the dynamism observed during heat extremes, a one-size-fits-all approach of providing impact-based heat forecast alerts can lead to inaccurate estimates of mortality and heat related illness risks. Moving forward, inter-agency coordination is required where heat related mortality and morbidity data (encompassing, all-cause mortality, cause-specific mortality and daily hospital admissions) needs to be examined along with region specific temperature thresholds. States should develop state specific guidelines using national guidelines issued by NDMA, and cities/districts should prepare and implement their local heat action plans with locally determined thresholds for early warning.

5.3 Surveillance and Heat Alerts

Continuous improvement through sustained collection and review of information is an objective of this Heat Action Plan. Throughout the pre-heat (February onwards) and heat season (March to June) the vulnerable wards can be surveyed daily to implement appropriate targeted strategies. Two key steps include:

1. Heat wave Forecasts from IMD outlining the maximum and minimum temperatures for the next 7 days should form the basis for issuing alerts to the local population.
2. Reports on numbers of heat related illnesses and fatalities at all hospitals and health centers should be taken into account.

The temperature forecasts are an integral part of declaring heat days and heat wave emergencies. Records on heat-related illness and mortality give an additional measure of the ongoing impacts of heat, independent of the current weather conditions.

5.4 Leveraging culture as a tool to manage extreme heat risk

By virtue of its history, Jodhpur is well-equipped to manage heat risks in its own traditional ways. These measures are time tested measures that serve the purpose of immediate response as well as are key steps to long-term adaptation actions. Two such measures are:

- Blue walling of homes - the traditional way of coloring houses which imparts the signature blue look of the city.
- Water harvesting - there have been multiple water harvesting techniques, at different levels in the city, which needs to be harnessed to ensure mitigation and management of future risks due to extreme heat.

The possibility of modifying the development plans of the city should also be explored to serve crucial purposes (to maintain the cultural integrity of the city in terms of built-up area and pattern, to ensure that emergent issues of UHI may be addressed)

6. Annexures

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

<table>
<tr><td colspan="8">Name of health facility:________________________
Block:______________
District:________________________</td><td colspan="5">Date of reporting: _._/_._/_._</td></tr>
<tr><td colspan="13">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……………</td></tr>
<tr><td colspan="13">(A). Total no. of patients in department (Casualty/Emergency of Medicine + Paediatrics):</td></tr>
<tr><td colspan="13">Daily line List of Suspected Heat Stroke CASES# at Health Facility</td></tr>
<tr><td rowspan="2">S. No</td><td rowspan="2">Hospital Regist-ration No.</td><td rowspan="2">Name</td><td rowspan="2">Age*</td><td rowspan="2">Sex (M/F)</td><td colspan="2">Address</td><td colspan="4">Outcome within date of reporting (tick the box)</td><td rowspan="2">Re-marks</td></tr>
<tr><td>Block</td><td>District</td><td>Admitted</td><td>Died</td><td>Referred</td><td>Reco-vered</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

*Age in completed years

Name of person filling the form:

Designation:

Signature:

Name of Facility In-Charge:

Signature of Facility In-Charge:

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 oC/≥104 oF, 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:
   - All public hospitals with casualty/emergency.
   - All private hospitals with casualty/emergency.
   - 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:
   - Person who will diagnose: A qualified medical doctor will diagnose HRI case as per case definition.
   - Where will the data be recorded: A qualified medical practitioner will write the
   - provisional diagnosis in the casualty/emergency register as suspected heatstroke.
   - 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 Heat Stroke DEATHS and Confirmed CVD DEATHS

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

Name of person filling the form:
Designation:
Signature:

Name of Facility In-Charge:
Signature of Facility In-Charge:
Date:

#Suspected Heatstroke: Altered mental status (including disorientation, delirium, seizure, obtundation) with elevated core body temperature ≥ 40 oC/≥104 oF, 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:
   - All public hospitals with OPDs & casualty/emergency.
   - All private hospitals are having casualty/emergency.
   - 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 Pediatrics 3. Casualty							
Date	**Total patients in the department**	**New Suspected Heat Stroke Cases (A)**	**Total Suspected Heat Stroke cases since 1st March 2020 (B)**	**All-cause deaths****			
				Suspected Heat Stroke deaths## (a)	**Confirmed CVD deaths (b)**	**Others including unknown (c)**	**Total deaths (a+b +c)**
01-03-20							
02-03-20							

Name of person filling the form:
Designation:
Signature:

Name of Facility In-Charge:
Signature of Facility In-Charge:
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 oC/≥104 oF, 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:
   - All public hospitals with casualty/emergency.
   - All private hospitals are having casualty/emergency.
   - 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.

7. Partner Acknowledgements

Jodhpur Nagar Nigam North

The Jodhpur Nagar Nigam North's major Objective as a Municipal Copration is to focus on Public health, which includes water supply, sewerage and sanitation, eradication of communicable diseases welfare includes public facilities such as education, recreation, regulatory functions related to prescribing and enforcing building regulations, encroachments on public land, birth & marriage registration and death certificate, public safety includes fire protection, street lighting, public works measures such as construction and maintenance of inner city roads, and development functions related to town planning and development of commercial markets.

In addition to the legally assigned functions, the sectoral departments of the state government often assign unilaterally, and on an agency basis, various functions such as family planning, nutrition and slum improvement, disease and epidemic control, etc. Besides the traditional core functions of municipalities, it also includes development functions like planning for economic development and social justice, urban poverty alleviation programs and promotion of cultural, educational and aesthetic aspects.

NRDC India

NRDC India aims to build a healthier and more prosperous future for all Indians. An independent organization, it seeks to advance national and global climate goals through community-based solutions that prioritize public health and equity, creating jobs and boosting resiliency. NRDC India is inspired by and associated with NRDC (Natural Resources Defense Council) – a global organization with more than three million members and 700 experts across the globe. NRDC works to safeguard the earth—its people, its plants and animals, and the natural systems on which all life depends.

Mahila Housing Trust (MHT)

Mahila Housing Trust (MHT) is improving urban built environments in poor communities through collective action. Since our establishment in 1994, we have mobilized women to exercise their civic rights and empowered them to take charge of their habitat improvement process. By forging unique relationships with poor communities and local governments, we have advanced access to basic services, promoted climate resilience, and deepened participatory governance.

8. Footnotes

1. Mrityunjay Bose, Increasing heat stress to trigger extreme weather across India, crop damage, DHNS, Mumbai March 16 2023. https://www.deccanherald.com/science-and-environment/increasing-heat-stress-to-trigger-extreme-weather-across-india-crop-damage-1200646.html; United Nations Intergovernmental Panel on Climate Change 2022, Climate Change 2022: Impacts, Adaptation and Vulnerability (Contribution of Working Group II to the Sixth Assessment Report of the IPCC). https://www.ipcc.ch/report/ar6/wg2/;World Meteorological Organization. 2022, Provisional State of the Global Climate in 2022, World Meteorological Department. https://unfccc.int/documents/622338

2. Krishnan, R., J. Sanjay, Chellappan Gnanaseelan, Milind Mujumdar, Ashwini Kulkarni, and Supriyo Chakraborty, eds. Assessment of Climate Change over the Indian Region: A Report of the Ministry of Earth Sciences (MoES), Government of India. Singapore: Springer Singapore, 2020. https://doi.org/10.1007/978-981-15-4327-2

3. Tanvi Deshpande, This April, more places in India saw mercury over 45 degrees in a decade, Business Standard, June 06 2022, https://www.business-standard.com/article/current-affairs/heatwaves-in-india-this-april-more-places-in-india-saw-mercury-over-45-degress-in-a-decade-122052500141_1.html#:~:text=The%20heat%20waves%20in%20March,(%C2%B0C)%20maximum%20temperature.

4. India Meteorological Department. 2023, Statement on Climate of India during 2022, Climate Research and Services, India Meteorological Department. https://mausam.imd.gov.in/Forecast/marquee_data/Statement_climate_of_india_2022_final.pdf; Centre for Science and Environment. 2022, State of India's Environment in India 2022. https://csestore.cse.org.in/usd/state-of-india-s-environment-2022.html

5. Vishwa Mohan, Extreme weather killed 2,227 in India in 2022, The Times of India, January 07 2023 available at: https://timesofindia.indiatimes.com/india/extreme-weather-killed-2227-in-india-in-2022/articleshow/96801024.cms

6. IMD 2022, Climate Research & Services, Pune, India Meteorological Department.

7. World Meteorological Organization. "Climate Breaks Multiple Records in 2016, with Global Impacts," March 20, 2017. https://public.wmo.int/en/media/press-release/climate-breaks-multiple-records-2016-global-impacts

8. Srivastava, Akhil, M. Mohapatra, and Naresh Kumar. "Hot Weather Hazard Analysis over India." Scientific Reports 12, no. 1 (November 17, 2022): 19768. https://doi.org/10.1038/s41598-022-24065-0

9. NSO 2022, EnviStats-India 2022: Vol I, Environment Statistics, National Statistical Office, Ministry of Statistics & Programme Implementation, Government of India, New Delhi

10. ICAP 2019, India Cooling Action Plan, Ozone Cell, Ministry of Environment, Forest and Climate Change, Government of India, March 2019. http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf

11. PTI, India Could Soon Experience Heat Waves That Break Human Survivability Limit: World Bank Report. Outlook India. 7 December 2022.
https://www.outlookindia.com/business/india-could-soon-experience-heat-waves-that-break-human-survivability-limit-world-bank-report-news-243041 (accessed 14 April 2023).

12. McKinsey Global Institute 2020, Will India get too hot to work? Climate risk and response: Physical hazards and socioeconomic impacts, Case Study, November 2020. https://www.mckinsey.com/capabilities/sustainability/our-insights/will-india-get-too-hot-to-work

13. Ministry of Earth Science, Government of India. Statement on Climate of India during 2022. https://mausam.imd.gov.in/Forecast/marquee_data/Statement_climate_of_india_2022_final.pdf

14. Hess, J.J., Lm, S., Knowlton, K., Saha, S., Dutta, P., Ganguly, P., Tiwari, A., Jaiswal, A., Sheffield, P., Sarkar, J. and Bhan, S.C., 2018. Building resilience to climate change: pilot evaluation of the impact of India's first heat action plan on all-cause mortality. Journal of environmental and public health, 2018. https://doi.org/10.1155/2018/7973519

15. Madan, P. and Limaye, V. 2022, Strengthening Preparedness for Extreme Heat in Jodhpur, June 10 2022. https://www.nrdc.org/bio/prima-madan/strengthening-preparedness-extreme-heat-jodhpur

16. World Health Organization. Heatwaves (Overview). https://www.who.int/health-topics/heatwaves

17. Chen, J., Liu, Y., Pan, T., Ciais, P., Ma, T., Liu, Y., Yamazaki, D., Ge, Q. and Penuelas, J., 2020. Global socioeconomic exposure of heat extremes under climate change. Journal of cleaner production, 277, p.123275. https://doi.org/10.1016/j.jclepro.2020.123275; Mukherjee, S. and Mishra, V., 2018. A sixfold rise in concurrent day and night-time heat waves in India under 2 C warming. Scientific reports, 8(1), pp.1-9. https://link.springer.com/content/pdf/10.1038/s41598-018-35348-w.pdf

18. Naveena, N., Satyanarayana, G.C., Rao, K.K., Umakanth, N. and Srinivas, D., 2021. Heat wave characteristics over India during ENSO events. Journal of Earth System Science, 130(3), pp.1-16. https://link.springer.com/article/10.1007/s12040-021-01674-3

19. Dimitrova, A., Ingole, V., Basagana, X., Ranzani, O., Mila, C., Ballester, J. and Tonne, C., 2021. Association between ambient temperature and heat waves with mortality in South Asia: Systematic review and meta-analysis. Environment International, 146, p.106170.
https://www.sciencedirect.com/science/article/pii/S0160412020321255; Nori-Sarma, A., Anderson, G.B., Rajiva, A., ShahAzhar, G., Gupta, P., Pednekar, M.S., Son, J.Y., Peng, R.D. and Bell, M.L., 2019. The impact of heat waves on mortality in Northwest India. Environmental research, 176, p.108546. https://doi.org/10.1016/j.envres.2019.108546; Gosling, S.N., Lowe, J.A., McGregor, G.R., Pelling, M. and Malamud, B.D., 2009. Associations between elevated atmospheric temperature and human mortality: a critical review of the literature. Climatic change, 92(3), pp.299-341. https://link.springer.com/article/10.1007/s10584-008-9441-x; Robine, J.M., Cheung, S.L.K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.P. and Herrmann, F.R., 2008. Death toll exceeded 70,000 in Europe during the summer of 2003. Comptes rendus biologies, 331(2), pp.171-178. https://www.sciencedirect.com/science/article/pii/S1631069107003770

20. Pai, D.S., NAIR, S. and Ramanathan, A.N., 2013. Long term climatology and trends of heat waves over India during the recent 50 years (1961-2010). Mausam, 64(4), pp.585-604. https://mausamjournal.imd.gov.in/index.php/MAUSAM/article/download/742/636

21. Mazdiyasni, O., AghaKouchak, A., Davis, S.J., Madadgar, S., Mehran, A., Ragno, E., Sadegh, M., Sengupta, A., Ghosh, S., Dhanya, C.T. and Niknejad, M., 2017. Increasing probability of mortality during Indian heat waves. Science advances, 3(6), p.e1700066. https://www.science.org/doi/full/10.1126/sciadv.1700066

22. Pattanaik, D.R., Mohapatra, M., Srivastava, A.K. and Kumar, A., 2017. Heat wave over India during summer 2015: an assessment of real time extended range forecast. Meteorology and Atmospheric Physics, 129(4), pp.375-393. https://link.springer.com/article/10.1007/s00703-016-0469-6

23. Nageswararao, M.M., Sinha, P., Mohanty, U.C. and Mishra, S., 2020. Occurrence of more heat waves over the central east coast of India in the recent warming era. Pure and Applied Geophysics, 177(2), pp.1143-1155. https://link.springer.com/article/10.1007/s00024-019-02304-2

24. Hersbach, H., Bell, B., Berrisford, P., Biavati, G., Horányi, A., Muñoz Sabater, J., Nicolas, J., Peubey, C., Radu, R., Rozum, I., Schepers, D., Simmons, A., Soci, C., Dee, D., Thépaut, J-N. (2023): ERA5 hourly data on single levels from 1940 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS), DOI: 10.24381/cds.adbb2d47

25. Yamamoto, T., Fujita, M., Oda, Y., Todani, M., Hifumi, T., Kondo, Y., Shimazaki, J., Shiraishi, S., Hayashida, K., Yokobori, S. and Takauji, S., 2018. Evaluation of a novel classification of heat-related illnesses: A multicentre observational study (heat stroke study 2012). International journal of environmental research and public health, 15(9), p.1962. https://www.mdpi.com/1660-4601/15/9/1962

26. Kovats, R.S., Hajat, S. and Wilkinson, P., 2004. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. Occupational and environmental medicine, 61(11), pp.893-898. https://oem.bmj.com/content/61/11/893.short

27. Chambers, J., 2020. Global and cross-country analysis of exposure of vulnerable populations to heat waves from 1980 to 2018. Climatic Change, 163(1), pp.539-558.
https://link.springer.com/article/10.1007/s10584-020-02884-2

28. Knowlton, K., Kulkarni, S.P., Azhar, G.S., Mavalankar, D., Jaiswal, A., Connolly, M., Nori-Sarma, A., Rajiva, A., Dutta, P., Deol, B. and Sanchez, L., 2014. Development and implementation of South Asia's first heat-health action plan in Ahmedabad (Gujarat, India). International journal of environmental research and public health, 11(4), pp.3473-3492. https://www.mdpi.com/1660-4601/11/4/3473

29. Natural Resources Defense Council. 2022. "Expanding Heat Resilience Across India: Heat Action Plan Highlights 2022." https://www.nrdc.org/sites/default/files/india-heat-resilience-20220406.pdf

30. Rajasthan Climate Change Project. Heat Action Plan. https://www.dmrelief.rajasthan.gov.in/documents/Heat_Action_Plan.pdf

31. Ministry of External Affairs (Government of India). 2022. "G-20 and India's Presidency
G-20 Development Working Group (DWG) meeting to be held in Mumbai from December 13 – 16, 2022." https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1882356

32. Dutta, P. 2023. "2023 an El Nino Year, what it means." https://timesofindia.indiatimes.com/home/environment/global-warming/explained-2023-an-el-nino-year-what-it-means/articleshow/97118225.cms

33. India Meteorological Department. 2023. "Seasonal outlook for rainfall and temperature during March to May 2023." https://mausam.imd.gov.in/amaravati/mcdata/Press_Release.pdf

34. Government of Rajasthan. All information about Jodhpur (geography, topography, climate, vegetation cover. https://jodhpur.rajasthan.gov.in/jankalyan-category-and-entry-type/42/1/4

35. Saxena, D. and Gupta, Nn (2020). Impact of Tourism on Economic Development of Rajasthan: A Case Study of Jaipur. https://www.inspirajournals.com/uploads/Issues/2127197027.pdf

36. https://cgwb.gov.in/District_Profile/Rajasthan/Jodhpur.pdf

37. https://jodhpur2.kvk2.in/district-profile.php

38. Sridharan N et al. 2019, Enhancing Institutional and Community Resilience to Climate Change Impacts in Jodhpur City: Heat Stress Report prepared in the BReUCom (Building Resilient Urban Communities) project, funded by the Erasmus+ Program of the European Union. https://www.breucom.eu/pluginfile.php/1808/block_html/content/Breucom_CS_10.pdf

39. NPDRR 2023, National Platform for Disaster Risk Reduction, Ministry of Home Affairs, Government of India

40. United Nations Intergovernmental Panel on Climate Change, 2014. "Mitigation of Climate Change." https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf

41. Jones, Brenda, and Jean Andrey. "Vulnerability index construction: methodological choices and their influence on identifying vulnerable neighbourhoods." International journal of emergency management 4, no. 2 (2007): 269-295. https://www.inderscienceonline.com/doi/abs/10.1504/IJEM.2007.013994; Tate, Eric. "Social vulnerability indices: a comparative assessment using uncertainty and sensitivity analysis." Natural Hazards 63 (2012): 325-347. https://link.springer.com/article/10.1007/s11069-012-0152-2; Wood, Nathan J., Christopher G. Burton, and Susan L. Cutter. "Community variations in social vulnerability to Cascadia-related tsunamis in the US Pacific Northwest." Natural hazards 52 (2010): 369-389. https://link.springer.com/article/10.1007/s11069-009-9376-1

42. Hajat, Shakoor, Scott C. Sheridan, Michael J. Allen, Mathilde Pascal, Karine Laaidi, Abderrahmane Yagouti, Ugis Bickis et al. "Heat–health warning systems: a comparison of the predictive capacity of different approaches to identifying dangerously hot days." American journal of public health 100, no. 6 (2010): 1137-1144. https://ajph.aphapublications.org/doi/abs/10.2105/AJPH.2009.169748; Menne, B., and F. Matthies. "Improving public health responses to extreme weather/heat-waves–EuroHEAT." Technical Summary, WHO (2009). https://apps.who.int/iris/handle/10665/107935

43. Rathi, Suresh Kumar, Soham Chakraborty, Saswat Kishore Mishra, Ambarish Dutta, and Lipika Nanda. "A heat vulnerability index: spatial patterns of exposure, sensitivity and adaptive capacity for urbanites of four cities of India." International journal of environmental research and public health 19, no. 1 (2021): 283. https://www.mdpi.com/1660-4601/19/1/283

44. Sorensen, Cecilia, Sujata Saunik, Meena Sehgal, Anwesha Tewary, Mini Govindan, Jay Lemery, and John Balbus. "Climate change and women's health: Impacts and opportunities in India." GeoHealth 2, no. 10 (2018): 283-297.

45. Ellena, Marta, Giulia Melis, Nicolás Zengarini, Eduardo Di Gangi, Guglielmo Ricciardi, Paola Mercogliano, and Giuseppe Costa. "Micro-Scale UHI Risk Assessment on the Heat-Health Nexus within Cities by Looking at Socio-Economic Factors and Built Environment Characteristics: The Turin Case Study (Italy)." Urban Climate 49 (2023): 101514. https://doi.org/10.1016/j.uclim.2023.101514.

46. India Meteorological Department Frequently Asked Questions on Heat Wave, available at: https://internal.imd.gov.in/section/nhac/dynamic/FAQ_heat_wave.pdf

47. NCDC 2020, Directorate General of Health Services, Ministry of Health and Family Welfare, Government of India, Posters on Heat Waves

48. U.S. Department of Energy. Cool Roofs. https://www.energy.gov/energysaver/cool-roofs

49. Akbari, Hashem, Tengfang Xu, Haider Taha, Craig Wray, Jayant Sathaye, Vishal Garg, Surekha Tetali, M. Hari Babu, and K. Niranjan Reddy. Using cool roofs to reduce energy use, greenhouse gas emissions, and urban heat-island effects: Findings from an India experiment. No. LBNL-4746E. Lawrence Berkeley National Lab., Berkeley, CA (United States), 2011. https://

50. Joshi, Jaykumar, Akhilesh Magal, Vijay S. Limaye, Prima Madan, Anjali Jaiswal, Dileep Mavalankar, and Kim Knowlton. 2022. “Climate Change and 2030 Cooling Demand in Ahmedabad, India: Opportunities for Expansion of Renewable Energy and Cool Roofs.” Mitigation and Adaptation Strategies for Global Change, https://doi.org/10.1007/s11027-022-10019-4

51. Vellingiri, Selvakumar, Priya Dutta, Srishti Singh, L. M. Sathish, Shyam Pingle, and Bijal Brahmbhatt (2020). “Combating climate change-induced heat stress: assessing cool roofs and its impact on the indoor ambient temperature of the households in the urban slums of Ahmedabad.” Indian Journal of Occupational and Environmental Medicine 24:1. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7227734/

52. Xu, Tengfang, Jayant Sathaye, Hashem Akbari, Vishal Garg, and Surekha Tetali. “Quantifying the direct benefits of cool roofs in an urban setting: Reduced cooling energy use and lowered greenhouse gas emissions.” Building and Environment 48 (2012): 1-6. https://doi.org/10.1016/j.buildenv.2011.08.011

53. Joshi, Jaykumar, Akhilesh Magal, Vijay S. Limaye, Prima Madan, Anjali Jaiswal, Dileep Mavalankar, and Kim Knowlton. “Climate Change and 2030 Cooling Demand in Ahmedabad, India: Opportunities for Expansion of Renewable Energy and Cool Roofs.” Mitigation and Adaptation Strategies for Global Change, July 2022. https://doi.org/10.1007/s11027-022-10019-4

54. Madan, Prima, Vijay Limaye, Sameer Kwatra, and David Goldstein (2023). “Telangana Announces a Groundbreaking Cool Roof Policy,” https://www.nrdc.org/bio/prima-madan/telangana-announces-groundbreaking-cool-roof-policy

NRDC India

म्हारो जोधपुर
SERVING THE PEOPLE OF SUNCITY
नगर निगम उत्तर

MHT
MAHILA HOUSING SEWA TRUST
Dignified Home, Dignified Work, Dignified Life