



PHOTOGRAPH: JOEL MICHAEL / CSE

HOW HOT IS TOO HOT?

Rising temperatures are testing the limits of human tolerance to heat. With their predominantly built-up landscape, urban areas offer no respite. A study by Centre for Science and Environment on the morphology and heat patterns of nine Indian cities over the past decade shows how these urban centres are turning into heat islands with a potentially serious impact on human health. An analysis by **Rajneesh Sareen, Mitashi Singh and Nimish Gupta**, with **Shagun** in Haryana and **Kiran Pandey, Akshit Sangomla and Rohini Krishnamurthy** in New Delhi



Biresh Kumar, a 38-year-old labourer, works at least six hours in the sun every day. Though it is only mid-April—early days of summer in north India—the afternoon temperatures hover around 38°C in Bhopani, the village in Haryana’s Faridabad district where Kumar works at a brick kiln. When the summer peaks in May-June, the mercury will likely cross 40°C. “I feel like I’m trapped in a heat island. But I have to work to repay a debt I owe to the labour contractor,” says Kumar.

Sitting on a cot under a tree at some distance is Kumar’s co-worker Somveer. For the past two days, Somveer has had body ache, weakness and fever, which has forced him to miss work and, as a result, forego his wage. He does not know the reason for his ailment, but says it could be due to constantly working under the scorching sun. The National Institute for Occupational Safety and Health, US, recommends that those who work in the heat should consume 237 ml of water every 15-20 minutes. But for workers like Kumar and Somveer, that would mean more breaks and missed targets, resulting

With the rise in temperatures due to global warming, millions of informal sector workers, like Biresh Kumar of Haryana, have no option but to work in scorching heat

in loss of wage. Neeraj Kaushik, medical officer in-charge at the Government Hospital in Kheri Kalan that Somveer and Biresh have access to, says he sees several labourers with complaints of fainting episodes. “They are weak and dehydrated, with severely chapped lips. If they have comorbidities, like diabetes, it becomes an emergency situation. If their vitals are weak, it takes a long time to resuscitate them,” he says.

Kumar and Somveer are just two of the nearly 440 million people employed in India’s unorganised sector, as per *Economic Survey 2021-22*. But their situation clearly depicts how informal workers are forced to face the brunt of rising temperatures caused by global warming. And the temperature rise is quite persistent. Sample these. This year, the earth witnessed its hottest March on record. March 2024 was also the 10th straight temperature record-breaking month, as per an April 9 report by the EU’s Copernicus Climate Change Service (see ‘Relentless heat’). For India, 2023 is the second-warmest year on record, with the average temperature 0.65°C higher than the baseline set for 1981-2010, states India Meteorological

Department’s recently released annual “Climate Summary of India”. All five of India’s warmest years on record have occurred in the past 14 years.

The severity of heat is not linked only to temperature rise. In peak summer, humidity levels shoot up as well, aggravating the heat stress. This is how it happens. Humans sweat when faced with extreme heat. The evaporation of sweat cools the body. But if the moisture in the air is too high, the rate of evaporation is slower or negligible. In such a situation, the heat felt by humans (or other animals and plants) is higher than the observed temperature. At such a point, the temperature of the body starts increasing, which could be lethal.

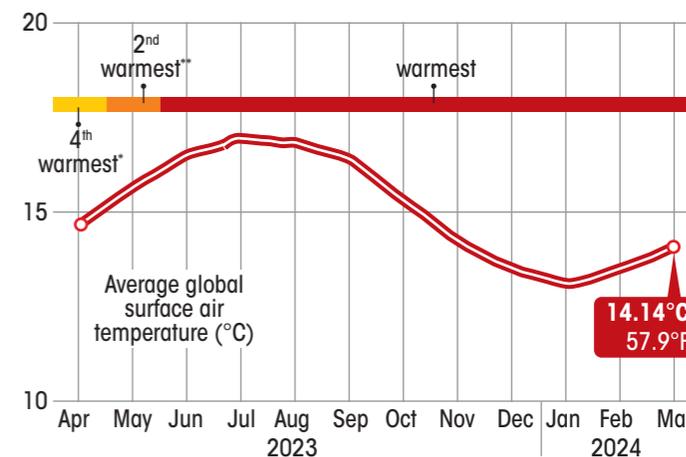
“As people get warmer, they sweat, and more blood is pumped to their skin so that they can maintain their core temperatures by losing heat to the environment. At certain levels of heat and humidity, these adjustments are no longer sufficient, and the body core temperature begins to rise,” says W Larry Kenney, professor of physiology and kinesiology at the Penn State College of Health and Human Development, US. “This is not an immediate threat, but it does require some form of relief. If people do not find a way to cool down within hours, it can lead to heat exhaustion, heat stroke and strain on the cardiovascular system that can lead to heart attacks in vulnerable people,” Kenney says.

GAUGING HEAT PLUS HUMIDITY

The combined effect of temperature and humidity can be captured by calculating the wet-bulb temperature of an area to assess the actual felt temperature. Wet-bulb temperature (named so because the value is obtained from a wet-bulb thermometer) is the lowest temperature to which air can be cooled by the evaporation of water given a constant pressure. Internationally, the safe limit of wet-bulb temperature for humans is below 30°C, while 35°C is the highest limit, above which there is possibility of death. Between 30°C and 35°C, the human body undergoes hyperthermia, when the body

Relentless heat

March 2024 was the warmest March on record and the 10th straight temperature record-breaking month



*2016 had the warmest April; ** 2020 had the warmest May
Source: European Union’s Copernicus Climate Change Service

temperature increases leading to discomfort and impacts on organs.

To mark the cities where humans would have to experience heat and humidity levels beyond these tolerable levels, Kenney and researchers from Purdue University, US, have simulated global temperature rise between 1.5°C and 4°C from pre-Industrial levels (see ‘Scary hot’ on p30). Last October, they published their findings in *Proceedings of the National Academy of Sciences*. Their study says that if global temperature rises by 1.5°C from the pre-Industrial levels, extreme heat and humidity will impact billions of people who will not be able to “naturally cool themselves.” If the temperature rise is 2°C above the pre-Industrial levels, “the 2.2 billion residents of Pakistan and India’s Indus River Valley, the one billion people living in eastern China and the 800 million residents of sub-Saharan Africa will annually experience many hours of heat that surpass human tolerance.” If warming of the planet continues to 3°C above pre-Industrial levels, the heat and humidity levels that surpass human tolerance would begin to affect the Eastern

Seaboard (the eastern US region that faces the Atlantic Ocean) and the middle of the US—from Florida to New York and from Houston to Chicago. South America and Australia would also experience extreme heat at that level of warming.

What's worse, the wet-bulb temperature threshold of 35°C cannot be applied to human adaptability across all climatic conditions, states a 2021 paper in the *Journal of Applied Physiology*. In high humidity conditions, that threshold could be well below 35°C. This means that there may be humid heatwaves close to the human survivability threshold already occurring in India and they are not being monitored. More importantly, the people impacted are not being informed about the occurrence of such conditions. The study was the first one to evaluate the impact of wet-bulb temperature on human health with empirical evidence and estimated that at 2°C of global warming, Kolkata and Delhi would experience 30-40 annual hours of humid heatwaves.

MISSING COMPONENT

On March 27, the India Meteorological Department (IMD) declared this year's first heatwave conditions in isolated pockets of west Rajasthan. But IMD's heatwave definition does not account for humidity, even when India has seen a 30 per cent rise in the magnitude of "moist heat stress" during 1980-2020, as per IMD's own report released in 2024. The IMD definition of heatwave does not take humidity into account because the weather agency does not calculate the wet-bulb temperature of a place.

Under such heat conditions, staying indoors is also not a solution for most, especially the poor. Take the case of Kumar and Somveer. Their makeshift houses, with brick walls and tin roof, have no ventilation. Many of the rooms do not even have a fan. "Staying indoors adds a higher vulnerability factor due to poor built environment conditions like lack of ventilation and cooling agencies," Ramit Debnath, assistant professor and an academic director at the University of Cambridge, UK, tells *Down To Earth*.

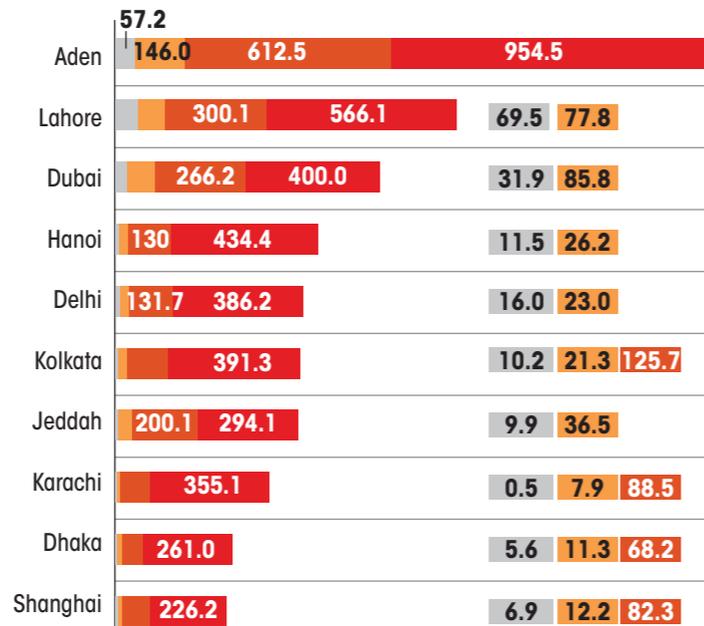
Scary hot

Where will wet-bulb temperatures[^] turn unbearable

Average global temperature rise from pre-Industrial levels



Annual hot-hours* for global cities at a global warming of 1.5°C and additional hot hours for further warming



[^]The temperature to which an object can be cooled solely by evaporation of water, given a constant atmospheric pressure. The human adaptability threshold of a wet-bulb temperature is 30.55°C. Temperatures beyond this can cause inability (in healthy young humans) to carry out basic activities; *The hours when the heat is beyond the human adaptability threshold of a wet-bulb temperature of 30.55°C; Source: Vecellio et al. Greatly enhanced risk to humans as a consequence of empirically determined lower moist heat stress tolerance. PNAS (2023)

AD 5

Since 2005, data shows a gradual rise in heat-related deaths among women in India as per an analysis in *Significance*, a journal published by Royal Statistical Society UK. And women in India spend 54 per cent more time indoors compared to men, it says. Debnath is one of the authors of the analysis.

For Kumar and Somveer, reducing the day time working hours by stretching their work to late evening or night is also not an option because in peak summer, temperatures do not decline significantly after sunset, while humidity levels often shoot up. "I was used to this work and never bothered much about the heat. But in the past two years, working under the sun has become a tough ask," Kumar says.



Excessive infrastructural development, erosion of green spaces, could create an urban heat island effect in cities

SWELTERING CITIES

Poorly planned, heat-trapping infrastructure, along with dwindling natural spaces, turn up the temperatures in major Indian cities

IN A warming world, urbanisation has a profound impact on heat. As a city's population grows, infrastructure needs to be developed to cater to its requirements.

Cities contribute more than two-thirds of global carbon dioxide emissions, according to the UN Environment Programme. However, their environmental impact goes beyond emissions. As a city grows, the way buildings, roads and railways are laid out; the density, height and size of buildings, and the materials used; the amount of green spaces and water bodies; and level of human activities such as use of vehicles and air-conditioners together determine how much heat is retained in the immediate area.

When released, this heat raises the temperatures of the nearby atmosphere. As the grey infrastructure gets denser and

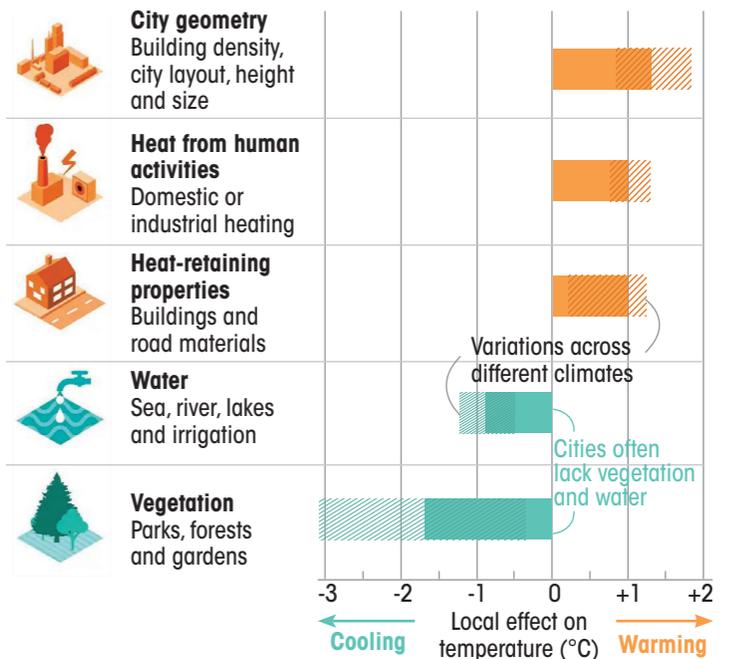
more concentrated, it erodes the natural spaces that act as heat sinks and keep the environment cool (see 'Influencing factors'). If left unchecked, such development could create an urban heat island effect, with cities recording high temperatures that can adversely impact the health of people, and also potentially be fatal.

To analyse the status of urban heat islands in the country and establish the ongoing heat burden that is a result of their development, Delhi-based think tank Centre for Science and Environment (CSE) conducted a study in nine cities—Delhi, Jaipur, Kolkata, Nagpur, Pune, Ahmedabad, Hyderabad, Chennai and Bhubaneswar. These cities, which are of different sizes and are located in different climatic zones, show that the problem of heat is not restricted to a specific kind of climate or geography.

CSE's analysis of heat patterns in these cities over the past 10 years (2014-23) shows

Influencing factors

Natural and built environments have potential to either warm up or cool down the cities



Source: UN Intergovernmental Panel on Climate Change

that four of them had more than 80 per cent of their area engulfed in extreme heat during the summer months. CSE determined this by considering the land surface temperatures (LSTs) of the cities, recorded by satellites from the Landsat series of the US Geological Survey and space agency NASA.

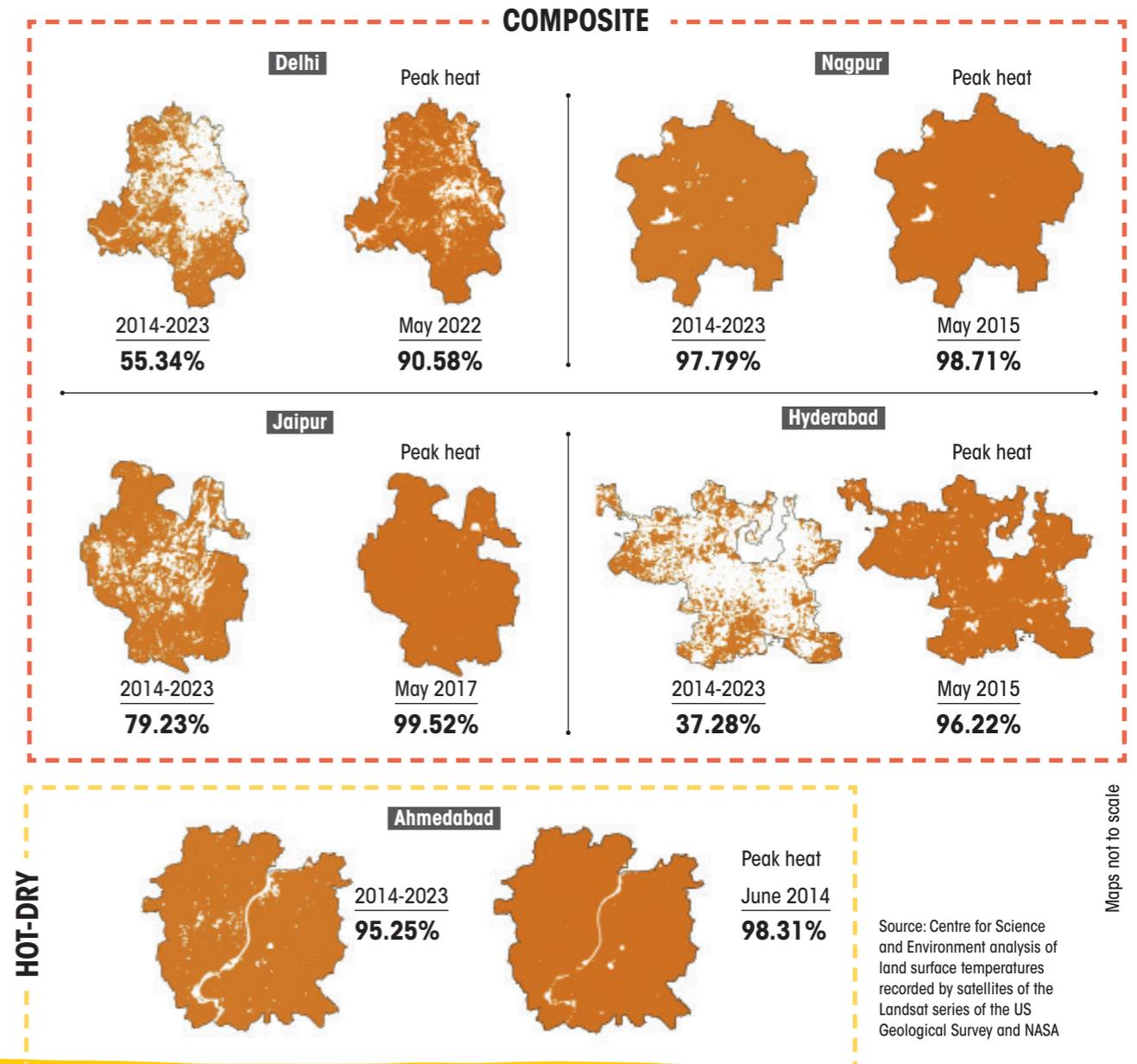
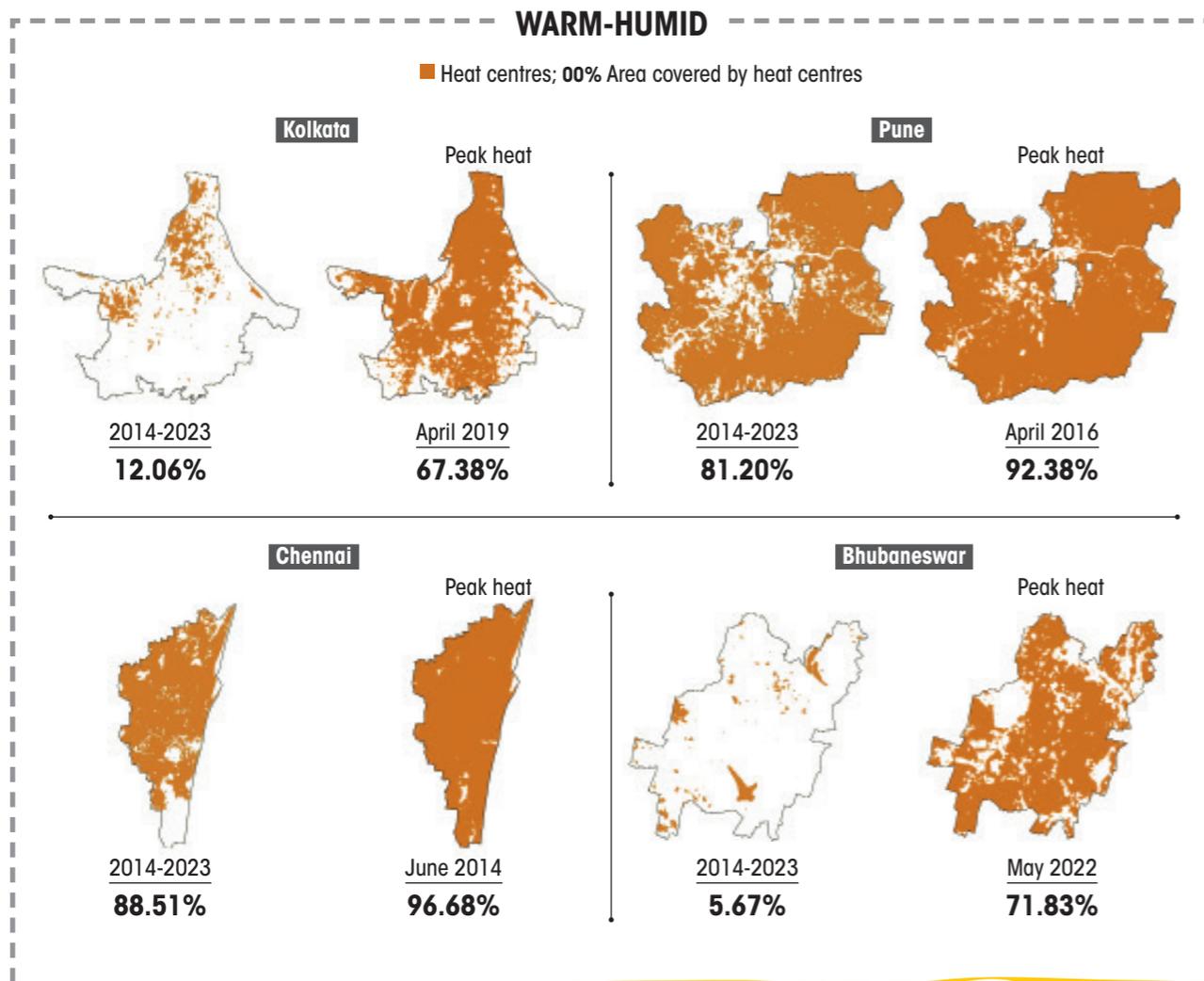
LST indicates the temperature of the earth's skin, which according to research can go 2-7°C above air temperature. To determine extreme heat conditions, CSE analysed LSTs more than 45°C for eight cities and more than 42°C for the coastal city of Chennai. This is in accordance with India Meteorological Department (IMD)'s threshold for heatwaves based on air temperature. When the temperature crosses 40°C in plains, IMD declares a heatwave, while for coastal areas the threshold is 37°C.

Nagpur (97.79 per cent) was the most

PHOTOGRAPH: VIKAS CHOUDHARY / CSE

Cities burning up

Six of nine cities showed high temperatures in the summer months of the past decade. During the years of peak heat in the cities, more than 90% of their respective geographic area was covered



heat-stressed during the summer months in 2014-23, followed by Ahmedabad (95.25 per cent), Chennai (88.51 per cent) and Pune (81.2 per cent) (see 'Cities burning up').

These areas also recorded extreme temperatures for more than six years during the decade under study, indicating that the populations living here have experienced prolonged heat exposure.

Of the remaining cities, Jaipur (79.23 per cent) and Delhi (55.34 per cent) also showed

extreme heat stress during the decade under analysis. Hyderabad (37.28 per cent), Kolkata (12.06 per cent) and Bhubaneswar (5.67 per cent) saw some respite, owing to the cities' geography and the presence of a large number of waterbodies here.

Analysis of LSTs also showed the years when the heat "peaked" in each city. In all the cities barring Kolkata and Bhubaneswar, the month when peak heat was experienced covered more than 90 per cent of their respective geographic areas.

HUMIDITY TURNING FOE

The heat crisis in Indian cities is not limited to just a rise in temperature. CSE's analysis reveals that humidity, which so far provided respite from heat, especially in coastal cities, is now exacerbating it.

Humans cope with heat through sweating, which helps the body stay cool. However, in times of heat and high humidity, this cooling process is slowed as the level of moisture in the air reaches a saturation point. At this point, the body's temperature cannot be reg-

ulated properly. Prolonged exposure to such conditions can be lethal.

The combined impact of temperature and relative humidity, or the level of moisture in the air below the saturation point, can be estimated by either the wet-bulb temperature or the heat index of a location.

To calculate the humidity levels of the nine cities under analysis, CSE studied the heat index or humidex based on US National Oceanic and Atmospheric Administration (NOAA) calculations. This assessment calcu-

lates humid heat—also called thermal discomfort or the “feel-like” temperature of a city—to warn whether it is in a “caution”, “extreme caution” or “danger” situation, based on the temperatures recorded.

CSE’s analysis suggests that in 2023, Chennai had nearly two months of humid heat at danger levels, recording humidex between 40°C and 52°C (see ‘Warning signs’). At this level, prolonged exposure to the heat or physical activity can likely result in heat cramps or heat exhaustion, with a possibility of heat stroke. Bhubaneswar and Kolkata were also reported to be in the danger range for more than a month each, while Delhi recorded 13 days, Jaipur reported four days and Nagpur saw three days with humidex at this level.

Extreme caution situations, with ther-

mal discomfort between 32.5°C and 40°C, were recorded in all the cities in 2023, except Pune.

Ahmedabad (85 days), Chennai (83 days), Kolkata (76 days), Nagpur (75 days) and Bhubaneswar (71 days) reported thermal discomfort of this level for more than two months, followed by Jaipur with about two months and Hyderabad and Delhi with one-and-a-half months each. Prolonged exposure to this level carries the risk of heat stroke, cramps or exhaustion.

The analysis also revealed high prevalence of caution humidex levels in most cities, with Pune experiencing 149 days, Hyderabad 101 days, Delhi 96 days and Jaipur 91 days. This category, according to NOAA’s humidex, includes temperatures between 26.6°C and 32.5°C, in which

prolonged exposure and physical activity can cause fatigue.

WHY CITIES ARE HEATING UP

The prevalence of heat stress in these cities indicates poorly planned grey infrastructure, comprising houses, commercial buildings, schools, roads, characterised by the large number of impervious surfaces including concrete, unsuitable roofing and walling materials, uninformed building design and layouts that neither mitigate heat nor support or use the predominant wind flow. The problem is compounded when a decline in blue-green spaces, comprising waterbodies and vegetation that act as natural heat sinks, is recorded.

For instance, between 1999 and 2021, Kolkata saw a 9 per cent increase in its built-up area, but lost 39 per cent of its surface water cover and 18.7 per cent of its green cover (see ‘Crucial covers lost’, p38-39). During the same period, Pune lost 31.8 per cent of its surface water and a massive 91.3 per cent of its green cover. Jaipur lost 21.5 per cent and 88.6 per cent of its surface water and green cover, respectively, while Delhi lost nearly half its surface water and 63.6 per cent of its green cover.

Adding to the pressure are anthropogenic activities like excessive use of private motorised vehicles and increasing use of refrigerators and air-conditioners in households, which are already under scanner for their role in increasing global warming. According to the India Cooling Action Plan, released in 2019, refrigeration and air-conditioning are already estimated to be responsible for 10 per cent of the global carbon dioxide emissions. According to an estimate published in a 2019 paper by the Indo-Swiss Building Energy Efficiency Project (BEEP), a bilateral initiative implemented by the Swiss Agency for Development and Cooperation and India’s Bureau of Energy Efficiency, 40 per cent of the urban households in India are set to own a room air

conditioner by 2037-38, up from less than 10 per cent currently.

SIGNS OF THERMAL INEQUITY

While all cities reel under heat stress, the impact on the people is not the same. In any city, children and the elderly see a higher health risk due to heat than other age groups. According to the US Centers for Disease Control and Prevention (CDC), the elderly are at risk due to comorbidities and inability to adapt quickly to changing temperatures. Already, heat-related deaths of adults over 65 years in age worldwide have increased by 85 per cent since the 1990s, according to “The 2023 report of the *Lancet* Countdown on Health and Climate Change”.

If global mean temperature continues to rise to just under 2°C, annual heat-related deaths of this population group are projected to increase by 370 per cent by midcentury, says the report.

Children, as per CDC, are more vulnerable due to their reliance on adults to keep them hydrated. Fears over exposing this population group to extreme heat is evidenced by the early start or extension of summer vacations in schools, which has become a trend

in the country.

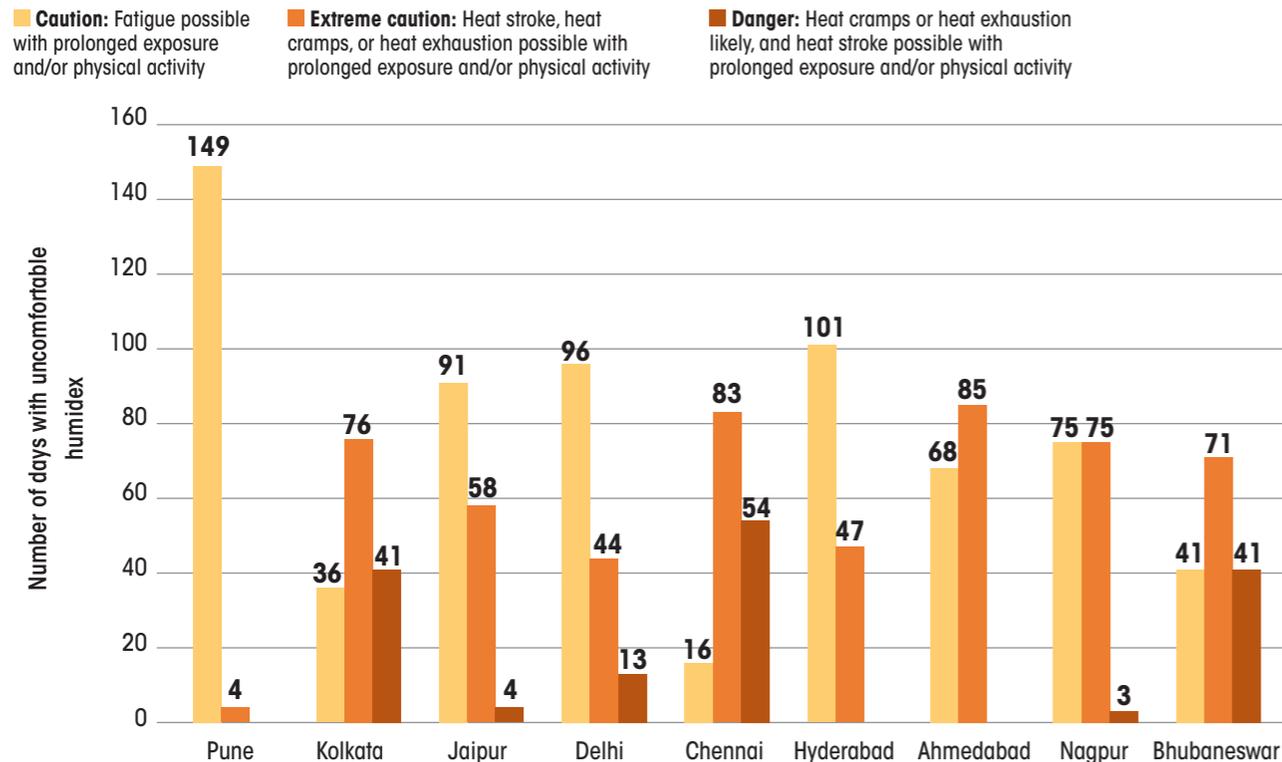
The poor population is also highly vulnerable, given that this group typically lives in congested and highly polluted locations. A study by researchers in the UK and US, published in April 2023 in the journal *PLOS Climate*, supports the argument. It says that 100 per cent of Delhi is in the danger humidex levels, with factors like presence of slums in high humidex locations aggravating the city’s heat-related vulnerability due to overcrowding, use of poor materials like tarpaulin and tin sheets, along with lack of access to electricity, water and sanitation, or healthcare. The poor are also at risk of prolonged heat exposure since their work is often outdoors.

A comprehensive climate heat vulnerability analysis conducted by CSE, covering aspects such as presence of green and blue

THE POOR POPULATION IN CITIES IS HIGHLY VULNERABLE TO HEAT STRESS AND ASSOCIATED HEALTH RISKS, GIVEN THAT THIS GROUP TYPICALLY LIVES IN CONGESTED AND HIGHLY POLLUTED LOCATIONS AND USES HEAT-TRAPPING ROOF MATERIALS SUCH AS TIN SHEETS

Warning signs

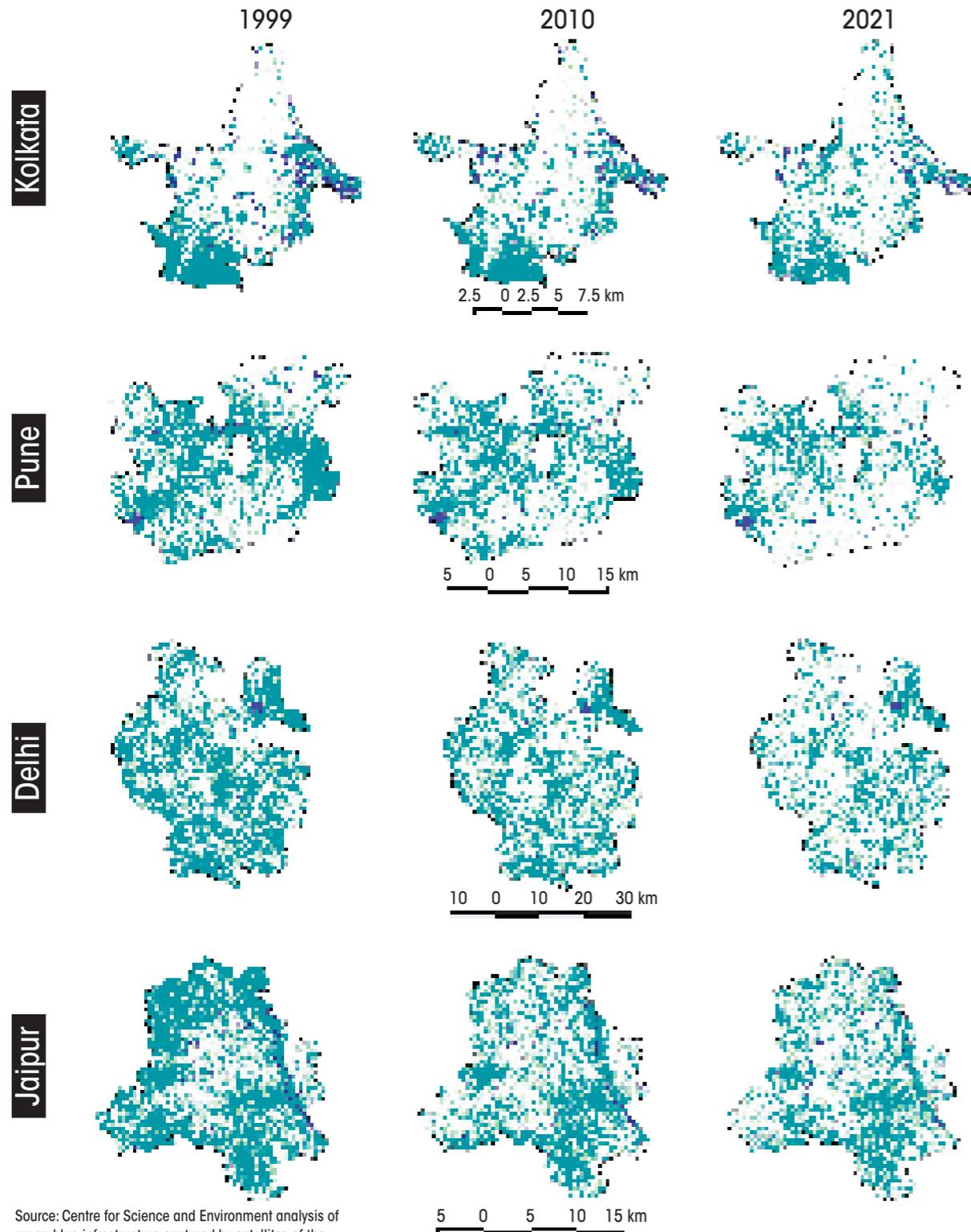
Cities showing prolonged exposure to humid heat indicate high health risks for people



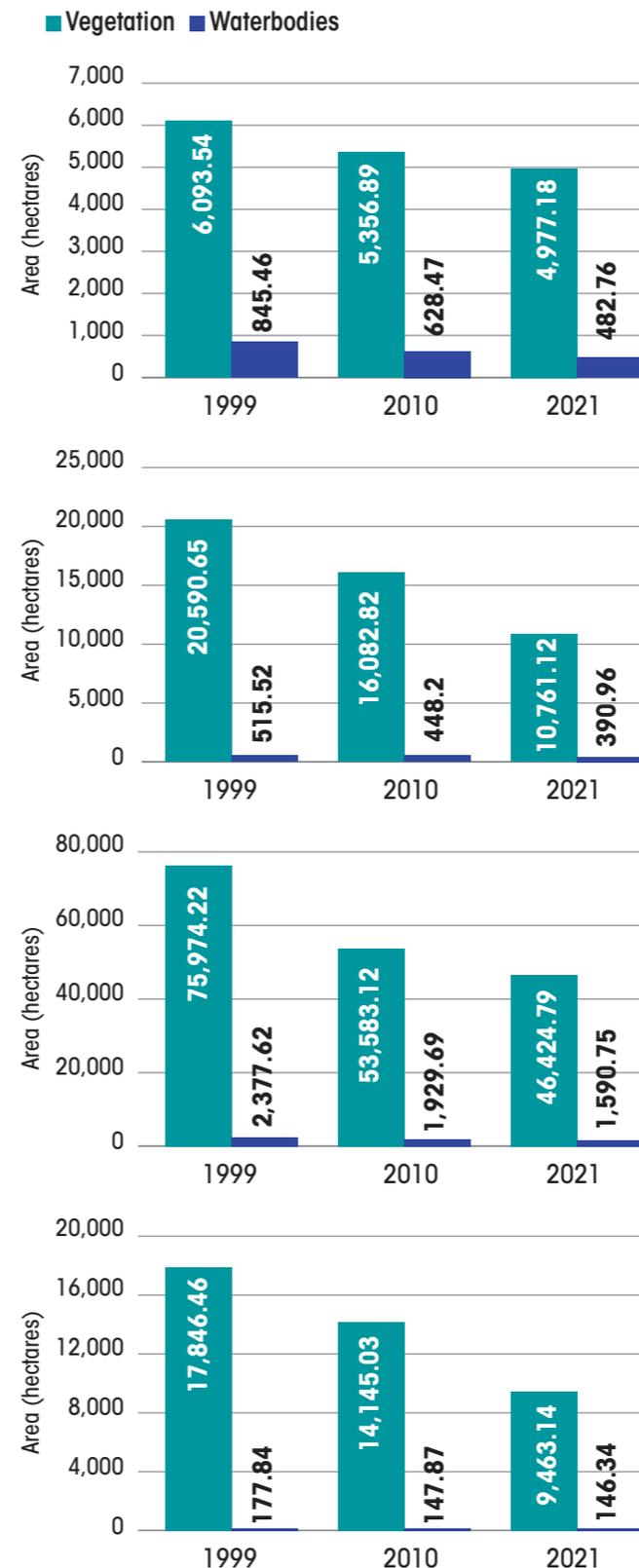
Note: Humidex is the thermal discomfort or “feel-like” temperature
Source: Centre for Science and Environment analysis of a humidex estimated using US National Oceanic and Atmospheric Administration (NOAA) calculations

Crucial covers lost

Decline in the blue-green cover, or waterbodies and vegetation that act as natural heat sinks, in cities compounds the problem of heat stress



Source: Centre for Science and Environment analysis of green-blue infrastructure captured by satellites of the Landsat series by US Geological Survey and NASA



spaces, population below poverty line, thermal performance of roof materials, access to electricity and water, reveals that nearly half of the wards in Kolkata have a high to moderate heat vulnerability. Approximately 3,755 hectares of the city are under notified slums, of which 73 per cent are heat-stressed areas. Around one million people live in these areas.

Despite the high heat risks the poor face, with little to no means of respite, currently they do not feature prominently in health resilience and response actions. This is proven by an independent assessment by Delhi-based think tank Centre for Policy Research. In a March 2023 report, the think tank evaluates about 37 heat action plans across the country, at the city, district and state levels. It finds that almost all heat action plans “are poor at identifying and targeting vulnerable groups”. Closing this gap is crucial to reduce casualties and economic losses and to improve productivity.

BUILT-IN HEAT TRAPS

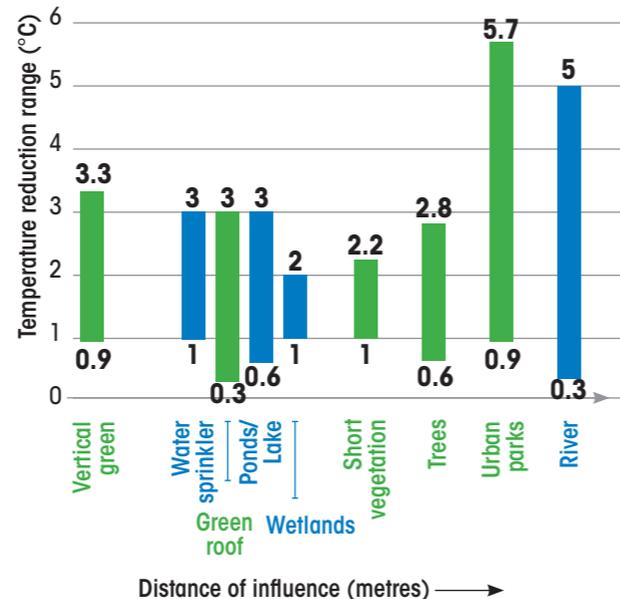
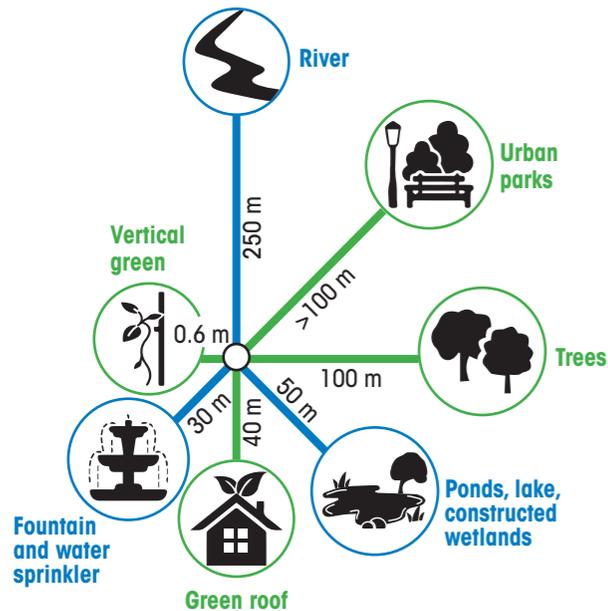
A closer look at the design and layout of the nine cities shows how the construction of grey infrastructure impacts heat regulation. Urban morphology enables a broad understanding of the built environment in a localised area. Urban morphology includes the geometry of the built environment, such as the height of buildings and spaces between two constructions, along with the availability of green cover and waterbodies in the vicinity (see ‘Morphology matters’ p44).

According to CSE’s analysis, in identified heat centres of cities, the compact mid-rise and open mid-rise morphologies showed relatively lower LSTs, from 46.36°C to 48.09°C. These morphologies comprise neighbourhoods with mid-rise buildings, which have the three to seven storeys apart from the ground floor, and good to moderate vegetation. Presence of green areas and mutual shading to block direct sunlight from falling on structures were found to be the key drivers in bringing down LSTs.

In contrast, areas with low-rise buildings

Microclimate enhancement

Provision of adequate space to blue and green cover is the most effective solution to cool cities



Source: Created by Centre for Science and Environment using information from "Blue Green Systems for urban heat mitigation: mechanisms, effectiveness and research directions", *Blue-Green Systems*, December 2022

exhibited LSTs ranging from 46.79°C to 52.35°C. This morphology was seen in neighbourhoods with row housing and industrial areas. CSE's analysis indicated that the maximum surface temperature in these areas was approximately 4°C higher than that observed in mid-rise constructions. This suggests not only sparse vegetation in the localities, but also complete exposure of the streets to sunlight, which may increase the amount of heat retained.

However, in terms of heat-trapping, the large low-rise morphology (50.53°C) in industrial areas and lightweight low-rise morphology (50.91°C-55.16°C) seen in informal settlements fared the worst. The reason for this was the use of poor roofing materials like galvanised iron sheets and plastic sheets, which could spike LST by as much as 7.33°C, according to CSE's study. Cooling solutions in such neighbourhoods could include using better roof materials like reflective paints and cool roofs to reflect the sun-

light rather than absorb it, and green roofs with adequate vegetation.

EMERGING CONCERN

Another urban feature that traps a high amount of heat is the uncovered parking lot. Such lots are typically made using heat-trapping asphalt or concrete. A 2018 report by the Institute of the Environment and Sustainability at University of California, Los Angeles, US, shows that surface temperatures can rise as high as 60°C in uncovered parking lots due to exposed cars and asphalt (see 'High exposure', p42).

Similarly, a 2020 study by researchers from the Indian Institute of Technology, Delhi, published in the journal *Urban Climate*, highlights the heat retention in concrete spaces of the Connaught Place area in the national capital. According to the study, this commercial and business hub has a good amount of greenery but is still 4°C hotter than the rest of Delhi, due to large un-

HEAT-SMART INITIATIVE

Armed with a weather monitoring unit and training on adverse impacts of heatwaves, three climate *sakhis* ensure safety of residents of an informal settlement in Delhi

PREETHA BANERJEE

VIVEKANANDA CAMP stands out in the well-designed diplomatic enclave of Chanakyapuri, Delhi. The 2,000-odd residences of the informal settlement, which mostly house waste-pickers from West Bengal and Haryana, must contend with continuous heat stress. The elders spend the whole day in direct sunlight, collecting waste and scrap to sell. "On hot afternoons, our children would often faint or vomit while walking back from school. We did not know how to help them," says Jharna, a resident.

The households also see poor water availability, relying mostly on large tankers that arrive at a fixed time. "If no adults are home when the tanker comes, the children run towards it with containers in hand, further exerting themselves," said Kastura, another resident.

Since March 2023, Jharna and Kastura, along with their neighbour Dulali Khatun, have been working as "climate *sakhis*" to help people of the settlement beat the heat stress. Through an initiative by Chintan Environmental Research and Action Group, a Delhi-based non-profit, the women have been trained on the adverse impacts of heatwaves and how to address them. They share this knowledge with others. "We know now that if anyone collapses due to heat or is short of breath, we should not force them to drink water since they can choke. Instead, we should loosen their clothes and place wet, cotton strips on their forehead and body to cool them down. We also advise people to cover their heads with a soft cloth or towel when going out," says Kastura.

The three *sakhis* have also been



Dulali Khatun (left) and Kastura, climate *sakhis* of Vivekananda Camp, warn people of the heat severity through colour-coded plates on a board in the settlement

equipped with a weather monitoring unit by Chintan and SEEDS India, another Delhi-based non-profit. "The unit consists of a tracker on the roof of my house and a digital display device in my room, which shows the outdoor and indoor temperature and humidity levels all day," explains Kastura. She shares the readings thrice a day with experts from Chintan, who analyse the metrics and advise her on the severity of the heat.

"Based on the readings, we put up plates coloured green, yellow or red on boards strategically placed in the neighbourhood to alert residents about the precautions to take to deal with heat," adds Kastura. "Red is the worst. We put it up usually when the temperature is close to 40°C, along with high humidity," she says. The red plate is accompanied by advice for people to avoid outdoor activity or take breaks after every 50 minutes of work, in case they cannot avoid heat exposure. The yellow plate asks residents to drink plenty of water, lassi, buttermilk and lemonade in lieu of fizzy drinks, tea or coffee.

"People who read the boards often tell us that they cannot avoid going outside, as it would hamper their earnings. We explain that the short-term loss in income is better than increasing the risk of long-term health impacts," says Jharna.

The climate *sakhis*' work has had multiple benefits, particularly for women. "To avoid direct sunlight, we began to promote use of gas for cooking rather than burning coal or wood in the open. Many households now cook indoors, which has also helped our health as we are no longer exposed to smoke," says Kastura. "Open burning of waste and bonfires during winter have also completely stopped," she adds.

The *sakhis* earn ₹11,000 through a fellowship programme by Chintan. They have started working in other informal settlements such as Sanjay Camp in Chanakyapuri, and those in RK Puram, Kotla, Bahapur and Rithala. "I want to share whatever I am learning with as many women as possible, because they care the most," says Jharna.

PHOTOGRAPH: KA SHREYA / CSE

covered parking spaces built using concrete.

The official website of the erstwhile North Delhi Municipal Corporation says that as of March 2021, the municipal area has 12,524 car parking spaces measuring a total of 200,505 sq m, which are uncovered.

With private car ownership increasing in urban areas, smart solutions that enhance shading in parking lots are required (see 'Cool down lots'). These areas also bring opportunity to innovate and decarbonise. For instance, coupling of solar PV panels mounted on shading devices or electric vehicle (EV) charging stations can help both adapt to and mitigate the rising heat.

FOCUS ON MICROCLIMATE

Enhancing blue and green spaces is the most effective solution to cool cities, forming the first line of defence due to their high potential to improve the microclimate. These elements can cool down ambient temperatures by as much as 5°C and up to a distance of more than 250 m (see 'Microclimate enhancement', p40).

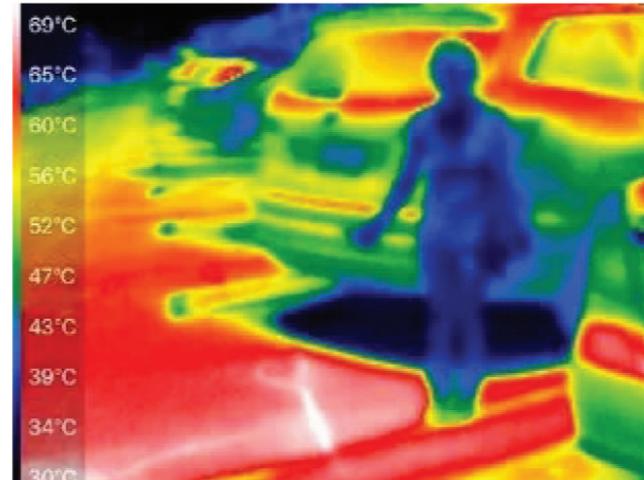
CSE's investigation, however, reveals a declining trend in green and blue spaces in all the nine cities. In fact, none of them even has the bare minimum greenery recommended by the World Health Organization (WHO) for healthy living. WHO's recommendations include ensuring at least 9 sq m of green space per individual with an ideal urban green space of 50 sq m per capita (per person in a city). Among the cities studied, Delhi has 10.41 sq m green space per capita Jaipur has 6.67 sq m and Kolkata has 6.61 sq m, according to a 2019 study by researchers from Sapporo, Japan, published in the journal *Urban Science*.

Pune offers a mere 1.4 sq m of green space per capita, as per a 2016 article in the journal *Ambio* published by researchers at the Indian Institute of Technology, Kharagpur.

The distribution of green spaces is also uneven. For instance, the central part of Delhi is lush, but the eastern region barely has any green spaces. The type of greenery

High exposure

Uncovered parking lots made from heat-trapping material record high temperatures



Source: "Improving Microclimates in Los Angeles' Heat Vulnerable Communities", Institute of the Environment and Sustainability, University of California, Los Angeles, US

present also determines their capability to mitigate heat. Trees with thick canopy are able to mitigate much more heat than grass and shrubs.

MITIGATION ACTIONS

While CSE's analysis is limited to nine cities, regions across the country are under threat. Big cities are struggling to withstand the warming climate and need retrofits to their existing infrastructure. On the other hand, smaller cities are on the brink of explosive growth and must urgently work on "heat-proof" development through master plans and by-laws.

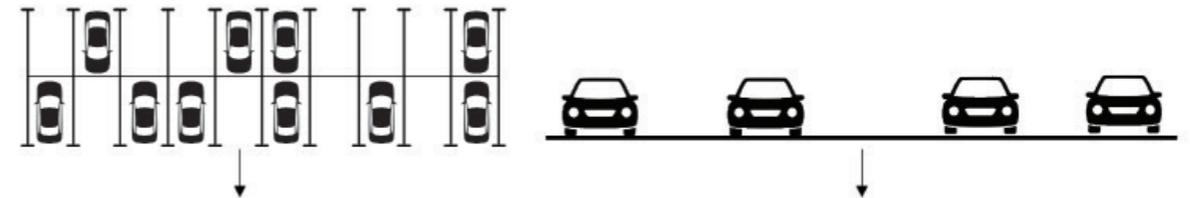
Urban local bodies (ULBs) hold great potential in facilitating necessary heat action, which the Union government has recognised. The emerging requirements of clean air, climate action and energy conservation are being tied directly to the functions of ULBs.

For instance, the 15th Finance Commission has carved out ₹1,21,055 crore for ULBs, of which ₹38,196 crore is for cities with million-plus populations. The grant for million-plus cities is tied to their performance in

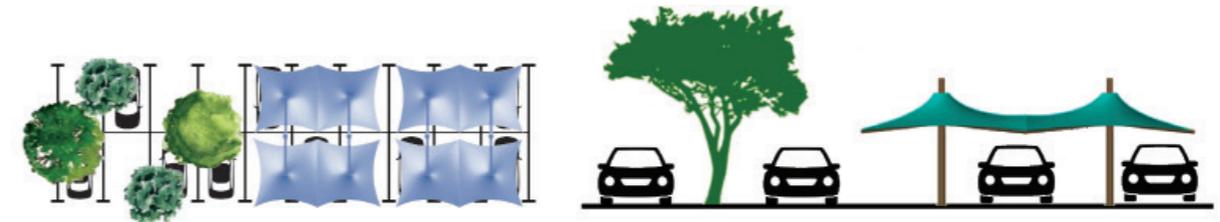
Cool down lots

With private car ownership increasing in urban areas, smart cooling solutions are required

Uncovered parking lots retain more heat



Addition of vegetation and shading can improve the microclimate



Source: Centre for Science and Environment analysis

improving ambient air quality and meeting service-level benchmarks for urban drinking water supply, sanitation and solid waste management. This makes the grant and its execution one of the most crucial implementation and monitoring tools for city-level works.

The guidelines laid out by the 15th Finance Commission have the potential to immediately start integration of measures to prevent and mitigate heat stress in cities. For instance, India's Long-Term Low-Emission Development Strategy, submitted to the UN Framework Convention on Climate Change (UNFCCC) during the 27th Conference of the Parties to UNFCCC in November 2022, has laid out several localised climate measures. These include preparation of city climate action plans and their integration with respective master plan and building by-laws. The Strategy document also suggests formation of a climate change cell at the ULB level to combine climate action underway under several different schemes, conduct vulnerability assessments, map the heat sinks and draw heat action plans.

Further, the City Investments to Innovate, Integrate and Sustain (CITIES) 2.0 initiative, conceived by the Union Ministry of Home Affairs, is preparing a three-tier framework for climate action. Facilitated by the National Institute of Urban Affairs, Delhi, along with the EU and European agencies, CITIES 2.0 is slated to run from 2023 to 2027. It proposes setting up a national climate data observatory, state climate centres for cities and state climate data platforms, and departments of climate action under ULBs. These institutions could be integrated with the existing 15th Finance Commission structure.

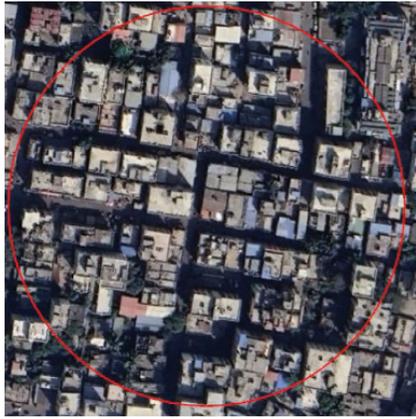
Current heat action is framed around disaster response. However, this can also be addressed with the 15th Finance Commission framework to inform cities of the need to prioritise and properly implement heat action measures.

At the same time, voluntary pursuits like the Green Climate Fund (GCF), established within the UNFCCC framework to assist developing countries in climate adaptation and mitigation practices, can be harnessed by Union ministries. This in-

Morphology matters

Design and layout of the built environment determines the local temperature

COMPACT MID-RISE



Kondhwa, Pune

OPEN MID-RISE



MG Road, Pune

OPEN LOW-RISE



Gultekadi, Pune

COMPACT LOW-RISE



Kharadi, Pune

LARGE LOW-RISE



Wagholi, Pune

LIGHTWEIGHT LOW-RISE



Hadapsar, Pune

Source: Google Earth

involves formulating a year-long procedure set in motion by a national designated authority that can prepare or collect a funding proposal prepared by an accredited entity for heat action in cities, and gain approval for it by a technical advisory panel and the GCF Board, which oversees the fund.

ULBS can also explore other voluntary tools like green bonds specifically earmarked for climate and heat related projects. For this, the governance bodies must set a defined criteria that must be outcome-oriented. Currently, green bonds encompass renewable energy, energy efficiency, clean transportation, green buildings, natural resources and land use, water and waste management, and pollution prevention and control. These areas overlap with the nature of action for heat mitigation.

While globally, first green bond was issued by the World Bank in 2008, Green Municipal Bonds have been raised by Ghaziabad, Ahmedabad, Surat, Visakhapatnam, Amravati, Indore, Bhopal, Pune, Hyderabad, Lucknow and Vadodara, according

BIG CITIES ARE STRUGGLING TO WITHSTAND THE WARMING CLIMATE AND NEED RETROFITS TO THEIR EXISTING INFRASTRUCTURE. ON THE OTHER HAND, SMALLER CITIES ARE ON THE BRINK OF EXPLOSIVE GROWTH AND MUST WORK ON HEAT-PROOF DEVELOPMENT THROUGH MASTER PLANS AND BY-LAWS

to a 2022 report published by South Pole, a Swiss carbon finance consultancy.

In terms of city-level master plans and by-laws, there is a need to conduct studies on what is driving the heat. The CSE study resulted in a heat mitigation pyramid that collects parameters affecting heat. As the analysis shows, the major drivers influencing heat include effective vegetation, waterbodies and choice of materials. Along with this, anthropogenic heat emitted from the exhausts of air-conditioners, vehicles and other appliances in households also needs to be studied as a contributor.

The pyramid highlights urban morphology that comprises aspect ratio, sky view factor and street orientation as a component that can affect the local environment negatively if not planned and designed in accordance to the native climate. While aspect ratio is the ratio of the height of the building to the width of the street, the sky view factor refers to the sky visible from a point on the ground and between the build-

ings, which can determine how much heat will be trapped and dissipated by the surfaces. If planned and designed properly, these elements can reduce heat-trapping and help cities cool down.

The direction in which a street is oriented determines the amount of heat gained due to sun exposure and wind speed. Streets account for about one-fifth of a city's area, according to the Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines released by the Union Ministry of Housing and Urban Affairs, and can significantly impact pedestrian comfort. Designing heat-resilient streetscapes by incorporating elements of shading and micro-climatic enhancement can help reduce the exposure. Some ways to achieve this would be through roadside plantations or shading devices, especially in busy commercial areas or central business districts, could enable pedestrian thermal comfort.

Moreover, installing water elements like swales, rain gardens, ponds and installing fountains at intersections and wide streets, particularly on the windward side, help as cooling solutions while improving a city's aesthetics. Water-sensitive urban design

and planning, combined with active systems like evaporative wind towers, have potential to reduce ambient temperature by 3-8°C.

Further, replacing sidewalks (footpaths), parking lots and other paved surfaces with hollow grass pavers to reduce heat-trapping. Such solutions need to be integrated with planning regulations.

CSE's analysis shows that a common morphological thread amongst the heat centres in cities was compact residential constructions and industrial zones. Such areas are dense and have limited scope for improving layouts or green and blue spaces. Therefore, use of good construction materials and retrofits here is crucial.

Retrofits include the installation of shading devices, providing insulation, use of reflective materials, cool and green roofs, among others. Cool roofs, for instance, could lower indoor temperatures by up to 5°C. While Telangana has released a cool roof policy and placed a target to achieve 300 sq km of cool roofs by 2028 to combat urban heat island effect, an addendum to the URDPFI Guidelines also recommends ensuring mandatory cool roofs as one of the city-planning strategies. 📍

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