DETAILED PROJECT REPORT

ASSESSMENT OF VULNERABILITY AND THRESHOLD OF HEAT-RELATED HEALTH HAZARDS IN FOUR CITIES OF INDIA

Submitted by

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List of Abbreviations

AIC	Akaike Information Criteria
AP	Andhra Pradesh
CO-PI	Co-Principal Investigator
DLNM	Distributed Lag Non-linear Model
DMHO	District Medical Health Officer
EWS	Early Warning System
FGD	Focus Group Discussions
HVI	Heat Vulnerability Index
IDI	In-depth Interview
IMD	Indian Meteorological Department
LT	Lower threshold
LPG	Liquefied Petroleum Gas
MRR	Mortality Risk Ratio
NDMA	National Disaster Management Authority
PHFI	Public Health Foundation of India
PI	Principal Investigator
RO	Reverse Osmosis
SRA	Senior Research Assistant
UT	Upper threshold
WB	West Bengal
WHO	World Health Organization (WHO)

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Introduction

Global warming and the El Nino events in 2015 and 2016 resulted in high temperatures across the planet (1,2). The World Health Organization (WHO) estimates that between 2030 and 2050 global climate change is predicted to cause a further 250,000 deaths per annum mainly associated with malaria, malnutrition, diarrhoea and heat stress (3). Rising temperature is nearly the universal phenomena and scientists are researching and reporting its impact on health, development and productivity. Chronic exposure to extend or changes in heat and humidity (including and beyond episodic heatwaves) results in impacts on behavioural, physical and psychological state and mortality (4). Impact is often amplified in urban areas and may cause impacts on labour and overall productivity, with associated economic aftermath as urban areas may face higher levels of temperature than adjacent suburb and rural areas due to the Urban Heat Island (UHI) effect (5). The mortality impact of high heat has been explored for several regions of the planet (6–8). India also witnessed a series of heat waves with considerable mortality (9–11). The destructive impact of one wave in India in May 2015, with over 2200 fatalities, demonstrated that extreme heat may be a serious issue even in countries regularly exposed to high temperatures (12). Heatwaves are expected to increase further not only in intensity, but also in duration and frequency (11,13,14)

Since 2010 onwards, heat waves in South Asia have been increasing especially in India 5. These heat waves have caught the attention of the public health experts, policy makers, and climatologists who wish to develop the early warning system, heat action plans and increase community awareness to improve preventive measures for heat waves (15). Due to climate change, extreme heat days are increasing which may lead to increase in all-cause mortality (16).

High temperature, especially alongside humidity may be a matter of concern for many of the cities / urban areas in reference to heat morbidity and mortality

Vulnerability to extreme heat events depends on the degree of exposure to the event, the individual's sensitivity and their capacity to adapt to the situation to protect health (17). Certain population groups are more vulnerable to heat health issues. More vulnerable population groups thus include the elderly, the very young, the mentally ill, those with certain pre-existing health problems (particularly heart, kidney, and lung or liver diseases) and housing and economic circumstances that increase health risks. (17–21). Vulnerable populations do not always recognize that they are at increased risk making these events more dangerous (22). At the same time, physiological and behavioral adaptations and changes in public health preparedness can reduce heatwave-related fatalities (19). In addition to this, the poor may be differentially impacted on account of gaps in health services, housing and basic amenities. The benefits of heatwave planning can be great. Much of the reduced mortality in France during the heatwave in 2006 compared to an event in 2003 has been attributed to early warning systems (17); and, the cost of running a heatwave warning system for Philadelphia was 'practically at the 'noise' level compared to the economic benefit of saving 117 lives in three years' (23).

Historically, many traditional and indigenous methods were used during the early Mughal era to cope with high temperatures in the Indian Sub-continent. Some of these methods were adapted to suit modern conditions by the early European colonists. Some of these adaptations included construction of high ceilings and spacious but lowered varandas (courtyard) to provide more shade. Thick layered thatch roofing also was used to keep temperatures inside the house lower during nights. They also used various techniques for home cooling like the wet tattie – 2 to 4-inch-thick screens made up of long roots of the Khas plant. With respect to clothing, light and lose fitting clothes made from cotton were worn. Colonists used hats to protect themselves from direct sunlight and followed lifestyle modifications in order to adapt to the tropical heat of the Indian sub-continent. Physical activity, intensive work or exercises were performed during early mornings or late evenings. Large breakfasts and light afternoon meals were the norm during the summer. These practices need to be reflected upon in the current context.

The project "Assessment of vulnerability and threshold of heat-related health hazards in four cities of India" consists of multi-city assessment of vulnerability due to heat waves and threshold analysis of heat related illnesses in India. States in India have experienced severe heat waves in summer in different years. Starting from 1975, heat wave conditions have affected India in different periods of time. The impoverished sections of the population, who are mostly engaged in farming, construction and other informal services, are the greatest victims of this phenomenon. The heat wave of 1998 in Odisha took away 2042 lives and subsequently such heat wave conditions have been expanded to other states. In the year 2015, casualties were abnormally high and most of the deaths were concentrated in Andhra Pradesh, Telangana, Punjab, Uttar Pradesh, Odisha and Bihar breaking the records of previous years. Experts in Odisha estimate that on an average 78 people die of heat stroke every year from April to June, as per official records, although this figure may be abysmally low as compared to the actual number of deaths as the 'Lagged effects' are not taken into account.

This study thus tries to capture the gamut of the vulnerabilities of the local population due to heat waves by looking at the exposure, sensitivity and coping capacities of the people. The study also aims to look into the threshold of heat related health hazards by scientifically analysing multi-sectoral data on morbidity and mortality. The purpose of the study is to use the results to identify vulnerable population and design appropriate strategies and interventions at community level. The threshold analysis will help to generate more robust evidence to inform the state- and region-wise Indian weather warning system, so that people can be warned of the forthcoming hazardous heat situations with more accuracy and also take up measures to tackle the issue. Such exercise of determining city-specific heat thresholds may also provide us a baseline comparator against which future heat-mitigating interventions can be objectively evaluated.

Methodology

Study Location:

Four Cities were selected across India from four states, which were recommended by an expert group of Task Force members for Heat Wave from the National Disaster Management Authority. The cities that were selected for the study were Karimnagar from Telangana, Kolkata from West Bengal, Ongole from Andhra Pradesh and Angul from Odisha. Figure 1 shows the location of the cities in India.

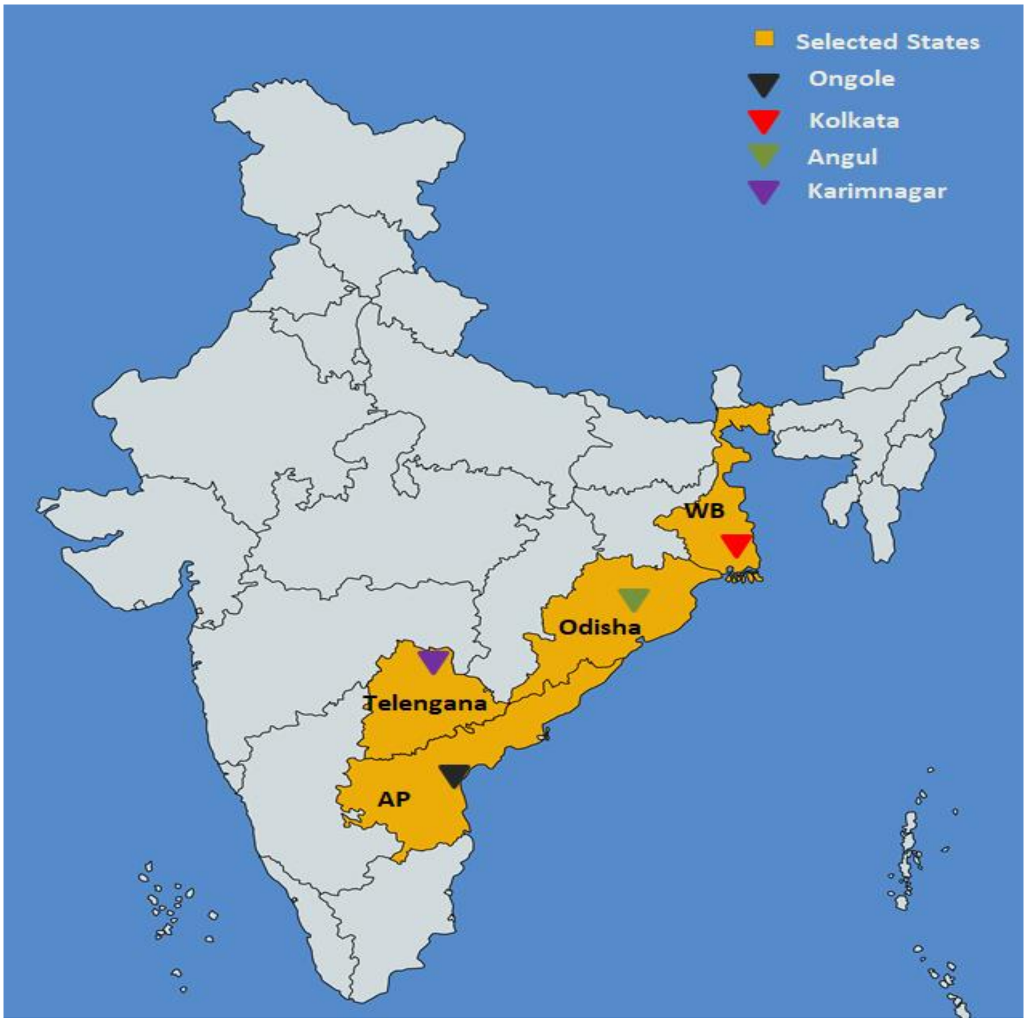

Figure 1: Map of the cities

Questionnaire / tool drafting:

One of the crucial components of the project is household level data collection to perceive the vulnerability of the people to heat waves across the four selected cities. The preparation of the questionnaire tool for this household survey started in March after project inception meeting at NDMA, New Delhi. The first step for finalising the questionnaire included finding a relevant framework and modifying it if required. The Extreme Heat Vulnerability Analysis Framework by Wilhemi and Hayden (2010) was selected as the base framework to carry out the survey. The framework depicts three crucial components which directly influence the vulnerability to extreme heat. These components are Exposure, Sensitivity and Adaptive Capacity; thus this framework suited the objectives that the project meant to study. The two other important components in the framework depicts external drivers and adaptation/response (24). These are city and institution specific and have an impact on the progression of vulnerability. After the selection of the framework, several key specifics from literature were used to expand the framework. The Literature studied for developing the questionnaire captured the whole gamut of the issues which are caused due to Heat waves. The literature covered studies done on heat wave vulnerability, exposure and coping capacities in India as well as across the globe. These studies and their results formed the base for selection of the domains and subdomains on which the questionnaire would be based. The domains which were decided after rigorous discussions through bi-weekly conference calls. The broad domains which were finalised for preparation of the questionnaire are as follows –

- Socio-economic factors
- WASH and Waste Management
- Food and nutrition
- Housing

- Locational characteristics
- Community
- Risk perception
- Early Warning System
- Quality of Life
- Co-morbidities
- Habits
- Livelihood/Occupation

Figure 2 depicts the original framework and Figure 3 depicts the initial modified framework for the study.

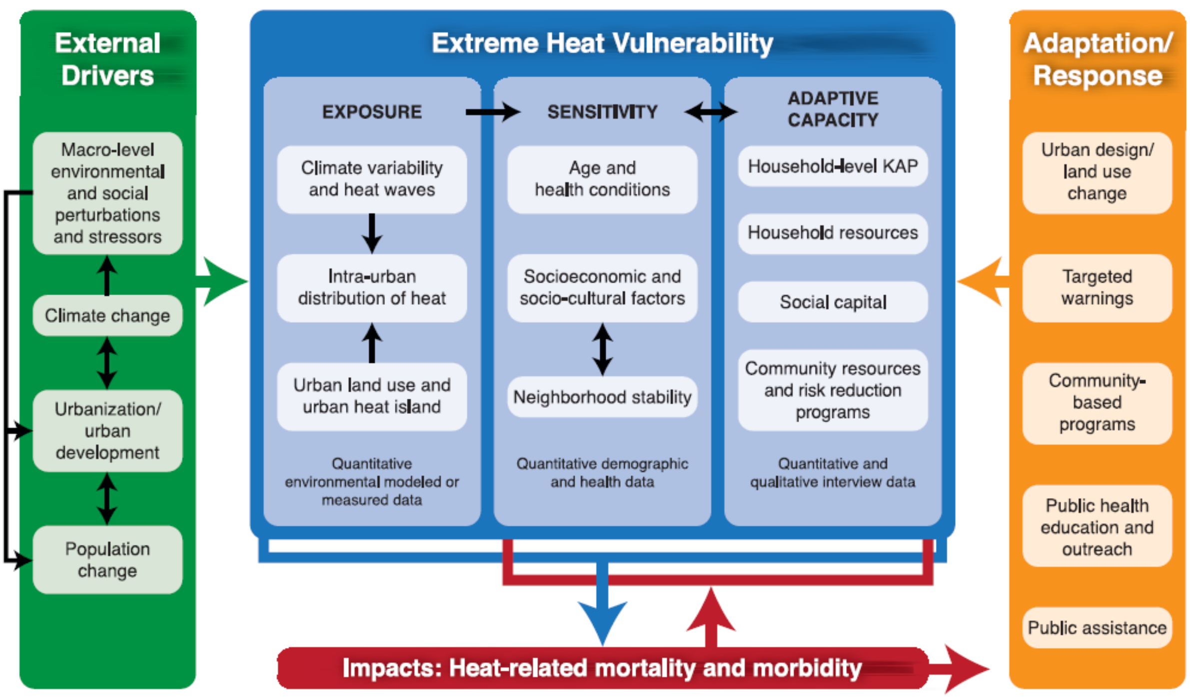

Figure 2: Extreme Heat Vulnerability Analysis Framework (Wilhemi and Hayden, 2010)

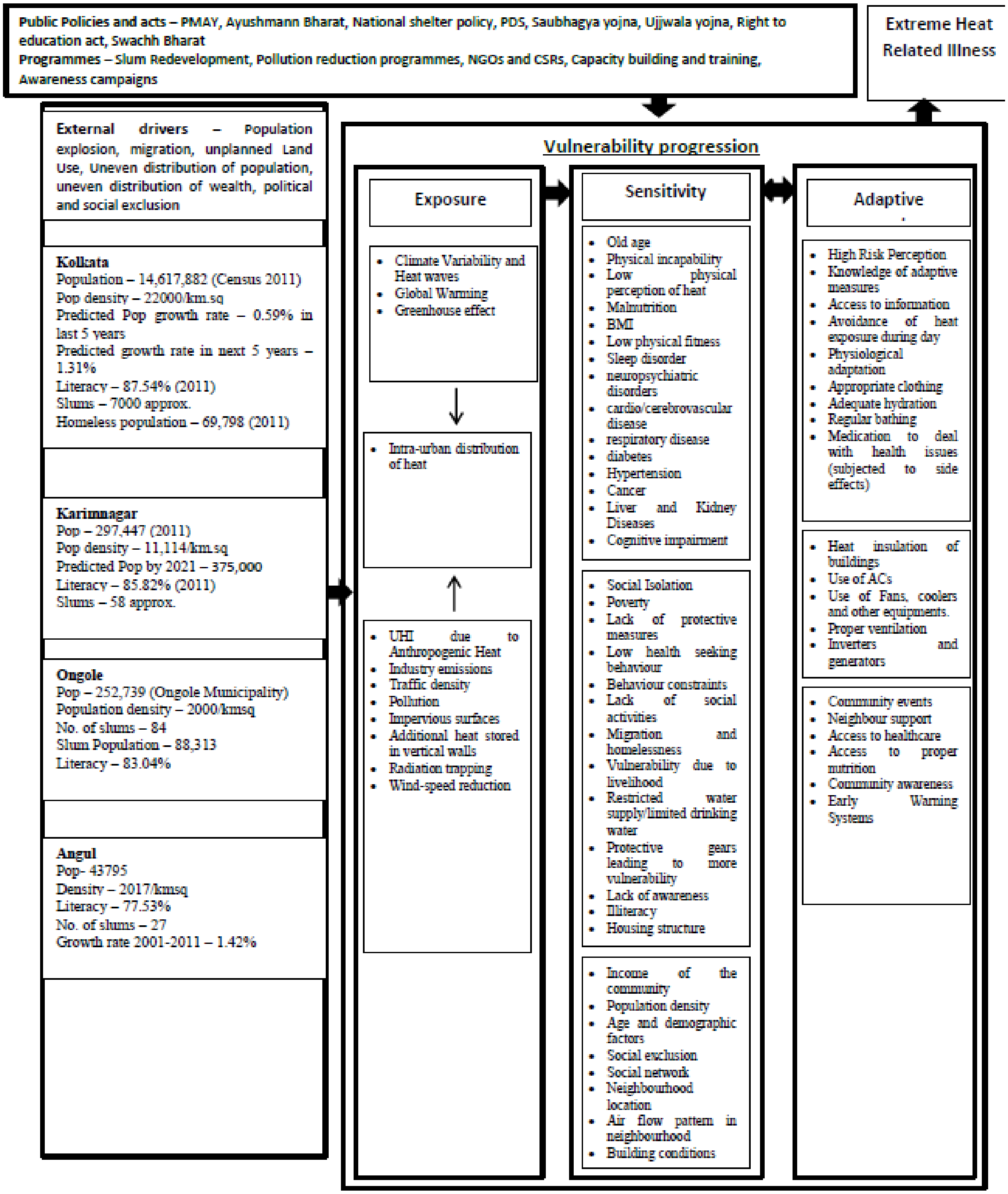

Figure 3: Initial Modified framework for the study

The first draft of the questionnaire was completed in April 2020. This draft was edited and more questions were added and certain questions were removed. The questionnaire was then tested in Kolkata by the Project staff. The pilot testing revealed certain discrepancies in the questionnaire which were then corrected for the second draft. This draft was the longest and the pilot testing for this draft took one and a half hour per questionnaire.

Incorporating Covid-19 modifications to the questionnaire (second draft):

The lockdown, social distancing measures, salary/profit cuts, unemployment, etc. due to the Covid-19 pandemic had created a tough situation for Indians as the normal measures taken to deal with extreme heat every year were affected. The changes in daily lives of people also brought changes to how they are impacted by extreme heat. Therefore, it was necessary to modify the questionnaire to get quantifiable data on how Covid-19 had an impact on extreme heat related issues and measures. Questions of response to extreme heat during Covid-19 were thus placed strategically in several sections of the second draft questionnaire to extract the required information.

The second draft (Covid-19 modified) was then reduced and made more comprehensive by removing the less relevant questions. The final draft was prepared by the first week of June 2020 after several iterations and incorporating the experts' comments and suggestions.

Questionnaire Review by Internal Team:

The questionnaire was reviewed by the internally constituted team of PHFI experts across all affiliated institutes. The suggestions given by the experts were incorporated into the final draft which made the tool sharper and comprehensive.

Validation and testing of questionnaire:

The pilot testing and validation was done over two cities. Before pilot testing, questionnaire, participant information sheet and consent form translated in to Telegu and Bangla (Bengali) languages (Local). As mentioned earlier, one part was done in Kolkata with 8 samples after the second draft was prepared. The second pilot testing was conducted in Karimnagar by the field officers with 16 samples; this served a double purpose, validation of questionnaire and hands on training of the field officers (after theoretical training by going one by one questions). For Angul, the questionnaire was translated to Odia in September and 8 samples were taken for language validation in Odisha.

Selection and training of field officers:

Field officers were appointed in the first week of June for Karimnagar and Ongole, after the questionnaire was finalised. The field officers were given three rounds of online training before they were sent to Karimnagar for data collection. The field officers for Kolkata were selected in July and field officers for Angul were selected in October. All of them were given three rounds of online training before they were sent to the field. The training provided to them is mentioned as follows -

> *First round of training* – The field officers were given a detailed introduction to the project and were oriented to the questionnaire. Every question in the questionnaire was discussed and all the possible options in each question were covered. After that hands on training was provided them through collection of 8 datasets from the community to understand and familiarise themselves with the questionnaire.

Second round training – The second round of training involved detailed discussion of collected data where every field officer presented one collected data sheet. Further orientation was given on how to collect data meticulously from the field with the prepared questionnaire. Field officers were asked to do a pilot test in the respective cities with randomly selected households.

Third round training – The results of the pilot test were discussed and small changes to the translated questionnaire made. Orientation on data entry was provided and further lectures were given to improve efficiency. The map and wards list for the four cities were discussed with the field officers and the sampling procedure was explained.

All the training was through online platform.

Sampling:

The study involved a three-stage sampling method where the wards were randomly selected from the available wards list of the Municipal Corporation of Karimnagar, Ongole and Kolkata. All the wards in the city of Angul were selected owing to the fact that Angul has only very few (23) wards. The next stage involved selection of the number of households per ward. Finally, the number of households were proportionately selected to evenly capture data from Slum and Non-slum households using systematic random sampling. Every 10th house was chosen after randomly selecting the first house from each ward.

Only adult members of the family or if available, head of the households were interviewed for the study to achieve uniformity in the data.

Precautionary Measures:

Due to the ongoing situation of Covid-19 in India, social distancing norms have to be followed. The field officers had been oriented on the several measures they can take to ensure their safety and study participant's safety. The field officers had been following strict social distancing norms along with the application of several protective measures including masks, face shields and sanitisers.

Before starting the field study, a letter has been sent to District Collector/Commissioned of all the cities for updating them about the study and field data collection.

Some glimpses from Karimnagar

Some glimpses from Ongole

Some glimpses from Kolkata

Some glimpses from Angul

Vulnerability Index Construction

A household's vulnerability to extreme heat is defined as a function of its exposure, sensitivity, and adaptive capacity (25) – as depicted in Eq. (1). Each of the three components depend on a range of individual household factors (both qualitative and quantitative), which may influence vulnerability to extreme heat.

$$Heat\_Vulnerability = f(Exposure, Sensitivity, Adaptive\_Capacity) \quad \text{... (1)}$$

Exposure, a distinct component of vulnerability, refers to the intensity and spatial distribution of heightened temperature (26) including other factors that elevate heat conditions. Exposure to heat can vary temporally with rising temperature over time, or spatially through which some zones of a particular city may be hotter than others. Here, exposure variable is captured through six indicators – (i) tall buildings surrounding the house; (ii) industrial junctions nearby the house; (iii) traffic nearby the house; (iv) roof type; (v) time spent outside; and, (vi) time spent directly under the sunlight. However, exposure is a necessary but not a sufficient determinant of vulnerability. It is possible to have higher exposure and yet have lower vulnerability due to effects of other components such as sensitivity and adaptive capacity.

Sensitivity refers to how well a household can cope with increased exposure or the extent to which increased exposure will affect a household physically (26,27). Here, sensitivity is variable is captured through eight indicators – (i) age; (ii) annual income; (iii) education level; (iv) incidence of hypertension; (v) incidence of diabetes; (vi) water shortage; (vii) power-cut; and (viii) help from neighbours.

Adaptive capacity refers to the ability of a household to actively mitigate or adapt to personal exposure (25,28,29), using available skills and resources (30), guaranteeing survival and sustainability (31). Existing studies (28,32–34) define the relationship between adaptive capacity and vulnerability in three ways. First, vulnerability and adaptive capacity are not mutually exclusive. Second, vulnerability is the consequence of a lack of adaptive capacity, among several other factors. Third, both are inversely proportional, so that high capacity entails low vulnerability and vice-versa. Here, adaptive capacity is taken to be influenced by seven indicators

– (i) vegetative patches nearby the house; (ii) water bodies nearby; (iii) wearing summer appropriate clothes; (iv) reduced time spent outside; (v) drinking more liquid during summers; (vi) use of protective gears such as umbrellas, hats, etc.; and, (vii) instruments for cooling the home.

A detailed description of the variables and their dimensions is presented in table 1.

Table 1: Description of variables and expected impact on vulnerability

Dimension	Indicator	Measurement	Expected Impact on Vulnerability
Exposure	Tall buildings	Tall buildings are defined by the total number of sides the house is surrounded by tall buildings	Positive
	Industrial junctions	Industrial junction is defined as a dummy variable. It takes a value 1 if there any factories or major industrial areas nearby the house and 0 otherwise	Positive
	Traffic Junctions	Traffic junction is defined as a dummy variable. It takes a value 1 if there is any highway or heavy traffic junction nearby the house and 0 otherwise	Positive
	Roof type	Roof type is categorized as into five groups as stated below: 1=concrete; 2=Asbestos; 3=Clay tiles; 4=Tin-sheet; 5=Straw	Positive
	Time spent outside	It is defined as the number of hours spent outside in a day on an average by the household	Positive
	Time spent under direct sunlight	It is defined as the number of hours spent directly under sunlight in a day on an average by the household	Positive
Sensitivity	Age	It is measured by the median age of the household (in number of years)	Positive
	Annual income	It is measured by the annual average income of the household (in Rs.)	Negative
	Education level	Education level is categorized as into six groups as stated below: 0=Illiterate; 1=Primary; 2=Middle; 3=High School; 4=Intermediate; 5=Graduation; 6=Other professional course	Negative
	Hypertension	It is measured by the number of household members who suffered from hypertension during the last 15 days	Positive
	Diabetes	It is measured by the number of household members who have diabetes	Positive
	Water shortage	Water shortage is defined as a dummy variable. It takes a value 1 if the household faces water shortage and 0 otherwise	Positive
	Power-cut	Power-cut is defined as a dummy variable. It takes a value 1 if the household faces power-cut in the summers and 0 otherwise	Positive
	Help from neighbours	Help is defined as a dummy variable. It takes a value 1 if the household receives any form of help from the neighbors and 0 otherwise	Positive
Adaptivity	Vegetative patches	Vegetative patches are defined as a dummy variable. It takes a value 1 if the household has any vegetative patches like parks, fields, etc., nearby their house and 0 otherwise	Negative
	Water bodies	Water bodies are defined as a dummy variable. It takes a value 1 if the household has any vegetative patches like parks, fields, etc., nearby their house and 0 otherwise	Negative
	Summer clothes	Summer clothes are defined as a dummy variable. It takes a value 1 if the household members wear summer appropriate clothes and 0 otherwise	Negative
	Reduced time	Reduced time is defined as a dummy variable. It takes a value 1 if the household members have reduced spending time outside during summer and 0 otherwise	Negative
	Drinking more liquid	Drinking more liquid is defined as a dummy variable. It takes a value 1 if the household members have increased the intake of liquids in the last one year to deal with heat and 0 otherwise	Negative
	Protective gears	Use of protective is defined as a dummy variable. It takes a value 1 if the household members use umbrellas/hats/head-covers to prevent direct sunlight and 0 otherwise	Negative
	Cooling home	Cool home is defined as a dummy variable. It takes a value 1 if the household uses fans or AC as a mode to keep their home cooler and 0 otherwise	Negative

Construction of Multi-dimensional Vulnerability Index

All the indicators (as depicted in Table 1) have been combined to assess the extent of household vulnerability. This is because any single indicator will only reveal partial information on the vulnerability of households to extreme heat. Use of individual indictors will fail to adequately capture the extent of vulnerability and may be misleading. In order to overcome this problem, a composite index of household vulnerability (HVI) has been constructed following a multidimensional approach. Such an approach enables to capture information on several dimensions in a 'single' metric. This metric can useful to compare the levels of vulnerability across households within a city and across cities at a specific point in time. It can also serve to monitor the progress of policy initiatives aimed at reducing vulnerability of households in the sampled cities over time.

For calculating the HVI, the i^{th} dimension is computed using the following formula:

$$d_i = \frac{M_i - A_i}{M_i - m_i} \qquad \text{... (2)}$$

Where,

$Ai =$ actual value of dimension i; $\mathrm{M}i =$ maximum value of dimension i; $\mathrm{m}i =$ minimum value of dimension i

This formula ensures that $0 \le d_i \le 1$. Higher the value of d_i , higher will be the household's vulnerability in respect of dimension i. When there are n dimensions, a household j will be represented by a point $D_j = (d_1, d_2, d_3, ...d_n)$ on the n dimensional Cartesian space. In the n-dimensional space, the point $O = (0,0,0,...0)$ represents the point of the least vulnerability, whereas the point $I = (1,1,1,....,1)$ represents the highest vulnerability in all dimensions. The multidimensional *HVI* for the j^{th} household is the simple average of the component indices for the dimensions. The exact formula is:

$$HVI_j = \frac{1}{n}\sum_{i=1}^{n} d_{ij} \qquad \text{... (3)}$$

Depending upon values of HVI values, the households within a city are categorized into two groups – high and low – and given below:

	Criteria	Extent of Vulnerability
(i)	$0.5 \le HVI \le 1$	High
(ii)	$0 \le HVI < 0.5$	Low

Bivariate and Multivariate analysis

Approach & Methodology

Model Specification (Angul City)

The dependent variable in the model is the likelihood that a household is 'highly' vulnerable to extreme heat (VULNERABILITY). It is assumed that a particular household's vulnerability to extreme heat in Angul city is influenced by a set of socio-economic, demographic, ecological, and health factors. While gender of the household head (GENDER) and distance of the nearest primary healthcare centre from the place of stay (DISTANCE) are used to control for the social characteristics, the economic aspect is captured by the number of rooms in the house (ROOM). On the other hand, the household size (SIZE) is used to capture the demographic characteristic. Perceived change in temperature and humidity (TEMPERATURE) and use of air coolers or air conditioners at workplace (COOLING) are used as proxies for ecological factors. Finally, the incidences of mild symptoms of high ambient heat (SYMPTOMS) and comorbid conditions in the household members (COMORBID) are expected to capture health condition. Accordingly, the following functional relationship is envisaged:

$$VULNERABILITY = f(GENDER, DISTANCE, ROOM, SIZE, TEMPERATURE, COOLING, SYMPTOMS, COMORBID) \quad \ldots (4)$$

Here, VULNERABILITY is measured with a dummy variable that takes the value '1' when a household's heat vulnerability index (HVI) score is greater than 0.5 (and less than or equal to 1), and '0' otherwise. Description of the independent variables along with their possible impact on the dependent variable is given in table 2.

Table 2: Description of Independent Variables (Angul City)

Variable	Measurement	Expected Impact
Gender of the respondent (GENDER)	Gender of the respondent is defined as a dummy variable. It takes a value 1 if the respondent is female and 0 otherwise	Negative
Distance of the nearest primary healthcare centre from the place of stay (DISTANCE)	Distance of the nearest primary healthcare centre from the place of stay is measured as an ordinal categorical variable. 1=less than 1 km; 2=between 1 km and 5 km; 3=more than 5 km	Positive
Household size (SIZE)	It is measured as the absolute number of family members in a house	Positive
Number of rooms in the house (ROOM).	It is measured as the absolute number of rooms in a house	Negative

Perceived change in temperature and humidity (TEMPERATURE)	Household's perception about changes in the level of temperature and humidity is defined as a categorical variable with '1' as increased slightly and '2' as increased drastically.	Negative
Use of air coolers or air conditioners at workplace (COOLING)	It is measured as a dummy variable. It takes the value '1' if there is a use of air-coolers or air-conditioners at workplace and '0' otherwise	Negative
Incidence of mild symptoms (SYMPTOMS)	It is measured as a dummy variable. It takes the value '1' if the household head has experienced mild symptoms of high ambient heat such as headache, dizziness, weakness and muscle pain during the summers, and '0' otherwise	Negative
Comorbid conditions in the household members (COMORBID)	It is measured as a dummy variable. It takes the value '1' if any member of the household has diabetes and/or hypertension, and '0' otherwise	Unknown

Model Specification (Kolkata City)

The dependent variable in the model is the likelihood that a household is 'highly' vulnerable to extreme heat (VULNERABILITY). It is assumed that a particular household's vulnerability to extreme heat in Angul city is influenced by a set of socio-economic, ecological, health, and behavioral factors. While occupation of the household head (OCCUPATION) and distance of the nearest primary healthcare centre from the place of stay (DISTANCE) are used to control for the social characteristics, the economic aspect is captured by the average income of the household in summer months (INCOME) and the number of rooms in the house (ROOM). On the other hand, the total number of accessible sources of water (WATER) is used to capture ecological aspect. The incidences of mild symptoms of high ambient heat (SYMPTOMS) and comorbid conditions in the household members (COMORBID) are expected to capture health condition. Finally, places for sleeping during hot nights (SLEEPING), intake of non-vegetarian foods (NONVEG), and changing the amount of food consumption (FOOD) during extreme hot days are used as proxies for behavioral changes.

Accordingly, the following functional relationship is envisaged:

$$VULNERABILITY = f(OCCUPATION, DISTANCE, INCOME, ROOM, \\ WATER, SYMPTOMS, COMORBID, SLEEPING, NON-VEG, FOOD) \quad \ldots (5)$$

Here, VULNERABILITY is measured with a dummy variable that takes the value '1' when a household's heat vulnerability index (HVI) score is greater than 0.5 (and less than or equal to 1), and '0' otherwise. Description of the independent variables along with their possible impact on the dependent variable is given in Table 3.

Table 3: Description of Independent Variables (Kolkata City)

Variable	Measurement	Expected Impact
Occupation of the household head (OCCUPATION)	Occupation of the household head is defined as a categorical variable. [1=professional/semi-professional; 2=clerical; 3=skilled/semi-skilled; 4=unskilled; 5=unemployed; 6=self-employed/business; 7=agriculture/allied]	Unknown
Distance of the nearest primary healthcare centre from the place of stay (DISTANCE)	Distance of the nearest primary healthcare centre from the place of stay is measured as an ordinal categorical variable. 1=less than 1 km; 2=between 1 km and 5 km; 3=more than 5 km	Positive
Average income of the household in summer (INCOME)	It is measured as the natural logarithm of the average household income during summer months	Negative
Number of rooms in the house (ROOM).	It is measured as the absolute number of rooms in a house	Negative
Sources of water (WATER)	It is measured as the absolute number of sources of water accessible to the households	Negative
Incidence of mild symptoms (SYMPTOMS)	It is measured as a dummy variable. It takes the value '1' if the household head has experienced mild symptoms of high ambient heat such as headache, dizziness, weakness and muscle pain during the summers, and '0' otherwise	Positive
Comorbid conditions in the household members (COMORBID)	It is measured as a dummy variable. It takes the value '1' if any member of the household has diabetes and/or hypertension, and '0' otherwise	Positive
Place of sleeping (SLEEPING)	Place of sleeping is measured as a categorical variable. 0=bed, 1=bare floor, 2=mattress floor, and 3= terrace	Unknown

Intake of non-vegetarian foods (NONVEG)	Intake of non-vegetarian foods is defined as a dummy variable. It takes the value '1' if the household avoids the intake of non-vegetarian foods during extreme summers, and '0' otherwise	Negative
Changes in the food consumption amount (FOOD)	Change in the amount of food consumption is defined as a dummy variable. It takes the value '1' if the household has reduced the amount of food consumption during summers, and '0' otherwise	Negative

Estimation Technique

Logit regression model with binary dependent variable is estimated to analyze the households' vulnerability to extreme heat. In a Logit model, the dependent variable is the natural logarithm of the odd ratio and is considered as a linear function of the explanatory variables, i.e.,

$$L_i = \ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \sum_{j=1}^{k} \beta_j X_{ij} + u_i \qquad \text{... (6)}$$

Here, k stands for the number of explanatory variables included in the model. The probability that the dependent variable is true (i.e., it takes a value 1) P_i follows logistic distribution, i.e.,

$$Pi = \frac{1}{1+e^{-Z_i}} = \frac{e^{Z_i}}{1+e^{Z_i}} \qquad \text{... (7)}$$

Where,

$$Z_i = \alpha + \sum_{j=1}^{k} \beta_j X_{ij} + u_i$$

Since the present study uses household level data and the dependent variable is binary in nature, the Logit becomes:

$$L_i = \ln\left(\frac{1}{0}\right)$$, if the dependent variable is true and

$$L_i = \ln\left(\frac{0}{1}\right)$$, if the dependent variable is not true

In both the cases, the expressions are meaningless. In order to overcome these problems, the above Logit model is estimated by applying the maximum likelihood method of estimation.

Further, since the present study uses cross-sectional data, the z statistics is computed for the Logit model. In addition, the study also applies both Pearson's χ^2 tests[1] and Hosmer–Lemeshow χ^2 test[2] to examine if the estimated Logit model suffers from the problem of lack of goodness-of-fit.

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[1] In Pearson's goodness-of-fit test the test statistic is defined as $HL = \sum_{j=1}^{n}\left[\frac{(O_j - E_j)}{E_j}\right] \sim \chi^2_{n-k}$ where, O_j is the observed number of cases and E_j for expected number of cases in the j^{th} group. We test the null hypothesis that the fitted model is correct. If the test statistic is not significant, it suggests the fitted model does not suffer from the problem of lack of goodness-of-fit.

[2] The Hosmer-Lemeshow (1989) statistic is another measure of goodness-of-fit. In this test, the observations are partitioned into 10 equal sized groups according to their predicted probabilities and the test statistic is defined as

$$HL = \sum_{j=1}^{10}\left[\frac{(O_j - E_j)}{E_j\left(1 - \frac{E_j}{n_j}\right)}\right] \sim \chi^2_8$$ where, O_j stands observed number of cases, E_j for expected number of cases, and n for number of cases in the j^{th} group. Here also, we test the null hypothesis that the fitted model is correct. If the test statistic is not significant, it suggests the fitted model does not have the problem of lack of goodness-of-fit.

Threshold Analysis Data Collection

Data collection for the threshold assessment part of the project involved acquiring raw daily data from two different government sources for the two different types of required data. The two types of data required were daily meteorological data (including minimum and maximum temperature, rainfall, relative humidity and wind speed and direction) and daily mortality data (divided into male, female and transgender daily deaths).

For the daily meteorological data, an approach was made to the Indian Meteorological Department (IMD) with the help of the National Disaster Management Authority (NDMA). A requisition for was filled through the online portal of IMD and an official request was filed. Post the acceptance, a certificate of undertaking, signed by the Vice President of PHFI, was forwarded to IMD, who then provided the team with the required data. For some data which was with the state meteorological departments, the team approached the specific organisation representatives with the help of IMD and NDMA to acquire the data.

For the daily mortality data, letters were sent to the district Municipal Commissioners and Health Officials for the selected cities. The letter was sent through email and a hard copy was delivered to the respective offices by the SRA. The SRA visited the municipal corporation offices of each city to explain the project and collect the required mortality data. The Birth and Death Registration Department of Karimnagar was the one which provided the mortality data for the city of Karimangar. The Deputy Collector of the district facilitated the process of the data collection for Karimnagar. In case of Ongole, the District Medical Health Officer (DMHO) facilitated the process, and the district health department provided the data to the team.

However, due to certain shortcomings, 6 months of mortality data from the year of 2017 could not be provided to the team. For Angul, the Deputy Medical Health Officer and the Digitisation section of the district facilitated the data collection procedure. The Data section office from the Municipal Corporation provided the data on mortality for the city. The team was unable to acquire the mortality data from the city of Kolkata due to several hindrances. The COVID-19's situation along with the elections and several sudden personnel changes within the Health Department of Kolkata lead to the team being unable to collect the required data.

Karimnagar and Ongole provided the data in a .pdf format where it was presented according to the date of death registration and details of the deceased. The files were extracted by the team to categorise according to the daily deaths (male, female and transgender) format. The data for Angul was provided in a spreadsheet in the desired format of the project.

Threshold Data Analysis

Study setting

We selected four cities, as mentioned above, Ongole from Andhra Pradesh, Karimnagar from Telengana, Angul from Odisha and Kolkata from West Bengal for assessment of the “threshold” temperature at which ambient heat starts affecting human health, especially the “point” at which the risk of mortality starts increasing significantly. All these cities experience hot and humid summers, though with varying intensities. The summer months generally start from March and continue up to July mainly, when the advent of the monsoon rains usher in relatively cooler weather. However, with changing climate, we see that this pattern is also undergoing changes, again with varying degrees in different parts of the country. Often late advent of monsoon extends the summer and drought like situations are exacerbated in the months of April to June. Absence of (or in some cases intensification) of pre-monsoon rains due to norwesters exaggerate or temper the hazardous effects of heat. The selection of these four cities also was prompted by the very reason that resilience of the citizenry inhabiting in these different parts of the country under different conditions may have varied response to ambient heat which would make the search for regional or city-wise threshold temperatures more worthwhile. Moreover, the different mitigation initiatives implemented with varying constituent packages and their varying successes can also influence the heat-health relationship locally.

The following picture summarizes the health effects of heat.

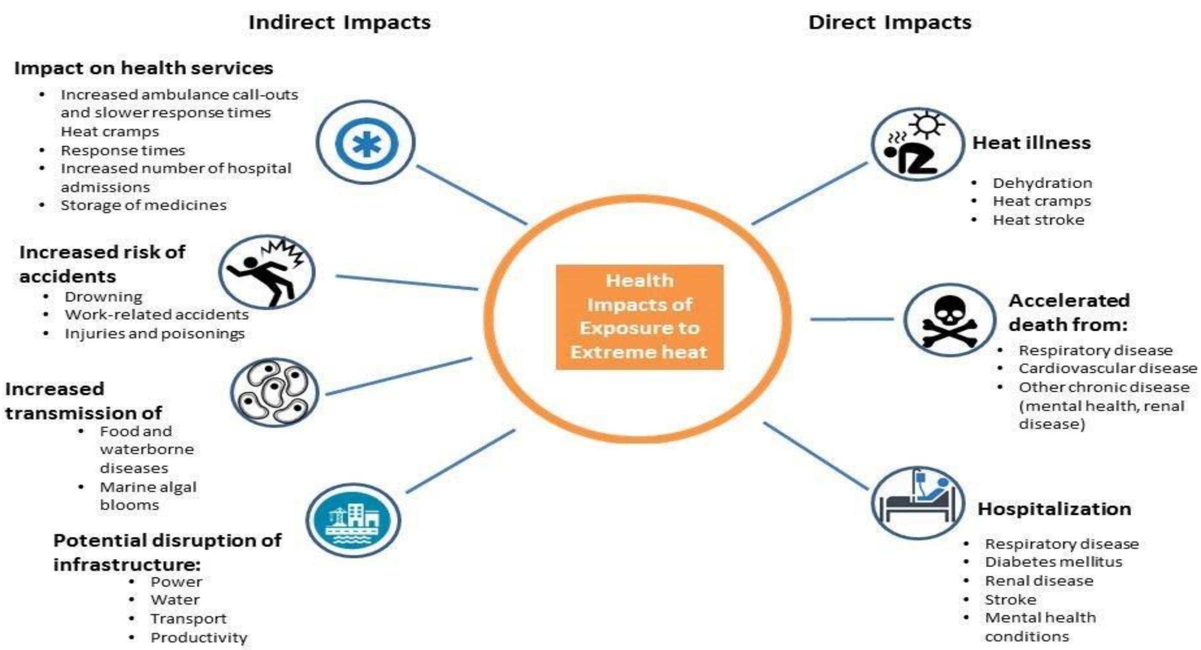

Figure 4: Health effects of exposure to extreme heat

Apart from causing direct heat illnesses that includes dehydration, heat cramps and heat stroke, the latter with high rate of fatality, ambient heat also increases morbidity and mortality due to all other types of health hazards. The burden of heat on health outcomes is felt much more due to the "overall" effect of raised temperature rather than its direct effect as heat illnesses. Therefore, to estimate the effect of heat on health it is better to use such "overall" outcomes than the heat illnesses for heat-health association analysis. The standard methodology used worldwide used for this purpose is **"deaths due to any cause"**, also referred to as **"all-cause**

mortality” (the two terms used interchangeably hereafter). Moreover, health systems and death certification system with its fair share of weaknesses in the Indian context often tends to grossly underestimate heat illnesses and fatalities that rise from them. Consequently, in this study, as we have also done for the city of Bhubaneswar previously (35), we considered all-cause mortality as the principal health outcome of ambient heat and carried out our estimation process accordingly.

Data

The months of March to July of 2013 to 2019 were considered for the analysis. Daily records of maximum (T-max) and minimum temperature (T-min) were collected from the respective Meteorological Centre of the Indian Meteorological Department. Humidity data, recorded every day, were also collected.

Data of daily deaths from any cause, for the same period, was collected from the respective Municipal Corporation and was studied as the health outcome. The deaths were population-adjusted into all-cause daily mortality rate per 100,000 population, as because the population of cities increased from 2013 to 2019

Statistical analysis

We used time-series methods to study the short-term association between T-max and all-cause mortality, fitting a Generalized Additive Model (equation 1) with quasi-poisson distribution.

log(M) = day of the year + day of the week+ humidity+ s(time, k=4)+ s(T-max, k = 4)........ [1]

where *M* is daily counts of all-cause mortality, *time* is a term representing each day, *day of the week* and *day of the year* are factor terms, *humidity* represent daily humidity time-series, *s* is a fixed thin-plate regression spline with k-1 degrees of freedom, and *T-max* represents daily maximum temperature(36).

We initially examined the same-day effect (lag 0 day effect) of T-max, as evidence shows that atmospheric heat has little lagged effect on health outcomes as opposed to cold atmospheric conditions, the effect of which is spread over a longer period(37–40). However, we also estimated the cumulative effect of T-max of the same-day plus lag 1 day (lag 0-1-day effect) on mortality. We used a regression spline with three degrees of freedom for T-max to model its non-linear relation with the death rates. Long-term trends and seasonality were controlled for and so was changing resilience of citizens across the different periods of the summer season (early days of summer likely to affect more than the later part of summer) by including a smooth function of time (natural cubic spline with 3 degrees of freedom), day of the year and day of the week in the model(36,41–44). Relative humidity was also included to account for its potential confounding effect on the heat-mortality relationship.

Visualizing the modelled exposure-response curve, we planned to identify two T-max thresholds: lower threshold (LT) and upper threshold (UT). The LT would be denoted by the lowest T-max at which the mortality risk ratio (MRR) climbed above (or in case of Angul “up to”) or touched the null value of 1.0 and stayed consistently above that value (or in close proximity to the null line). The UT denoted the lowest T-max when the MRR was statistically significant that is the temperature at which the lower bound of the 95% confidence interval of MRR exceeded 1.0.

We then estimated the MRR for each degree Celsius (^{o}C) increase above the LT, using LT as the value for centring T-max in subsequent quasi-Poisson models. We also estimated the MRRs for 80th, 95th and 99th percentiles of T-max, comparing them with LT.

Intuitively, the T-min of the day is likely to play an important role in determining the hazardous effects of T-max, because it can offset some of the deleterious effects of daytime heat by letting the physiological milieu of the body to cool down during the night. Therefore, we examined the interaction between T-max and T-min in our model.

Then, we used the Distributed Lag Non-linear Model (DLNM) to examine the relationship between mortality and the two dimensions of heat simultaneously(45,46)– the maximum temperature and its lag structure- in the same model. Basis functions of DLNM included 2nd degree basic spline functions with 5 degrees of freedom to define the non-linear association of temperature with death; with 5 periods of lag, stratified at 0-1 and 2-5, to specify the lag space of the predictor. Model selection and specification was done using Akaike Information Criteria (AIC).

“Slice” graphs were plotted to visualize the relationship of both the dimensions of the predictor, T-max and lag with all-cause mortality; each dimension considered one at a time, and with the other specified at a constant point. The specified lags used for slice graphs were 0, 2 and 5, whereas the specified T-max were 90th, 95th and 99th percentiles.

R statistical software-version 3.4.1 was used for the analysis.

Results and Discussion:

Ongole:

Socio-economic details

The first segment of the analysis shows the descriptive statistics for socio-economic details for the four cities. The mean age of the respondents for Ongole city was 42.7 ± 14.8 years. The mean years spent in Ongole city for the 504 respondents was 32.5 ± 17.7 years. An important determinant of socio-economic status is income and expenditure level. The mean income for the respondents in Ongole was 15563.3 ± 12262.5 rupees. Mean income during the summer averaged at 14575.7 ± 11842.1 rupees. There were a total of 116 (23%) households who had a change in income during extreme summer. The mean expenditure for the 504 respondents in was 10093.1 ± 6796.2 rupees. Extreme summer also leads to a change in expenditure for people. Out of the 504 respondents interviewed, 437 (86.7%) reported an increase in monthly expenditure while only 5 respondents reported a decrease in monthly family expenditure. COVID-19 had an impact on the expenditure of the respondents and 448 (88.9%) respondents reported an increase in expenditure during COVID-19 lockdown while only 4 (0.8%) reported a decrease in monthly expenditure.

Out of the 504 respondents surveyed, 171 (33.9%) were male whereas 333 (66.1%) were female. As for the religion of the respondents, 259 (51.4%) were following Hinduism, whereas 179 (35.5%) and 60 (11.9) belonged to Islam and Christianity respectively. A total of 375 (74.4%) of the population surveyed were married and 59 (11.7%) were widowed. Only 6 (1.2%) households had pregnant women. Among the respondents, 196 (38.9%) were illiterate, 34 (6.7%) had primary education, 63 (12.5%) had middle school certificate, 91 (18.1%) had high school certificate, 54 (10.7) had intermediate or post-high school diploma and only 64 (12.7) had professional course or college/university level degree.

WASH and Waste Management

For understanding people's behaviour during extreme heat, amount of water used is a very important indicator. The respondents reported an average use of 4.2 ± 3.0 buckets of water per day. A bucket was considered to be of 20 litres for the survey and the same measurement was used to get data from the respondents. During extreme summer, the mean number of buckets of water increased to 4.8 ± 3.7. As for the source of water, 440 (88%) respondents get access to water from the municipality through pipelines, 45 (9%) gets water from groundwater sources and 24 (4.8%) families get water from bore wells. However, there will be some families who get water from multiple sources. Out of the 504 respondents, 230 (45.6%) respondents have reported getting water for less amount of time in extreme summer as compared to the other seasons. A total of 269 (53.4%) respondents do not have any change in the time duration for water they receive in the summer season and other seasons. Out of the total 504 respondents interviewed, 240 (47.6%) have reported water shortage during the summer season as compared to only 80 (15.9%) respondents reporting water crisis during other seasons. A total of 386 (76.6%) respondents have reported that their households require extra water during summer season. Extra water is required for various purposes, but mostly for drinking and bathing during the summer. A total of 364 (72.2%) and 342 (67.9%) households have mentioned that they require extra water for drinking and bathing respectively during extreme summer. Out of the 504 respondents, 491 (97.4%) respondents have personal toilets in their households. For cleaning of drinking water, 122 (24.2%) households use reverse osmosis (RO) systems in their homes, 78 (15.5%) households have mentioned boiling the water for making it potable, however, 245 (48.6%) households mentioned that they do not use any sort of water purification technique for drinking water. As for handwashing habits, >99.6% of people have reported washing hands after defecating, before eating and after eating, during both normal summers and summers of COVID-19. Around 92% people have admitted to washing hands before cooking and before serving food but that percentage increased to 94% during the COVID-19 lockdown summer.

Food habits

Food habits also play a major role in behavioural mitigation to heat waves. Amongst the 504 respondents interviewed, 98 (19.4%) have reported a significant change in the quantity of food they intake during extreme summer days as compared to other days. Amongst the food avoided during extreme summer days, 69 (13.7%) respondents have mentioned avoiding chicken, 49 (9.7%) have mentioned avoiding red meat, 35 (6.9%) have mentioned avoiding eggs and 23 (4.6%) respondents have mentioned avoiding fish. Therefore, most of the food avoided is non-vegetarian with some respondents avoiding multiple non-vegetarian food during extreme summer days.

Housing and Locational characteristics

Out of the 504 respondents interviewed, 252 (50%) had pucca houses while 237 (47%) respondents had semi-pucca houses. Only 13 (2.6%) households were Kutchha. A total of 262 (52%) households had concrete roofs but 179 (35.5%) households had asbestos roof. Out of the 504 respondents interviewed, only 16 (3.2%) mentioned having a false ceiling in their house. A total of 479 (95%) households had indoor kitchen whereas only 19 (3.8%) had outdoor kitchen. A total of 118 (23.4%) households reported having regular power-cuts during extreme summer season as compared to only 22 (4.4%) households reporting power-cuts during other seasons. A total of 266 (52.8%) households had 3 rooms while 100 (19.8%) ad 106 (21%) households had two and four rooms respectively. Only 52 (10.3%) households reported having no windows in their kitchen. Only 7 (1.4%) houses had ceiling fans and another 7 (1.4%) households had exhaust fans in their kitchens. A total of 486 (96.4%) respondents have mentioned using liquefied petroleum gas (LPG) cylinders as their primary source of fuel. Only 5 (1.0%) respondents had to change their source of fuel during summers and 7 (1.4%) respondents had to change their fuel during COVID-19 lockdown.

As for the locational characteristics, 40 (7.9%) households out of the 504 households interviewed had tall buildings on three sides affecting ventilation. However, 369 (73.2%) households had no tall building on any side. 238 (47.2%) households had vegetative patches like parks or grounds nearby 167 (33.1%) households had water bodies like ponds, lakes or streams nearby. These water bodies and green patches can reduce the impact of heat waves. On the other hand, 91 (18.1%) households had industrial sites nearby and 107 (21.2%) households had traffic junctions nearby which increase the ambient heat.

Community Help

Community plays a very important role in coping during tough situations. Out of the 504 respondents, 419 (83.1%) mentioned that they will get help from their extended family in emergency situations while 69 (13.7%) mentioned that they won't get help. In case of getting help from neighbours, 385 (76.4%) mentioned that they will get help from their neighbours while 89 (17.7%) mentioned that they won’t get any help. During COVID-19 situation, due to social distancing norms, 105 (20.8%) people mentioned that they will not get any help from either extended family or neighbours. A total of 414 (81.2%) people also reported that they do not or will not get any help from local clubs, associations or societies.

Risk Perception

Risk perception can influence how people understand a hazard and what coping measures they take to prevent any damage from the hazard. Out of the 504 respondents interviewed, 321 (63.7%) believe that heat waves are caused by a lack of rainfall and 99 (19.6%) believe that air pollution contributes to increase in heat waves. 469 (93.1%) respondents believe that heat waves can be harmful, however, only 391 (77.6%) respondents believe that they can be seriously affected by heat waves. Only 38 (7.5%) respondents have visited a physician for heat related illness. A total of 331 (65.7%) respondents believe that heat stroke is the most harmful effect heat wave can have on a human being. A total of 462 (91.7%) respondents believe that temperature and humidity have increased in the last few years.

The temperature and humidity at home can determine if heat waves can lead to harmful impacts. A total of 228 (45.2%) respondents mentioned having a warm feeling inside their houses and 66 (13.1%) have mentioned feeling very warm inside their homes. Out of the 504 respondents interviewed, 92 (18.3%) have reported having fully wet skin at home during summer, which suggests high humidity. A total of 209 (41.5%) people feel suffocation inside their homes which can lead to heat related illnesses.

Coping Measures

A total of 347 (68.8%) respondents have reported avoiding the sun as a coping measure which they take to avoid extreme heat during normal summer. A total of 345 (68.5%) respondents reported drinking more liquid to save themselves from extreme summer. During COVID-19 lockdown, number of respondents who choose avoiding sun increased to 377 (74.8%) and respondents drinking more liquid decreased to 280 (55.5%). A total of 84 (16.7%) and 83 (16.5%) respondents have also reported finding a cooler location during their day to day lives in normal summer and COVID-19 summers respectively. To avoid the sun, 397 (78.8%) respondents have reported staying indoors as a coping measure and 311 (61.7%) respondents have reported using umbrella and hat while going outdoors. In COVID-19 summers, respondents using umbrella and hats went down to 122 (24.2%) while respondents staying indoors increased to 463 (91.9%). For keeping their house cool, 442 (87.7%) respondents mentioned using either fans or air-conditioning systems and 60 (11.9%) respondents mentioned wiping their floor with water. There are some measures which the respondents wanted to take but they couldn't or haven't. A total of 271 (53.8%) respondents wanted to buy air-conditioning systems or air coolers and 60 (11.9%) respondents wanted to change their roof. A total of 388 (77%) respondents mentioned that the government should plant more trees in the city to help the citizens in battling extreme heat. A total of 237 (47%) of the people also mentioned that the government should build more shades and resting areas in the city. Due to the COVID-19 lockdown, many respondents faced problems in taking the necessary coping measures. A total of 288 (57.1%) residents were physically restrained from taking coping measures and 154 (30.6%) were financially restrained from taking necessary coping measures for heat waves during the COVID-19 pandemic summer months.

Early Warning System

Out of the 504 respondents, 411 (81.5%) have reported getting crucial information related to heat waves from television. A total of 123 (24.4%) respondents get heat related information from their friends/relatives and 111 (22%) respondents receive information on heat waves from newspapers. A total of 383 (76%) respondents believe that the government is doing enough to spread information on heat waves whereas 121 (24%) people believe that the government is not doing enough to spread information on heat waves. Most of the people 272 (58%) have mentioned that they have not received major information on heat waves. Only 13 (2.6%) respondents have received any form of sensitisation on heat waves and only 15 (3%) people have attended campaigns, seminars and speeches on heat waves.

Quality of life

Quality of life factors in while understanding vulnerability of an individual to heat waves. Out of the 504 respondents interviewed, 253 (50.2%) respondents felt that they have a good physical environment whereas 32 (6.4%) respondents felt that they either have poor or very poor physical environment. During extreme summer, the respondents who felt that their physical environment is poor or very poor increased to 86 (16.1%) and respondents who felt that they have a good physical environment decreased to 173 (34.3%). During COVID-19, the number of respondents who thinks they have a poor or very poor physical environment became 65 (12.9%) and respondents who think they have a good physical environment became 179 (35.5%). Only 36 (7.2%) respondents had poor or very poor sleep satisfaction during other seasons except summer and during extreme summer that number increased to 71 (14.1%). A total of 224 (44.4%) respondents felt that they do not have required energy to work during extreme summer seasons. A total of 127 (25.2%) respondents reported discomfort due to air pollution in their locality.

Co-Morbidities

Presence of co-morbidities can increase the chance of a person being affected by heat waves. Out of the 504 respondents interviewed, 85 (16.9%) respondents mentioned suffering from weakness and 80 (15.9%) respondents mentioned suffering from mild headaches while at home. The other co-morbidities in the section were recorded for the respondent as well as their family members. Data was collected for a total of 1716 individuals. Out of the 1716 individuals only 5 (0.3%) suffered from mental conditions and 4 (0.2%) had hearing disability. A total of 116 (6.8%) individuals had suffered from heat fatigue and a staggering 26 (1.5%) individuals had suffered from heat strokes. In the 15 days before the interviews were taken, 140 (8.2%) people had suffered from hypertension and out of that 137 (8%) people are in medication for hypertension. A total of 129 (7.5%) of individuals suffered from diabetes and each one of them were on medication for the same.

Habits and Behaviour

Behaviour and habits often are impacted by how one individual is affected by a hazard and how coping measures are taken. As for the habits and behaviour of the respondents, a total of 424 (84.1%) respondents keep their windows open during extreme summer and 80 (15.9%) do not. During the summers of COVID-19, 416 (81.5%) respondents kept their windows open whereas 88 (17.5%) kept their windows closed. A total of 213 (42.3%) respondents keep their blinds and drapes closed during extreme summer days whereas 291 (57.7%) respondents keeps their blinds and drapes open during extreme summer. Only 58 (11.5%) respondents reported using bed-nets during regular times while during extreme summer the number of respondents using bed-nets became 55 (10.9%). A total of 189 (37.5%) respondents reported wearing different kinds of clothes in summer seasons as compared to other seasons. Out of the 504 respondents, 324 (64.3%) reported decreasing time spent outside during extreme summer. A total of 406 (80.6%) respondents reported sleeping in beds and 62 (12.3%) respondents reported sleeping in the bare floor at night during normal days. During extremely hot nights, 400 (79.4%) respondents reported sleeping in beds while 68 (13.5%) slept on the bare floor. The mean number of baths taken in regular days was 1.39 ± 0.49 while during extreme summer days, the mean significantly increases to 1.79 ± 0.43. During the COVID-19 summer days, the mean number of baths per day was 1.71 ± 0.48. For the 504 respondents, mean number of litres of water drank during normal summers was 3.18 ± 0.90 while during extreme summers, the mean significantly increased to 4.43 ± 0.95.

Occupation

201 working respondents were interviewed in Ongole out of which 191 were currently employed. A total of 65 (32.3%) respondents were unskilled workers, 39 (19.4%) were skilled workers and 18 (9%) were semi-skilled workers. 10 (5%) respondents were professionals in their field and 9 (4.5%) respondents were semi-professionals. Out of the workable population, 41 (20.4%) respondents were self-employed, 6 (3%) were agricultural workers and 2 (1%) were clerical workers. Out of the 191 employed respondents, 4 (2.1%) respondents had a change in type of work during extreme summer days and 187 (97.9%) continued with their regular occupation.

Only 14 (7.3%) respondents had a change in type of work during the summer days of COVID-19 and 177 (92.7%) continued with their old occupation. A total of 178 (93.2%) respondents worked in day shifts during regular days and during extremely hot days, 175 (91.6%) respondents worked day shifts. The mean duration of work was 7.9 ± 2.1 and it significantly reduced to 7.0 ± 2.3 during extreme summer days. As for travelling to and fro from work, 77 (40.8%) respondent walked during regular seasons and 76 (39.8%) respondents walked during extreme summer seasons. Only 4 (2%) respondents are exposed to a direct source of heat like furnaces or boilers at their workplace. A total of 155 (81.2%) respondents reported discomfort due to PPE kits worn at the workplace. As for the type of dress worn at workplace, 147 (77%) reported wearing half sleeves during regular season and during summer seasons the number increased to 153 (80.1%). During the COVID-19 lockdown, the number of respondents wearing half-sleeves decreased to 149 (78%). Only 4 (2.1%) of the respondents had air-conditioning systems in their workplace but only 2 (50%) of them used the air-conditioning systems during COVID-19 period. A total of 46 (24.1%) respondents did not have drinking water at the workplace and 36 (18.8%) respondents had difficulty in getting water at workplace. As for protecting themselves from heatwaves at workplace, 140 (73.3%) respondents reported taking several breaks and 111 (58.1%) reported drinking lots of water. During the COVID-19 summers, 138 (72.3%) respondents reported taking several breaks and 107 (56%) reported drinking lots of water.

Karimnagar:

Socio-economic details

The first segment of the analysis shows the descriptive statistics for socio-economic details for the four cities. The mean age of the respondents for Karimnagar city was 38.6 ± 15.0 years. The mean years spent in Karimnagar for the 500 respondents was 33.4 ± 16.8 years. An important determinant of socio-economic status is income and expenditure level. The average income of the respondents was 28933.2 ± 26013.2 rupees. Mean income during the summer reduced to 27145.2 ± 26184.1 rupees. There were a total of 132 (26.4%) households who had a change in income during extreme summer. The mean expenditure for the 500 respondents stood at 14460.5 ± 10299.1 rupees. Extreme summer also leads to a change in expenditure. Out of the 500 respondents interviewed, 440 (88%) reported an increase in monthly expenditure while only 5 (1%) respondents reported a decrease in monthly family expenditure. COVID-19 had an impact on the expenditure of the respondents and 459 (91.8%) respondents reported an increase in expenditure during COVID-19 lockdown while only 8 (1.6%) reported a decrease in monthly expenditure.

Out of the 500 respondents interviewed, 231 (46.2%) were male whereas 266 (53.2%) were female and 3 (0.6%) were transgender. As for the religion of the respondents, 445 (89%) were following Hinduism, whereas 28 (5.6%) and 26 (5.2%) belonged to Islam and Christianity respectively. A total of 338 (67.6%) of the population surveyed were married and 127 (25.4%) were single and unmarried. Only 6 (1.2%) households had pregnant women. Among the respondents, 104 (20.8%) were illiterate, 17 (3.4%) had primary education, 43 (8.6%) had middle school certificate, 70 (14%) had high school certificate, 81 (16.2%) had intermediate or post-high school diploma and only 180 (36%) had professional course or college/university level degree.

WASH and Waste Management

For understanding people's behaviour during extreme heat, amount of water used is a very important indicator. The respondents reported an average use of 11.8 ± 5.9 buckets of water per day. A bucket was considered to be of 20 litres for the survey and the same measurement was used to get data from the respondents. During extreme summer, the mean number of buckets of water increased to 14.7 ± 7.2. As for the source of water, 464 (92.8%) respondents got access to water from the municipality through pipelines, 151 (30.2%) got water from groundwater sources and 27 (5.4%) families got water from bore wells. However, there will be some families who got water from multiple sources. Out of the 500 respondents, 149 (29.8%) respondents have reported getting water for less amount of time in extreme summer as compared to the other seasons. A total of 334 (66.8%) respondents do not have any change in the time duration for water they receive in the summer season and other seasons. Out of the total 500 respondents interviewed, 107 (21.4%) have reported water shortage during the summer season as compared to only 36 (7.2%) respondents reporting water crisis during other seasons. A total of 350 (70%) respondents have reported that their households require extra water during summer season. Extra water is required for various purposes, but mostly for drinking, bathing and cleaning of house during the summer. A total of 348 (69.6%) and 289 (57.8%) households have mentioned that they require extra water for drinking and bathing respectively during extreme summer. A total of 185 (37%) respondents require extra water for cleaning of their houses. Out of the 500 respondents, 441 (88.2%) respondents had personal toilets in their households while 45 (9%) used shared toilets. For purifying drinking water, 181 (36.2%) households used water filtration systems in their homes, 50 (10%) used water purifiers, 52 (10.4%) used RO systems and 33 (6.6%) households have mentioned boiling the water for making it potable. However, 158 (31.6%) households mentioned that they do not use any sort of water purification technique for drinking water. As for handwashing habits, more than 496 (99.2%) respondents have reported washing hands after defecating, before eating and after eating, during both normal summers and summers of COVID-19. A total of 401 (80.2%) respondents have admitted to washing hands before cooking which increased to 435 (87%) during COVID-19 and 453 (90.6%) respondents agreed to wash hands before serving food but that number increased to 487 (97.4%) during the COVID-19 lockdown summer.

Food habits

Food habits also play a major role in behavioural mitigation to heat waves. Amongst the 500 respondents interviewed, 116 (23.2%) have reported a significant change in the quantity of food they intake during extreme summer days as compared to other days. Amongst the food avoided during extreme summer days, 84 (16.8%) respondents have mentioned avoiding chicken, 58 (11.6%) have mentioned avoiding red meat, 47 (9.4%) have mentioned avoiding eggs and 44 (8.8%) respondents have mentioned avoiding fish. Therefore, most of the food avoided is non-vegetarian with some respondents avoiding multiple non-vegetarian food during extreme summer days.

Housing and Locational characteristics

Out of the 500 respondents interviewed, 332 (66.4%) had pucca houses while 119 (23.8%) respondents had semi-pucca houses. Only 42 (8.4%) households were Kutchha. A total of 344 (68.8%) households had concrete roofs and 50 (10%) households had asbestos roof. Out of the 500 respondents interviewed, only 25 (5%) mentioned having a false ceiling in their house. A total of 487 (97.4%) households had indoor kitchen whereas only 11 (2.2%) had outdoor kitchen. A total of 82 (16.4%) households reported having regular power-cuts during extreme summer season as compared to only 40 (8%) households reporting power-cuts during other seasons. A total of 69 (13.8%) had only one room, 128 (25.6%) had two rooms, 184 (36.8%) households had three rooms while 75 (15%) households had four rooms. Only 63 (12.6%) households reported having no windows in their kitchen. Only 17 (3.4%) houses had ceiling fans and another 45 (9%) households had exhaust fans in their kitchens. Only 4 (0.8%) houses had chimneys. A total of 479 (95.8%) respondents have mentioned using LPG cylinders as their primary source of fuel. Only 3 (0.6%) respondents had to change their source of fuel during summers and 3 (0.6%) respondents had to change their fuel during COVID-19 lockdown.

As for the locational characteristics, 135 (27%) households out of the 500 households interviewed had tall buildings on one side, 83 (16.6%) on two sides, 14 (2.8%) on three sides and 7 (1.4%) on four sides, affecting ventilation. However, 261 (52.2%) households had no tall building on any side. Only 37 (7.4%) households had vegetative patches like parks or grounds nearby. Only 58 (11.6%) households had water bodies like ponds, lakes or streams nearby. These water bodies and green patches can reduce the impact of heat waves. On the other hand, 27 (5.4%) households had industrial sites nearby and 68 (13.6%) households had traffic junctions nearby which increase the ambient heat.

Community Help

Community plays a very important role in coping during tough situations. Out of the 500 respondents, 406 (81.2%) mentioned that they will get help from their extended family in emergency situations while 73 (14.6%) mentioned that they won't get help. In case of getting help from neighbours, 365 (73%) mentioned that they will get help from their neighbours while 80 (16%) mentioned that they won't get any help. During COVID-19 situation, due to social distancing norms, 80 (16%) people mentioned that they will not get any help from either extended family or neighbours. A total of 315 (63%) people also reported that they do not or will not get any help from local clubs, associations or societies.

Risk Perception

Risk perception can influence how people understand a hazard and what coping measures they take to prevent any damage from the hazard. Out of the 500 respondents interviewed, 216 (43.2%) believe that heat waves are caused by a lack of rainfall and 148 (29.6%) believe that air pollution contributes to increase in heat waves. A total of 82 (16.4%) respondents also believed that global warming is the root cause of increasing heat waves. A total of 477 (95.4%) respondents believe that heat waves can be harmful, however, only 416 (83.2%) respondents believe that they can be seriously affected by heat waves. A total of 54 (10.8%) respondents have visited a physician for heat related illness. A total of 351 (70.2%) respondents believe that heat stroke is the most harmful effect heat wave can have on a human being. A total of 492 (98.4%) respondents believe that temperature and humidity have increased in the last few years.

The temperature and humidity at home can determine if heat waves can lead to harmful impacts. A total of 231 (46.2%) respondents mentioned having a warm feeling inside their houses, 49 (9.2%) have mentioned feeling very warm and 17 (3.4%) mentioned feeling hot inside their homes. Out of the 500 respondents interviewed, 68 (13.6%) have reported having fully wet skin at home during summer, which suggests high humidity. A total of 163 (32.6%) people feel suffocation inside their homes which can lead to heat related illnesses.

Coping Measures

A total of 349 (69.8%) respondents have reported avoiding the sun as a coping measure which they take to avoid extreme heat during normal summer. A total of 341 (68.2%) respondents reported drinking more liquid to save themselves from extreme summer. During COVID-19 lockdown, number of respondents who choose avoiding sun increased to 432 (86.4%) and respondents drinking more liquid decreased to 277 (55.4%). A total of 256 (51.2%) and 238 (47.6%) respondents have also reported finding a cooler location during their day to day lives in normal summer and COVID-19 summers respectively. To avoid the sun, 303 (60.6%) respondents have reported staying indoors as a coping measure and 354 (70.8%) respondents have reported using umbrella and hat while going outdoors. In COVID-19 summers, respondents using umbrella and hats decreased to 193 (38.6%) while respondents staying indoors increased to 421 (84.2). For keeping their house cool, 455 (91.0%) respondents mentioned using either fans or air-conditioning systems, 22 (4.4%) mentioned sprinkling the roof with water and 60 (11.9%)

respondents mentioned wiping their floor with water. There are some measures which the respondents wanted to take but they couldn't or haven't. A total of 199 (39.8%) respondents wanted to buy air-conditioning systems or air coolers and 40 (8%) respondents wanted to change their roof. A total of 249 (49.8) respondents also mentioned they want to increase greenery near their households. A total of 389 (77.8%) respondents mentioned that the government should plant more trees in the city to help the citizens in battling extreme heat. A total of 209 (41.8%) of the people also mentioned that the government should build more shades and resting areas in the city. Due to the COVID-19 lockdown, many respondents faced problems in taking the necessary coping measures. A total of 93 (18.6%) residents were physically restrained from taking coping measures and 144 (28.8%) were financially restrained from taking necessary coping measures for heat waves during the COVID-19 pandemic summer months. Out of the respondents, 270 (54%) mentioned that their coping measures to heat were not affected by COVID-19.

Early Warning System

Out of the 500 respondents, 383 (76.6%) have reported getting crucial information related to heat waves from television. A total of 133 (26.6%) respondents gets heat related information from their friends/relatives and 170 (34%) respondents receive information on heat waves from newspapers. A total of 338 (67.6%) respondents believe that the government is doing enough to spread information on heat waves whereas 152 (30.4%) people believe that the government is not doing enough to spread information on heat waves. 364 (72.8%) people have mentioned that they have not received major information on heat waves. Only 2 (0.4%) respondents have received any form of sensitisation on heat waves and only 5 (1%) people have attended campaigns, seminars and speeches on heat waves.

Quality of life

Quality of life factors in while understanding vulnerability of an individual to heat waves. Out of the 500 respondents interviewed, 258 (51.6%) respondents felt that they have a good physical environment whereas 63 (12.6%) respondents felt that they either have poor or very poor physical environment. During extreme summer, the respondents who felt that their physical environment is poor or very poor increased to 78 (15.6%) and respondents who felt that they have a good physical environment decreased to 213 (42.6%). During COVID-19, the number of respondents who thinks they have a poor or very poor physical environment became 59 (11.3%) and respondents who think they have a good physical environment became 226 (45.2%). Only 16 (3.2%) respondents had poor or very poor sleep satisfaction during other seasons except summer and during extreme summer that number increased to 55 (11%). A total of 189 (37.8%) respondents felt that they do not have required energy to work during extreme summer seasons. A total of 49 (9.8%) respondents reported discomfort due to air pollution in their locality.

Co-Morbidities

Presence of co-morbidities can increase the chance of a person being affected by heat waves. Out of the 500 respondents interviewed, 91 (18.2%) respondents mentioned suffering from weakness, 29 (5.8%) respondents mentioned suffering from mild headaches and 28 (5.6%) mentioned suffering from muscle pains while at home. The other co-morbidities in the section were recorded for the respondent as well as their family members. Data was collected for a total of 1606 individuals. Out of the 1606 individuals only 7 (0.4%) suffered from locomotive disorder and 7 (0.4%) had hearing disability. A total of 107 (6.7%) individuals had suffered from heat fatigue and a 17 (1.1%) individuals had suffered from heat exhaustion. In the 15 days before the interviews were taken, 150 (9.3%) people had suffered from hypertension and out of that 149 (9.3%) people are in medication for hypertension. A total of 100 (6.2%) of individuals suffered from diabetes and each one of them were on medication for the same.

Habits and Behaviour

Behaviour and habits often are impacted by how one individual is affected by a hazard and how coping measures are taken. As for the habits and behaviour of the respondents, a total of 436 (87.2%) respondents keep their windows open during extreme summer and 64 (12.8) do not. During the summers of COVID-19, 408 (81.6%) respondents kept their windows open whereas 62 (18.4%) kept their windows closed. A total of 157 (31.4%) respondents keep their blinds and drapes closed during extreme summer days whereas 343 (68.6%) respondents keeps their blinds and drapes open during extreme summer. Only 38 (7.6%) respondents reported using bed-nets during regular times and they kept using bed-nets even during extremely hot nights. A total of 217 (43.4%) respondents reported wearing different kinds of clothes in summer seasons as compared to other seasons. Out of the 500 respondents, 346 (69.2%) reported decreasing time spent outside during extreme summer. A total of 369 (73.8%) respondents reported sleeping in beds and 84 (16.8%) respondents reported sleeping in the bare floor at night during normal days. During extremely hot nights, 358 (71.6%) respondents reported sleeping in beds while 89 (17.8%) slept on the bare floor. The mean number of baths taken in regular days was 1.4 ± 0.5 while during extreme summer days, the mean significantly increases to 2.0 ± 0.3. During the COVID-19 summer days, the mean number of baths per day was 2.0 ± 0.4. For the 500 respondents, mean number of litres of water drank during normal summers was 3.4 ± 1.0 while during extreme summers, the mean significantly increased to 4.8 ± 1.1.

Occupation

223 working respondents were interviewed in Ongole out of which 208 were currently employed. A total of 77 (34.5%) respondents were unskilled workers, 18 (8.1%) were skilled workers and 19 (8.5%) were semi-skilled workers. A total of 37 (16.6%) respondents were professionals in their field and 22 (9.9%) respondents were semi-professionals and 27 (12.1%) respondents were self-employed, 3 (1.3%) were agricultural workers and 4 (1.8%) were clerical workers. Out of the 208 employed respondents, 10 (4.8%) respondents had a change in type of work during extreme summer days and 198 (95.2) continued with their regular occupation. Only 16 (7.7%) respondents had a change in type of work during the summer days of COVID-19 and 192 (92.3%) continued with their old occupation. A total of 181 (87%) respondents worked in day shifts during regular days, 182 (87.5%) respondents worked day shifts in extreme hot days. The mean duration of work was 8.1 ± 2.0 and it significantly reduced to 7.0 ± 2.3 during extreme summer days. As for travelling to and fro from work, 111 (53.4%) respondent took their bikes to work during regular seasons and 108 (51.9%) respondents took their bikes to work during extreme summer seasons. Only 16 (7.7%) respondents are exposed to a direct source of heat like furnaces or boilers at their workplace. A total of 153 (73.6%) respondents reported discomfort due to PPE kits worn at the workplace. As for the type of dress worn at workplace, 146 (70.2%) reported wearing half sleeves

during regular season and during summer seasons the number increased to 148 (71.2%). During the COVID-19 lockdown, the number of respondents wearing half-sleeves decreased to 139 (66.8%). Only 32 (15.4%) of the respondents had air-conditioning systems in their workplace but only 23 (71.9%) of them used the air-conditioning systems during COVID-19 period. A total of 55 (26.4%) respondents did not have drinking water at the workplace and 31 (14.9%) respondents had difficulty in getting water at workplace. As for protecting themselves from heatwaves at workplace, 148 (71.2%) reported drinking lots of water, 130 (62.5%) respondents reported taking several breaks and 75 (36.1%) respondents mentioned finding a cooler location. During the COVID-19 summers, 128 (61.5%) respondents drinking lots of water, 114 (54.8%) reported taking several breaks and 70 (33.7%) mentioned finding a cooler location.

Kolkata:

Socio-economic details

The first segment of the analysis shows the descriptive statistics for socio-economic details for the four cities. The mean age of the respondents for Kolkata city was 39.6 ± 13.1 years. An important determinant of socio-economic status is income and expenditure level. The average income of the respondents was 29838.0 ± 28357.6 rupees. Mean income during the summer reduced to 27688.0 ± 27811.9 rupees. There were a total of 66 (13.2%) households who had a change in income during extreme summer. The mean expenditure for the 500 respondents was 17850.0 ± 18663.3 rupees. Extreme summer also leads to a change in expenditure. Out of the 500 respondents interviewed, 95 (19%) reported an increase in monthly expenditure while 380 (76%) respondents reported no change in monthly family expenditure. COVID-19 had an impact on the expenditure of the respondents and 229 (45.8%) respondents reported an increase in expenditure during COVID-19 lockdown while 109 (21.8%) reported a decrease in monthly expenditure.

Out of the 500 respondents interviewed, 321 (64.2%) were male whereas 174 (34.8%) were female and 1 (0.2%) was a transgender. As for the religion of the respondents, 469 (93.8%) were following Hinduism, whereas 21 (4.2%) and 2 (0.4%) belonged to Islam and Christianity respectively. A total of 332 (66.4%) of the population surveyed were married and 134 (26.8%) were single and unmarried. A total of 19 (3.8%) households had pregnant women. Among the respondents, 8 (1.6%) were illiterate, 20 (4%) had primary education, 51 (10.2%) had middle school certificate, 110 (22%) had high school certificate, 52 (10.4%) had intermediate or post-high school diploma and 252 (50.8%) had professional course or college/university level degree.

WASH and Waste Management

For understanding people's behaviour during extreme heat, amount of water used is a very important indicator. The respondents reported an average use of 12.8 ± 4.2 buckets of water per day. A bucket was considered to be of 20 litres for the survey and the same measurement was used to get data from the respondents. During extreme summer, the mean number of buckets of water increased to 15.0 ± 4.7. As for the source of water, 322 (64.4%) respondents got access to water from the municipality through pipelines, 155 (31.2%) got water from groundwater sources, 67 (13.4%) got water from tube wells and 35 (7%) families got water from bore wells. However, there will be some families who got water from multiple sources. Out of the 500 respondents, only 13 (2.6%) respondents have reported getting water for less amount of time in extreme summer as compared to the other seasons. A total of 484 (96.8%) said that there is no change of time duration for which they get water during summer from other seasons. Out of the total 500 respondents interviewed, 50 (10%) have reported water shortage during the summer season as compared to only 28 (5.6%) respondents reporting water crisis during other seasons. A total of 348 (69.6%) respondents have reported that their households require extra water during summer season. Extra water is required for various purposes, but mostly for drinking and bathing during the summer. A total of 359 (71.8%) and 263 (52.6%) households have mentioned that they require extra water for drinking and bathing respectively during extreme summer. Out of the 500 respondents, 348 (69.6%) respondents had personal toilets in their households while 138 (27.6%) used shared or community toilets. For purifying drinking water, 99 (19.8%)

households used water filtration systems in their homes, 157 (31.4%) used water purifiers, 129 (25.8%) used RO systems and 86 (17.2%) households have mentioned boiling the water for making it potable. Only 9 (2.6%) households mentioned that they do not use any sort of water purification technique for drinking water. As for handwashing habits, more than 470 (94%) respondents have reported washing hands after defecating, before eating and after eating, during both normal summers and summers of COVID-19. Only 225 (45%) respondents have admitted to washing hands before cooking which increased to 269 (53.8%) during COVID-19 and 261 (52.2%) respondents agreed to wash hands before serving food but that number increased to 303 (60.6%) during the COVID-19 lockdown summer.

Food habits

Food habits also play a major role in behavioural mitigation to heat waves. Amongst the 500 respondents interviewed, 125 (25%) have reported a significant change in the quantity of food they intake during extreme summer days as compared to other days. Amongst the food avoided during extreme summer days, 169 (33.8%) respondents have mentioned avoiding red meat, 35 (7%) have mentioned avoiding eggs, 32 (6.4%) have mentioned avoiding chicken and 21 (4.2%) respondents have mentioned avoiding fish. A total of 71 (14.2%) respondents also mentioned about avoiding milk and milk products during extreme summer. Therefore, most of the food avoided is non-vegetarian with some respondents avoiding multiple non-vegetarian food during extreme summer days.

Housing and Locational characteristics

Out of the 500 respondents interviewed, 386 (77.2%) had pucca houses while 95 (19%) respondents had semi-pucca houses. Only 19 (3.8%) households were Kutchha. A total of 358

(71.6%) households had concrete roofs and 70 (14%) households had asbestos roof. Out of the 500 respondents interviewed, only 21 (4.2%) mentioned having a false ceiling in their house. A total of 472 (94.4%) households had indoor kitchen whereas 25 (5%) had outdoor kitchen. 18 (3.6%) households reported having regular power-cuts during extreme summer season as compared to 14 (2.8%) households reporting power-cuts during other seasons. A total of 114 (22.8%) had only one room, 205 (41%) had two rooms, 120 (24%) households had three rooms while 36 (7.2%) households had four rooms. A total of 115 (23%) households reported having no windows in their kitchen. A total of 209 (41.8%) households had exhaust fans in their kitchens and 103 (20.6) houses had chimneys. A total of 452 (90.4%) respondents have mentioned using LPG cylinders and 25 (5%) mentioned using kerosene as their primary source of fuel. Only 4 (0.8%) respondents had to change their source of fuel during summers as compared to 20 (4%) respondents having to change their fuel during COVID-19 lockdown summers.

As for the locational characteristics, 46 (9.2%) households out of the 500 households interviewed had tall buildings on one side, 173 (34.6%) on two sides, 143 (28.6%) on three sides and 120 (24%) on four sides, affecting ventilation. Only 18 (3.6%) households had no tall building on any side. 370 (74%) households had vegetative patches like parks or grounds nearby. 237 (47.5%) households had water bodies like ponds, lakes or streams nearby. These water bodies and green patches can reduce the impact of heat waves. On the other hand, 27 (5.4%) households had industrial sites nearby and 220 (44%) households had traffic junctions nearby which increase the ambient heat.

Community Help

Community plays a very important role in coping during tough situations. Out of the 500 respondents, 434 (86.8%) mentioned that they will get help from their extended family in emergency situations while 29 (5.8%) mentioned that they won't get help. In case of getting help from neighbours, 383 (76.6%) mentioned that they will get help from their neighbours while 63 (12.6%) mentioned that they won't get any help. During COVID-19 situation, due to social distancing norms, 99 (19.8%) people mentioned that they will not get any help from either extended family or neighbours. A total of 225 (45%) people also reported that they do not or will not get any help from local clubs, associations or societies.

Risk Perception

Risk perception can influence how people understand a hazard and what coping measures they take to prevent any damage from the hazard. Out of the 500 respondents interviewed, 273 (54.6%) believe that heat waves are caused by air pollution and 256 (51.2%) believe that global warming contributes to increase in heat waves. A total of 102 (20.4%) respondents also believed that lack of rainfall is the root cause of increasing heat waves. A total of 409 (81.8%) respondents believe that heat waves can be harmful while 50 (10%) respondents believed heat waves cannot be harmful. However, 303 (60.6%) respondents believe that they can be seriously affected by heat waves but a staggering 190 (38%) respondents believe otherwise. A total of 66 (13.2%) respondents have visited a physician for heat related illness. A total of 154 (30.8%) respondents believe that heat stroke is the most harmful effect heat wave can have on a human being while

134 (26.8%) believe the most harmful effect of heat wave is heat exhaustion. A total of 462 (92.4%) respondents believe that temperature and humidity have increased in the last few years.

The temperature and humidity at home can determine if heat waves can lead to harmful impacts. A total of 238 (47.6%) respondents mentioned having a warm feeling inside their houses, 18 (3.6%) have mentioned feeling very warm and 203 (40.6%) mentioned feeling normal inside their homes. Out of the 500 respondents interviewed, 244 (48.8%) have reported having wet skin at home during summer and, which suggests high humidity. A total of 162 (32.4%) people feel suffocation inside their homes which can lead to heat related illnesses.

Coping Measures

A total of 391 (78.2%) respondents have reported drinking more liquid as a coping measure which they take to avoid extreme heat during normal summer. A total of 120 (24%) respondents mentioned wearing appropriate clothes and 77 (15.4%) mentioned avoiding the sun as a coping mechanism during extreme summer. During COVID-19 lockdown, number of respondents who choose avoiding sun increased to 241 (48.2%) and respondents drinking more liquid decreased to 318 (64.6%). A total of 128 (25.6%) and 84 (16.8%) respondents have also reported finding a cooler location during their day to day lives in normal summer and COVID-19 summers respectively. To avoid the sun, 324 (64.8%) respondents have reported using umbrella or hats and 214 (42.8%) respondents have reported dressing properly. Only 38 (7.6%) respondents also mentioned staying indoors to avoid sun. In COVID-19 summers, respondents using umbrella and hats and wearing appropriate clothing decreased to 132 (26.4%) and 173 (34.6%) respectively while respondents staying indoors increased to 139 (27.8). For keeping their house cool, 310

(62%) respondents mentioned using either fans or air-conditioning systems, 45 (9%) mentioned sprinkling the roof with water and 100 (20%) respondents mentioned wiping their floor with water. There are some measures which the respondents wanted to take but they couldn't or haven't. A total of 232 (46.4%) respondents wanted to buy more fans and exhaust fans, 135 (27%) wanted to buy air-conditioning systems or air coolers and 39 (7.8%) respondents wanted to add more windows to their households. The 134 (26.8%) respondents also mentioned they want to increase greenery near their households. A total of 359 (71.8%) respondents mentioned that the government should plant more trees in the city to help the citizens in battling extreme heat. A total of 173 (35.6%) respondents also mentioned that the government should raise awareness of the citizens. Due to the COVID-19 lockdown, many respondents faced problems in taking the necessary coping measures. A total of 231 (46.2%) residents were physically restrained from taking coping measures and 188 (37.6%) were financially restrained from taking necessary coping measures for heat waves during the COVID-19 pandemic summer months. 111 (22.2%) mentioned that their coping measures to heat were not affected by COVID-19.

Early Warning System

Out of the 500 respondents, 347 (69.4%) have reported getting crucial information related to heat waves from television. A total of 209 (41.8%) respondents receive information on heat waves from newspapers. A total of 79 (15.8%) respondents believe that the government is doing enough to spread information on heat waves whereas 412 (82.4%) people believe that the government is not doing enough to spread information on heat waves. 450 (90%) people have mentioned that they have not received major information on heat waves. Only 10 (2%)

respondents have received any form of sensitisation on heat waves and only 2 (0.4%) people have attended campaigns, seminars and speeches on heat waves.

Quality of life

Quality of life factors in while understanding vulnerability of an individual to heat waves. Out of the 500 respondents interviewed, 364 (72.8) respondents felt that they a physical environment which is neither good nor bad whereas 107 (21.4%) respondents felt that they either have poor or very poor physical environment. During extreme summer, the respondents who felt that their physical environment is poor or very poor increased to 169 (33.8%) and respondents who felt that they have a neither good nor bad physical environment decreased to 301 (60.2%). During COVID-19, the number of respondents who thinks they have a poor or very poor physical environment became 259 (51.8%) and respondents who think they have a good physical environment became 217 (43.4%). 58 (11.6%) respondents had poor or very poor sleep satisfaction during other seasons except summer and during extreme summer that number increased to 71 (14.2%). A total of 312 (62.4%) respondents felt that they do not have required energy to work during extreme summer seasons. A total of 221 (44.2%) respondents reported discomfort due to air pollution in their locality.

Co-Morbidities

Presence of co-morbidities can increase the chance of a person being affected by heat waves. Out of the 500 respondents interviewed, 117 (23.4%) respondents mentioned suffering from weakness, 49 (9.8%) respondents mentioned suffering from mild headaches and 33 (6.6%) mentioned suffering from muscle pains while at home. The other co-morbidities in the section were recorded for the respondent as well as their family members. Data was collected for a total of 1606 individuals. Out of the 1540 individuals only 6 (0.4%) had hearing disability. A total of 284 (18.4%) individuals had suffered from heat fatigue and 83 (5.4%) individuals had suffered from heat rashes. 56 (3.8%) also suffered from heat exhaustion. In the 15 days before the interviews were taken, 43 (2.8%) were suffering from anaemia and out of that 11 (0.7%) were on medication. 100 (6.5%) people had suffered from hypertension and out of that 79 (5.1%) people are in medication for hypertension. A total of 135 (9.6%) of individuals suffered from diabetes and 105 (6.8%) of them were on medication for the same. 34 (2.2%) individuals also suffered from skin disease and out of them 21 (1.4%) were on medication.

Habits and Behaviour

Behaviour and habits often are impacted by how one individual is affected by a hazard and how coping measures are taken. As for the habits and behaviour of the respondents, A total of 223 (44.6%) respondents keeps their windows open during extreme summer and 277 (55.4%) do not. During the summers of COVID-19, 285 (57%) respondents kept their windows open whereas 215 (43%) kept their windows closed. A total of 306 (61.2%) respondents keep their blinds and drapes closed during extreme summer days whereas 194 (38.8%) respondents keeps their blinds and drapes open during extreme summer. 172 (34.4%) respondents reported using bed-nets during regular times and this number decreased to 127 (25.4%) during summer. A total of 188 (37.6%) respondents reported wearing different kinds of clothes in summer seasons as compared to other seasons. Out of the 500 respondents, 445 (89%) reported no change time spent outside during extreme summer as compared to other seasons. A total of 470 (94%) respondents reported sleeping in beds and 16 (3.2%) respondents reported sleeping in the bare floor at night during normal days. During extremely hot nights, 387 (77.4%) respondents reported sleeping in beds while 73 (14.6%) slept on the bare floor. The mean number of baths taken in regular days was 1.1 ± 0.4 while during extreme summer days, the mean significantly increases to 1.9 ± 0.9. During the COVID-19 summer days, the mean number of baths per day was 1.8 ± 0.8. For the 500 respondents, mean number of litres of water drank during normal summers was 3.9 ± 1.7 while during extreme summers, the mean significantly increased to 4.8 ± 1.9.

Occupation

Of 500 households, 382 working respondents were interviewed in Ongole out of which 367 were currently employed. A total of 61 (16%) respondents were unskilled workers, 28 (7.3%) were skilled workers and 47 (12.3%) were semi-skilled workers. 12 (3.1%) respondents were professionals in their field and 67 (17.5%) respondents were semi-professionals. 86 (22.5%) respondents were self-employed, 2 (0.5%) were agricultural workers and 47 (12.3%) were clerical workers. Out of the 208 employed respondents, 14 (3.8%) respondents had a change in type of work during extreme summer days and 353 (96.2%) continued with their regular occupation. A total of 153 (41.7%) respondents had a change in type of work during the summer days of COVID-19 and 214 (58.3%) continued with their old occupation. 249 (67.8%) respondents worked in day shifts during regular days, 257 (70%) respondents worked day shifts in extreme hot days. The mean duration of work was 8.0 ± 3.3 and it significantly increased to 8.8 ± 2.3 during extreme summer days. As for travelling to and fro from work, 131 (35.7%) respondent walked to work, 81 (22.1%) took the bus and 37 (10.1%) took their cars to work during regular days. During extremely hot days 138 (37.6%) people walked, 73 (19.9%) took the bus, 39 (10.6%) took their cars to work during extreme summer seasons. 26 (7.1%) respondents are exposed to a direct source of heat like furnaces or boilers at their workplace. A total of 156 (42.5%) respondents reported discomfort due to PPE kits worn at the workplace. As for the type of dress worn at workplace, 174 (47.4%) reported wearing half sleeves during regular season and during summer seasons the number increased to 183 (49.9%). During the COVID-19 lockdown, the number of respondents wearing half-sleeves decreased to 153 (41.7%). A total of 107 (29.2%) of the respondents had air-conditioning systems in their workplace but only 63 (58.9%) of them used the air-conditioning systems during COVID-19 period. A total of 159 (43.3%) respondents did not have drinking water at the workplace and 79 (21.5%) respondents had difficulty in getting water at workplace. As for protecting themselves from heatwaves at workplace, 233 (63.5%) reported drinking lots of water and 71 (19.3%) respondents mentioned finding a cooler location. During the COVID-19 summers, 154 (42%) respondents mentioned drinking lots of water and 56 (15.3%) mentioned finding a cooler location whereas 102 (27.8%) respondents said they did nothing.

Angul:

Socio-economic details

The first segment of the analysis shows the descriptive statistics for socio-economic details for the four cities. The mean age of the respondents for Angul city was 37.4 ± 13.0 years. The mean years spent in Angul city for the 510 respondents was 24.5 ± 14.2 years. An important determinant of socio-economic status is income and expenditure level. The mean income for the respondents in Angul was 12297.7 ± 11200.4 rupees. This is the lowest among all the cities. Mean income during the summer averaged at 10971.2 ± 10977.0 rupees. There were a total of 222 (43.5%) households who had a change in income during extreme summer. The mean expenditure for the 510 respondents in was 8578.8 ± 12101.0 rupees. Extreme summer also leads to a change in expenditure for people. Out of the 510 respondents interviewed, 437 (86.7%) reported an increase in monthly expenditure while only 5 respondents reported a decrease in monthly family expenditure. COVID-19 had an impact on the expenditure of the respondents and 328 (64.3%) respondents reported an increase in expenditure during COVID-19 lockdown while only 13 (2.5%) reported a decrease in monthly expenditure.

Out of the 510 respondents surveyed, 173 (33.9%) were male whereas 334 (65.5%) were female. As for the religion of the respondents, 502 (98.4%) were following Hinduism, whereas 5 (1%) and 1 (0.2%) belonged to Islam and Christianity respectively. A total of 395 (77.3%) of the population surveyed were married and 35 (6.9%) were widowed. Only 9 (1.8%) households had pregnant women. Among the respondents, 124 (24.5%) were illiterate, 73 (14.3%) had primary education, 84 (16.5%) had middle school certificate, 129 (25.3%) had high school certificate, 51 (10%) had intermediate or post-high school diploma/professional course or college/university level degree.

WASH and Waste Management

For understanding people's behaviour during extreme heat, amount of water used is a very important indicator. The respondents reported an average use of 51.6 ± 25.7 buckets of water per day. A bucket was considered to be of 20 litres for the survey and the same measurement was used to get data from the respondents. During extreme summer, the mean number of buckets of water increased to 50.6 ± 53.3. As for the source of water, 334 (65.5%) respondents get access to water from the municipality through pipelines, 82 (16.1%) gets water from tube wells and 102 (20%) families get water from bore wells. However, there will be some families who get water from multiple sources. Out of the 510 respondents, only 26 (5.1%) respondents have reported getting water for less amount of time in extreme summer as compared to the other seasons. 482 (94.5%) respondents do not have any change in the time duration for water they receive in the summer season and other seasons. Out of the total 510 respondents interviewed, 138 (27.1%) have reported water shortage during the summer season as compared to only 64 (12.5%) respondents reporting water crisis during other seasons. A total of 498 (97.6%) respondents have reported that their households require extra water during summer season. Extra water is required for various purposes, but mostly for drinking and bathing during the summer. A total of 495 (97.1%) and 451 (88.4%) households have mentioned that they require extra water for drinking and bathing respectively during extreme summer. Out of the 510 respondents, only 310 (60.8%) respondents have personal toilets in their households, others have shared/community toilets or prefer open defecation. For cleaning of drinking water, 51 (10%) households use Filters and 41 (8%) use water purifiers systems in their homes, 50 (9.8%) households have mentioned boiling the water for making it potable, however, 361 (70.8%)

households mentioned that they do not use any sort of water purification technique for drinking water. As for handwashing habits, >99.8% of people have reported washing hands after defecating, before eating and after eating, during both normal summers and summers of COVID-19. Around 75% people have admitted to washing hands before cooking and before serving food.

Food habits

Food habits also play a major role in behavioural mitigation to heat waves. Amongst the 510 respondents interviewed, 194 (38%) have reported a significant change in the quantity of food they intake during extreme summer days as compared to other days. Amongst the food avoided during extreme summer days, 53 (10.4%) respondents have mentioned avoiding chicken, 63 (12.4%) have mentioned avoiding red meat, 38 (7.5%) have mentioned avoiding eggs and 20 (3.9%) respondents have mentioned avoiding fish. Therefore, most of the food avoided is non-vegetarian with some respondents avoiding multiple non-vegetarian food during extreme summer days.

Housing and Locational characteristics

Out of the 510 respondents interviewed, 218 (42.7%) had pucca houses while 232 (45.5%) respondents had semi-pucca houses. Only 59 (11.6%) households were Kutchha. A total of 243 (47.6%) households had concrete roofs but 193 (37.8%) households had asbestos roof. Out of the 510 respondents interviewed, only 9 (1.8%) mentioned having a false ceiling in their house. A total of 326 (63.9%) households had indoor kitchen whereas 173 (33.9%) had outdoor kitchen. A total of 487 (95.5%) households reported having regular power-cuts during extreme summer season as compared to only 132 (25.9%) households reporting power-cuts during other seasons. A total of 212 (41.6%) households had 2 rooms while 197 (38.6%) and 63 (12.4%) households had one and three rooms respectively. A staggering total of 274 (54.7%) households reported having no windows in their kitchen. Only 30 (5.9%) houses had had exhaust fans in their kitchens. A total of 380 (74.5%) respondents have mentioned using LPG cylinders as their primary source of fuel while 95 (18.6%) used charcoal. Only 24 (4.7%) respondents had to change their source of fuel during summers and during COVID-19 lockdown.

As for the locational characteristics, 102 (20%) households out of the 510 households interviewed had tall buildings on three sides affecting ventilation. However, 198 (38.8%) households had no tall building on any side. 26 (5.1%) households had vegetative patches like parks or grounds nearby 103 (20.2%) households had water bodies like ponds, lakes or streams nearby. These water bodies and green patches can reduce the impact of heat waves. On the other hand 58 (11.4%) households had industrial sites nearby and 46 (9%) households had traffic junctions nearby which increase the ambient heat.

Community Help

Community plays a very important role in coping during tough situations. Out of the 510 respondents, 415 (81.4%) mentioned that they will get help from their extended family in emergency situations while 93 (18.2%) mentioned that they won't get help. In case of getting help from neighbours, 377 (73.9%) mentioned that they will get help from their neighbours while 122 (23.9%) mentioned that they won't get any help. During COVID-19 situation, due to social distancing norms, 174 (34.1%) people mentioned that they will not get any help from either extended family or neighbours. A total of 412 (80.8%) people also reported that they do not or will not get any help from local clubs, associations or societies.

Risk Perception

Risk perception can influence how people understand a hazard and what coping measures they take to prevent any damage from the hazard. Out of the 510 respondents interviewed, 260 (51%) believe that heat waves are caused by air pollution and 67 (13.1%) believe that urban heat islands contribute to increase in heat waves. A total of 494 (96.9%) respondents believe that heat waves can be harmful, however, 454 (89%) respondents believe that they can be seriously affected by heat waves. Only 41 (8%) respondents have visited a physician for heat related illness. A total of 465 (91.2%) respondents believe that heat stroke is the most harmful effect heat wave can have on a human being. A total of 500 (98%) respondents believe that temperature and humidity have increased in the last few years.

The temperature and humidity at home can determine if heat waves can lead to harmful impacts. A total of 98 (19.2%) respondents mentioned having a warm feeling inside their houses and 32 (6.3%) have mentioned feeling very warm inside their homes. Out of the 510 respondents interviewed, 25 (4.9%) have reported having fully wet skin at home during summer, which suggests high humidity. 197 (38.6%) people feel suffocation inside their homes which can lead to heat related illnesses.

Coping Measures

A total of 409 (80.2%) respondents have reported drinking lots of fluid as a coping measure which they take to avoid extreme heat during normal summer. A total of 336 (65.9%) respondents reported avoiding the sun to save themselves from extreme summer. 207 (40.6%) also reported using fans/ACs or coolers. During COVID-19 lockdown, number of respondents who choose avoiding sun increased to 345 (67.6%) and respondents drinking more liquid decreased to 399 (78.2%). People using fans/ACs or coolers increased to 219 (42.9%). A total of 85 (16.7%) and 79 (15.5%) respondents have also reported finding a cooler location during their day to day lives in normal summer and COVID-19 summers respectively. To avoid the sun, 327 (64.1%) respondents have reported using umbrellas or hats and 294 (57.6%) respondents have reported staying indoors. In COVID-19 summers, respondents using umbrella and hats went down to 312 (62.4%) while respondents staying indoors remained the same. For keeping their house cool, 341 (66.9%) respondents mentioned using either fans or air-conditioning systems and 344 (67.5%) respondents mentioned wiping their floor with water. There are some measures which the respondents wanted to take but they couldn't or haven't. A total of 275 (53.9%) respondents wanted to buy more fans and exhaust fans and 98 (19.2%) respondents wanted to change their roof. A total of 242 (47.5%) respondents mentioned that the government should plant more trees in the city to help the citizens in battling extreme heat. A total of 205 (40.2%) of the people also mentioned that the government should provide free drinking water in the roads. Due to the COVID-19 lockdown, many respondents faced problems in taking the necessary coping measures. A total of 155 (30.4%) residents were physically restrained from taking coping measures and 450 (88.2%) were financially restrained from taking necessary coping measures for heat waves during the COVID-19 pandemic summer months.

Early Warning System

Out of the 510 respondents, 376 (73.7%) have reported getting crucial information related to heat waves from television. A total of 277 (54.3%) respondents gets heat related information from their friends/relatives. A total of 396 (77.6%) respondents believe that the government is not doing enough to spread information on heat waves whereas 114 (22.4%) people believe that the government is doing enough to spread information on heat waves. 503 (98.6%) people have mentioned that they have not received major information on heat waves. Only 7 (1.4%) respondents have received any form of sensitisation on heat waves and only 9 (1.8%) people have attended campaigns, seminars and speeches on heat waves.

Quality of life

Quality of life factors in while understanding vulnerability of an individual to heat waves. Out of the 510 respondents interviewed, 98 (19.2%) respondents felt that they have a good physical environment whereas 37 (7.3%) respondents felt that they either have poor or very poor physical environment. During extreme summer, the respondents who felt that their physical environment is poor or very poor increased to 90 (17.6%) and respondents who felt that they have a good physical environment decreased to 88 (16.3%). During COVID-19, the number of respondents who thinks they have a poor or very poor physical environment became 106 (20.7%) and respondents who think they have a good physical environment became 87 (17.1%). Only 17 (3.3%) respondents had poor or very poor sleep satisfaction during other seasons except summer and during extreme summer that number increased to 323 (63.3%). A total of 216 (42.4%) respondents felt that they do not have required energy to work during extreme summer seasons. A total of 270 (52.9%) respondents reported discomfort due to air pollution in their locality.

Co-Morbidities

Presence of co-morbidities can increase the chance of a person being affected by heat waves. Out of the 510 respondents interviewed, 356 (69.8%) respondents mentioned suffering from mild headache and 347 (68%) respondents mentioned suffering from mild headaches while at home.

The other co-morbidities in the section were recorded for the respondent as well as their family members. Data was collected for a total of 1798 individuals. Out of the 1798 individuals only 12 (0.7%) suffered from mental conditions and 11 (0.6%) had locomotive disability. A total of 178 (9.9%) individuals had suffered from heat fatigue and a staggering 41 (2.2%) individuals had suffered from heat strokes. In the 15 days before the interviews were taken, 143 (8%) people had suffered from hypertension and out of that 126 (7%) people are in medication for hypertension. A total of 76 (4.2%) of individuals suffered from diabetes and out of them 64 (3.6%) were on medication.

Habits and Behaviour

Behaviour and habits often are impacted by how one individual is affected by a hazard and how coping measures are taken. As for the habits and behaviour of the respondents, a total of 444 (87.1%) respondents keep their windows open during extreme summer and 66 (12.9%) do not. During the summers of COVID-19, 438 (85.9%) respondents kept their windows open whereas 72 (14.1%) kept their windows closed. A total of 429 (84.1%) respondents keep their blinds and drapes closed during extreme summer days whereas 81 (15.9%) respondents keeps their blinds and drapes open during extreme summer. A total of 421 (82.5%) respondents reported using bed-nets during regular times while during extreme summer the number of respondents using bed-nets became 423 (82.9%). A total of 186 (36.5%) respondents reported wearing different kinds of clothes in summer seasons as compared to other seasons. Out of the 510 respondents, 407 (79.8%) reported decreasing time spent outside during extreme summer. A total of 371 (72.7%) respondents reported sleeping in beds and 75 (14.7%) respondents reported sleeping in the bare floor at night during normal days. During extremely hot nights, 371 (72.7%) respondents reported sleeping in beds while 78 (15.3%) slept on the bare floor. The mean number of baths taken in regular days was 1.2 ± 0.5 while during extreme summer days, the mean significantly increases to 1.9 ± 0.4. During the COVID-19 summer days, the mean number of baths per day was 1.3 ± 0.5. For the 510 respondents, mean number of litres of water drank during normal summers was 3.1 ± 1.2 while during extreme summers, the mean significantly increased to 4.5 ± 1.5.

Occupation

199 working respondents were interviewed in Angul out of which 168 were currently employed. A total of 75 (37.7%) respondents were unskilled workers, 11 (5.5%) were skilled workers and 12 (6%) were semi-skilled workers. 16 (8%) respondents were professionals in their field and 5 (2.5%) respondents were semi-professionals. 42 (21.1%) respondents were self-employed, 1 (0.5%) was agricultural workers and 5 (2.5%) were clerical workers. Out of the 168 employed respondents, 2 (1.2%) respondents had a change in type of work during extreme summer days and 166 (98.8%) continued with their regular occupation. 2 (1.2%) respondents had a change in type of work during the summer days of COVID-19 and 166 (98.8) continued with their old occupation. 161 (95.8%) respondents worked in day shifts during regular days and during extremely hot days, 141 (83.9%) respondents worked day shifts. The mean duration of work was 7.9 ± 2.4 and it significantly reduced to 7.3 ± 2.6 during extreme summer days. As for travelling to and fro from work, 80 (47.6%) respondent walked during regular seasons and 81 (48.2%) respondents walked during extreme summer seasons. Only 8 (5.8%) respondents are exposed to a direct source of heat like furnaces or boilers at their workplace. A total of 127 (75.6%) respondents reported discomfort due to PPE kits worn at the workplace. As for the type of dress

worn at workplace, 87 (51.8%) reported wearing full sleeves during regular season and during summer seasons the number decreased to 84 (50%). During the COVID-19 lockdown, the number of respondents wearing full-sleeves decreased to 76 (45.2%). Only 6 (3.6%) of the respondents had air-conditioning systems in their workplace but only 3 (50%) of them used the air-conditioning systems during COVID-19 period. A total of 88 (52.4%) respondents did not have drinking water at the workplace and 51 (30.4%) respondents had difficulty in getting water at workplace. As for protecting themselves from heatwaves at workplace, 104 (61.9%) respondents reported drinking lots of water and 89 (53.0) reported finding a cooler location. During the COVID-19 summers, 105 (62.5%) respondents reported drinking lots of water and 75 (44.6%) reported finding a cooler location.

Tables: City-wise Analysis

Table 4: Socio-economic details

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
Age	42.7 ± 14.8 *	38.6 ± 15.0 *	39.6 ± 13.1 *	37.4 ± 13.0 *
Years in the city	32.5 ± 17.7 *	33.4 ± 16.8 *	6.5 ± 16.6 *	24.5 ± 14.2 *
Income	15563.3 ± 12262.5 *	28933.2 ± 26013.2 *	29838.0 ± 28357.6 *	12297.7 ± 11200.4 *
Income in summer	14575.7 ± 11842.1 *	27145.2 ± 26184.1 *	27688.0 ± 27811.9 *	10971.2 ± 10977.0 *
Households with a change of income in extreme summer	116 (23.0)	132 (26.4)	66 (13.2)	222 (43.5)
Expenditure	10093.1 ± 6796.2 *	14460.5 ± 10299.1 *	17850.0 ± 18663.3 *	8578.8 ± 12101.0 *
Change in monthly expenditure in summer				
Increased	437 (86.7)	440 (88.0)	95 (19.0)	328 (64.3)
Decreased	5 (1.0)	5 (1.0)	25 (5.0)	13 (2.5)
No Change	62 (12.3)	55 (11.0)	380 (76.0)	169 (32.1)
Change in monthly expenditure in COVID Summer				
Increased	448 (88.9)	459 (91.8)	229 (45.8)	267 (52.4)
Decreased	4 (0.8)	8 (1.6)	109 (21.8)	143 (28.0)
No Change	52 (10.3)	33 (6.6)	162 (32.4)	100 (18.6)
Gender				
Male	171 (33.9)	231 (46.2)	321 (64.2)	173 (33.9)
Female	333 (66.1)	266 (53.2)	174 (34.8)	334 (65.5)
Trans	0 (0)	3 (0.6)	5 (1.0)	3 (0.6)
Religion				
Hinduism	259 (51.4)	445 (89.0)	469 (93.8)	502 (98.4)
Christianity	60 (11.9)	26 (5.2)	2 (0.4)	1 (0.2)
Islam	179 (35.5)	28 (5.6)	21 (4.2)	5 (1.0)

Others	6 (1.2)	1 (0.2)	8 (1.6)	2 (0.4)
Households with pregnant women	6 (1.2)	6 (1.2)	19 (3.8)	9 (1.8)
Marital status				
Single	26 (5.2)	80 (16.0)	38 (7.6)	4 (0.8)
Unmarried	26 (5.2)	47 (9.4)	96 (19.2)	68 (13.3)
Married	375 (74.4)	338 (67.6)	332 (66.4)	395 (77.3)
Separated	1 (0.2)	4 (0.8)	1 (0.2)	2 (0.4)
Divorced	4 (0.8)	6 (1.2)	8 (1.6)	7 (1.4)
Widowed	59 (11.7)	21 (4.2)	24 (4.8)	35 (6.9)
No response	13 (2.6)	4 (0.8)	1 (0.2)	0 (0)
Education Level				
Illiterate	196 (38.9)	104 (20.8)	8 (1.6)	124 (24.5)
Primary School	34 (6.7)	17 (3.4)	20 (4.0)	73 (14.3)
Certificate	63 (12.5)	43 (8.6)	51 (10.2)	84 (16.5)
Middle School	91 (18.1)	70 (14.0)	110 (22.0)	129 (25.3)
Certificate				
High School Certificate	54 (10.7)	81 (16.2)	52 (10.4)	44 (8.6)
Intermediate or post HS Diploma				
Graduate/Post-graduate / Professional/Honours	64 (12.7)	180 (36.0)	252 (50.8)	51 (10.0)
No Response	2 (0.4)	5 (1.0)	5 (1.0)	4 (0.8)

*Mean ± S.D

Table 5: Wash and Waste Management

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
Buckets of water required in household	4.2 ± 3.0 *	11.8 ± 5.9 *	12.8 ± 4.2 *	51.6 ±225.7 *
Buckets of water required in summer of COVID-19	4.8 ± 3.7 *	14.7 ± 7.2 *	15.0 ± 4.7 *	50.6 ± 53.3 *
Source of household water **				
Municipality line	440 (88.0)	464 (92.8)	322 (64.4)	334 (65.5)
Ground water	45 (9.0)	151 (30.2)	155 (31.2)	2 (0.4)
Community tank	19 (3.8)	5 (1.0)	2 (0.4)	0 (0)
Tube well	0 (0)	15 (3.0)	67 (13.4)	82 (16.1)
Bore Well	24 (4.8)	27 (5.4)	35 (7.0)	102 (20.0)
Ponds/streams	0 (0)	0 (0)	0 (0)	0 (0)
Others	18 (3.6)	16 (3.2)	3 (0.6)	1 (0.2)
Change in time duration of water during extreme summer				
Increased	5 (1.0)	8 (1.6)	3 (0.6)	2 (0.4)
Decreased	230 (45.6)	149 (29.8)	13 (2.6)	26 (5.1)
No Change	269 (53.4)	343 (68.6)	484 (96.8)	482 (94.5)
Water shortage				
In normal days	80 (15.9)	36 (7.2)	28 (5.6)	64 (12.5)
In extreme summer days	240 (47.6)	107 (21.4)	50 (10.0)	138 (27.1)
Extra water required in household				
Yes	386 (76.6)	350 (70.0)	348 (69.6)	498 (97.6)
No	118 (23.4)	150 (30.0)	152 (30.4)	12 (2.4)
Purpose of extra water **				
Drinking	364 (72.2)	348 (69.6)	359 (71.8)	495 (97.1)
Bathing	342 (67.9)	289 (57.8)	263 (52.6)	451 (88.4)
Cleaning house	64 (12.7)	185 (37.0)	17 (3.4)	379 (74.3)

Cooking	43 (8.5)	10 (2.0)	3 (0.6)	340 (66.7)
Others	2 (0.4)	4 (0.8)	0 (0.0)	6 (1.2)
Type of toilet				
Personal	491 (97.4)	441 (88.2)	348 (69.6)	310 (60.8)
Shared	5 (1)	45 (9.0)	118 (23.6)	18 (3.5)
Community	1 (0.2)	2 (0.4)	20 (4.0)	1 (0.2)
Others	7 (1.4)	12 (2.4)	14 (2.8)	178 (34.9)
Type of water purification				
Filter	40 (7.9)	181 (36.2)	99 (19.8)	51 (10.0)
Purifier	10 (2)	50 (10.0)	157 (31.4)	41 (8.0)
RO	122 (24.2)	52 (10.4)	129 (25.8)	2 (0.4)
Chlorine	1 (0.2)	1 (0.2)	7 (1.4)	0 (0)
Alum	0 (0)	0 (0)	0 (0.0)	0 (0)
Boiling	78 (15.5)	33 (6.6)	86 (17.2)	50 (9.8)
None	245 (48.6)	158 (31.6)	13 (2.6)	361 (70.8)
Others and No Response	8 (1.6)	25 (5.0)	7 (1.4)	5 (1.0)
Hand washing habit – Normal time				
After defecating	503 (99.8)	498 (99.6)	473 (94.6)	509 (99.8)
Before eating	502 (99.6)	496 (99.2)	476 (95.2)	509 (99.8)
After eating	503 (99.8)	496 (99.2)	477 (95.4)	474 (92.9)
Before cooking	463 (91.9)	401 (80.2)	225 (45.0)	455 (89.2)
Before serving food	464 (92.1)	453 (90.6)	261 (52.2)	378 (74.1)
Hand washing habit – COVID-19 time				
After defecating	499 (99.0)	492 (98.4)	470 (94.0)	509 (99.8)
Before eating	504 (100.0)	498 (99.6)	475 (95.0)	507 (99.4)
After eating	504 (100.0)	498 (99.6)	474 (94.8)	476 (93.3)
Before cooking	474 (94.0)	435 (87.0)	269 (53.8)	454 (89.0)
Before serving food	474 (94.0)	487 (97.4)	303 (60.6)	386 (75.7)

*Mean ± S.D. **(cumulative % might exceed 100 due to multiple option/responses)

Table 6: Food Habits

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
Food avoided in summer				
Dal (pulses)	1 (0.2)	2 (0.4)	5 (1.0)	1 (0.2)
Eggs	35 (6.9)	47 (9.4)	35 (7.0)	38 (7.5)
Chicken	69 (13.7)	84 (16.8)	32 (6.4)	53 (10.4)
Fish	23 (4.6)	44 (8.8)	21 (4.2)	20 (3.9)
Fruits	0 (0)	1 (0.2)	4 (0.8)	3 (0.6)
Red Meat	49 (9.7)	58 (11.6)	169 (33.8)	63 (12.4)
Leafy Vegetables	0 (0)	2 (0.4)	6 (0.2)	3 (0.6)
Milk	0 (0)	1 (0.2)	71 (14.2)	7 (1.4)
Significant change in quantity of food	98 (19.4)	116 (23.2)	125 (25.0)	194 (38.0)

Table 7: Housing and Locational Characteristics

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
Housing Category				
Kutchha	13 (2.6)	42 (8.4)	19 (3.8)	59 (11.6)
Semi-Pucca	237 (47.0)	119 (23.8)	95 (19.0)	232 (45.5)
Pucca	252 (50.0)	332 (66.4)	386 (77.2)	218 (42.7)
No response	2 (0.4)	7 (1.4)	0 (0)	1 (0.2)
Type of roof				
Concrete	262 (52.0)	344 (68.8)	358 (71.6)	243 (47.6)
Asbestos	179 (35.5)	50 (10.0)	70 (14.0)	193 (37.8)
Clay tiles	45 (8.9)	42 (8.4)	39 (7.8)	30 (5.9)
Tin sheds	5 (1.0)	46 (9.2)	21 (4.2)	10 (2.0)
Straw	7 (1.4)	9 (1.8)	0 (0.0)	31 (6.1)
Others	6 (1.2)	8 (1.6)	12 (2.4)	3 (0.6)
Households having false ceiling				
Yes	16 (3.2)	25 (5.0)	21 (4.2)	9 (1.8)
No	488 (96.8)	475 (95.0)	478 (95.8)	501 (98.2)
Location of kitchen				
Indoor	479 (95.0)	487 (97.4)	472 (94.4)	326 (63.9)
Outdoor	19 (3.8)	11 (2.2)	25 (5.0)	173 (33.9)
No response	6 (1.2)	2 (0.4)	3 (0.6)	1 (2.2)
Power cut				
In normal days				
Yes	22 (4.4)	40 (8.0)	14 (2.8)	132 (25.9)
No	482 (95.6)	451 (90.2)	485 (99.0)	378 (74.1)
No response	0 (0)	9 (1.8)	1 (0.2)	0 (0)
In Summer days				
Yes	118 (23.4)	82 (16.4)	18 (3.6)	487 (95.5)
No	386 (76.5)	408 (81.6)	479 (95.8)	22 (4.3)
No response	0 (0)	10 (2.0)	3 (0.2)	1 (0.2)
Number of rooms in house				
One room	1 (0.2)	69 (13.8)	114 (22.8)	197 (38.6)

Two rooms	100 (19.8)	128 (25.6)	205 (41.0)	212 (41.6)
Three rooms	266 (52.8)	184 (36.8)	120 (24.0)	63 (12.4)
Four rooms	106 (21.0)	75 (15.0)	36 (7.2)	24 (4.7)
Five rooms	27 (5.4)	23 (4.6)	23 (4.6)	8 (1.6)
Others	2 (0.4)	21 (4.2)	23 (4.6)	5 (1.0)
Households with no windows in kitchen	52 (10.3)	63 (12.6)	115 (23.0)	274 (54.7)
Type of kitchen amenities				
Ceiling fan	7 (1.4)	17 (3.4)	11 (2.2)	0 (0)
Exhaust fan	7 (1.4)	45 (9.0)	209 (41.8)	30 (5.9)
Table/stand fan	0 (0)	0 (0)	55 (11.0)	0 (0)
Chimney	0 (0)	4 (0.8)	103 (20.6)	1 (0.2)
None	490 (97.2)	434 (86.8)	122 (24.4)	579 (93.9)
Type of fuel used				
LPG	486 (96.4)	479 (95.8)	452 (90.4)	380 (74.5)
Kerosene	2 (0.4)	0 (0)	25 (5.0)	0 (0.2)
Coal	1 (0.2)	0 (0)	2 (0.4)	22 (4.3)
Charcoal	7 (1.4)	11 (2.2)	4 (0.8)	95 (18.6)
Others	8 (1.6)	10 (2.0)	17 (3.4)	12 (2.4)
Change in fuel				
During Normal Summer	5 (1.0)	3 (0.6)	4 (0.8)	24 (4.7)
During Covid-19 Summer	7 (1.4)	3 (0.6)	20 (4.0)	24 (4.7)
Households surrounded by tall buildings				
One Side	47 (9.3)	135 (27.0)	46 (9.2)	40 (7.8)
Two Sides	39 (7.7)	83 (16.6)	173 (34.6)	117 (28.9)
Three Sides	40 (7.9)	14 (2.8)	143 (28.6)	102 (20.0)
Four Sides	9 (1.8)	7 (1.4)	120 (24.0)	48 (9.4)
None	369 (73.2)	261 (52.2)	18 (3.6)	198 (38.8)
Presence of locational characters **				
Vegetative patches	238 (47.2)	37 (7.4)	370 (74.0)	26 (5.1)
Water bodies	167 (33.1)	58 (11.6)	237 (47.5)	103 (20.2)
Industrial areas	91 (18.1)	27 (5.4)	27 (5.4)	58 (11.4)
Traffic junctions	107 (21.2)	68 (13.6)	220 (44.0)	46 (9.0)
Nearest primary healthcare centre				

Less than 1km	162 (32.1)	44 (8.8)	130 (26.0)	90 (17.6)
1km to 5km	259 (51.4)	412 (82.4)	193 (38.6)	191 (37.5)
More than 5km	82 (16.3)	38 (7.6)	160 (32.0)	229 (44.9)
No response	1 (0.2)	6 (1.2)	17 (3.4)	0 (0)

**(cumulative % might exceed 100 due to multiple option/responses)

Table 8: Community Help

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
From extended family				
Yes	419 (83.1)	406 (81.2)	434 (86.8)	415 (81.4)
No	69 (13.7)	73 (14.6)	29 (5.8)	93 (18.2)
Maybe	12 (2.4)	11 (2.2)	20 (4.0)	2 (0.4)
No response	4 (0.8)	10 (2.0)	17 (3.4)	0 (0)
From neighbours				
Yes	385 (76.4)	365 (73.0)	383 (76.6)	377 (73.9)
No	89 (17.7)	80 (16.0)	63 (12.6)	122 (23.9)
Maybe	28 (5.6)	47 (9.4)	35 (7.0)	11 (2.2)
No response	2 (0.4)	8 (1.6)	19 (13.8)	0 (0)
From clubs/associations/societies				
Yes	88 (17.5)	185 (37.0)	275 (55.0)	98 (19.2)
No	416 (81.5)	315 (63.0)	225 (45.0)	412 (80.8)
From neighbours/family during Covid-19				
Yes	351 (69.6)	296 (59.2)	255 (51.0)	82 (16.1)
No	105 (20.8)	80 (16.0)	99 (19.8)	174 (34.1)
Maybe	35 (6.9)	111 (22.2)	126 (25.2)	252 (49.4)
No response	13 (2.6)	13 (2.6)	20 (4.0)	2 (0.4)

Table 9: Risk Perception

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
Cause of increasing heat waves **				
Global warming	22 (4.4)	82 (16.4)	256 (51.2)	61 (12.0)
Air pollution	99 (19.6)	148 (29.6)	273 (54.6)	260 (51.0)
Local winds	55 (10.9)	50 (10.0)	23 (4.6)	32 (6.3)
Lack of rainfall	321 (63.7)	216 (43.2)	102 (20.4)	28 (5.5)
Urban heat island	10 (2.0)	7 (1.4)	53 (10.6)	67 (13.1)
Others	164 (32.5)	205 (41.0)	44 (8.8)	126 (24.7)
Can heat waves be harmful				
Yes	469 (93.1)	477 (95.4)	409 (81.8)	494 (96.9)
No	20 (4.0)	11 (2.2)	50 (10.0)	8 (1.6)
Don't know / No response	15 (3.0)	12 (2.4)	41 (8.2)	6 (1.2)
Can heatwaves seriously harm the respondent				
Yes	391 (77.6)	416 (83.2)	303 (60.6)	545 (89.0)
No	108 (21.4)	80 (16.0)	190 (38.0)	56 (11.0)
Don't Know / No response	5 (1.0)	4 (0.8)	7 (1.4)	0 (0)
No. of respondents who have visited a doctor for heat related illness	38 (7.5)	54 (10.8)	66 (13.2)	41 (8.0)
Most harmful effect of heat waves	114 (22.6)	86 (17.2)	97 (19.4)	
Heat Fatigue	17 (3.4)	12 (2.4)	62 (12.4)	2 (0.4)
Heat Rash	2 (0.4)	8 (1.6)	32 (6.4)	2 (0.4)
Heat Cramps	1 (0.2)	10 (2.0)	17 (3.4)	2 (0.4)
Heat Syncope	12 (2.4)	16 (3.2)	134 (26.8)	21 (4.1)
Heat Exhaustion	331 (65.7)	351 (70.2)	154 (30.8)	4 (0.8)
Heat Stroke	12 (2.4)	10 (2.0)	2 (0.4)	465 (91.2)
Others	15 (3.0)	7 (1.4)	2 (0.4)	1 (0.2)

Don’t Know / No response				13 (2.5)
Feeling of temperature at home				
Slightly cool	14 (2.8)	15 (3.0)	33 (6.6)	60 (11.8)
Normal	195 (38.7)	183 (36.6)	203 (40.6)	316 (62.0)
Warm	228 (45.2)	231 (46.2)	238 (47.6)	98 (19.2)
Very Warm	66 (13.1)	49 (9.2)	18 (3.6)	32 (6.3)
Hot	1 (0.2)	17 (3.4)	2 (0.4)	0 (0)
Don’t Know / No response	0 (0)	5 (1.0)	6 (1.2)	4 (0.8)
Feeling of humidity at home				
Dry				
Appropriate and	1 (0.2)	16 (3.2)	38 (7.6)	67 (13.1)
desirable	183 (36.3)	310 (62.0)	70 (14.0)	314 (61.6)
Wet Skin	143 (28.4)	70 (14.0)	244 (48.8)	65 (12.7)
Clothes sticking to skin surface	33 (6.5)	22 (4.4)	92 (18.4)	35 (6.9)
Fully wet skin	92 (18.3)	68 (13.6)	47 (9.4)	25 (4.9)
Sweat loss from skin surface	45 (8.9)	7 (1.4)	3 (0.6)	2 (0.4)
Don’t Know / No response	7 (1.4)	7 (1.4)	6 (1.2)	2 (0.4)
Feeling of suffocation inside home				
Yes	209 (41.5)	163 (32.6)	162 (32.4)	197 (38.6)
No	293 (58.1)	332 (66.4)	335 (67.0)	311 (61.0)
Don’t Know / No response	2 (0.4)	5 (1.0)	3 (0.6)	2 (0.4)
Trend of heat and humidity in the last few years				
Increased	462 (91.7)	492 (98.4)	462 (92.4)	500 (98.0)
Decreased	37 (7.3)	1 (0.2)	20 (4.0)	0 (0)
No change	2 (0.4)	1 (0.2)	15 (3.0)	9 (1.8)
Don’t Know / No response	3 (0.6)	6 (1.2)	3 (0.6)	1 (0.2)

******(cumulative % might exceed 100 due to multiple option/responses)

Table 10: Coping Measures

Variable	**Number of Respondents (%) / 504 Ongole**	**Number of Respondents (%) / 500 Karimnagar**	**Number of Respondents (%) / 500 Kolkata**	**Number of Respondents (%) / 510 Angul**
Coping to avoid heat in normal summer **				
Avoid sun	347 (68.8)	349 (69.8)	77 (15.4)	336 (65.9)
More liquid	345 (68.5)	341 (68.2)	391 (78.2)	409 (80.2)
Cooler location	84 (16.7)	256 (51.2)	128 (25.6)	85 (16.7)
Appropriate dress	33 (6.5)	15 (3.0)	120 (24.0)	11 (2.2)
Fan/ AC/ Cooler	37 (7.3)	61 (12.2)	41 (8.2)	207 (40.6)
Other measures	42 (8.3)	23 (4.6)	4 (0.8)	1 (0.2)
Coping to avoid heat in COVID-19 summer **				
Avoid sun	377 (74.8)	277 (55.4)	241 (48.2)	345 (67.6)
More liquid	280 (55.5)	432 (86.4)	318 (64.6)	399 (78.2)
Cooler location	83 (16.5)	238 (47.6)	84 (16.8)	79 (15.5)
Appropriate dress	30 (6.0)	10 (2.0)	83 (16.6)	13 (2.5)
Fan/ AC/ Cooler	29 (5.8)	44 (8.8)	34 (6.8)	219 (42.90
Others	10 (2.0)	8 (1.6)	0 (0.0)	2 (0.4)
Coping against the sun in normal summer days **				
Proper clothing	23 (4.6)	58 (11.6)	214 (42.8)	26 (5.1)
Umbrella/hat	311 (61.7)	354 (70.8)	324 (64.8)	327 (64.1)
Staying indoor	397 (78.8)	303 (60.6)	38 (7.6)	294 (57.6)
None	4 (0.8)	11 (2.2)	37 (7.4)	6 (1.2)
Others	6 (1.2)	3 (0.6)	0 (0.0)	1 (0.2)
Coping against the sun in COVID-19 summer days **				
Proper clothing	15 (3.0)	42 (8.4)	173 (34.6)	25 (4.9)
Umbrella/hat	122 (24.2)	193 (38.6)	132 (26.4)	312 (62.4)
Staying indoor	463 (91.9)	421 (84.2)	139 (27.8)	293 (57.5)
None	6 (1.2)	6 (1.2)	121 (24.2)	8 (1.6)
Others	1 (0.2)	3 (0.6)	3 (0.6)	0 (0)
Methods for keeping house cool **	442 (87.7)	455 (91.0)	310 (62.0)	

Fan/AC	23 (4.6)	22 (4.4)	45 (9.0)	341 (66.9)
Sprinkle on roof	60 (11.9)	19 (3.8)	100 (20.0)	33 (6.5)
Wipe floor with water	7 (1.4)	5 (1.0)	10 (2.0)	344 (67.5)
Flood terrace	9 (1.8)	1 (0.2)	2 (0.4)	33 (6.5)
Others				2 (0.4)
Measures respondents are willing to take **				
Change roof	60 (11.9)	40 (8.0)	12 (2.4)	98 (19.2)
Add windows	20 (4.0)	4 (0.8)	39 (7.8)	26 (5.1)
External colour change	5 (1.0)	15 (3.0)	7 (1.4)	11 (2.2)
Buy fans or exhausts	51 (10.1)	36 (7.2)	232 (46.4)	275 (53.9)
Buy AC or Coolers	271 (53.8)	199 (39.8)	135 (27.0)	189 (37.1)
Increase greenery	173 (34.3)	249 (49.8)	134 (26.8)	26 (5.1)
Others	60 (11.9)	46 (9.2)	2 (0.4)	5 (1.0)
Measures Govt. should take **				
Build shades and resting areas	237 (47.0)	209 (41.8)	59 (11.8)	139 (27.3)
Plant more trees	388 (77.0)	389 (77.8)	359 (71.8)	242 (47.5)
Raise awareness	66 (13.1)	53 (10.6)	173 (35.6)	169 (33.1)
Free water in roads	136 (27.0)	95 (19.0)	79 (15.8)	205 (40.2)
Others	28 (5.6)	49 (9.8)	4 (0.8)	20 (3.9)
Restraints in coping due to COVID **				
Physically restrained	288 (57.1)	93 (18.6)	231 (46.2)	155 (30.4)
Financially restrained	154 (30.6)	144 (28.8)	188 (37.6)	450 (88.2)
No impact	31 (6.2)	270 (54.0)	111 (22.2)	19 (3.7)

******(cumulative % might exceed 100 due to multiple option/responses)

Table 11: Early Warning System

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
Source of information on heat waves **				
Radio	17 (3.4)	56 (11.2)	42 (8.4)	12 (2.4)
TV	411 (81.5)	383 (76.6)	347 (69.4)	376 (73.7)
Newspaper	111 (22.0)	170 (34.0)	209 (41.8)	20 (3.9)
Health workers/social service person	90 (17.9)	9 (1.8)	13 (2.6)	12 (2.4)
Health facility/doctor	82 (16.3)	2 (0.4)	19 (3.8)	16 (3.1)
Friends/relatives	123 (24.4)	133 (26.6)	35 (7.0)	277 (54.3)
Posters/pamphlets	2 (0.4)	5 (1.0)	9 (1.8)	0 (0)
Others	9 (1.8)	13 (2.6)	44 (8.8)	0 (0)
Is Govt. doing enough on heat wave warning				
Yes	383 (76.0)	338 (67.6)	79 (15.8)	114 (22.4)
No	120 (23.8)	152 (30.4)	412 (82.4)	396 (77.6)
Don't Know / No response	1 (0.2)	10 (2.0)	9 (1.8)	0 (0)
Received information on heat waves				
Yes	232 (42.0)	136 (27.2)	50 (10.0)	7 (1.4)
No	272 (58.0)	364 (72.8)	450 (90.0)	503 (98.6)
Received sensitization on heat waves				
Yes	13 (2.6)	2 (0.4)	10 (2.0)	7 (1.4)
No	491 (97.3)	498 (99.6)	490 (98.0)	503 (98.6)
Attended campaigns/seminars/speeches on heat waves				
Yes	15 (3.0)	5 (1.0)	2 (0.4)	9 (1.8)

No	489 (97.0)	495 (99.0)	498 (99.6)	501 (98.2)

******(cumulative % might exceed 100 due to multiple option/responses)

Table 12: Quality of Life (In Rank Variables, 1 = Very Poor, 2 = Poor, 3 = Neither Poor nor Good, 4 = Good, 5 = Very Good)

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
Rank of health of physical environment				
1	6 (1.2)	13 (2.6)	16 (3.2)	5 (1.0)
2	26 (5.2)	50 (10.0)	91 (18.2)	32 (6.3)
3	217 (43.1)	175 (35.0)	364 (72.8)	375 (73.5)
4	253 (50.2)	258 (51.6)	26 (5.2)	96 (18.8)
5	2 (0.4)	4 (0.8)	3 (0.6)	2 (0.4)
Rank of health of physical environment in extreme summer				
1	6 (1.2)	18 (3.6)	16 (3.2)	24 (4.7)
2	80 (15.9)	60 (12.0)	153 (30.6)	66 (12.9)
3	243 (48.2)	206 (40.9)	301 (60.2)	332 (65.1)
4	173 (34.3)	213 (42.6)	29 (5.8)	88 (17.3)
5	2 (0.4)	3 (0.6)	1 (0.2)	0 (0)
Rank of health of physical environment in extreme summer of COVID-19				
1	8 (1.6)	21 (4.2)	40 (8.0)	39 (7.6)
2	57 (11.3)	38 (7.6)	219 (43.8)	67 (13.1)
3	257 (51.0)	212 (42.4)	217 (43.4)	317 (62.2)
4	179 (35.5)	226 (45.2)	23 (4.6)	85 (16.7)
5	3 (0.6)	3 (0.6)	1 (0.2)	2 (0.4)
Rank of sleep satisfaction in normal nights				
1	6 (1.2)	2 (0.4)	3 (0.6)	1 (0.2)
2	30 (6)	14 (2.8)	55 (11.0)	16 (3.1)
3	89 (17.7)	61 (12.2)	73 (14.6)	83 (16.3)
4	374 (74.2)	413 (82.6)	364 (72.8)	409 (80.2)
5	5 (1)	10 (2.0)	5 (1.0)	1 (0.2)

Rank of sleep satisfaction in extreme summer nights				
1	9 (1.8)	3 (0.6)	2 (0.4)	16 (3.1)
2	62 (12.3)	52 (10.4)	69 (13.8)	307 (60.2)
3	182 (36.1)	139 (27.8)	135 (27.0)	80 (15.7)
4	247 (49.0)	299 (59.8)	293 (58.6)	104 (20.4)
5	5 (1.0)	7 (1.4)	1 (0.2)	3 (0.6)
Energy to work in summer present				
Yes	280 (55.6)	311 (62.2)	188 (37.6)	294 (57.6)
No	224 (44.4)	189 (37.8)	312 (62.4)	216 (42.4)
Discomfort due to air pollution present				
Yes	127 (25.2)	49 (9.8)	221 (44.2)	270 (52.9)
No	377 (74.8)	451 (90.2)	279 (55.8)	240 (47.1)

Table 13: Co-Morbidities

Variable	Number of Respondents (%) / 1716 Ongole	Number of Respondents (%) / 1606 Karimnagar	Number of Respondents (%) / 1540 Kolkata	Number of Respondents (%) / 1798 Angul
Impact of heat wave while at home ***				
Mild headache	80 (15.9)	29 (5.8)	49 (9.8)	356 (69.8)
Dizziness	16 (3.2)	11 (2.2)	15 (3.0)	86 (16.9)
Weakness	85 (16.9)	91 (18.2)	117 (23.4)	347 (68.0)
Muscle pain	31 (6.2)	28 (5.6)	33 (6.6)	52 (10.2)
Red acne	0 (0)	0 (0)	4 (0.8)	50 (9.8)
Lower concentration	7 (1.4)	7 (1.4)	3 (0.6)	76 (14.9)
Disabilities				
Hearing	4 (0.2)	7 (0.4)	6 (0.4)	3 (0.2)
Speech	2 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)
Visual	1 (0.1)	4 (0.2)	1 (0.1)	7 (0.4)
Locomotive	2 (0.1)	7 (0.4)	1 (0.1)	11 (0.6)
Mental	5 (0.3)	2 (0.1)	1 (0.1)	12 (0.7)
Heat related illness				
Heat Fatigue	116 (6.8)	107 (6.7)	284 (18.4)	178 (9.9)
Heat Rashes	41 (2.4)	33 (2.1)	83 (5.4)	47 (2.6)
Heat cramps	54 (3.2)	31 (1.9)	19 (1.2)	18 (1.0)
Heat Syncope	9 (0.5)	5 (0.3)	6 (0.4)	9 (0.5)
Heat Exhaustion	33 (1.9)	17 (1.1)	56 (3.8)	161 (9.0)
Heat Stroke	26 (1.5)	12 (0.7)	5 (0.3)	41 (2.2)
Suffering from below mentioned diseases during the last 15 days				
Anemia	3 (0.2)	8 (0.5)	43 (2.8)	21 (1.2)
Muscle disorder	10 (0.6)	14 (0.9)	26 (1.7)	40 (2.2)
Cardiac	16 (0.9)	11 (0.7)	35 (2.8)	26 (1.4)
Hypertension	140 (8.2)	150 (9.3)	100 (6.5)	143 (8.0)
Diabetes	129 (7.5)	100 (6.2)	135 (9.6)	76 (4.2)
Cancer	1 (0.1)	2 (0.1)	6 (0.4)	4 (0.2)

Stroke	3 (0.8)	2 (0.1)	7 (0.5)	5 (0.3)
Kidney	2 (0.1)	8 (0.5)	9 (0.6)	4 (0.2)
Lung	5 (0.3)	6 (0.4)	6 (0.4)	19 (1.1)
Skin	1 (0.1)	4 (0.2)	34 (2.2)	29 (1.6)
Psoriasis	2 (0.1)	4 (0.2)	1 (0.1)	6 (0.3)
Vertigo	1 (0.1)	3 (0.2)	17 (1.1)	32 (1.8)
Medication for the diseases in the last 15 days				
Anemia	2 (0.1)	4 (0.2)	11 (0.7)	14 (0.8)
Muscle disorder	10 (0.6)	13 (0.8)	21 (1.4)	27 (1.5)
Cardiac	13 (0.8)	9 (0.6)	33 (2.1)	22 (1.2)
Hypertension	137 (8.0)	149 (9.3)	79 (5.1)	126 (7.0)
Diabetes	129 (7.5)	100 (6.2)	105 (6.8)	64 (3.6)
Cancer	1 (0.1)	1 (0.1)	6 (0.4)	4 (0.2)
Stroke	0 (0)	2 (0.1)	7 (0.5)	5 (0.3)
Kidney	2 (0.1)	5 (0.3)	9 (0.6)	4 (0.2)
Lung	5 (0.3)	6 (0.4)	6 (0.4)	18 (1.0)
Skin	1 (0.1)	4 (0.2)	21 (1.4)	23 (1.3)
Psoriasis	0 (0)	1 (0.1)	0 (0.0)	5 (0.3)
Vertigo	1 (0.1)	3 (0.2)	9 (0.6)	24 (1.3)

***is for 500 people interviewed in Kolkata, 500 in Karimnagar, 504 in Ongole and 510 in Angul

Table 14: Habits and Behaviour

Variable	Number of Respondents (%) / 504 Ongole	Number of Respondents (%) / 500 Karimnagar	Number of Respondents (%) / 500 Kolkata	Number of Respondents (%) / 510 Angul
Windows open during extreme hot days				
Yes	424 (84.1)	436 (87.2)	223 (44.6)	444 (87.1)
No	80 (15.9)	64 (12.8)	277 (55.4)	66 (12.9)
Windows open during extreme hot days of COVID				
Yes	416 (82.5)	408 (81.6)	285 (57.0)	438 (85.9)
No	88 (17.5)	62 (18.4)	215 (43.0)	72 (14.1)
Blinds/drapes in extreme summer				
Yes	213 (42.3)	157 (31.4)	306 (61.2)	429 (84.1)
No	291 (57.7)	343 (68.6)	194 (38.8)	81 (15.9)
Bed Nets in normal times				
Yes	58 (11.5)	38 (7.6)	172 (34.4)	421 (82.5)
No	444 (88.1)	462 (92.4)	328 (65.6)	89 (17.5)
Bed Nets in summer				
Yes	55 (10.9)	38 (7.6)	127 (25.4)	423 (82.9)
No	449 (89.1)	462 (92.4)	373 (74.6)	87 (17.1)
Wear different type of cloth during summer than regular time				
Yes	189 (37.5)	217 (43.4)	188 (37.6)	186 (36.5)
No	315 (62.5)	283 (56.6)	312 (62.4)	324 (63.5)
Time spent outside during summer				
Increased	4 (0.8)	4 (0.8)	12 (2.4)	2 (0.4)
Decreased	324 (64.3)	346 (69.2)	22 (4.4)	407 (79.8)
No Change	168 (33.3)	141 (28.2)	445 (89.0)	99 (19.4)
Don’t Know / No response	8 (1.6)	9 (1.8)	21 (4.2)	2 (0.4)

Sleeping place in normal nights				
Bed	406 (80.6)	369 (73.8)	470 (94.0)	371 (72.7)
Bare floor	62 (12.3)	84 (16.8)	16 (3.2)	75 (14.7)
Mattress	28 (5.6)	41 (8.2)	5 (1.0)	63 (12.4)
Roof	1 (1.0)	0 (0)	0 (0)	0 (0)
Others	0 (0)	3 (0.6)	5 (1.0)	0 (0)
Don't Know / No response	7 (1.4)	3 (0.6)	4 (0.8)	1 (0.2)
Sleeping place in extreme summer nights				
Bed	400 (79.4)	358 (71.6)	387 (77.4)	371 (72.7)
Bare floor	68 (13.5)	89 (17.8)	73 (14.6)	78 (15.3)
Mattress	28 (5.6)	41 (8.2)	2 (0.4)	65 (12.7)
Roof	1 (1)	4 (0.8)	1 (0.2)	0 (0)
Others	0 (0)	3 (0.6)	2 (0.4)	0 (0)
Don't Know / No response	7 (1.4)	5 (1.0)	35 (7.0)	1 (0.2)
Number of Baths in normal days	1.4 ± 0.49*	1.4 ± 0.5*	1.1 ± 0.4*	1.2 ± 0.5*
Number of Baths extreme hot day	1.8 ± 0.43*	2.0 ± 0.3*	1.9 ± 0.9*	1.9 ± 0.4*
Number of Baths Covid-19 hot days	1.7 ± 0.48*	2.0 ± 0.4*	1.8 ± 0.8*	1.3 ± 0.5*
Litres of drinking water per day	3.2 ± 0.90*	3.4 ± 1.0*	3.9 ± 1.7*	3.1 ± 1.2*
Litres of water in extreme heat days	4.4 ± 0.95*	4.8 ± 1.1*	4.8 ± 1.9*	4.5 ± 1.5*

*Mean ± S.D

Table 15: Occupation Status

Variable	**Number of Respondents (%) / 201 Ongole**	**Number of Respondents (%) / 223 Karimnagar**	**Number of Respondents (%) / 382 Kolkata**	**Number of Respondents (%) / 199 Angul**
Category of employment				
Professional	10 (5.0)	37 (16.6)	12 (3.1)	16 (8.0)
Semi-professional	9 (4.5)	22 (9.9)	67 (17.5)	5 (2.5)
Clerical	2 (1.0)	4 (1.8)	47 (12.3)	5 (2.5)
Skilled Worker	39 (19.4)	18 (8.1)	28 (7.3)	11 (5.5)
Semi-skilled	18 (9.0)	19 (8.5)	59 (15.4)	12 (6.0)
Unskilled worker	65 (32.3)	77 (34.5)	61 (16.0)	75 (37.7)
Unemployed	10 (5.0)	15 (6.7)	15 (3.9)	31 (15.6)
Self-employed	41 (20.4)	27 (12.1)	86 (22.5)	42 (21.1)
Agricultural worker	6 (3.0)	3 (1.3)	2 (0.5)	1 (0.5)
Others	1 (0.5)	1 (0.4)	5 (1.3)	1 (0.5)

Table 16: Vulnerability of Working Population (Currently Working)

Variable	Number of Respondents (%) / 191 Ongole	Number of Respondents (%) / 208 Karimnagar	Number of Respondents (%) / 367 Kolkata	Number of Respondents (%) / 168 Angul
Change in type of work				
Yes	4 (2.1)	10 (4.8)	14 (3.8)	2 (1.2)
No	187 (97.9)	198 (95.2)	353 (96.2)	166 (98.8)
Change in type of work during COVID-19 summer				
Yes	14 (7.3)	16 (7.7)	153 (41.7)	2 (1.2)
No	177 (92.7)	192 (92.3)	214 (58.3)	166 (98.8)
Working shift in normal days				
Day shift	178 (93.2)	181 (87.0)	249 (67.8)	161 (95.8)
Night shift	3 (1.6)	1 (0.5)	2 (0.5)	2 (1.2)
Others / No response	10 (5.2)	26 (12.5)	116 (31.6)	5 (3.0)
Working Shift during Summer days				
Day shift	175 (91.6)	182 (87.5)	257 (70.0)	141 (83.9)
Night shift	3 (1.6)	3 (1.4)	11 (3.0)	1 (0.6)
Others / No Response	13 (6.8)	23 (11.1)	99 (27.0)	26 (15.5)
Duration of work	7.9 ± 2.1 *	8.1 ± 2.0 *	8.0 ± 3.3 *	7.9 ± 2.4 *
Duration of work during extreme hot day	7.0 ± 2.3 *	7.0 ± 2.3 *	8.8 ± 2.3 *	7.3 ± 2.6 *
Mode of transport to work place	4 (2.1)	7 (3.4)	37 (10.1)	
Car	47 (24.6)	111 (53.4)	39 (10.6)	2 (1.2)
Bike	4 (2.1)	4 (1.9)	39 (10.6)	44 (26.2)
Cycle	53 (27.7)	31 (14.9)	18 (4.9)	30 (17.9)
Auto	77 (40.3)	47 (22.6)	131 (35.7)	3 (1.8)
Walk	2 (1.0)	8 (3.8)	81 (22.1)	80 (47.6)
Bus	0 (0)	0 (0)	5 (1.4)	6 (3.6)
Local train	0 (0)	0 (0)	4 (1.1)	0 (0)
Metro rail	4 (2.1)	0 (0)	13 (3.5)	0 (0)

Others				3 (1.8)
Mode of transport during extreme summer				
Car	4 (9.9)	9 (4.3)	39 (10.6)	2 (1.2)
Bike	47 (24.6)	108 (51.9)	38 (10.4)	44 (26.2)
Cycle	4 (2.1)	4 (2.1)	39 (10.6)	30 (17.9)
Auto	54 (28.3)	30 (14.4)	18 (4.9)	3 (1.8)
Walk	76 (39.8)	46 (22.1))	138 (37.6)	81 (48.2)
Bus	2 (1.0)	10 (4.8)	73 (19.9)	6 (3.6)
Local train	0 (0)	0 (0)	7 (1.9)	0 (0)
Metro rail	0 (0)	0 (0)	3 (0.8)	0 (0)
Others	4 (2.1)	1 (0.5)	12 (3.3)	2 (1.2)
Exposed to direct source of heat				
Yes	4 (2.0)	16 (7.7)	26 (7.1)	8 (5.8)
No	187 (97.9)	192 (92.3)	341 (92.9)	160 (95.2)
Did the COVID-19 PPE led to discomfort				
Yes	155 (81.2)	153 (73.6)	156 (42.5)	127 (75.6)
No	36 (18.8)	55 (16.4)	211 (57.5)	41 (24.4)
Clothes while working in normal time				
Light / Sleeveless	6 (3.1)	6 (2.9)	6 (1.6)	16 (9.5)
Half sleeve	147 (77.0)	146 (70.2)	174 (47.4)	61 (36.3)
Full sleeves	35 (18.3)	50 (24.0)	126 (34.3)	87 (51.8)
More than two layers	1 (0.5)	0 (0)	2 (0.5)	2 (1.2)
Others / No response	2 (1.0)	6 (2.9)	59 (16.1)	2 (1.2)
Clothes while working in summer				
Light / Sleeveless	5 (2.6)	8 (3.8)	7 (1.9)	15 (8.9)
Half sleeve	153 (80.1)	148 (71.2)	183 (49.9)	62 (36.9)
Full sleeves	30 (15.7)	47 (22.6)	116 (31.6)	84 (50.0)
More than two layers	1 (0.5)	0 (0)	2 (0.5)	2 (1.2)
Others / No response	2 (1.0)	5 (2.3)	59 (16.1)	5 (3.0)

Clothes while working in Covid-19 Summer Light Sleeveless Half sleeve Full sleeves More than two layers Others / No response	4 (2.1) 149 (78.0) 28 (14.7) 1 (0.5) 9 (4.7)	6 (2.9) 139 (66.8) 45 (21.6) 0 (0) 18 (8.7)	4 (1.1) 153 (41.7) 123 (33.5) 2 (0.5) 85 (23.2)	15 (8.9) 2 (36.9) 76 (45.2) 2 (1.2) 13 (7.7)
AC / Cooler at work Yes No	4 (2.1) 187 (97.9)	32 (15.4) 176 (84.6)	107 (29.2) 260 (70.8)	6 (3.6) 162 (96.4)
Were the A/C used in lockdown? *** Yes No	2 (50.0) 2 (50.0)	23 (71.9) 9 (28.1)	63 (58.9) 44 (41.1)	3 (50.0) 3 (50.0)
Drinking water at workplace Yes No	145 (75.9) 46 (24.1)	153 (73.6) 55 (26.4)	208 (56.7) 159 (43.3)	80 (47.6) 88 (52.4)
Coping for extreme heat at workplace ** Take several breaks Drink lots of water Find a cooler location Wear appropriate clothing Nothing Others	140 (73.3) 111 (58.1) 16 (8.4) 9 (4.7) 13 (6.8) 2 (1.0)	130 (62.5) 148 (71.2) 75 (36.1) 5 (2.4) 9 (4.3) 1 (0.5)	49 (13.4) 233 (63.5) 71 (19.3) 31 (8.4) 12 (3.3) 4 (1.1)	43 (25.6) 104 (61.9) 89 (53.0) 4 (2.4) 29 (17.3) 0 (0)
Coping for extreme heat at workplace during COVID-19 ** Take several breaks Drink lots of water Find a cooler location	138 (72.3) 107 (56.0) 17 (8.9)	114 (54.8) 128 (61.5) 70 (33.7)	43 (11.7) 154 (42.0) 56 (15.3) 21 (5.7)	46 (27.4) 105 (62.5) 75 (44.6)

Wear appropriate clothing	6 (3.1)	7 (3.4)	102 (27.8)	3 (1.8)
Nothing	10 (5.2)	12 (5.8)	3 (0.8)	29 (17.3)
Others	2 (1.0)	9 (4.3)		0 (0)
Difficulty in getting water at workplace				
Yes	36 (18.8)	31 (14.9)	79 (21.5)	51 (30.4)
No	155 (81.2)	177 (85.1)	288 (78.5)	117 (69.7)

* Mean ± S.D

****** (cumulative % might exceed 100 due to multiple option/responses)

***Out of 107 respondents who have A/C at workplace in Kolkata, 32 in Karimnagar, 6 in Angul and 4 in Ongole

Slum and Non/Slum Analysis

The Slum and Non-slum data reveal on income and expenditure reveals that income of slum population in all the four cities is always less than income of non-slum population. However, the expenditure also follows a similar trend as it is less for slum population. The difference between the income and expenditure of slum and non-slum population is the highest in Kolkata and the lowest in Angul. Analysis of the locational characteristics show that there are more vegetative patches and water bodies in slum areas than non-slum areas in Ongole and Karimnagar, however it is opposite for Angul and almost similar for slum and non-slum areas in Kolkata. Traffic junctions and industrial areas are more in proximity to non-slum areas in Angul. In Karimnagar, Industrial areas are more near slums but traffic junctions are more near non-slum areas. The statistics are almost similar for slum and non-slum in Kolkata and Ongole. All the four cities have more non-slum houses with concrete roofs. Many houses in slum areas in all the four cities are using asbestos. Slum areas are also found to be using clay tiles, tin sheds and straw roofs more than non-slum areas. However, there are also a number of slum houses which had concrete roofs across the four cities. Co-morbid conditions often lead to an increase in vulnerability. Across the four cities, it was noticed that Non-slum population reported more co-morbid conditions overall than slum populations. Apart from a few examples, majority of the cases of co-morbid conditions across the four cities were from non-slum house households. In Angul, the difference between Slum and Non-slum households having victims of Hypertension and Diabetes was stark with non-slum households leading the charts. On effects of extreme heat, Ongole reported more number of mild headache victims for slum population and more weakness for non-slum population, Karimnagar reported more mild headache and more weakness for both slum and non-slum population but also reported more muscle pain victims among slum dwellers. Kolkata showed a greater number of people in slums were feeling weak and more number in non-slums were feeling headaches. Angul reported almost similar stats for weakness between slum and non-slum, however, headache was reported higher among non-slum population more than slum population. Data from Ongole showed that more that more respondents from the non-slum population liked to keep their curtains open during day time. This was similar for Kolkata. Data from Kolkata also revealed that more non-slum respondents wore different clothes during the summer. In Karimnagar, it was seen that less number of respondents in slum areas liked to keep their windows open extreme hot days as compared to non-slum respondents. In Angul, there was no such stark difference. Data from Ongole and Karimnagar showed that more respondents from non-slum areas chose to drink more liquids during extreme heat, this was the opposite in Kolkata and Angul where more respondents from slum areas did the same. Both the slum and non-slum population didn't prefer avoiding the sun much in Kolkata, however in Angul and Ongole more slum-dwellers chose to avoid the sun. In Angul, many respondents mentioned using fans/ACs/coolers during extreme summer. In Karimnagar, many repondents mentioned finding a cooler location to combat extreme heat. In the context of measures, the respondents are willing to take, more number of non-slum respondents mentioned wanting to buy ACs, Coolers, fans or exhaust fans and increase greenery. However, many slum respondents mentioned about wanting to change the type of roof they had. To avoid sun exposure, many respondents in non-slum areas across Kolkata, Ongole and Karimnagar preferred staying indoor while it is the opposite in Angul. Many non-slum respondents in Kolkata, Karimnagar and Ongole also preferred wearing hats or using umbrellas. Most respondents, irrespective of slums and non-slums mentioned planting more trees as a way in which the Government can help them combat heat waves. Other help required included keeping free water on the roads and raising awareness.

Income and Expenditure (Slum vs Non-Slum)

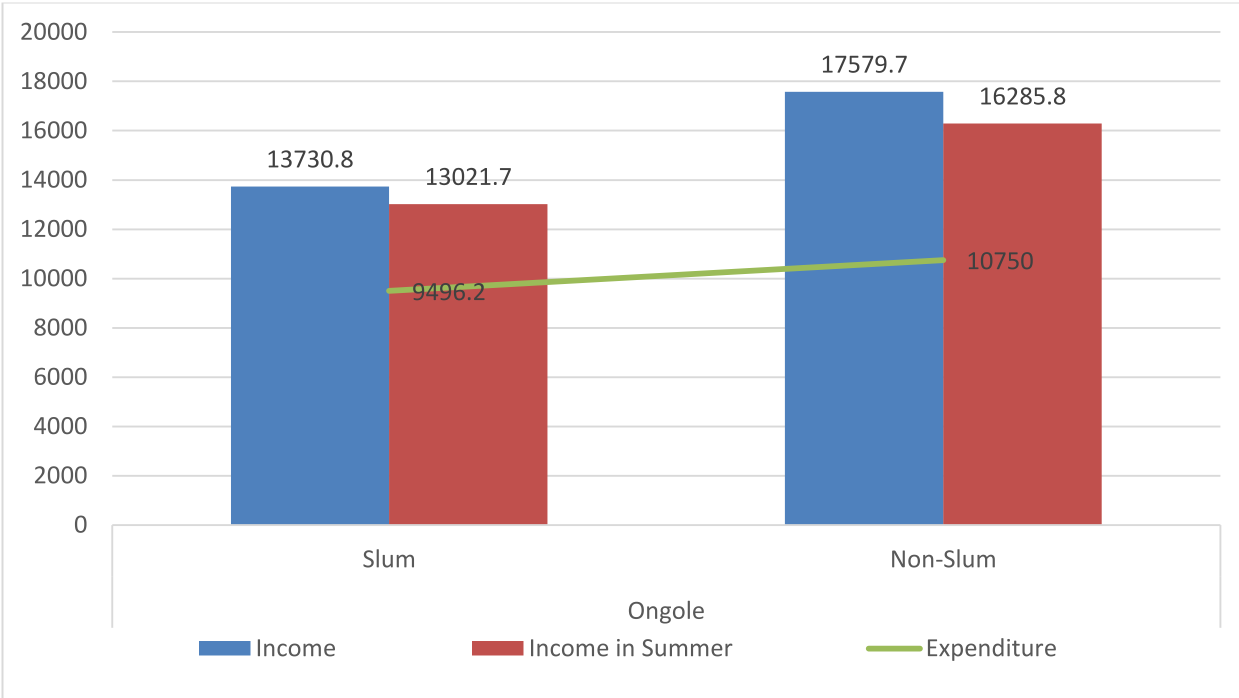

Figure 5: Income and Expenditure - Ongole

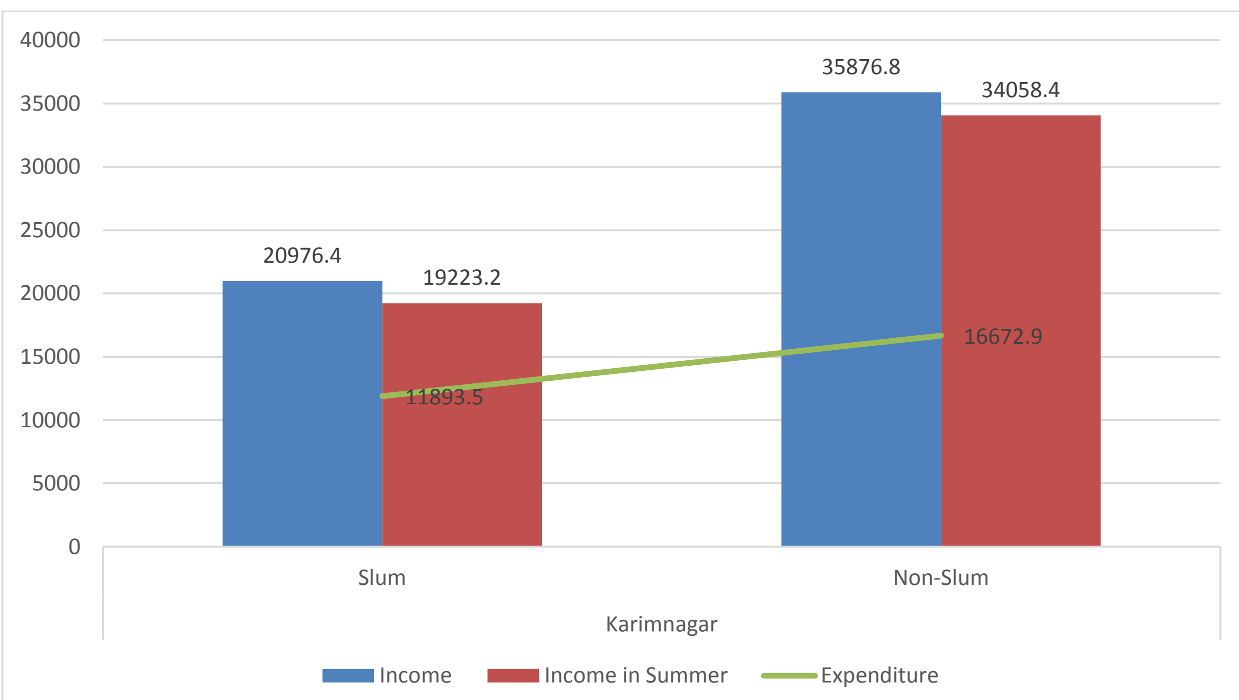

Figure 6: Income and Expenditure - Karimnagar

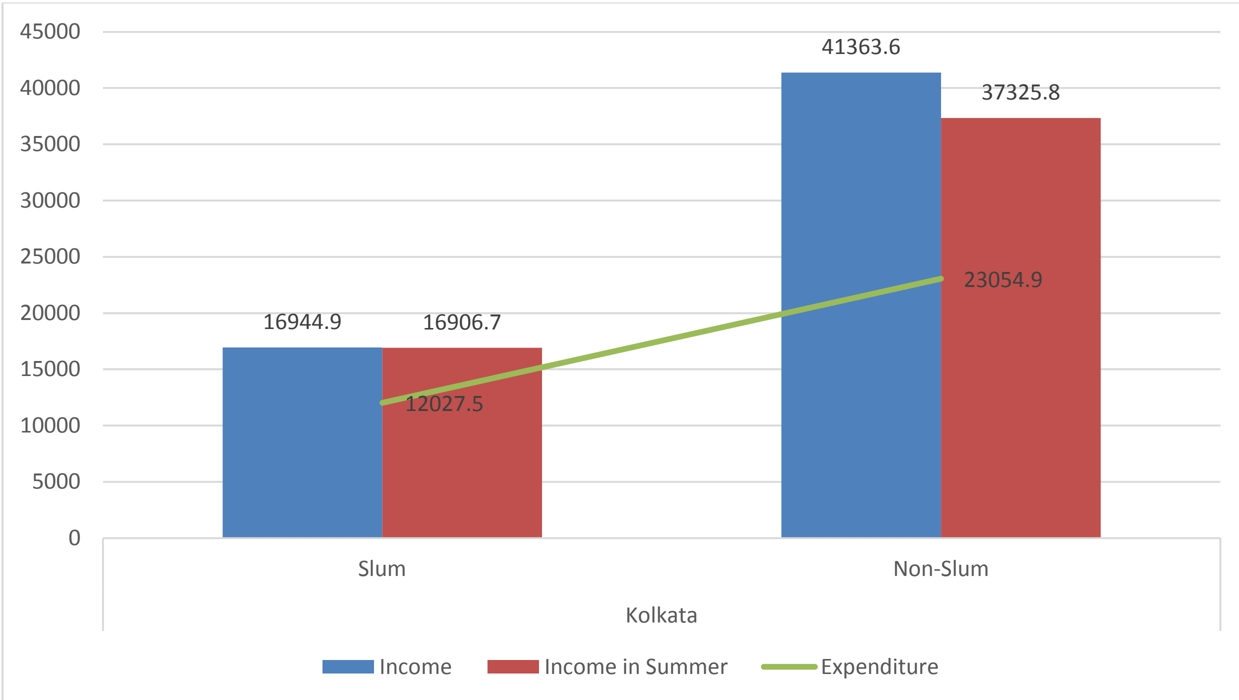

Figure 7: Income and Expenditure - Kolkata

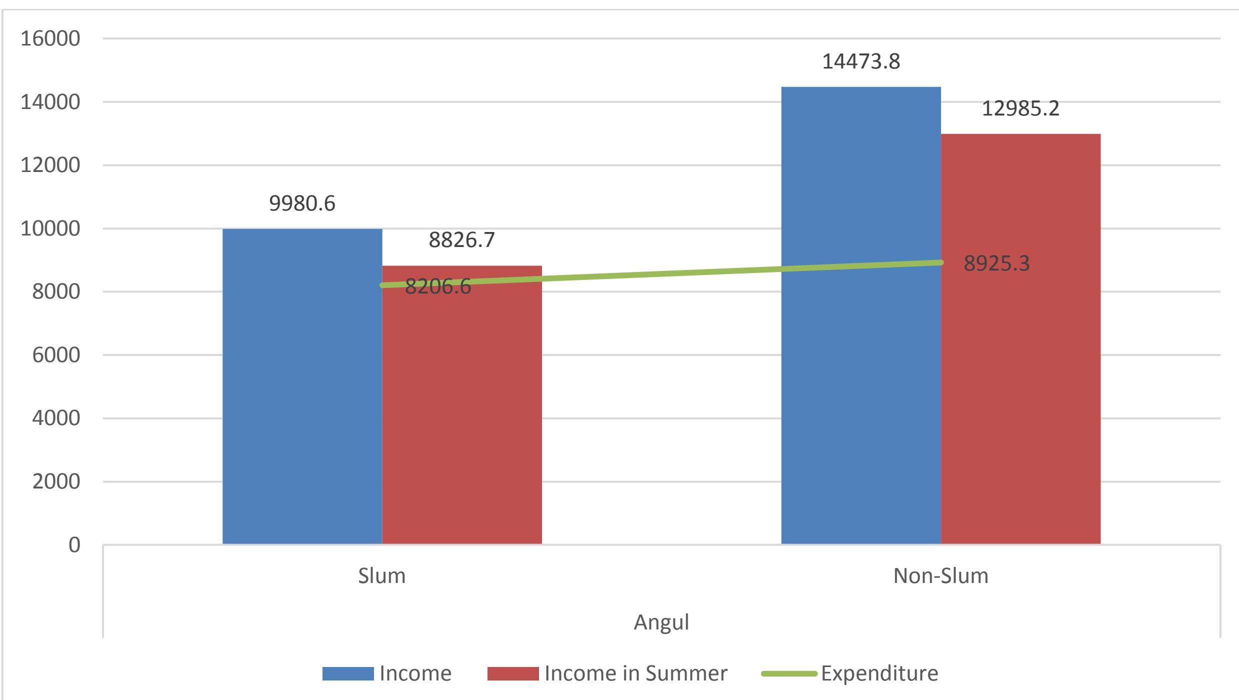

Figure 8: Income and Expenditure - Angul

Locational Characteristics

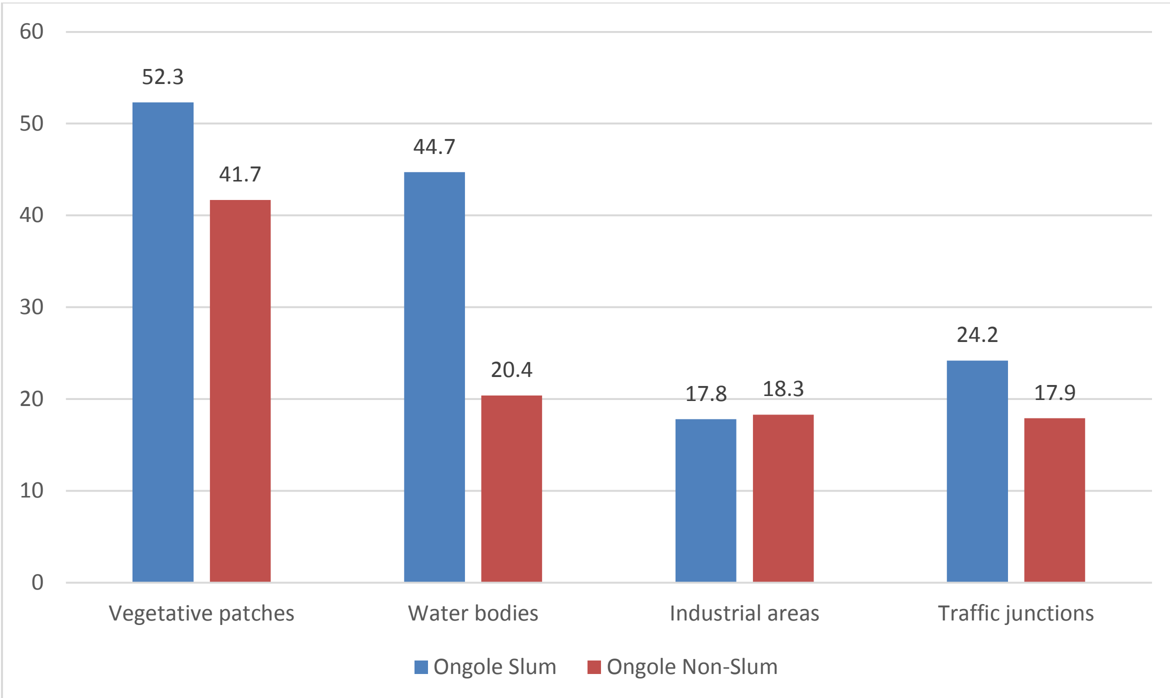

Figure 9: Locational Characteristics - Ongole

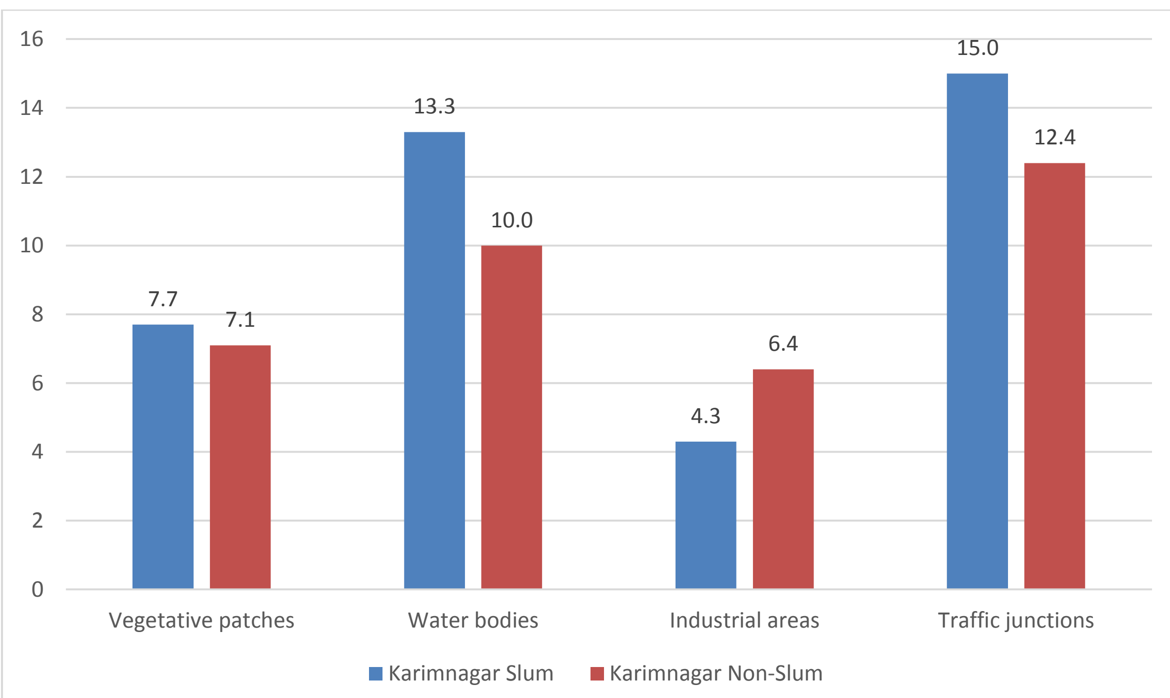

Figure 10: Locational Characteristics - Karimnagar

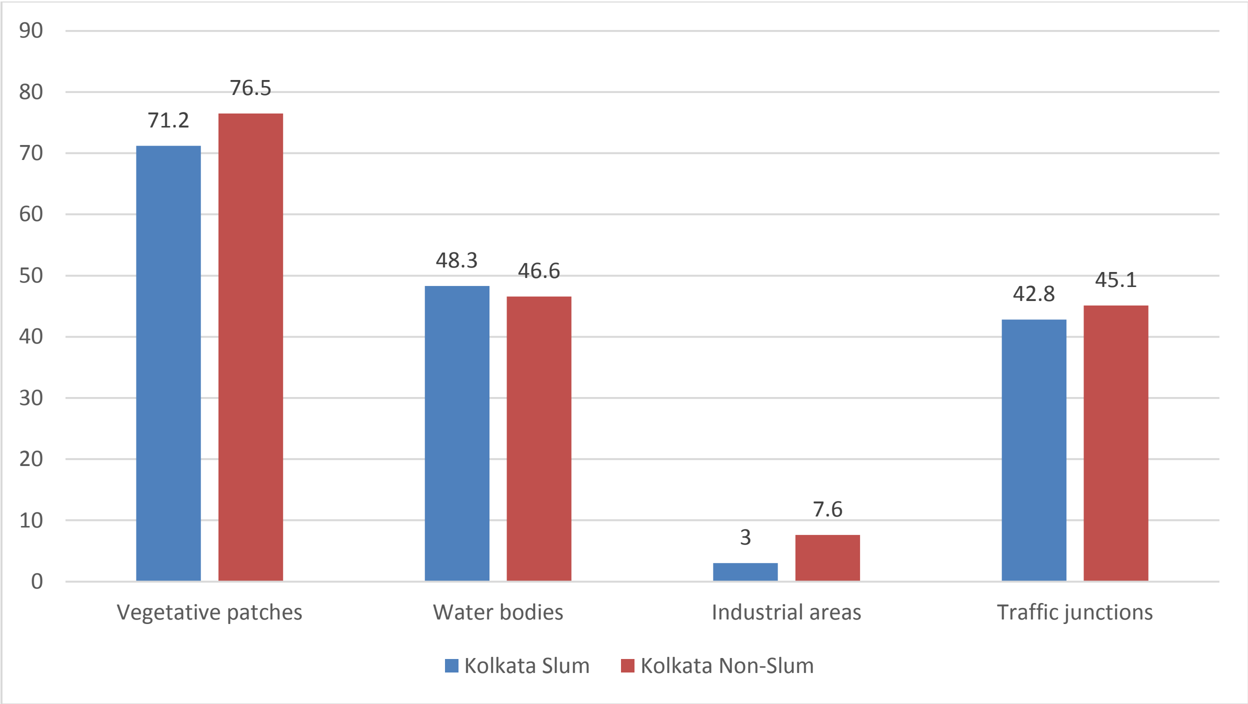

Figure 11: Locational Characteristics - Kolkata

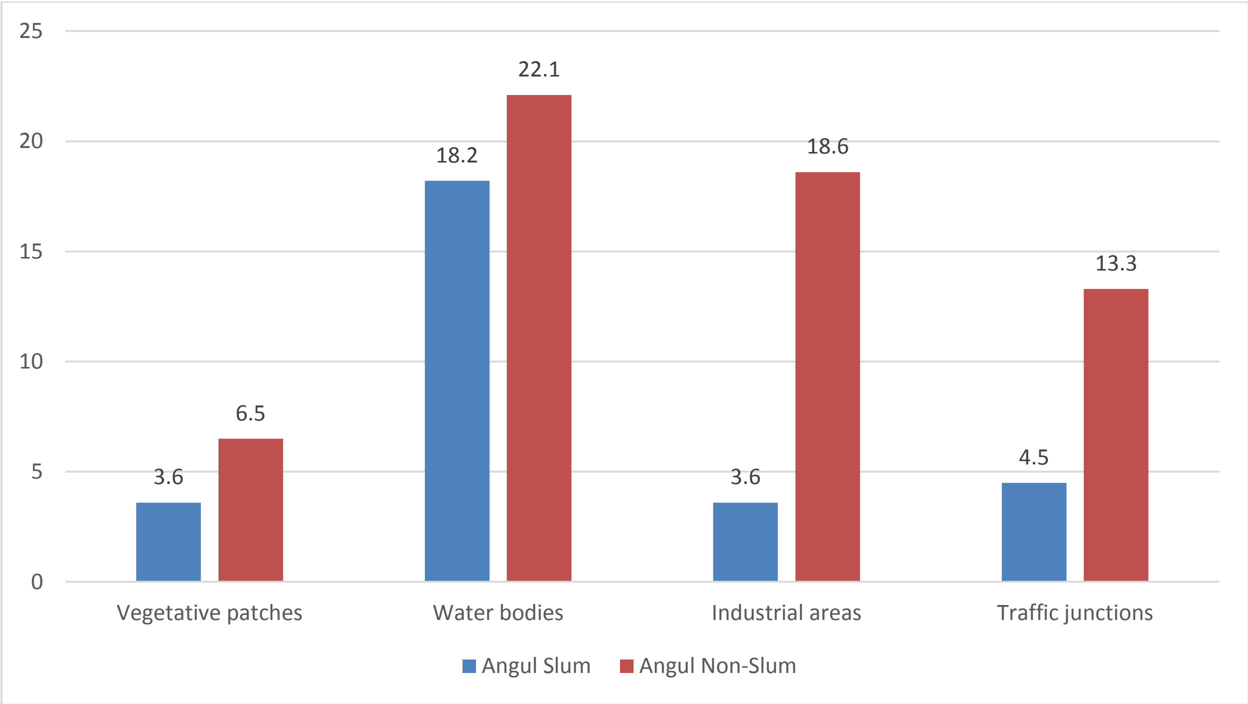

Figure 12: Locational Characteristics - Angul

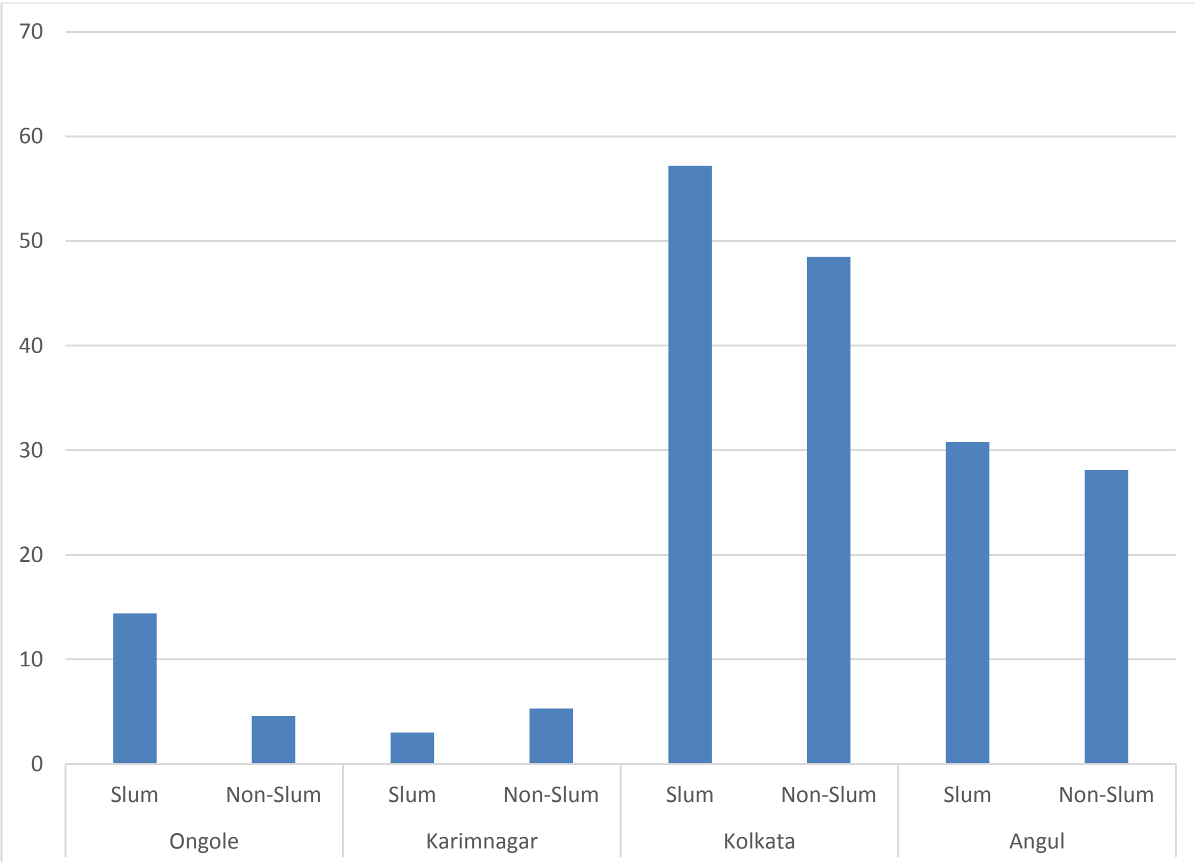

Figure 13: Households surrounded by buildings on 3 or 4 sides

Roof Type

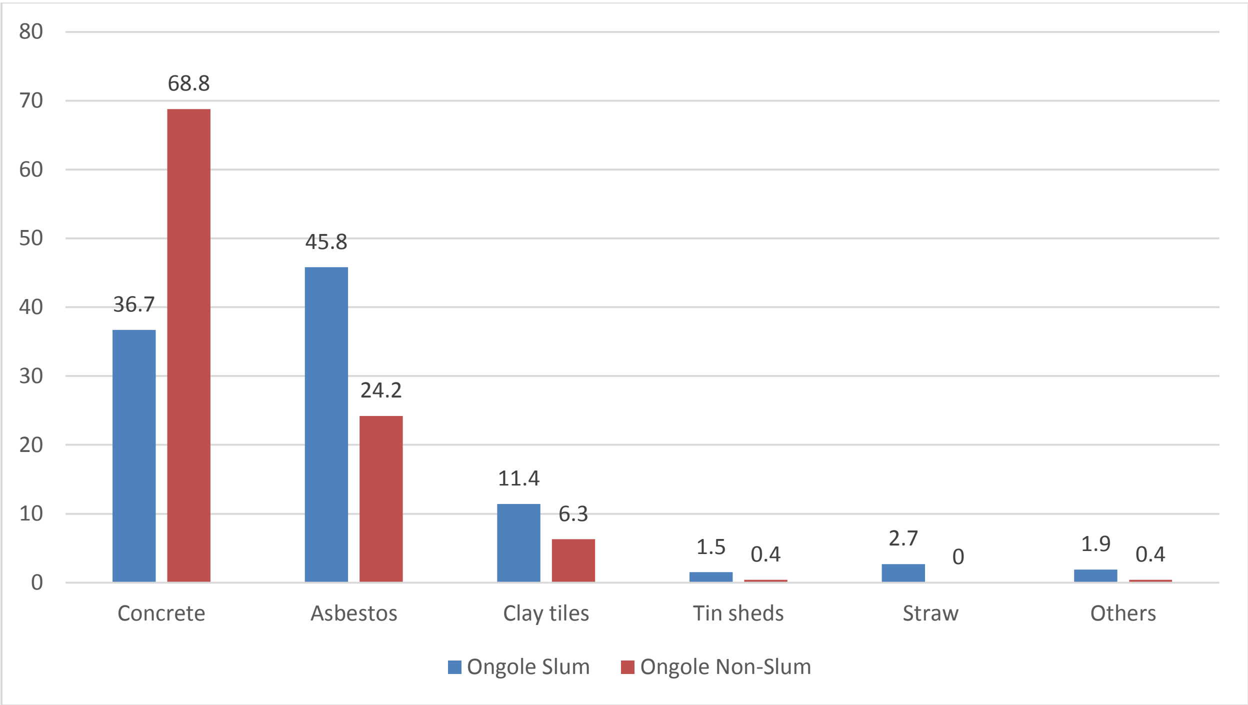

Figure 14: Roof Type - Ongole

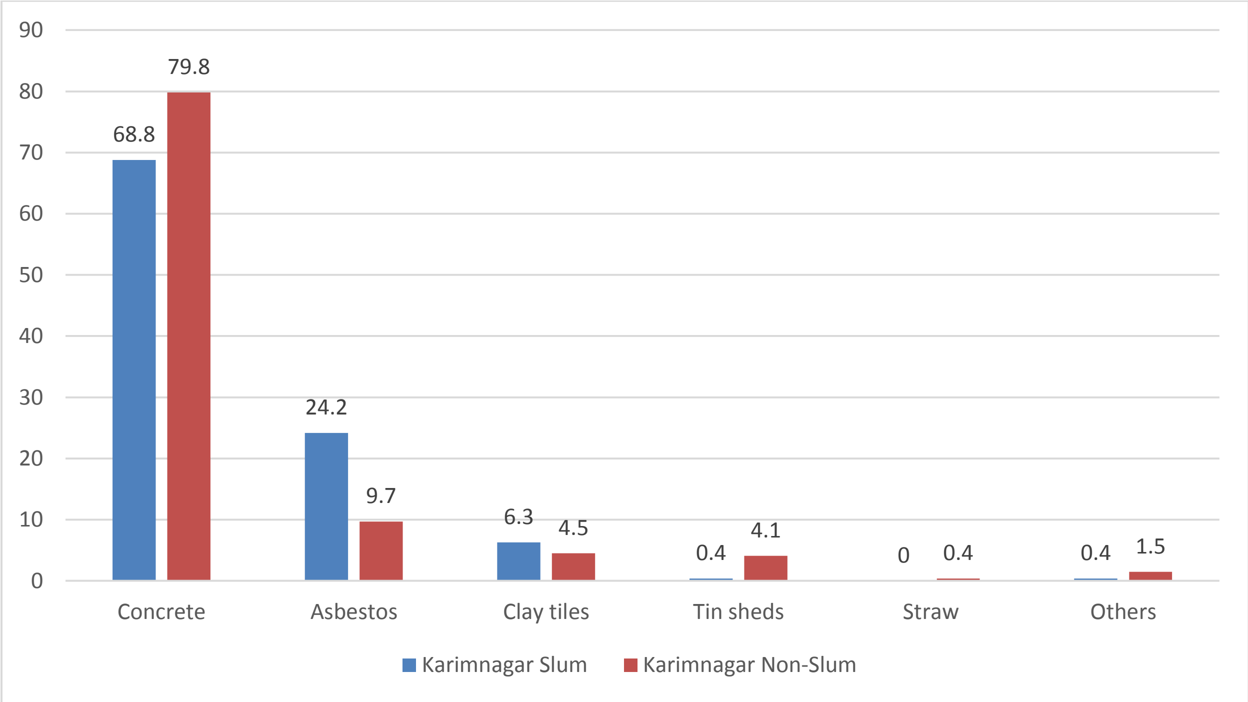

Figure 15: Roof Type - Karimnagar

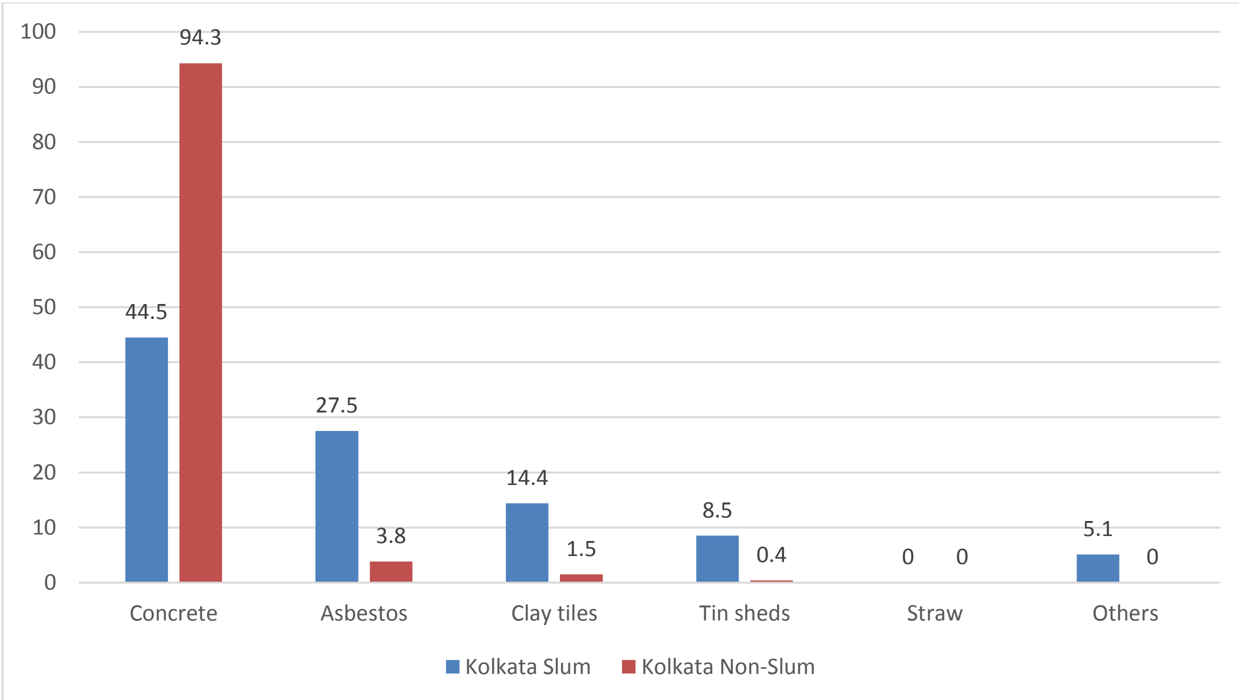

Figure 16: Roof Type - Kolkata

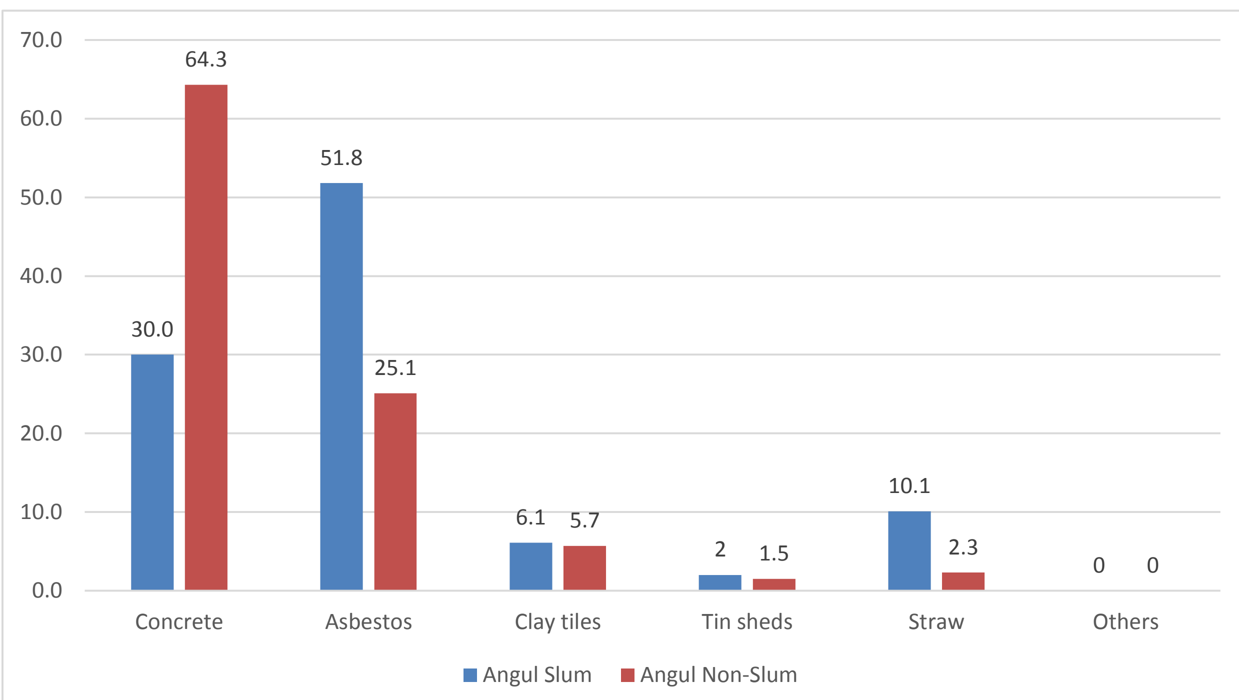

Figure 17: Roof Type - Angul

Co-morbidities

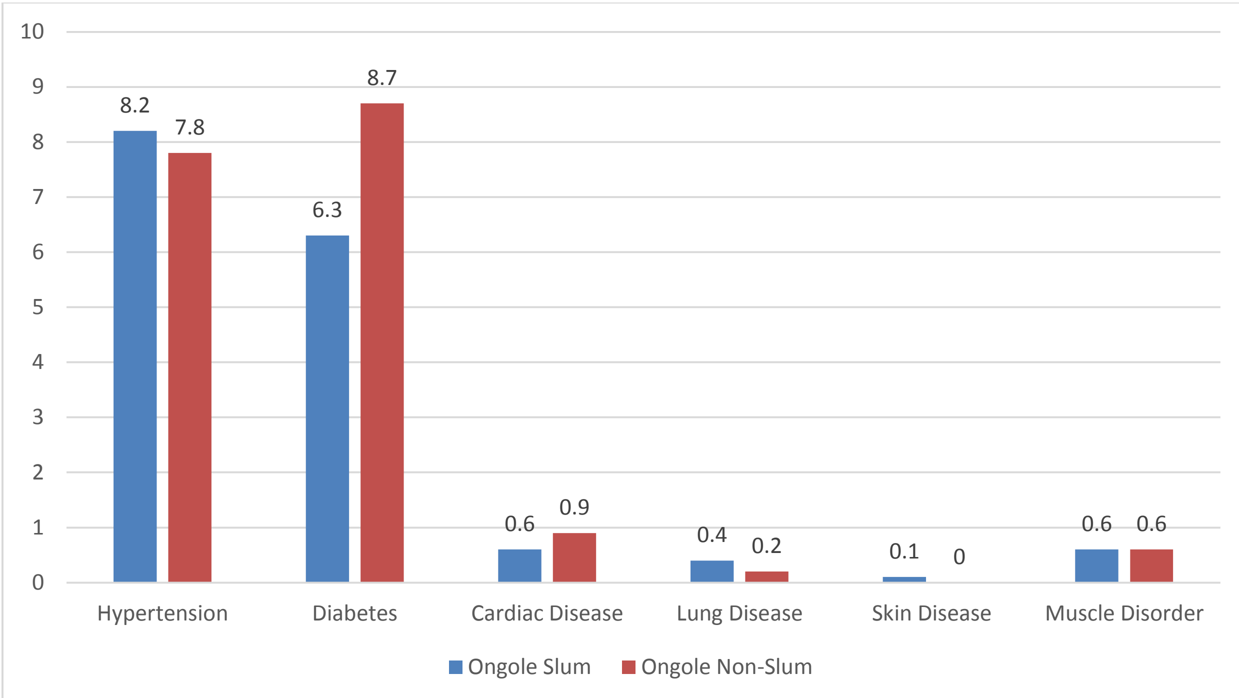

Figure 18: Co-morbidities - Ongole

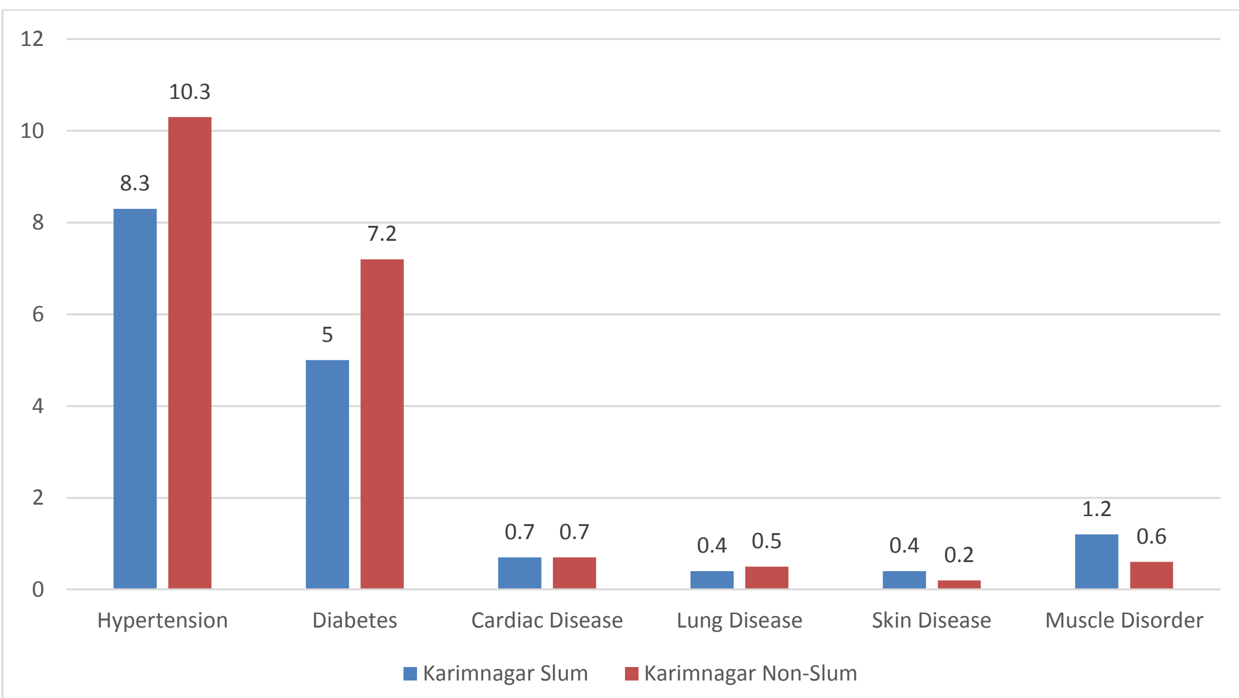

Figure 19: Co-morbidities - Karimnagar

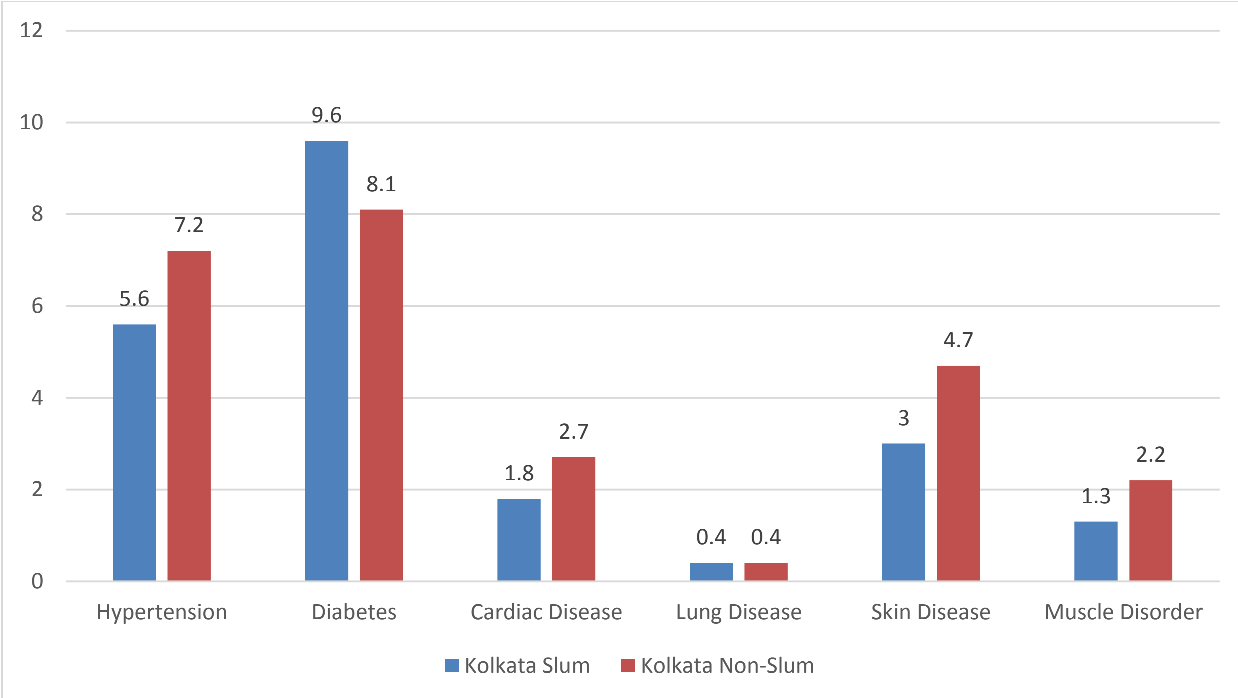

Figure 20: Co-morbidites - Kolkata

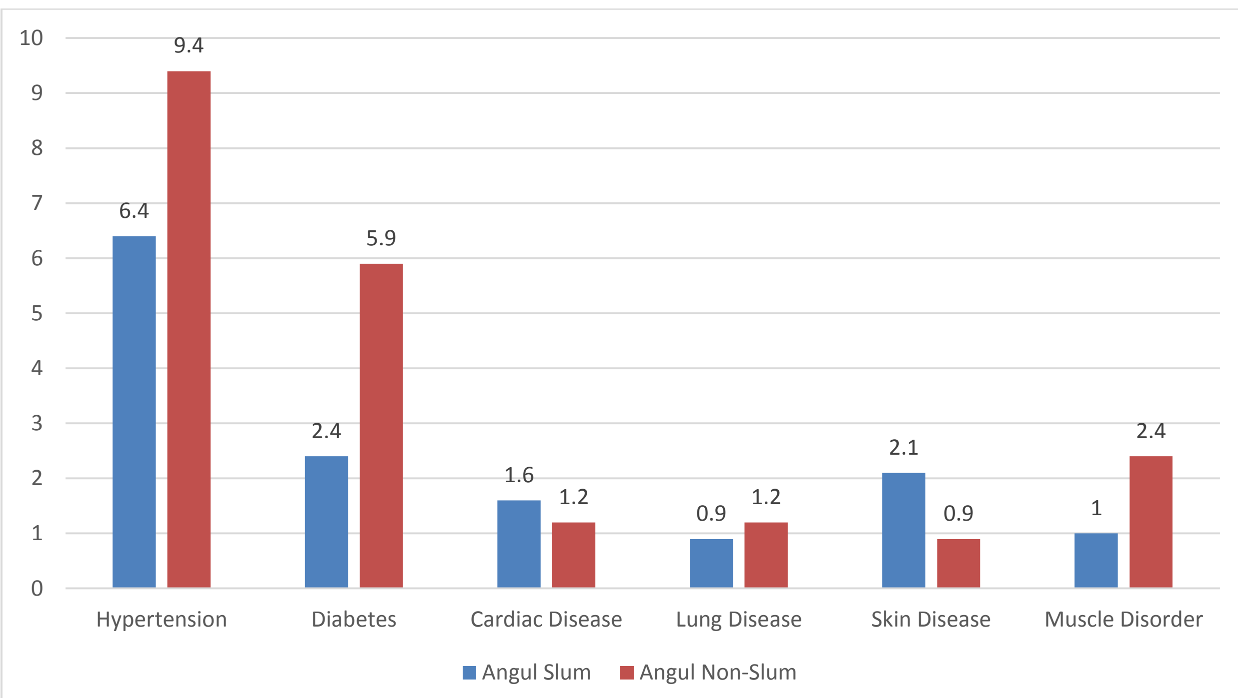

Figure 21: Co-morbidities - Angul

Effect of extreme heat

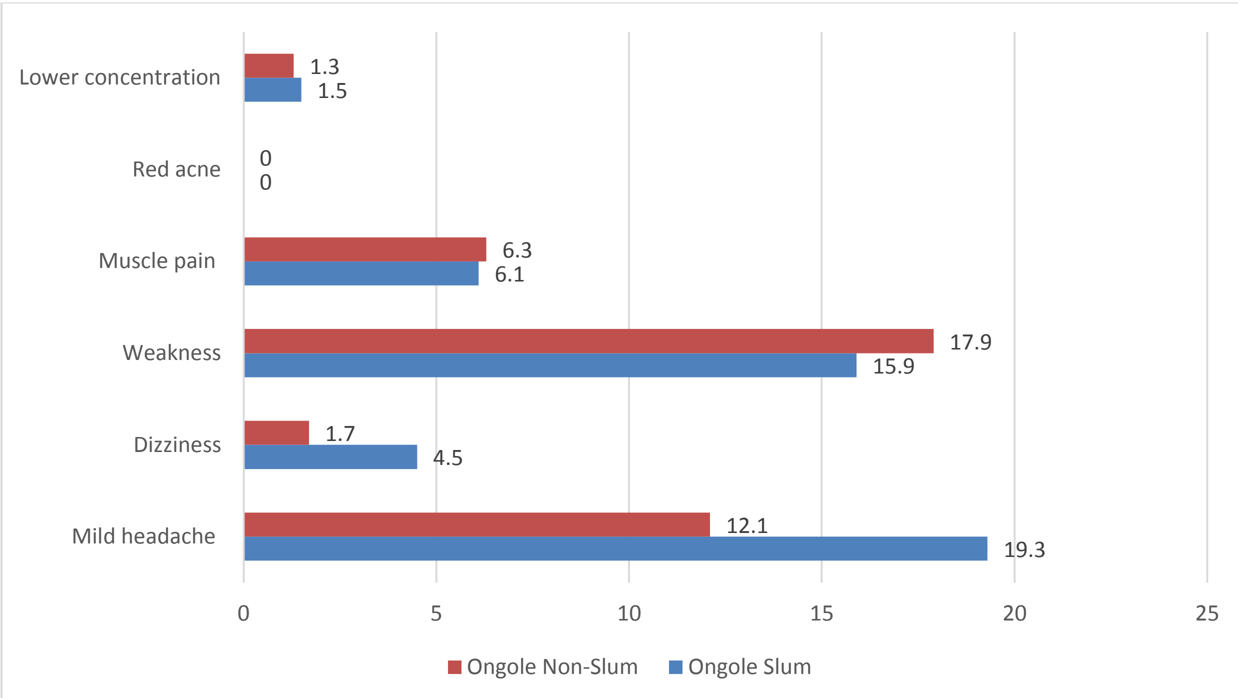

Figure 22: Extreme Heat Impacts - Ongole

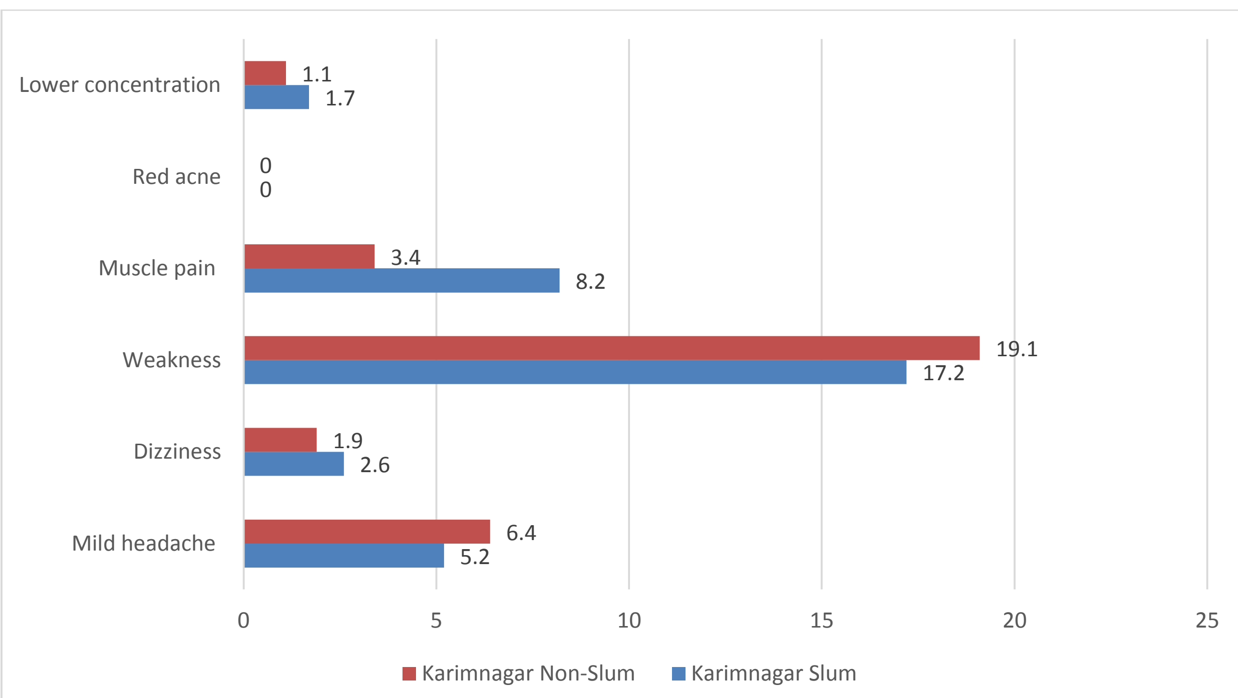

Figure 23: Extreme Heat Impact - Karimnagar

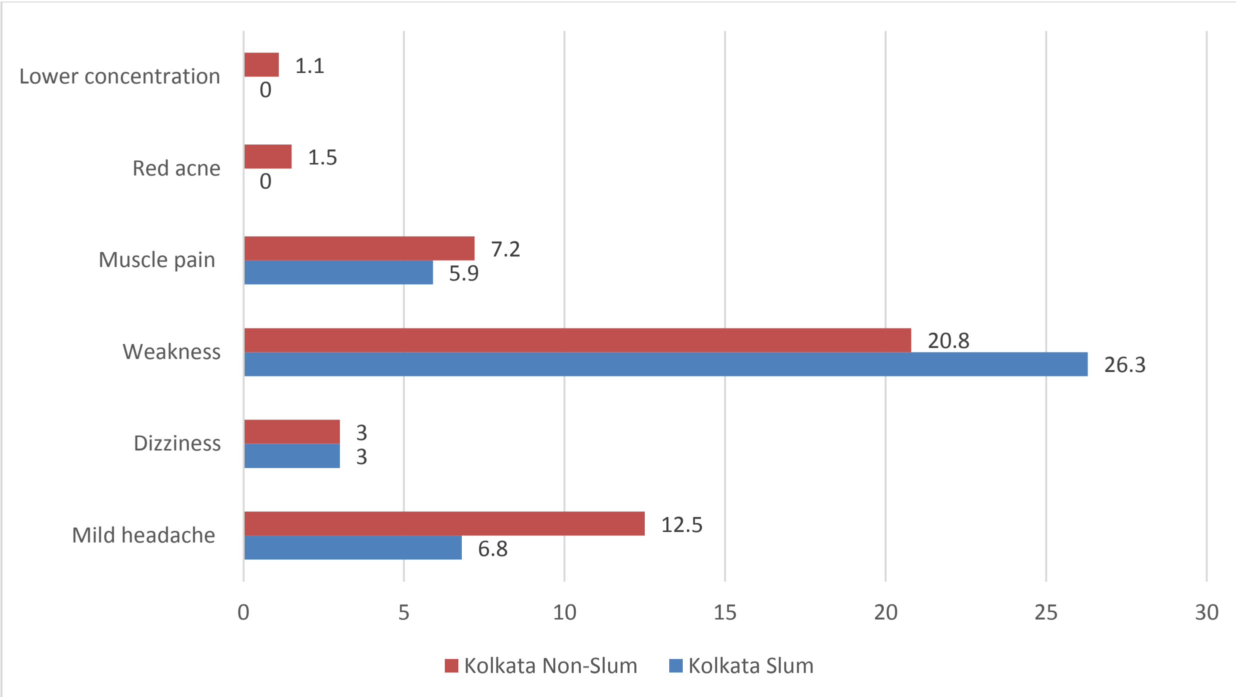

Figure 24: Extreme Heat Impact - Kolkata

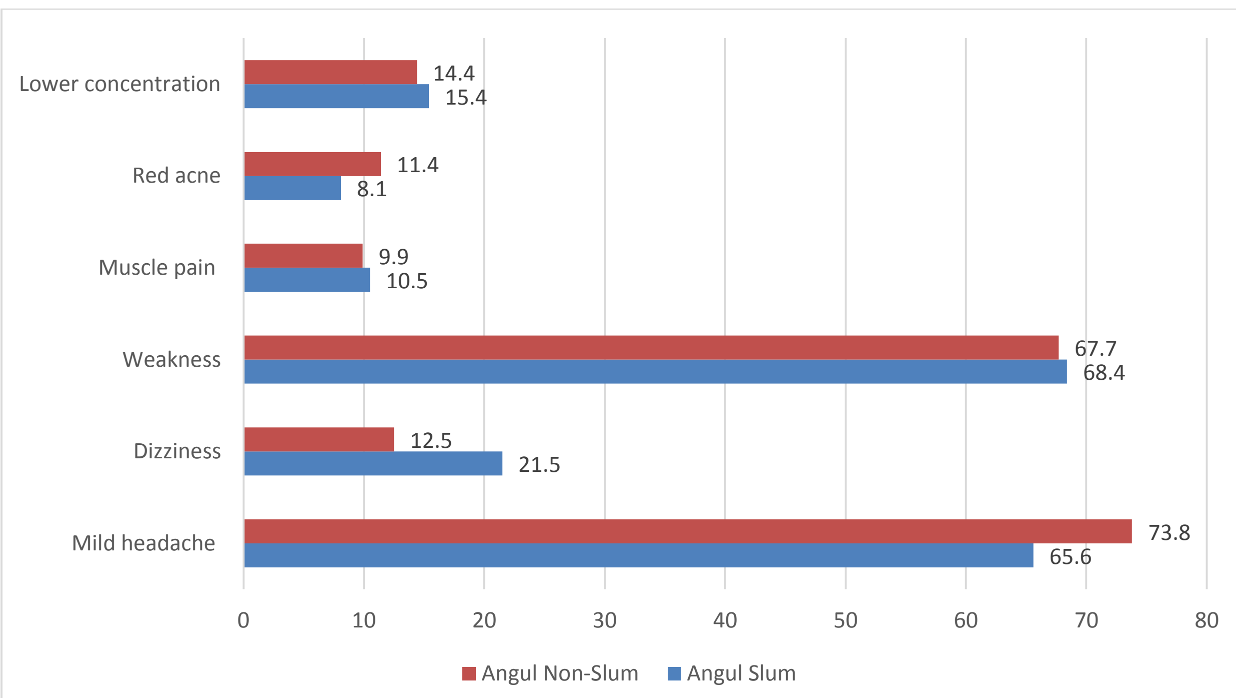

Figure 25: Extreme Heat Impact - Angul

Habits during summer

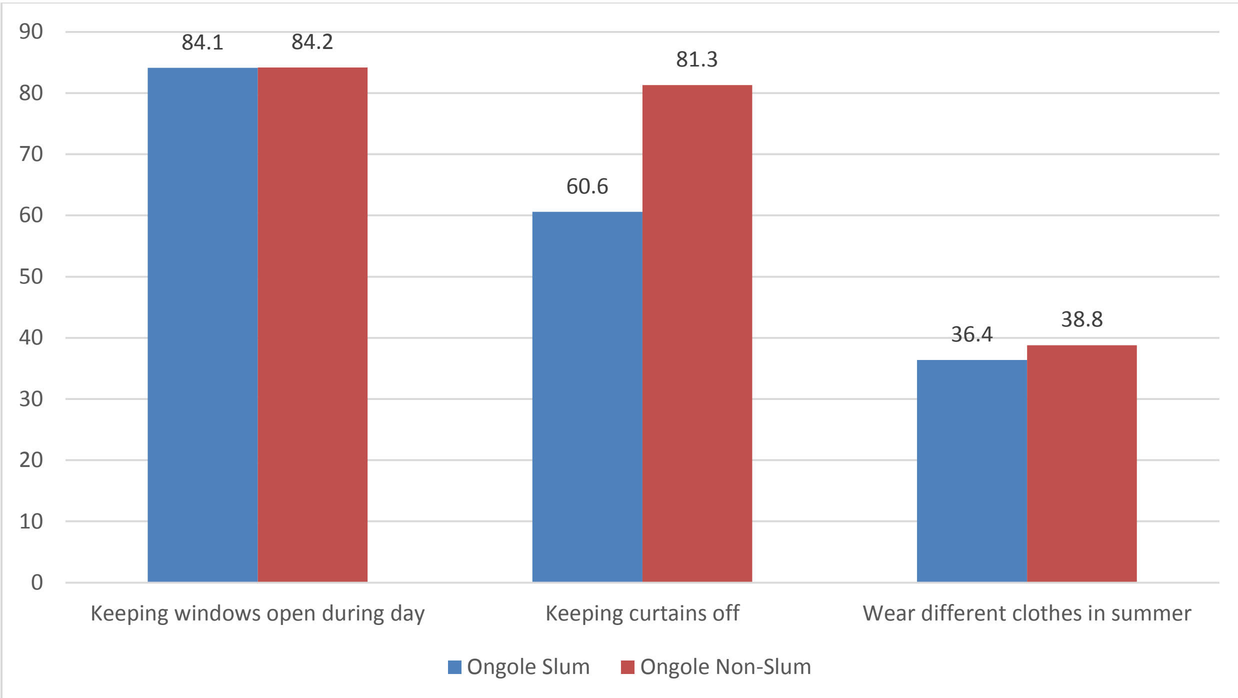

Figure 26: Summer Habits - Ongole

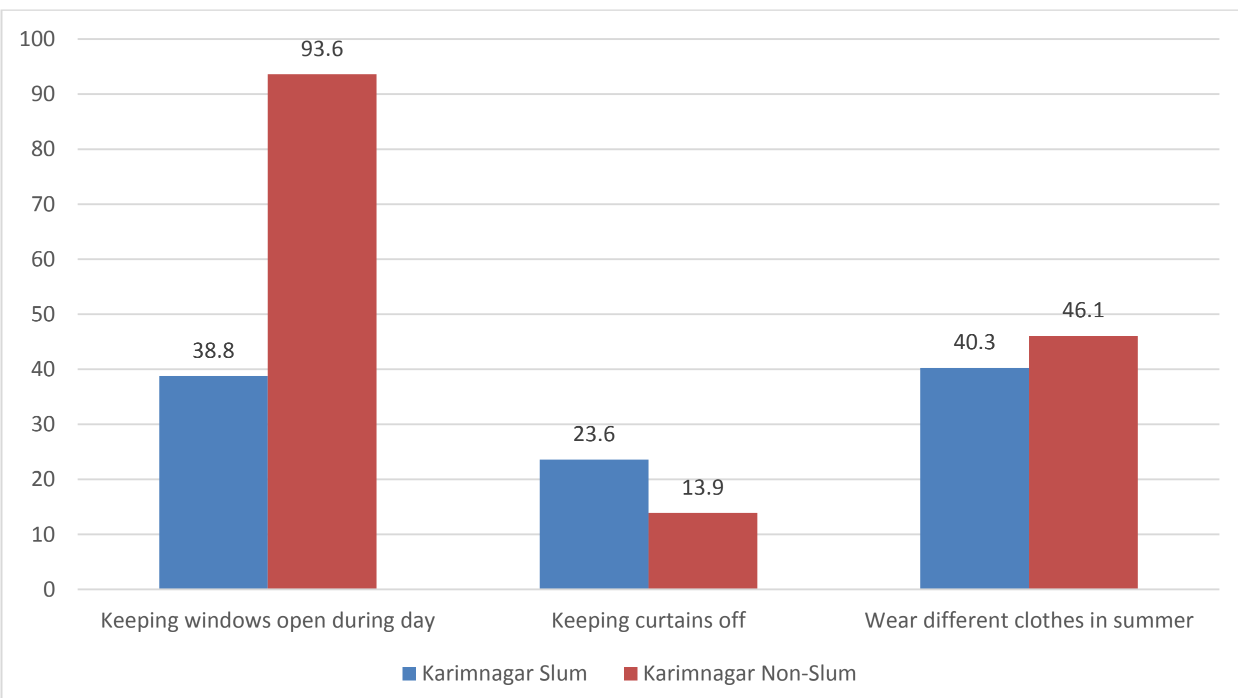

Figure 27: Summer Habits - Karimnagar

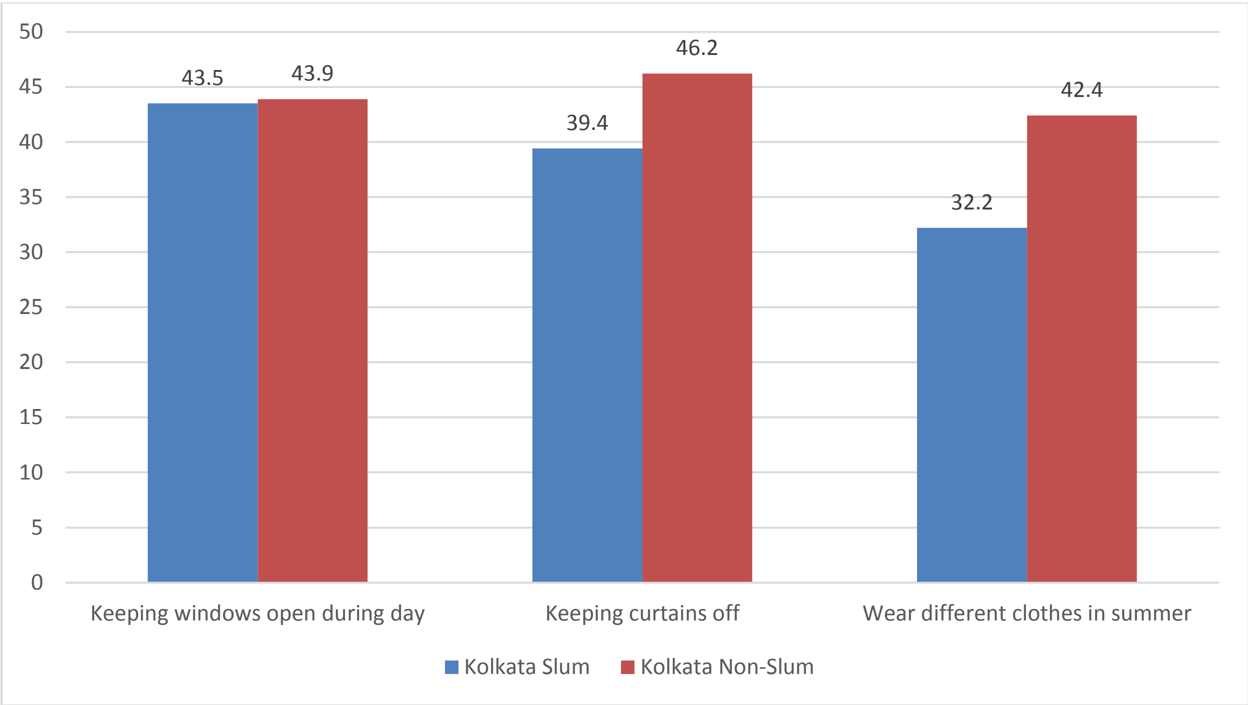

Figure 28: Summer Habits - Kolkata

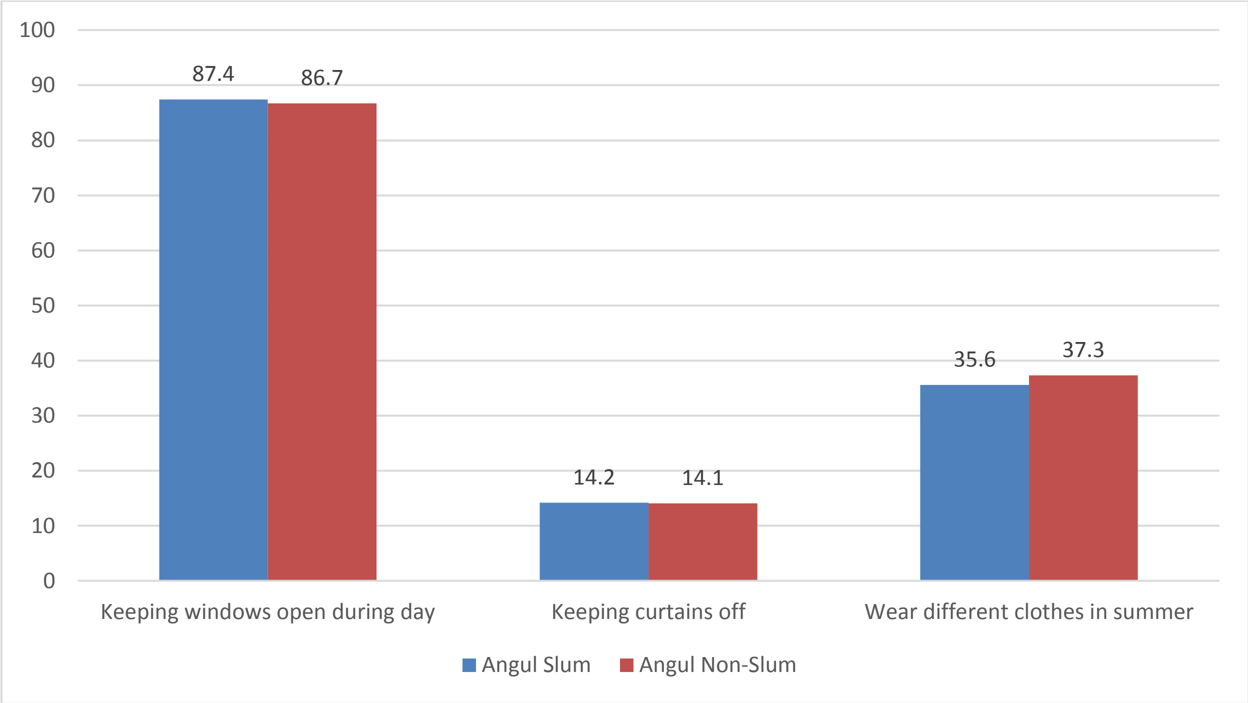

Figure 29: Summer Habits - Angul

Preferred Coping Measures

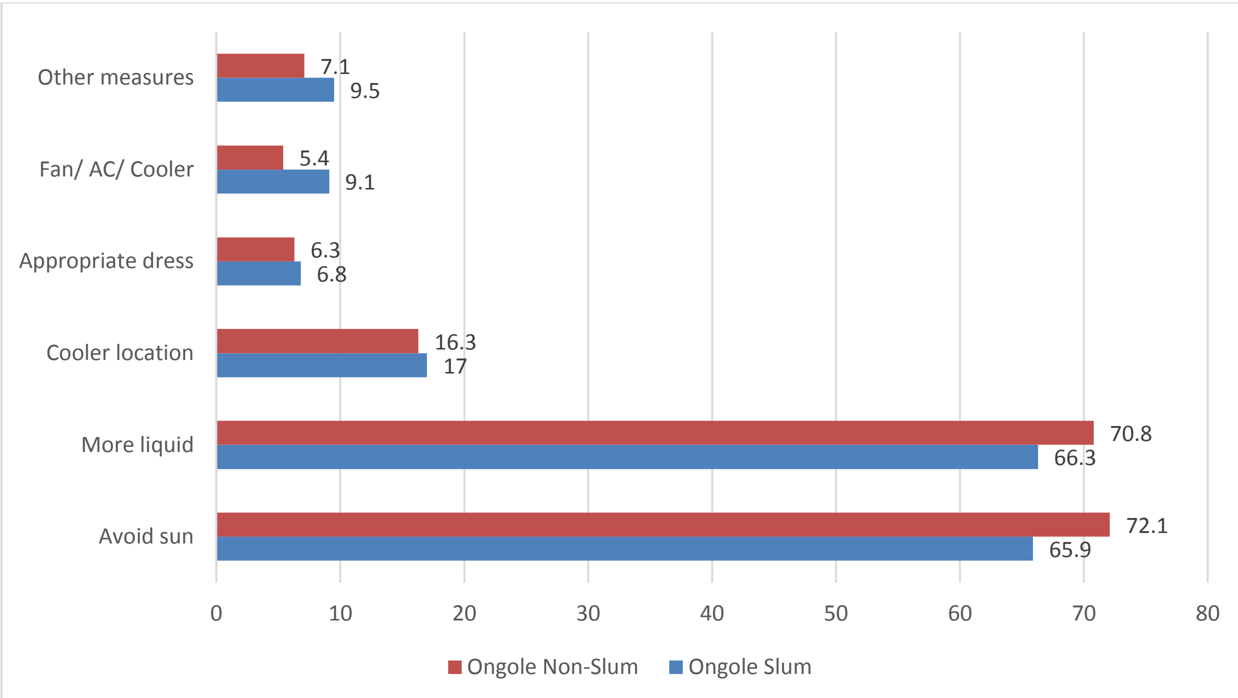

Figure 30: Preferred Coping Mechanism - Ongole

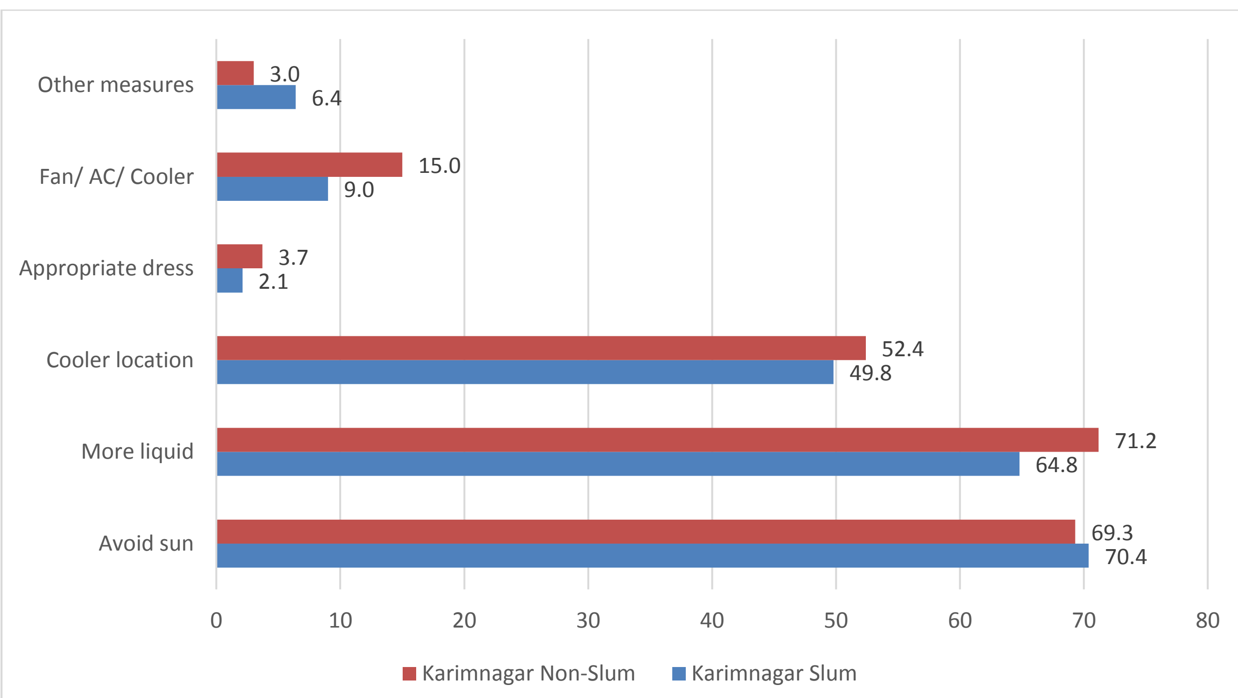

Figure 31: Preferred Coping Mechanism - Karimnagar

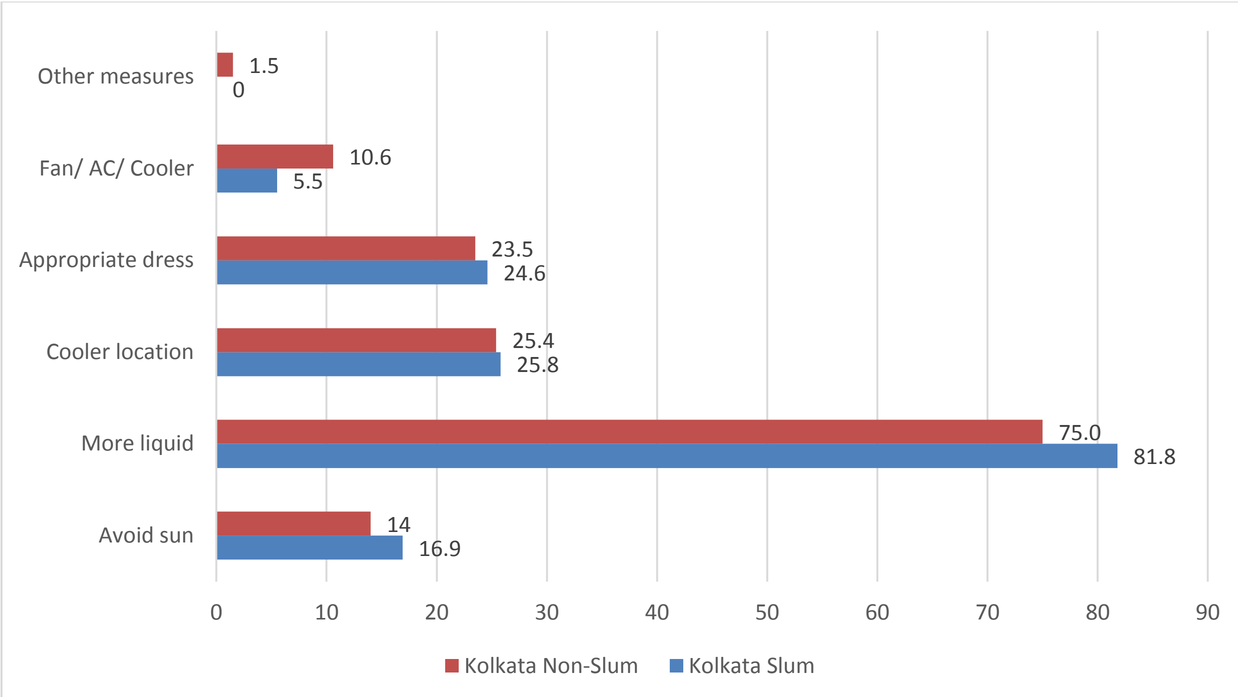

Figure 32: Preferred Coping Mechanism - Kolkata

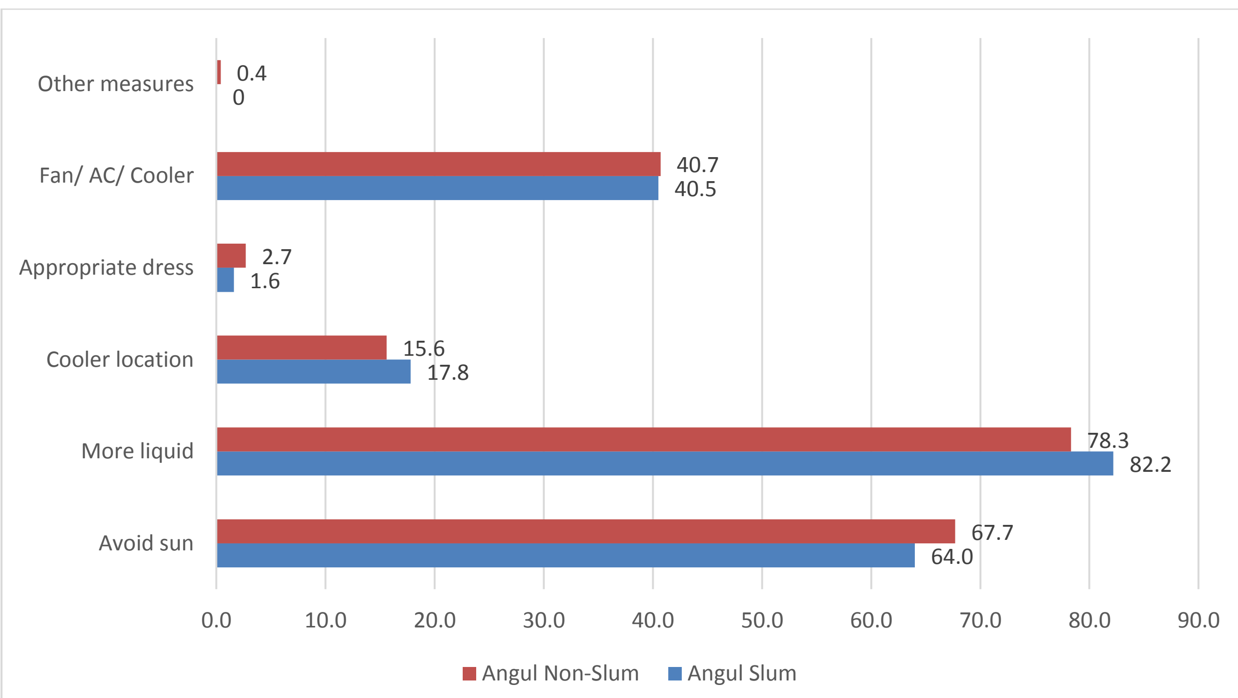

Figure 33: Preferred Coping Mechanism - Angul

Coping measures respondents are willing to avail

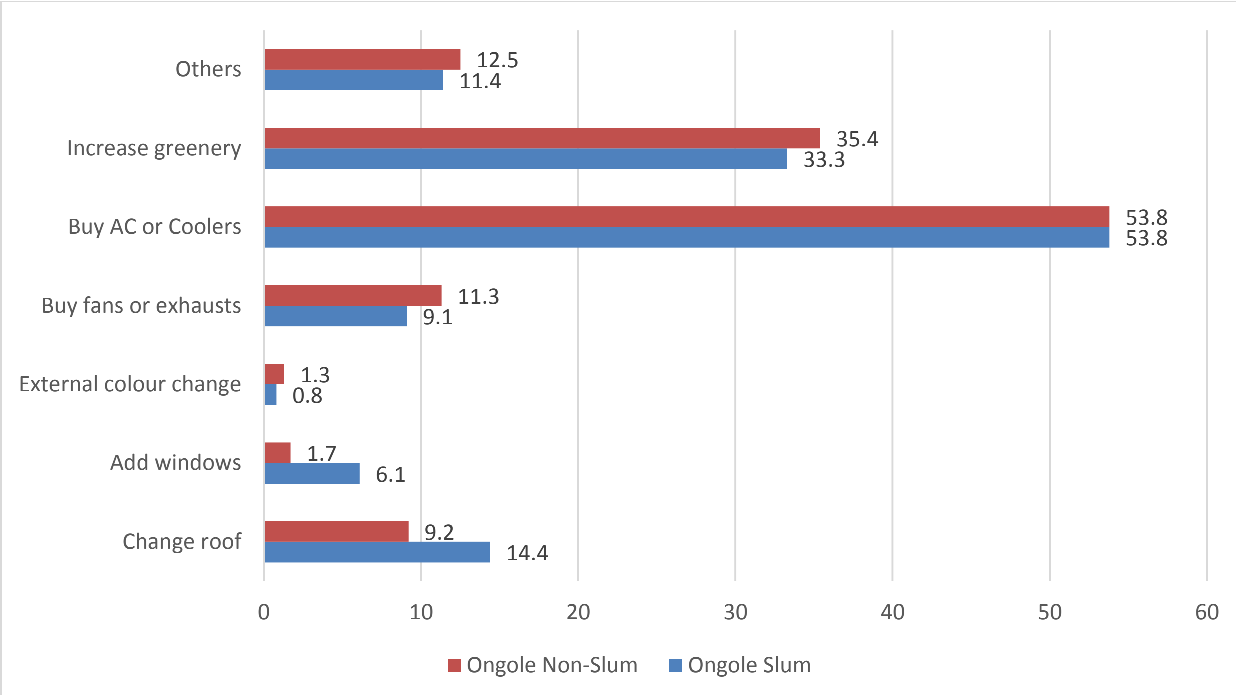

Figure 34: Measures respondents are willing to take - Ongole

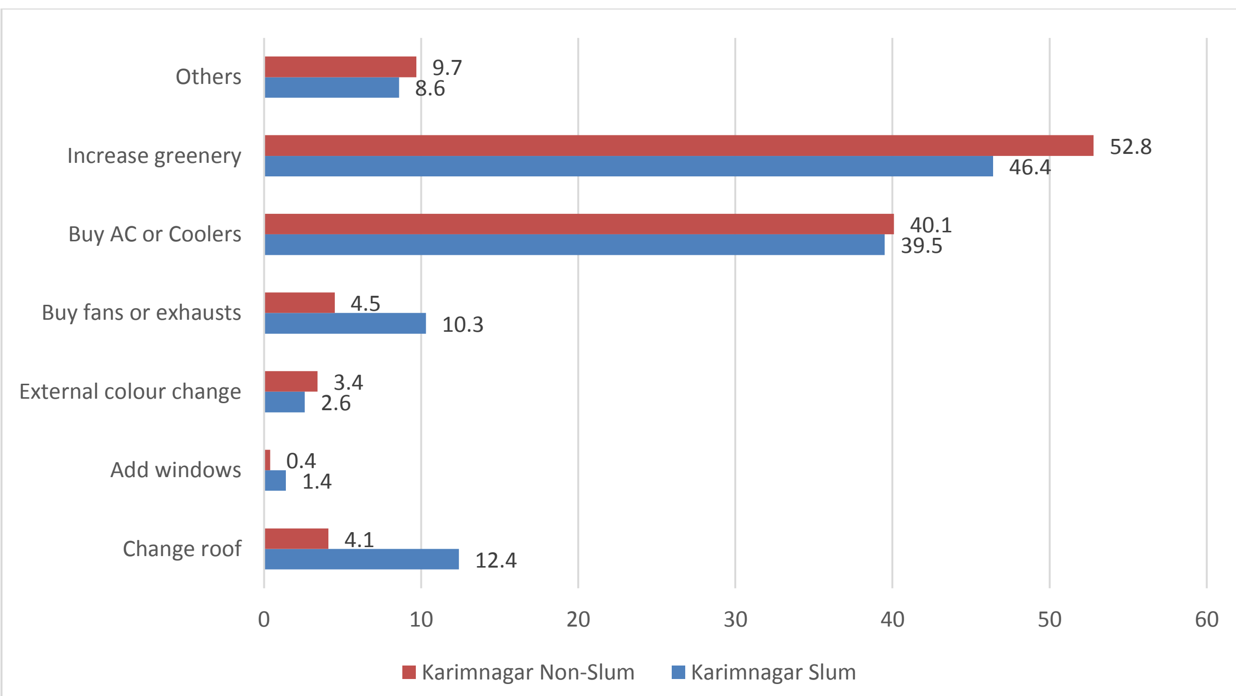

Figure 35: Measures respondents are willing to take - Karimnagar

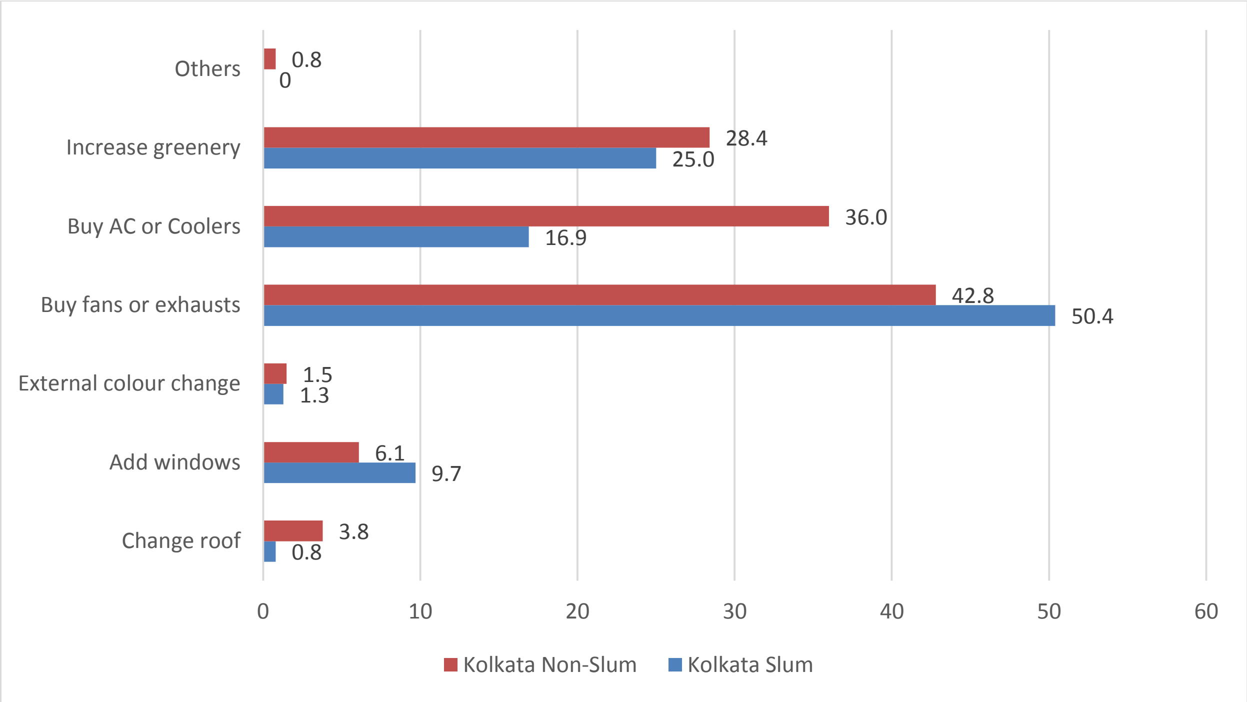

Figure 36: Measures respondents are willing to take - Kolkata

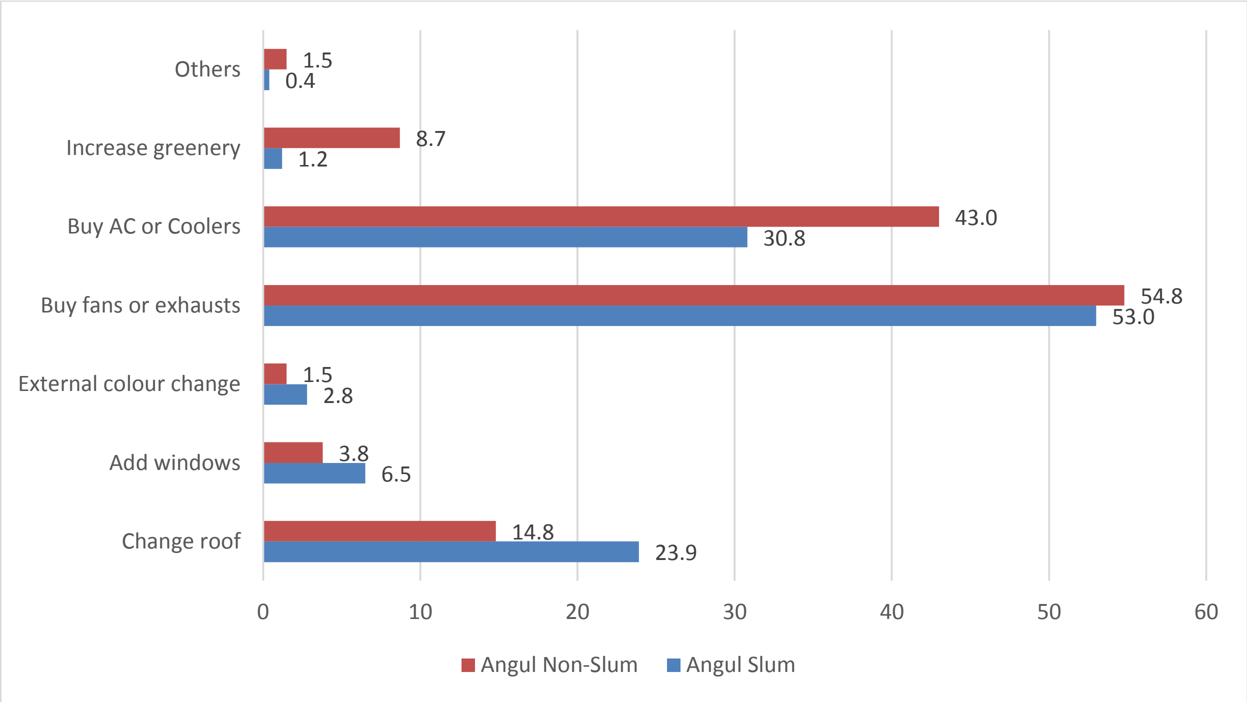

Figure 37: Measures respondents are willing to take - Angul

Measures to avoid sun exposure

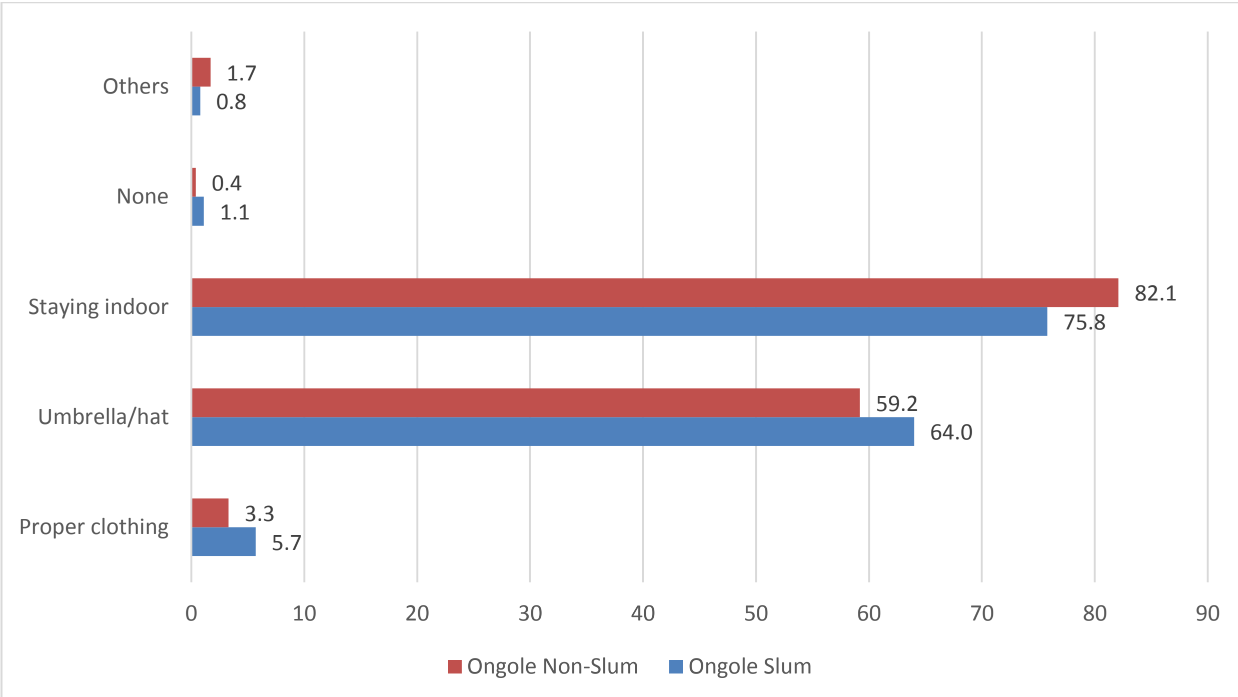

Figure 38: Coping Against Sun - Ongole

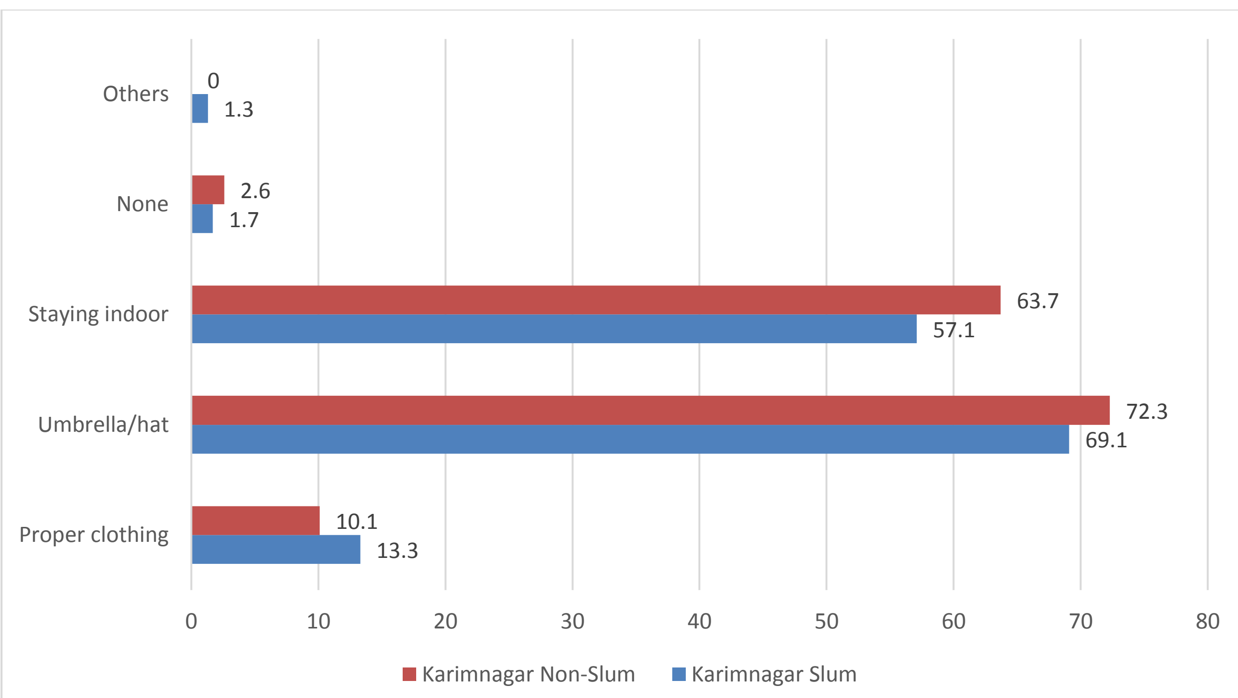

Figure 39: Coping Against Sun - Karimnagar

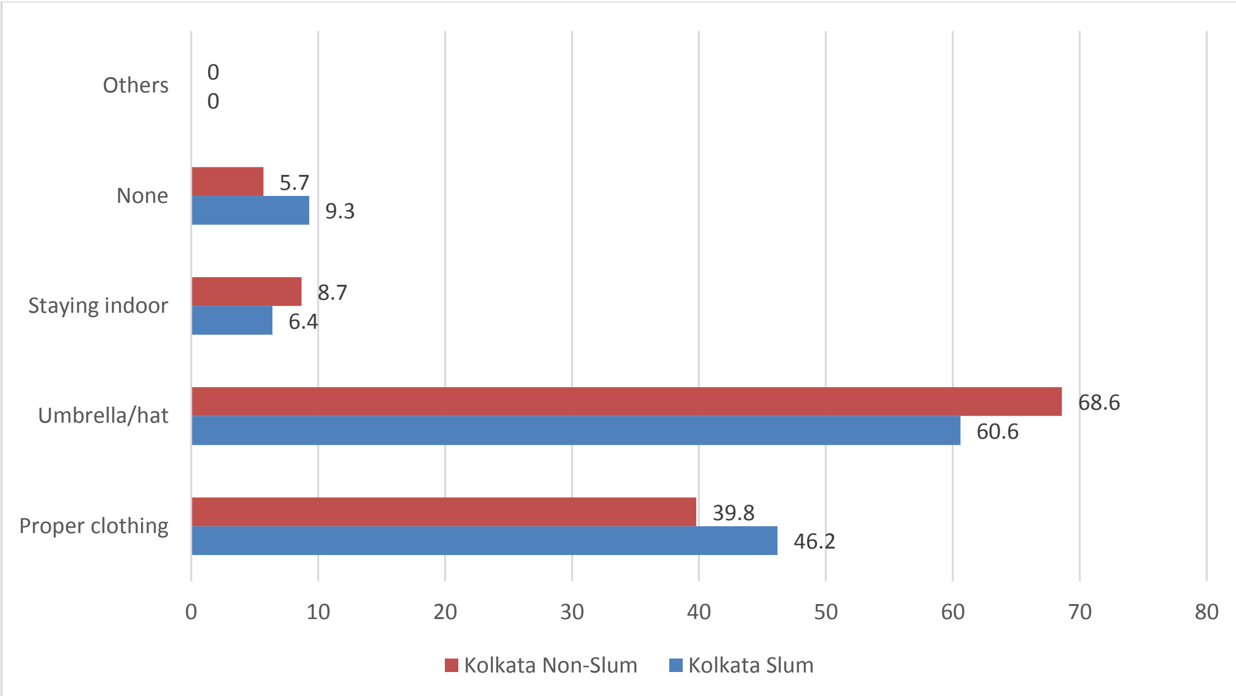

Figure 40: Coping Against Sun - Kolkata

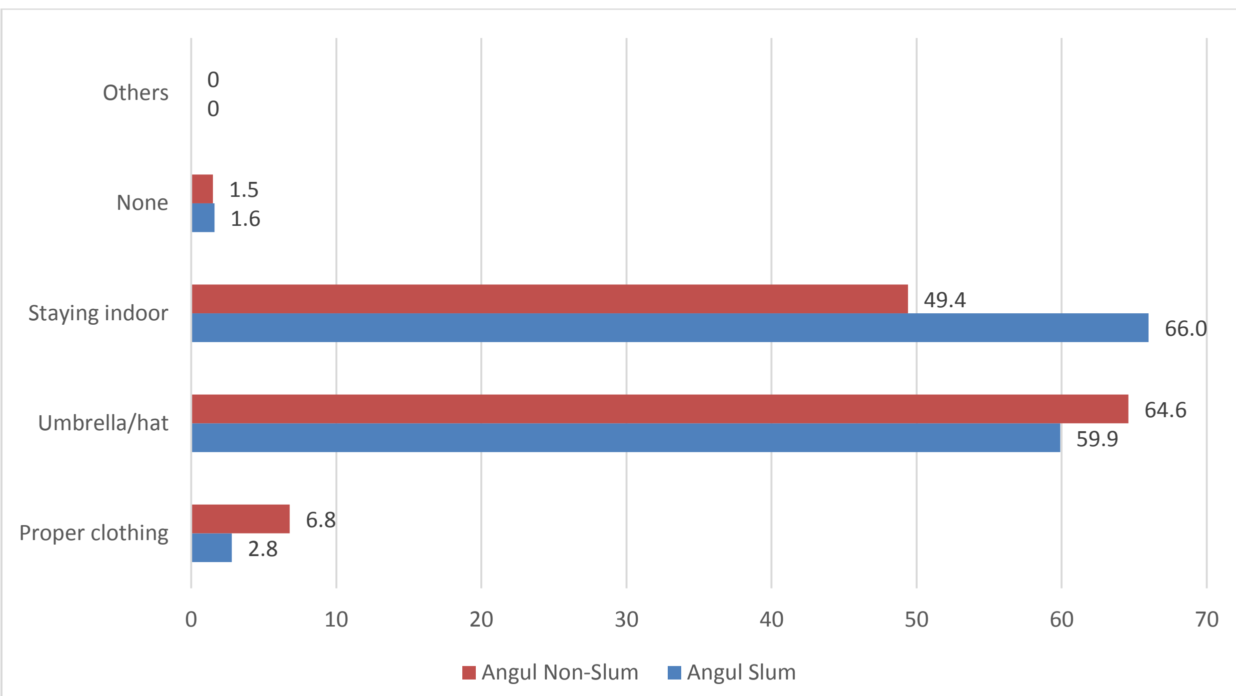

Figure 41: Coping Against Sun - Angul

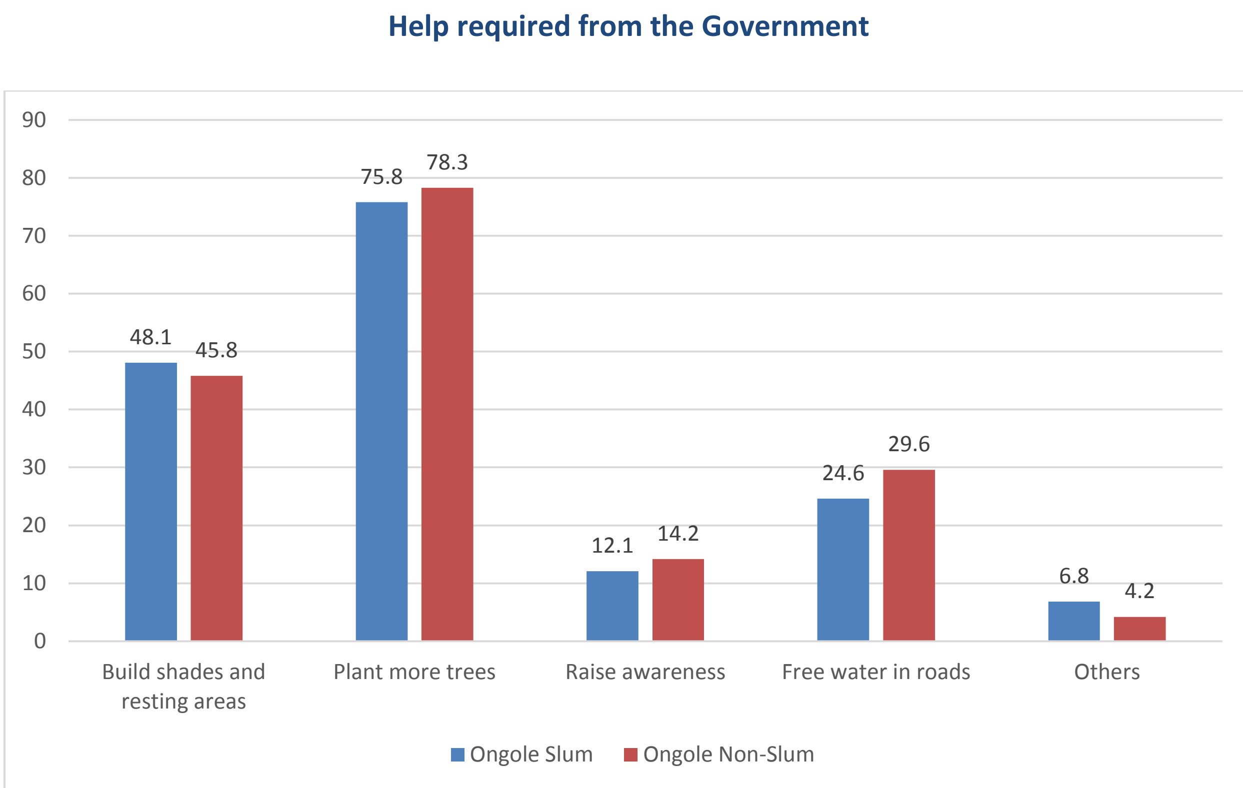

Figure 42: Help required from the Government - Ongole

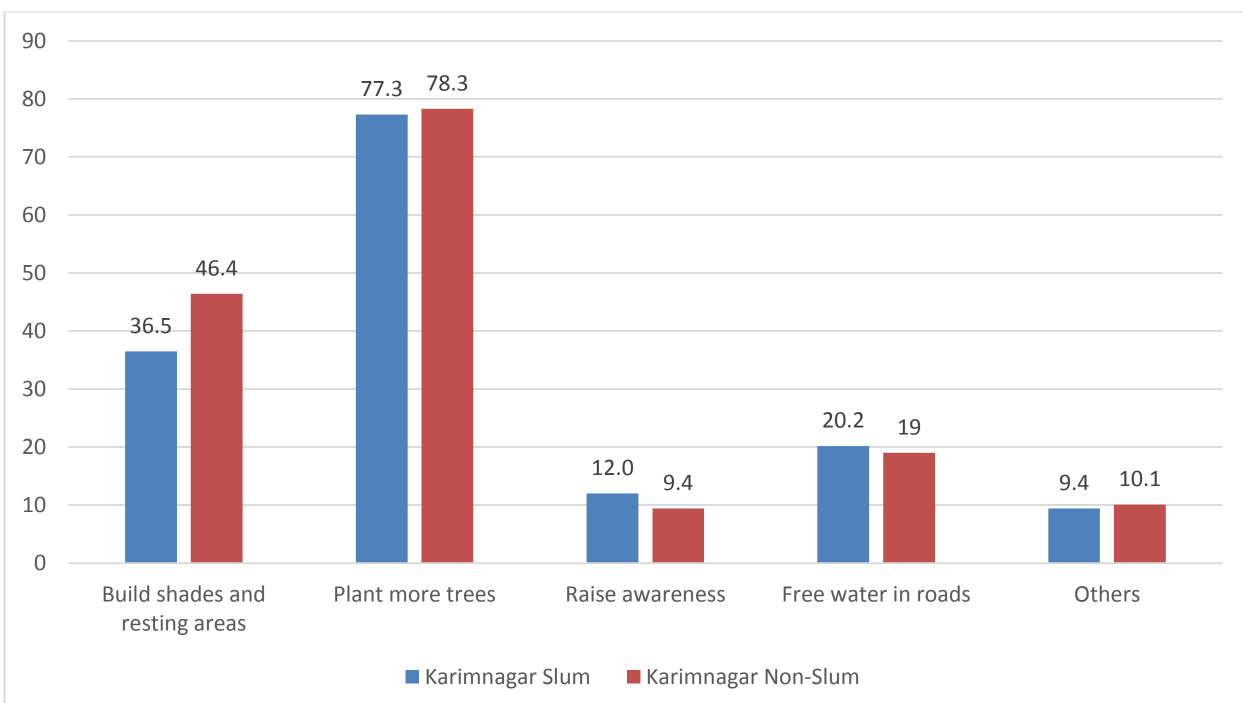

Figure 43: Help required from the Government - Karimnagar

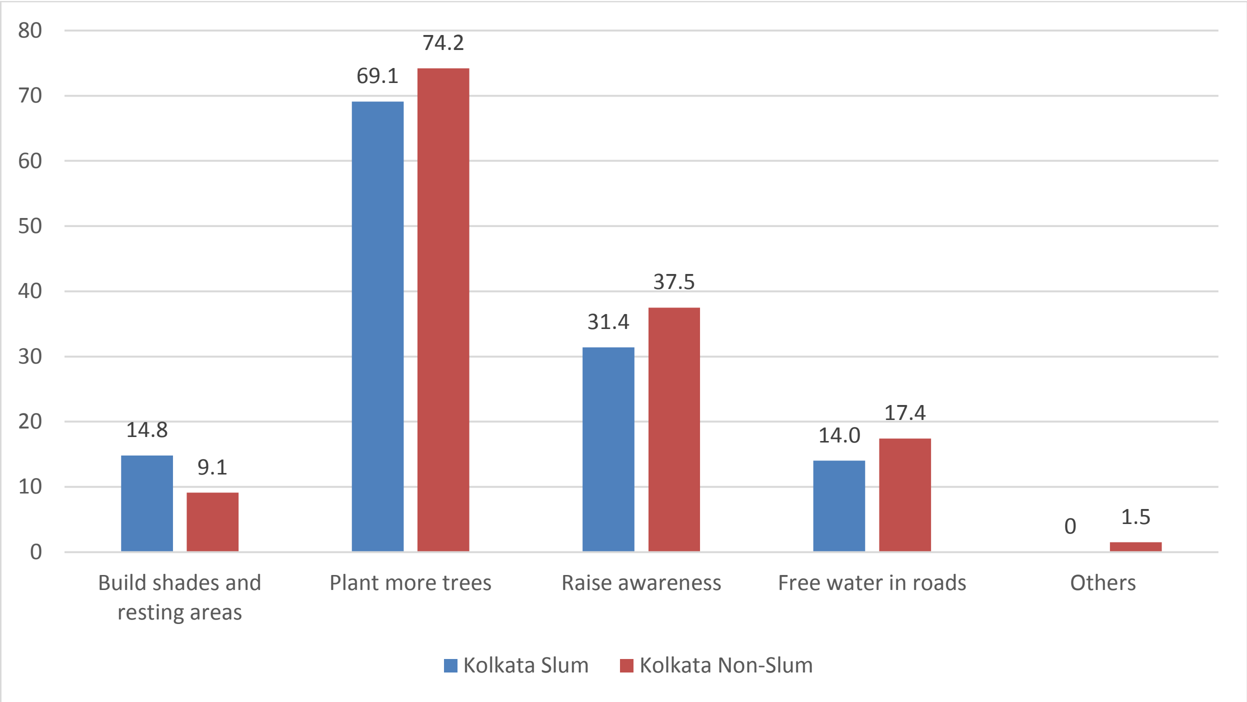

Figure 44: Help required from the Government - Kolkata

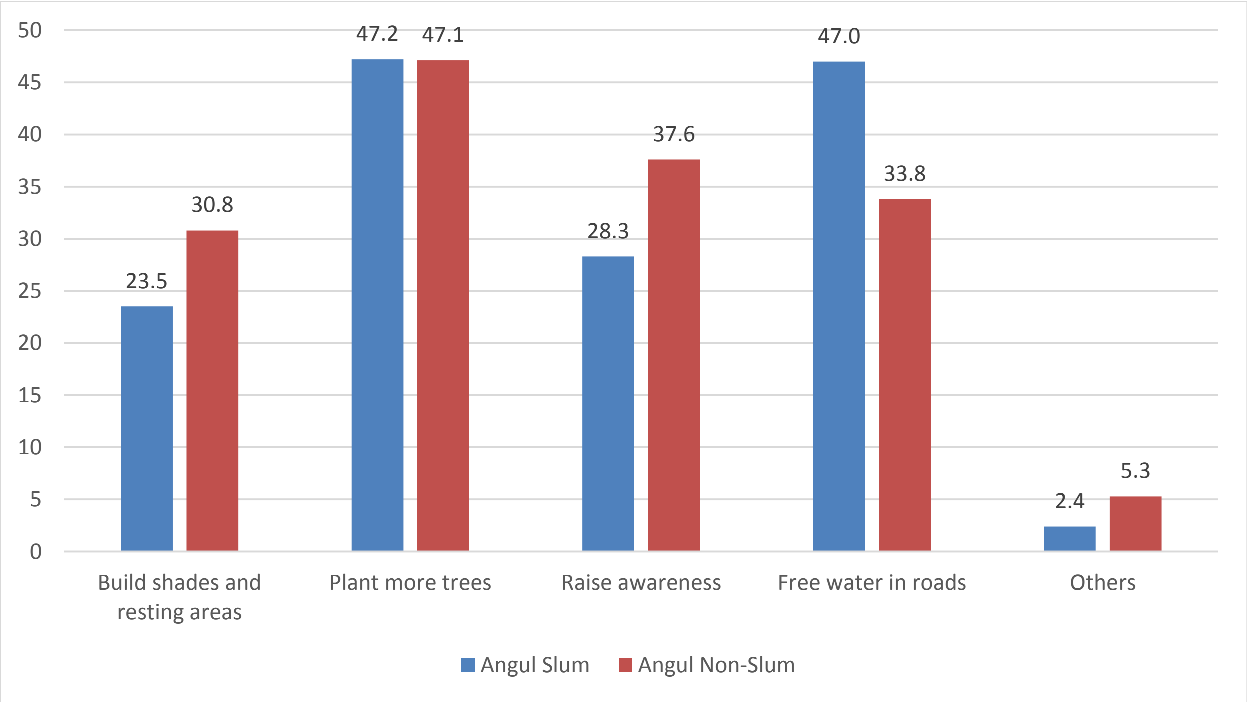

Figure 45: Help required from the Government - Angul

Vulnerability Index:

Household Characteristics and Descriptive Statistics

Tables 4-16 shows the descriptive statistics from the 4 surveyed cities. The population of Ongole has the highest mean age at 42.7 ± 14.8 while Angul had the lowest at 37.4 ± 13.0. Among the cities, Kolkata had a majority of Male respondents, while the other 3 had female majority among respondents. Majority of respondents across all the cities were married. The surveyed population of Kolkata had the highest mean household income, followed by Karimnagar and Ongole, while Angul had the lowest. The household expenditure trend corresponded with the household income. Karimnagar had the most number of households where there was an increase in average expenditure during summer, followed by Ongole, Angul and Kolkata with the least. Kolkata had a majority of graduate or higher qualified respondents, while Ongole had the most number of respondents who were illiterate.

On the exposure front, Kolkata had the most number of houses surrounded by tall buildings on either three or four sides (>52%) leading to a blockage in air-flow. Kolkata is followed by Angul, Ongole and Karimnagar in terms of households surrounded by tall buildings on 3 or 4 sides. Angul had the most number of households with roof made of asbestos or tin (~40%) followed by Ongole, Karimnagar and Kolkata. This leads to heat entrapment within the building. Kolkata had the most number of houses near industrial and traffic junctions, followed by Ongole, Karimnagar and Angul. Kolkata also had the highest mean hours of respondents being exposed to direct sunlight.

On the sensitivity to heat issue, all the cities had relatively similar number of respondents and family members who were suffering from Hypertension and Diabetes. Many households (~48%) faced water shortage during summer months in Ongole, followed by Angul, Karimnagar and Kolkata. In terms of power cut during summer, Angul had the most number of households reporting the same, followed by Ongole, Karimnagar and Kolkata. Angul also had the highest number of respondents who mentioned getting no help from neighbours during emergency, followed by Karimnagar, Ongole and Kolkata.

Describing adaptive capacity, Kolkata had most number of households either near a waterbody or vegetative patches, followed by Ongole, Angul and Karimnagar. More than 36% population in all the cities change the type of cloth they wear during extreme summer days to protect themselves from heat. A majority of respondents in Ongole, Karimnagar and Angul (~65-80%) reduce the time spent outside during summer months, while only 4.4% respondents do the same in Kolkata. All the four cities rely mostly on drinking lots of fluid, using umbrella/hats and using fans/ACs/coolers to protect themselves from extreme summer.

Using the data on all three dimensions (exposure, sensitivity, and adaptive capacity) for the sampled households, the HVI scores have been computed for all the four cities – Kolkata, Angul, Ongole, and Karimnagar. Distribution of households by HVI values across the four surveyed cities is presented in table 17.

Table 17: Household Vulnerability in Surveyed Cities (% age share)

Vulnerability	Kolkata			Angul			Ongole			Karimnagar		
	High	Low	Total	High	Low	Total	High	Low	Total	High	Low	Total
Overall HVI	336 (67.2)	164 (32.8)	500 (100)	375 (73.5)	135 (26.5)	510 (100)	331 (65.7)	173 (34.3)	504 (100)	332 (66.4)	168 (33.6)	500 (100)
Exposure	365 (73.0)	135 (27.0)	500 (100)	260 (51.0)	250 (49.0)	510 (100)	260 (51.6)	244 (48.4)	504 (100)	260 (52.0)	240 (48.0)	500 (100)
Sensitivity	386 (77.2)	114 (22.8)	500 (100)	476 (93.3)	34 (06.7)	510 (100)	344 (68.3)	160 (31.7)	504 (100)	361 (72.2)	139 (27.8)	500 (100)
Adaptive Capacity	193 (38.6)	307 (61.4)	500 (100)	173 (34.7)	333 (65.3)	510 (100)	289 (57.3)	215 (42.7)	504 (100)	249 (49.8)	251 (50.0)	500 (100)

Source: Authors' computations based on data from primary survey

Kolkata

In Kolkata, overall 67.2 percent of the sample households have high vulnerability to extreme heat whereas the rest 32.8 percent have low vulnerability. Maximum vulnerability is seen in sensitivity parameter wherein as many as 77.2 percent of the households are found to be highly vulnerable, followed by exposure (73.0 percent) and adaptive capacity (38.6 percent).

Angul

In Angul, overall 73.5 percent of the sample households have high vulnerability to extreme heat whereas the rest 26.5 percent have low vulnerability. Maximum vulnerability is seen in sensitivity parameter wherein as many as 93.3 percent of the households are found to be highly vulnerable, followed by exposure (51.0 percent) and adaptive capacity (34.7 percent).

Ongole

In Ongole, overall 65.7 percent of the sample households have high vulnerability to extreme heat whereas the rest 34.3 percent have low vulnerability. Maximum vulnerability is observed in sensitivity parameter wherein as many as 68.3 percent of the households are found to be highly vulnerable, followed by adaptive capacity (57.3 percent) and exposure (51.6 percent).

Karimnagar

In Karimnagar, overall 66.4 percent of the sample households have high vulnerability to extreme heat whereas the rest 33.6 percent have low vulnerability. Maximum vulnerability is observed in sensitivity parameter wherein as many as 72.2 percent of the households are found to be highly vulnerable, followed by exposure (52.0 percent) and adaptive capacity (49.8 percent).

Bivariate and Multi-variate analysis

Determinants of Households' Vulnerability to Extreme Heat through Bivariate and Multi-variate analysis in Karimnagar and Ongole

Table 18: Bivariate Analysis (Karimnagar)

	Marital Status						Change in Food Consumption		No. of Rooms					
HVI	Single	Unmarried	Married	Divorced	Widowed	Separated	No	Yes	01	02	03	04	05	06
Low	25	8	123	02	01	09	134	34	29	43	62	26	05	03
High	55	39	219	02	5	12	250	82	40	85	122	49	30	02
Total	80	47	342	04	06	21	384	116						
Pearson Chi-Square	Pearson $\chi^2(5) = 8.91$ Probability = 0.12						Pearson $\chi^2(1) = 1.25$ Probability = 0.26		Pearson $\chi^2(5) = 11.67$ Probability = 0.17					

	Suffocation inside house on extreme summer days		Feel enough energy during extreme summer days		Perceived most harmful effect of heat waves						
HVI	No	Yes	No	Yes	Heat fatigue	Heat rash	Heat cramps	Heat exhaustion	Heat syncope	Heat stroke	Others
Low	139	39	87	81	31	03	00	00	03	128	02
High	208	124	99	233	55	09	08	10	13	223	08
Total	337	163	186	314	86	12	08	10	16	351	10
Pearson Chi-Square	Pearson $\chi^2(1) = 4.99$ Probability = 0.04		Pearson $\chi^2(1) = 23.05$ Probability = 0.001		Pearson $\chi^2(1) = 14.61$ Probability = 0.17						

	Distance to Nearest PHC			Treatment done for any impact of Extreme Heat					Comorbid conditions in the Household Members	
HVI	Less than 1 km	Between 1 km and 5 km	More than 5 km	No treatment	First aid at home	Visit govt. facility	Visit private facility	others	No	Yes
Low	08	142	17	133	15	13	04	03	122	46
High	36	270	21	286	16	20	05	05	301	31
Total	44	412	38	419	31	33	09	08	423	77
Pearson Chi-Square	Pearson $\chi^2(1) = 7.71$ Probability = 0.08			Pearson $\chi^2(5) = 6.71$ Probability = 0.24					Pearson $\chi^2(1) = 27.87$ Probability = 0.001	

Table 19:Bivariate Analysis (Ongole)

	Marital Status						Change in Food Consumption		No. of Rooms					
HVI	Single	Unmarried	Married	Divorced	Widowed	Separated	No	Yes	01	02	03	04	05	06
Low	11	04	139	01	01	17	156	17	00	36	100	32	05	00

High	15	22	249	00	03	42	250	81	01	64	168	74	22	02
Total	26	26	388	01	04	59	406	98	01	100	268	106	27	02
Pearson Chi-Square	Pearson $\chi^2(1)$ = 8.1 Probability = 0.25						Pearson $\chi^2(1)$ = 15.5 Probability = 0.01		Pearson $\chi^2(5)$ = 6.5 Probability = 0.26					

	Suffocation inside house on extreme summer days		**Visited a doctor for heat related illness**		**Perceived change in temperature and humidity during last six months**		**Use of Coolers/ACs at Workplace**		**Sources of Water**		
HVI	No	Yes	No	Yes	No	Yes	No	Yes	00	01	02
Low	113	60	156	17	169	04	75	98	04	59	10
High	182	149	310	21	296	35	111	220	17	298	16
Total	295	209	466	38	465	39	186	318	21	457	26
Pearson Chi-Square	Pearson $\chi^2(1)$ = 4.99 Probability = 0.04		Pearson $\chi^2(1)$ = 1.98 Probability = 0.16		Pearson $\chi^2(1)$ = 8.86 Probability = 0.27		Pearson $\chi^2(1)$ = 4.71 Probability = 0.06		Pearson $\chi^2(1)$ = 2.41 Probability = 0.29		

	Distance to Nearest PHC			**Incidence of Mild Symptoms**		**Comorbid conditions in the Household Members**	
HVI	Less than 1 km	Between 1 km and 5 km	More than 5 km	No	Yes	No	Yes
Low	51	85	37	143	30	124	49
High	111	175	45	218	113	269	62
Total	162	260	82	361	143	393	111
Pearson Chi-Square	Pearson $\chi^2(1)$ = 5.13 Probability = 0.09			Pearson $\chi^2(1)$ = 15.78 Probability = 0.001		Pearson $\chi^2(1)$ = 6.09 Probability = 0.001	

Table 20: Results of Logistic Regression on Determinants of Household Vulnerability to Extreme Heat (Karimnagar)

Log likelihood = -275.2888				LR chi2(22) = 87.77 Prob > chi2 = 0.0000 Pseudo R2 = 0.1375	
Heat VI	Coef.	Std. Err.	Z	P>|z|	[95% conf. Interval]

Ms						
1	.9689408	.4776652	2.03	0.043	.0327342	1.905147
2	.1949088	.3029517	0.64	0.520	- .3988657	.7886833
3	-. 1478445	1.090442	-0.14	0.892	-2.285071	1.989382
4	1.961188	1.342679	1.46	0.144	-6704149	4.59279
5	.4515193	.5782981	0.78	0.435	-.6819242	1.584963
Avoid non-veg	.4628201	.2579232	1.79	0.073	-.0427001	.9683403
No. of rooms	.1864651	.100622	1.85	0.064	-.0107503	.3836806
suffocation	.7874184	.2648577	2.97	0.003	.2683069	1.30653
Energy present in summer	.6221527	.2281487	2.73	0.006	.1749895	1.069316
Distance from PHC						
<1km	-.6777319	.444391	-1.53	0.127	-1.548722	.1932583
1-5km	-1.11705	.5626204	-1.99	0.047	-2.219766	-0143344
>5km	-.6475992	1.350855	-0.48	0.632	-3.295226	2.000028
hhwt						
1	.0541113	.7423987	0.07	0.942	-1.400963	1.509186
4	1.879778	.687044	2.74	0.006	.5331965	3.226359
5	.0973579	.3079827	0.32	0.752	-5062771	.700993
6	.7694539	.9376232	0.82	0.412	-1.068254	2.607161
7	.92041	1.40084	0.66	0.511	-1.825186	3.666006
Type of treatment						
1	-1.007362	.4248581	-2.37	0.018	-1.840068	-1746553
2	-.1643372	.4352534	-0.38	0.706	-1.017418	.6887437
3	-1.243814	.8181653	-1.52	0.128	-2.847388	.3597608
5	-1.058769	1.119168	-0.95	0.344	-3.252298	1.134761
Comorbid	-1.157768	.2942651	-3.93	0.000	-1.734517	-5810192
_cons	-.0117434	.6833941	-0.02	0.986	-1.351171	1.327684

Table 21: Results of Logistic Regression on Determinants of Household Vulnerability to Extreme Heat (Ongole)

Logistic regression Log likelihood = -283.94074				Number of obs = 504 LR chi2 (15) = 80.43 Prob > chi2 = 0.0000 Pseudo R2 = 0.1241		
hvi	Coef.	Std. Err.	Z	P>|z|	[95% conf. Interval]	
ms						
1	1.196375	.7141082	1.68	0.094	-.2032512	2.596002
2	.4768488	.4503027	1.06	0.290	-.4057282	1.359426
4	1.643284	1.313246	1.25	0.211	-.9306315	4.217199
5	.9010634	.5480547	1.64	0.100	-.173104	1.975231
cfood	1.013866	.3163105	3.21	0.001	.3939087	1.633823
room	.3608066	.1371769	2.63	0.009	.0919448	.6296684
Suffo	.5075574	.217961	2.33	0.020	.0803618	.9347531
Dphc						
1	-.0537435	.2351479	-0.23	0.819	-.514625	.4071379
2	-.4918666	.3090669	-1.59	0.112	-1.097627	.1138933
Vdoc	-.7708101	.3823762	-2.02	0.044	-1.520254	-.0213666
1. pct	1.11599	.5607964	1.99	0.047	.0168496	2.215131
Acwp	.5887171	.2135814	2.76	0.006	.1701053	1.007329
Comor	-.8136018	.2534283	-3.21	0.001	-1.310312	-.3168914
SOW	-.917239	.3781343	-2.43	0.015	-1.658369	-.1761093
Mild	.922381	.2563666	3.60	0.000	.4199117	1.42485
_cons	- 373354	.6294886	-0.59	0.553	-1.607129	.8604209

Tables 18 - 21 depicts the bivariate and multi-variate analysis done for Karimnagar and Kolkata. It is essential to present the results before going in details of Angul and Kolkata, as bivariate and Multi-variate analysis were carried out for Ongole and Karimnagar, but they did not yield robust results. The pseudo-R2 values turned out to be extremely low while higher order tests further confirmed the models suffering from goodness-of-fit. Majority of results concerning non-parametric tests (for bivariate analysis) did not turn up significant even at 10 percent significance level for Karimnagar and Ongole. Therefore, the two cities have been excluded from further analysis and discussion on multi-variate and bi-variate statistics.

Determinants of Households' Vulnerability to Extreme Heat through bivariate and multi-variate analysis in Angul

The cross-tabulation of HVI with the qualitative independent variables taken in the model is depicted in table 22. For the quantitative independent variables used in the model, a pairwise correlation is presented in table 23. As may be seen from both tables, each of the independent variables holds a statistically significant relationship with the outcome variable.

It is observed that the share of females witnessing high heat vulnerability (78.2 percent) is substantially greater than the share of males who are experiencing high heat vulnerability (64.9 percent). It is also credibly evident that as distance of the nearest PHC from residents becomes greater, a larger share of the households suffers from high heat vulnerability. For instance, 59.2 percent of the households who travel between 1 and 5 kilometers for reaching the nearest PHC experience high heat vulnerability. This figure is as high as 92.6 percent for those who are made to commute more than 5 kilometers. Similarly, as households' perception towards the extent of changes in the ambient temperature and humidity at home increases, a larger share of households are found to be suffering from high heat vulnerability. Moreover, a considerable share of households (94.4 percent) who use air-conditioners/air-coolers at workplace is seen to have low heat vulnerability. On the contrary, a large share of households (87.9 percent) who do not use air-conditioners/air-coolers at workplace is seen to have high heat vulnerability. Further, shares of households with presence of mild symptoms or comorbid conditions are seen to have low vulnerability to extreme heat as compared to those without any such medical conditions.

Table 22: Cross-Tabulation of HVI with Qualitative Independent Variables (Angul City)

	HVI	Low	High	Total	Pearson Chi-Square
GENDER	Male	61 (35.1)	113 (64.9)	174 (100)	Pearson χ2(1) = 10.01***
	Female	74 (22.0)	262 (78.0)	336 (100)	
DISTANCE	Less than 1 km	40 (44.4)	50 (55.6)	90 (100)	Pearson χ2(2) = 77.89***
	Between 1 km and 5 km	78 (40.8)	113 (59.2)	191 (100)	
	More than 5 km	17 (07.4)	212 (92.6)	229 (100)	
TEMPERATURE	Slightly increased	111 (29.5)	265 (70.5)	376 (100)	Pearson χ2(1) = 6.84***
	Drastically increased	24 (17.9)	110 (82.1)	134 (100)	
COOLING	Using ACs/Coolers at workplace	84 (94.4)	5 (5.6)	89 (100)	Pearson χ2(1) = 255.47***
	Not using ACs/Coolers at workplace	51 (12.1)	370 (87.9)	421 (100)	
SYMPTOMS	Yes	127 (30.0)	296 (70.0)	423 (100)	Pearson χ2(1) = 16.08***
	No	08 (09.2)	79 (90.8)	87 (100)	
COMORBID	Yes	42 (45.2)	51 (54.8)	93 (100)	Pearson χ2(1) = 20.41***
	No	93 (22.3)	324 (77.7)	417 (100)	

Note: Figures in the parenthesis refer to percentage share in total.
*Significant at 10 percent; **Significant at 5 percent; ***Significant at 1 percent
Source: Primary Survey

Table 23: Pairwise Correlation of HVI with Quantitative Independent Variables (Angul City)

	HVI	SIZE	ROOM
HVI	1.00		
SIZE	–0.11**	1.00	
ROOM	–0.23***	0.47***	1.00

Note: *Significant at 10 percent;
**Significant at 5 percent;
***Significant at 1 percent
Source: Primary Survey

Summary statistics of the variables used in the regression model are displayed in table 24. The regression result of the estimated Logit model is presented in table 25.

Table 24: Summary Statistics of Variables used for Regression Analysis (Angul City)

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
VULNERABILITY	510	0.73	0.44	0	1
GENDER	510	0.66	0.47	0	1
DISTANCE-2 (>1 km and <5 km)	510	0.37	0.48	0	1
DISTANCE-3 (5 km and more)		0.45	0.50	0	1
SIZE	510	4.26	1.76	1	15
ROOM	510	1.89	0.93	1	6
TEMPERATURE	510	0.26	0.44	0	1
COOLING	510	0.17	0.38	0	1
SYMPTOMS	510	0.83	0.38	0	1
COMORBID	510	0.18	0.39	0	1

Table 25: Results of Logistic Regression on Determinants of Household Vulnerability to Extreme Heat (Angul City)

Variable		Coefficient	Robust SE	z- Statistic
GENDER		1.155***	0.351	3.29
DISTANCE	>1 km and <5 km	– 0.311	0.405	– 0.77
Base: less than 1 km	5 km and more	1.650***	0.513	3.21
SIZE		0.154	0.105	1.46
ROOM		– 0.345*	0.198	– 1.75
TEMPERATURE		0.881**	0.433	2.03
COOLING		– 5.339***	0.586	– 9.11
SYMPTOMS		– 1.372**	0.677	– 2.03
COMORBID		– 1.298***	0.384	– 3.39
Likelihood Ratio χ^2 (9)		326.8***		
Log Pseudo Likelihood		– 131.34		
Pseudo R^2		0.55		
Pearson χ^2 (285)$^\beta$		296.76 (0.30)$^\alpha$		
Hosmer – Lemeshow χ^2 (8)$^\beta$		5.97 (0.65)$^\alpha$		
Number of Observations		510		

Note: *Significant at 10 percent; **Significant at 5 percent; ***Significant at 1 percent

$^\beta$Degrees of freedom for the χ^2 statistic; $^\alpha$indicates the level of significance

Source: Primary Survey

The value of the likelihood ratio [χ^2 (9) = 326.8] with a p-value of 0.001 shows that the model, as a whole, fits significantly. Further, value of the Pseudo R^2 is fairly high indicating goodness of fit for the estimated model. The test statistic of Pearson's χ^2 tests and Hosmer – Lemeshow χ^2 test suggest that the estimated Logit model does not suffer from the problem of goodness-of-fit. The problem of heteroscedasticity is controlled by using White's heteroscedasticity corrected robust standard errors.

In the Logit model, the coefficients of GENDER, DISTANCE (5 km and more), ROOM, TEMPERATURE, COOLING, SYMPTOMS, and COMORBID are found to be statistically significant. While the coefficients of GENDER, DISTANCE (5 km and more), and TEMPERATURE are positive, they are negative for ROOM, COOLING, SYMPTOMS, and COMORBID. It means that the female respondents have higher vulnerability to extreme heat. Heat vulnerability is also higher for households who reside more than 5 km away from the nearest primary healthcare centre (PHC) as compared to those who stay within the radius of 1 km. Further, the households who perceive a drastic increase in temperature and humidity in the last few years have higher vulnerability to extreme heat.

On the other hand, vulnerability to extreme heat is lower for households who stay in houses with a greater number of rooms or use air-coolers / air-conditioners at workplace. It is also lower for people who have experienced mild symptoms of high ambient heat (such as headache, dizziness, weakness and muscle pain) during the summers. Vulnerability to extreme heat is also lower for households which has members with comorbid conditions, such as diabetes and hypertension.

However, the coefficients of SIZE and DISTANCE (>1 km and <5 km) are not statistically significant. It means that households' vulnerability to extreme heat does not differ significantly depending upon their household size or if the distance their house from the nearest PHC is within 1 to 5 km.

Determinants of Households' Vulnerability to Extreme Heat through bivariate and multi-variate analysis in Kolkata

The cross-tabulation of HVI with the qualitative independent variables taken in the model is depicted in table 26. For the quantitative independent variables used in the model, a pairwise correlation is presented in table 27. As may be seen from both tables, each of the independent variables holds a statistically significant relationship with the outcome variable.

Share of respondents witnessing high vulnerability is substantially higher for those working as clerks (83.0 percent) followed by those respondents who are engaged in unskilled (68.3 percent), skilled/semi-skilled (65.9%), professionals/semi-professionals (65.9 percent), and self-employed/business (59.3 percent) activities. On the contrary, higher of share of respondents working in agriculture and allied sector witness low vulnerability to extreme heat. Further, heat vulnerability is also more for a large share of respondents who are unemployed. Interestingly, it is observed that as the distance between place of stay and nearest PHC increase, a larger share of household experiences lower vulnerability. Further, shares of households with presence of mild symptoms or comorbid conditions are seen to have low vulnerability to extreme heat as compared to those who are without these medical conditions. A larger share of households who predominantly sleep on mattress floor (80.0 percent) have high vulnerability to extreme heat, followed by those who sleep on bed (71.7 percent). On the contrary, majority of households who sleep on bare floor (55.3 percent) experience low vulnerability to extreme heat. Moreover, households that have avoided the intake of non-veg food or reduced the quantity of food consumption during summers face low vulnerability to extreme heat as compared to those who did not.

Table 26: Cross-Tabulation of HVI with Qualitative Independent Variables (Kolkata City)

	HVI	Low	High	Total	Pearson Chi-Square
OCCUPATION	Professional/Semi-professional	30 (34.1)	58 (65.9)	88 (100)	Pearson χ2(6) = 13.04**
	Clerical	08 (17.0)	39 (83.0)	47 (100)	
	Skilled/Semi-skilled	31 (34.1)	60 (65.9)	91 (100)	
	Unskilled	20 (31.7)	43 (68.3)	63 (100)	
	Unemployed	26 (27.4)	69 (72.6)	95 (100)	
	Self-employed/Business	44 (40.7)	64 (59.3)	108 (100)	
	Agriculture and allied	05 (62.5)	03 (37.5)	08 (100)	
DISTANCE	Less than 1 km	29 (22.3)	101 (77.7)	130 (100)	Pearson χ2(2) = 44.18***
	Between 1 km and 5 km	50 (23.8)	160 (76.2)	210 (100)	
	More than 5 km	85 (53.1)	75 (46.9)	160 (100)	
SYMPTOMS	Yes	72 (42.9)	96 (57.1)	168 (100)	Pearson χ2(1) = 11.61***
	No	92 (27.7)	240 (72.3)	332 (100)	
COMORBID	Yes	47 (43.5)	61 (56.5)	108 (100)	Pearson χ2(1) = 07.18***
	No	117 (29.8)	275 (70.2)	392 (100)	
SLEEPING	Bed	116 (28.3)	294 (71.7)	410 (100)	Pearson χ2(2) = 23.66***
	Bare Floor	47 (55.3)	38 (44.7)	85 (100)	
	Mattress Floor	1 (20)	4 (80)	5 (100)	
NON-VEG	Yes	77 (42.3)	105 (57.7)	182 (100)	Pearson χ2(1) = 11.74***
	No	87 (27.4)	231 (72.6)	318 (100)	
FOOD	Yes	46 (36.8)	79 (63.2)	125 (100)	Pearson χ2(1) = 7.21*
	No	118 (31.5)	257 (68.5)	375 (100)	

Note: Figures in the parenthesis refer to percentage share in total.
*Significant at 10 percent; **Significant at 5 percent; ***Significant at 1 percent
Source: Primary Survey

Table 27: Pairwise Correlation of HVI with Quantitative Independent Variables (Kolkata City)

	HVI	INCOME	ROOM	WATER
HVI	1.00			
INCOME	0.14***	1.00		
ROOM	0.11*	0.34***	1.00	
WATER	–0.20***	0.04	–0.05	1.00

Note: *Significant at 10 percent;

**Significant at 5 percent; ***Significant at 1 percent

Source: Primary Survey

Summary statistics of the variables used in the regression model are displayed in table 28.

The regression result of the estimated Logit model is presented in table 29.

Table 28: Summary Statistics of Variables used for Regression Analysis (Kolkata City)

Variable		**Obsn.**	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
VULNERABILITY		500	0.672	0.470	0	1
OCCUPATION *Base:* Professional / Semi-Professional	Clerical	500	0.094	0.292	0	1
	Skilled/semi-skilled	500	0.182	0.386	0	1
	Unskilled	500	0.126	0.332	0	1
	Unemployed	500	0.190	0.393	0	1
	Self-employed / Business	500	0.216	0.412	0	1
	Agriculture & allied	500	0.016	0.126	0	1
DISTANCE *Base: less than 1 km*	>1 km and <5 km	500	0.420	0.494	0	1
	5 km and more	500	0.320	0.467	0	1
INCOME		500	9.869	0.875	7	12
ROOM		500	2.328	1.155	1	8
WATER		500	1.160	0.612	0	3
SYMPTOMS		500	0.336	0.473	0	1
COMORBID		500	0.216	0.412	0	1
SLEEPING *Base: Bed*	Bare Floor	500	0.170	0.376	0	1
	Mattress Floor	500	0.010	0.100	0	1
NONVEG		500	0.364	0.482	0	1
FOOD		500	0.250	0.433	0	1

Table 29: Results of Logistic Regression on Determinants of Household Vulnerability to Extreme Heat (Kolkata City)

Variable		Coefficient	Robust SE	z- Statistic
OCCUPATION *Base:* Professional / Semi-Professional	Clerical	0.343	0.518	0.66
	Skilled/semi-skilled	0.195	0.386	0.51
	Unskilled	0.580	0.447	1.30
	Unemployed	0.889**	0.389	2.28
	Self-employed / Business	– 0.285	0.369	– 0.77
	Agriculture & allied	– 1.635**	0.818	– 2.00
DISTANCE *Base: less than 1 km*	>1 km and <5 km	– 0.248	0.294	– 0.84
	5 km and more	– 1.455***	0.312	– 4.66
INCOME		0.532***	0.152	3.49
ROOM		– 0.231**	0.103	– 2.22
WATER		– 0.431**	0.188	– 2.28
SYMPTOMS		– 0.702***	0.257	– 2.73
COMORBID		– 1.075***	0.264	– 4.06
SLEEPING *Base: Bed*	Bare Floor	– 1.229***	0.311	– 3.94
	Mattress Floor	0.997	1.366	0.73
NONVEG		– 0.481*	0.268	– 1.80
FOOD		0.387	0.283	1.37
Likelihood Ratio χ^2 (17)		123.2***		
Log Pseudo Likelihood		– 254.8		
Pseudo R^2		0.195		
Pearson χ^2 $(455)^\beta$		463.9 $(0.37)^\alpha$		
Hosmer – Lemeshow χ^2 $(8)^\beta$		8.8 $(0.36)^\alpha$		
Number of Observations		500		

Note: *Significant at 10 percent; **Significant at 5 percent; ***Significant at 1 percent

$^\beta$Degrees of freedom for the χ^2 statistic; $^\alpha$indicates the level of significance

Source: Primary Survey

The value of the likelihood ratio [χ^2 (17) = 123.2] with a p-value of 0.001 shows that the model, as a whole, fits significantly. Further, value of the Pseudo R^2 is 0.195 indicating goodness of fit for the estimated model. The test statistic of Pearson's χ^2 tests and Hosmer – Lemeshow

χ^2 test suggest that the estimated Logit model does not suffer from the problem of goodness-of-fit. The problem of heteroscedasticity is controlled by using White's heteroscedasticity corrected robust standard errors.

In the Logit model, the coefficients of OCCUPATION (unemployed, agriculture & allied), DISTANCE (5 km and more), INCOME, ROOM, WATER, SYMPTOMS, COMORBID, SLEEPING (bare floor), and NONVEG are found to be statistically significant.

While the coefficients of OCCUPATION (unemployed) and INCOME are positive, they are negative for OCCUPATION (agriculture & allied), DISTANCE (5 km and more), ROOM, WATER, SYMPTOMS, COMORBID, SLEEPING (bare floor), and NONVEG. It means that as compared to professional and semi-professional workers, heat vulnerability is more for those who are unemployed. Interestingly, heat vulnerability is also higher for respondents with higher average income during summer months.

On the other hand, vulnerability to extreme heat is lower for respondents involved in agriculture and allied activities as compared to those working as professionals or semi-professionals. Unlike what is observed for Angul city, heat vulnerability is lower for respondents who reside more than 5 km away from the nearest PHC as compared to those who stay within a radius of 1 km. Vulnerability to extreme heat is also lower for respondents who stay in homes with a greater number of rooms or access to more sources of water. In line with what is seen in case of Angul, heat vulnerability lower for respondents with mild symptoms of high ambient heat during the summers or comorbid conditions such as diabetes and hypertension. While it is true that heat conditions can alter human behaviour, subtle behavioural changes in human can also dampen the adverse impacts of heat conditions. The results show that respondents who sleep on bare floor (as compared to bed) during hot nights or those who avoid consumption of non-vegetarian food during hot summers are more likely to have lower heat vulnerability.

However, the coefficients of FOOD, DISTANCE (>1 km and <5 km) and OCCUPATION (clerical, skilled/semi-skilled, unskilled, self-employed / business) are not statistically significant. It means that respondents' vulnerability to extreme heat does not differ significantly depending upon their changes in food consumption quantity or if the distance their house from the nearest PHC is within 1 to 5 km. Heat vulnerability also does not significantly differ for respondents depending upon where they work as clerks or skilled/semi-skilled workers or unskilled labour or run their own business.

Discussions

The Sustainable Development Goals (SDGs) contain separate targets for poverty (SDG 1), gender equality (SDG 5), sustainability (SDG 11), and climate action (SDG 13) (47). This is notably true for health impacts, making climate change a risk-multiplier for gender-based health disparities (47). The WHO has recently placed the "health impacts of climate and environmental change" as one of four top health priorities for the next 5 years and called for placing the well-being of women, children, and adolescents at the centre of global health and development (47).

Systematic review suggest that climate change is associated with worse human health (48). Heat is possibly the climate-related illness of greatest concern. The frequency and intensity of heatwaves and other extreme weather events is increasing rapidly owing to climate change and is set to escalate in the coming decades. Heatwaves and rising mean temperatures both present major health threats, especially for populations with limited physiological ability or socioeconomic means to respond or adapt to high temperatures (49). In the United States, extreme heat events are causing more deaths than all weather-related fatalities combined (50). High temperatures adversely impact the human body by interfering with its ability to dissipate heat and thermo-regulate, leading to heat exhaustion and possibly heat stroke, a condition characterized by a core temperature ≥40.6°C and central nervous system dysfunction (51). In India, climate change is having wide-spread impacts, which are anticipated to worsen under future climate scenarios (52). India is already the fifth most vulnerable country globally in terms of extreme climate events (53). The average annual temperatures in India in 2030, compared to the 1970s, are projected to increase between 1.7 and 2.2°C, with a commensurate increase in the intensity and duration of heatwaves (52).

Women differ from men in their physiologic compensation to elevated temperatures, which contributes to their biologic vulnerability (47). Cultural vulnerabilities include poor access to healthcare and cooling facilities due to personal safety concerns and a lack of access to personal transportation, culturally prescribed heavy clothing garments that limit evaporative cooling, and a lack of awareness of women's vulnerabilities to heat among local, national, and global decision makers and health care personnel (47). Further, pregnant women are more susceptible to increasing ambient temperatures and heat waves since their ability to thermos-regulate is compromised (54). Furthermore, pregnancies are susceptible to complications at all stages of gestation. Such complications may affect maternal health, foetal health, perinatal health, or postnatal health of the mother and/or child (55), and are complex in both aetiology and outcome. Low birth weight was previously hypothesized as a consequence of sustained heat exposure and maternal heat stress (54). While there is not conclusive evidence at this point, there may be a connection between adverse birth events and extreme deviation in ambient temperature. However, there is a very little evidence that temperature extremes adversely impact birth outcomes, including, but not limited to: changes in length of gestation, birth weight, stillbirth, and neonatal stress in unusually hot temperature exposures.

The study conducted over four cities with a sample size of 500 households per city has revealed several key factors which can help determine the vulnerability as well as coping mechanisms adopted by the cities. Evidence generated through comprehensive analysis of the collected data has revealed some striking similarities and some major differences in how different cities behave during extreme heat days. The characteristics of households, localities and the perception and behaviour of public contributes to attenuation or amplification of different sets of vulnerabilities. While discussing on the vulnerabilities, it is crucial to bring down the vulnerability assessment framework used for the study. The three major components of the framework which contributes to the progression of vulnerability are exposure, sensitivity and adaptive capacity or adaptive behaviour.

Exposure:

There are several factors which surfaced through this study that indicates amplification or attenuation ambient heat. One of the key factors which can increase the ambient heat inside of a household is air flow. In this study, surrounding tall buildings were considered as factors leading to obstruction in air flow leading to increase in ambient heat across the household. Kolkata reported the highest number of households (>50%) which are surrounded by tall buildings on three or four sides. Angul follows with 29.4% households. Karimnagar and Ongole have comparatively lower number of households surrounded by tall buildings. Another factor which leads to an increase in ambient heat is the use of tin or asbestos roofs. These roofs are good conductors of heat and therefore they lead to quick increase in temperature of the room they are covering. A study conducted in Bhubaneswar, revealed that populations having roofs made of tin or asbestos are more exposed to high ambient heat (56). In this study, it has been found that the cities of Ongole and Angul have many households (36.5% and 39.8% respectively) with tin or asbestos roofs which can lead to an increase in vulnerability for the population of cities. Kolkata and Karimnagar are not that far behind with 19.2 and 18.2% households having tin and asbestos roofs respectively. These findings are similar with that of other studies conducted to determine heatwave vulnerability (56,57). Ambient heat is also influenced by other factors like proximity to traffic junctions and industrial zones. Among the four cities, Kolkata has the maximum number of households which are located near traffic junctions, but the number of industrial zones nearby are comparatively lower than other cities. Ongole has around 21% households nearby traffic areas. Ongole also has the highest percentage of households (18.1%) with industrial zones nearby, followed by Angul. This may lead to an increase in ambient heat (58). While the factors like tall buildings nearby and type of roof in house leads to entrapment of heat leading to increase in ambient heat, factors like proximity to traffic junctions and industrial zones lead to generation of more heat. Therefore, the comparative effect of these factors can lead to rise in extreme heat. Apart from this, there are also factors related to occupation which can lead to a further exposure to ambient heat. During transport to work, individuals who walk to work or take a cycle/bike can be exposed to direct sunlight, which can lead to an increase in vulnerability. In Kolkata, Ongole and Angul, around In Kolkata, Ongole and Angul, around 40% population walk to work while many other also reach their workplace through bikes and cycles. This is in accordance with a similar study conducted in India (59).

Sensitivity:

Sensitivity is a key factor which leads to an increase in vulnerability. Several factors can lead to an increase in sensitivity, which can range from household socio-economic conditions like income and expenditure to co-morbid conditions in household individuals.

Several socio-economic factors can contribute to the increase in sensitivity. According to several studies (57,60) household income is one such factor. To analyse the income, this study has considered people living below poverty line (BPL) as sensitive indicator for heat vulnerability. This is due to their economic inability to take certain coping measures which can lead to increase in resilience to ambient heat. Angul is the city with the highest number of people living under the below poverty line (22%). The percentages are 11.2 for Ongole, 7.8 for Karimnagar and the lowest for Kolkata with only 3.8 people belonging to BPL category. Poverty is one of the biggest drivers of heat vulnerability and several studies have shown that with increase in poverty percentage, the vulnerability increases (57,59–61).

Age is a factor which can increase heat vulnerability of people. The rise of age, and with certain co-morbid conditions like diabetes and hypertension, may lead to an increase in sensitivity to ambient heat. Apart from that, age also forces people to slow down their movements and response; this also can lead to an increase in sensitivity to ambient heat. People above the age of sixty are considered to be more vulnerable to extreme heat than people of other age groups. In this study, it was revealed that Ongole had 16.7% people above the age of 60 whereas Karimnagar had 10.8%, Kolkata had 7.8% and Angul had the least with 4.5%. This coincides with other research studies which has mentioned that people above the age of 60 are more vulnerable than other age groups (56–58,62).

Literacy is also a factor which has been considered in several studies while calculating their vulnerability index for high ambient heat (57,58,60). Literate individuals might be more aware about certain measures about how to tackle high ambient heat than their illiterate counterparts. In this study, Ongole came with the highest percentage of illiterates at 38.9%

followed by Angul at 24.5% and Karimnagar at 20.8%. Kolkata had the least percentage of illiterates with only 1.6%.

A major factor which contributes to the increase in sensitivity to high ambient heat is co-morbidities. Co-morbidities increases the susceptibility to extreme heat by many folds. The two major co-morbid conditions (Diabetes and Hypertension) which were found in our study coincided with other studies (56,59,60) The total percentage of individuals having hypertension and diabetes stands at 12.2% for Angul. The other cities show almost a similar number of individuals with hypertension and diabetes with 15.5% for Karimnagar to 16.1% to Kolkata. These percentages of people across the cities are more vulnerable to high ambient heat than individuals without any co-morbid conditions according to other studies (56,59,60).

Community cohesion is a factor which can influence sensitivity towards extreme heat. It can act as a coping measure but also can act as an amplifier of heat vulnerability. In this study, people who mentioned that they will not be getting any help from their neighbours are considered as vulnerable population for ambient heat. It is similar to the findings of another study (59). The percentages of people who will not be getting any help from neighbours during heat emergency stands between 12.6 for Kolkata to 23.9 for Angul. During situations of emergency, this percentage of individuals across the different cities will not be able to acquire help from their neighbours, thus decreasing their resilience and increasing their vulnerability.

Sensitivity to extreme heat is also influenced by ability to take coping measures like using fans or Air Conditioners are influenced by the availability of electricity in households (57). Power cuts (Load shedding) often force households to not avail such measures. To the best of knowledge, Studies have not considered the influence of power cuts on the vulnerability of high ambient heat. This possible explanation may be that power cut may not be an issue for other cities in India or abroad. Angul is much more vulnerable than the other cities in terms of power cuts with staggering 95.5% households facing power cuts in extreme summer season. Ongole has 23.4% households and Karimnagar has 16.4% households which face power cuts in the summer. Kolkata is the least vulnerable in terms of power cut with only 3.6%.

One more factor which may lead to increase in sensitivity to high ambient heat is the availability of water during summer season (58). In this study, Ongole was found to have the highest percentage of houses facing water shortage during the summer at 47.6%. Karimnagar and Angul are moderately vulnerable with 27.1% and 21.4% households facing water shortage during the summer. Kolkata seems the least vulnerable among the four cities with 10% households facing water shortage during the summer.

Coping Capacities:

There are several coping mechanisms and other factors which lead to an increase of coping capacities for the populations of the cities. For current analysis, coping capacities have been divided into environmental capacity and habits which leads to decrease in vulnerability. For environmental capacity, the factors considered in this study were presence of vegetative patches and water bodies near households. For habits, the considered factors were wearing summer appropriate clothes, drinking more fluid, using umbrellas and hats while going outside and use of fans and ACs while at home.

Presence of vegetative patches nearby house can lead to a decrease in the ambient heat of the area. It also facilitates regular wind flow and leads to an overall cooling of the nearby physical environment. Studies have pointed out that presence of vegetative areas near a locality lead to the decrease in overall ambient temperature of that area (58,60). In this study, it was observed that Kolkata is the city with the highest percentage (74%) of households with patches of greenery nearby. A total of 74% households in Kolkata are in close proximity of a green patch. It is followed by Ongole with 47.1%. Karimnagar and Angul have an exceptionally low number of houses near green patches. On the other hand, water bodies also play a major role in decreasing ambient heat. This is also in accordance with many similar studies conducted on vulnerability of cities to ambient heat (58,60). In this study, it was found that Kolkata also has the highest percentage (47.5) of houses with a water body in proximity. Ongole also has a percentage of households near water bodies with around 33% followed by Angul at 20% and Karimnagar with only 11%.

Personal habits also contribute to decrease in heat vulnerability. Among the factors which constitute of personal coping behaviour were wearing summer appropriate clothes which can lead to decrease in the impact of high ambient heat. Karimnagar leads with 43.5% respondents wearing appropriate clothes in summer, the other cities follow with around 37%.

Another such personal behaviour which leads to decrease in vulnerability was less time spent outside during the summer season. Around 65-70% citizens in Ongole and Karimnagar reduces time spent outside to battle extreme heat during summer. This coincides with other studies (56,59). Angul leads in this resilience strategy with 79.8% respondents decreasing time spent outside. Kolkata has remarkably low percentage of residents willing to reduce time spent outside with only 4.4%. This can be due to the number of working people and the nature of work of the people in the studied population.

Few more habit factors merit attention like drinking more fluids, using hats or umbrellas and using fans or ACs. Angul leads in terms of people taking more fluids during extreme summer while Karimnagar leads in terms people using umbrella or hats while being outside and using fans or ACs while at home. All these factors can lead to a decrease in vulnerability according to studies (56,59).

Implications of Multi-variable analysis

Angul

The Logit regression results find that women respondents are likely to be more vulnerable to extreme heat as compared to their male counterparts. But women usually stay at home doing household chores while men go out and work. The finding is paradoxical though possible when such women lack basic sanitation facilities or lack adequate access to electricity, running water, toilet, or stay in rooms having limited air circulation at home, or so on. Indoor cooking and use of unclean/dirty forms of fuel can also put women at a greater risk to heat extremes[3]. Descriptive statistics indicate that a higher share of males use umbrellas or hats

[3] Angul district is one of the largest producers of coal in the country. Thus, coal is abundantly available to the local people at either free of cost or significantly low prices.

or wear appropriate clothes when they go out as compared to females. This possibly explains why women are more vulnerable to extreme heat as compared to their male counterparts in Angul city.

Heat vulnerability is higher for households who live more than 5 km away from the nearest PHC. This can be viewed from two perspectives. First, Angul is the largest mining district of Odisha. Second, the households who reside in close proximity with the mining areas are more likely to get affected by a range of pollution-led health hazards. As a result, such households are compelled to visit healthcare centres more frequently. Therefore, both the frequency of visits and the distance to the medical centre increases exposure to extreme heat making the households more vulnerable.

Households who perceive a drastic increase in temperature and humidity at home have higher vulnerability to extreme heat. Anecdotal evidence suggests that majority of respondents who perceive a drastic increase in temperature and humidity also have major traffic junctions or industries situated near their houses. Lack of continuous electricity supply, inadequate possession of durable electric appliances (like fans, air-coolers, etc.), and stuffy houses may compel people to venture outdoors, thereby, making them more vulnerable to extreme heat.

Heat vulnerability is lower for households who stay in houses with a greater number of rooms or use air-coolers / air-conditioners at workplace. More number of rooms may lead to lower heat vulnerability especially when the size of the household is low. Use of air-coolers or air-conditioners at workplace make people less sensitive to extreme heat conditions.

People who experience mild symptoms of high ambient heat are more likely to stay put at home in order to recuperate. Therefore, they are less vulnerable to extreme heat. Heat vulnerability is lower for households which has members with comorbid conditions such as diabetes or hypertension. It is likely that the household members who suffer from diabetes or hypertension belong to higher age-group and supposedly not the primary bread earners. This perhaps compel rest of the family members provide constant care to them, ending up by reducing their outdoor activities. Hence, expose to heat vulnerability is lower.

Kolkata

The Logit model finds that the people who are unemployed are more vulnerable to extreme heat. This may be so because unemployed (semi employed) people would explore outside in search of work and regular source of income, ending up spending a bulk amount of the day time outside. It is well established that unemployed people with lower incomes is a key factor that increases household vulnerability. On the other hand, people involved in agricultural and allied activities are seen to have lower heat vulnerability. It is probably because they are engaged in single harvest crop (either Rabi or Kharif) and remain relatively unengaged for one half of the year. This may lead to low exposure and hence lower vulnerability to extreme heat. Farmers or individuals who are associated with farming and allied activities are also more likely to develop better physiological adaptations because of their lifelong exposure to extreme conditions.

Respondents with more average income during the summer months are more vulnerable to extreme heat. In order to earn more income, the respective respondents need to pay more outside visits or work over time or diversify economic activities. In either of the cases, the probability of becoming more vulnerable to extreme heat cannot be ruled out.

Heat vulnerability is lower for respondents who reside more than 5 km away from the nearest PHC. This is contrary to what is observed for Angul. The frequency of medical visits by the respondents in Kolkata may be far less due to lower incidence of diseases as compared to Angul. Qualitative analysis has revealed that a considerable share of households in Kolkata prefer treatment at private healthcare facilities as compared to Angul. Preference for seeking private health care treatment by households in Kolkata also stems out from the fact that the average household income levels in the city is relatively much higher than that in Angul. Further, the means and quality of transportation to and from the PHCs may be relatively better with Kolkata having air-conditioned cabs, buses and metro-railway networks to travel within the city with ease. These few factors together may result in lower heat for the said respondents.

Alike the experience in Angul, heat vulnerability in Kolkata is lower for respondents who stay in houses with a greater number of rooms. More number of rooms may lead to lower heat vulnerability especially when the size of the household is low. Moreover, having higher number of rooms can facilitate separate areas for kitchen, where the ambient heat is generally high.

Vulnerability to extreme heat is also lower for respondents with access to more sources of water. This is because multiple sources of water ensure greater amount of water availability for the respondents during times of water scarcity and rationing. In addition, the time spent outside to fetch water for domestic purpose is also likely to be less for respondents with more available sources.

People who experience mild symptoms of high ambient heat are more likely to stay put at home in order to recuperate. Therefore, they are less vulnerable to extreme heat. Heat vulnerability is lower for respondents which has members with comorbid conditions such as diabetes or hypertension. It is likely that the household members who suffer from diabetes or hypertension belong to higher age-group and supposedly not the primary bread earners. This perhaps compel rest of the family members provide constant care to them, ending up by reducing their outdoor activities. Hence, expose to heat vulnerability is lower.

Respondents which avoid consumption of non-vegetarian foods during summers tend to have lower heat vulnerability. This is very mighty well expected. For instance, meat consumption in the summer season increases the pressure on the digestive system. It contains high quantum of fats, proteins and carbohydrates, which heat up the body while digesting. Hence, non-consumption of non-vegetarian food reduces vulnerability to extreme heat.

Results and Discussion of Threshold Assessment

Description of the atmospheric parameters

The following table describes the various basic heat and atmosphere related attributes of the three cities captured during the study period.

Table 30 Descriptive table of meteorological data (March to July, 2013 to 2019) of three cities

	Karimnagar	**Ongole**	**Angul**
Daily Maximum Temperature	Lowest: 24.40 Highest: 47.20 Mean: 37.78	Lowest: 26.50 Highest: 46.90 Mean: 36.88	Lowest: 25.1 Highest: 47.0 Mean: 37.09
Daily Minimum Temperature	Lowest: 13.50 Highest: 33.0 Mean: 25.50	Lowest: 20.0 Highest: 33.5 Mean: 27.2	Lowest: 13.0 Highest: 36.20 Mean :23.26
Daily Average Humidity (average of those recorded at 08.30 hours and 17.30 hours)	Lowest: 19.50 Highest: 94.0 Mean: 55.52	Lowest: 31.00 Highest: 91.50 Mean: 61.64	Lowest: 35.0 Highest: 97.0 Mean: 67.79

From the above table it is apparent that the temperature profiles of the three cities with regards to ambient temperature and humidity were comparable. However, Angul and Ongole had modestly (yet significantly) higher average humidity but lower minimum temperature in the summer months. But, in all the three cities the most important atmospheric determinant that is maximum temperature, especially their highest and lowest points were not very dissimilar and so was their means.

On plotting the daily maximum and minimum summer temperatures in the three cities over the seven years of study period, no secular trend of increasing temperature was not tangible (please see the three city graphs below)

Three city time-series plot of maximum and minimum temperature, March to July, 2013 to 2019

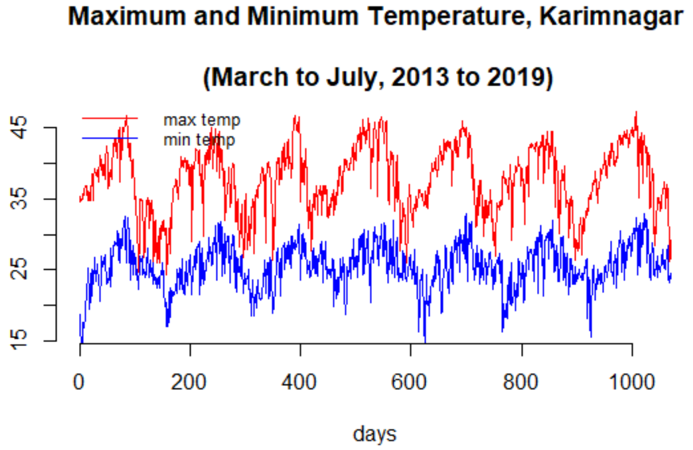

Figure 46: Karimnagar time-series plot of maximum and minimum temperature, March to July, 2013 to 2019

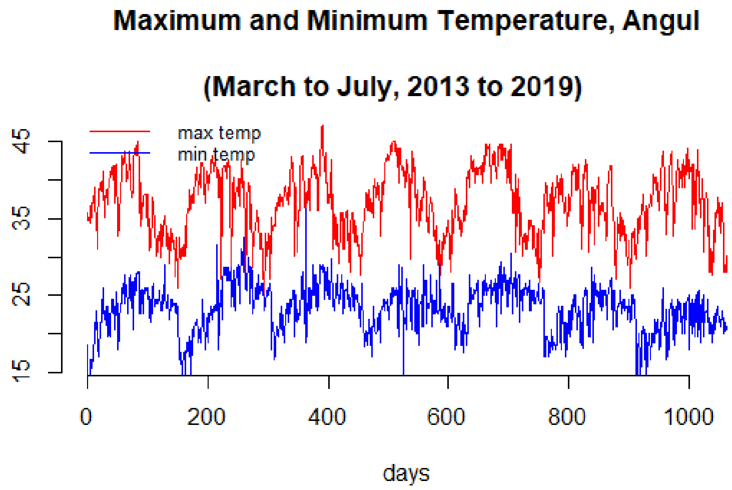

Figure 47: Angul time-series plot of maximum and minimum temperature, March to July, 2013 to 2019

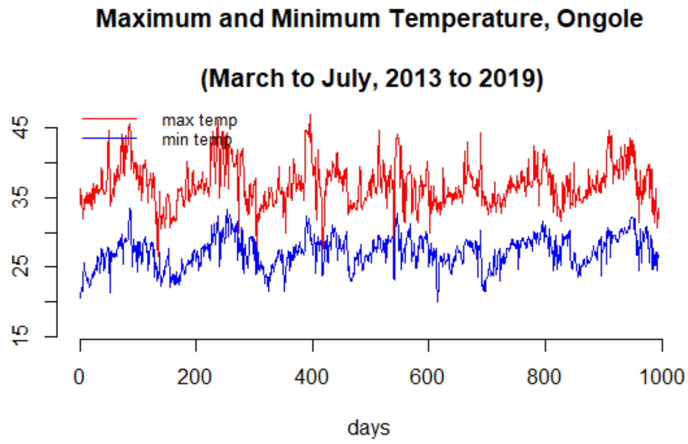

Figure 48: Angul time-series plot of maximum and minimum temperature, March to July, 2013 to 2019

Frequency (year-wise) of heat wave situations in the three districts

Table 31 Frequency of heat wave situations

City	Year	Heat-wave summer days
Ongole	2013	22 (14.40%)
	2014	39 (25.50%)
	2015	17 (11.10%)
	2016	10 (6.50%)
	2017	4 (5.20%)
	2018	11 (7.20%)
	2019	24 (15.70%)
	Total	**127 (12.7%)**
Karimnagar	2013	44 (28.80%)
	2014	38 (24.80%)
	2015	31 (20.30%)
	2016	77 (50.30%)
	2017	58 (37.90%)
	2018	40 (26.10%)
	2019	70 (45.80%)
	Total	**358 (33.4%)**
Angul	2013	33 (21.70%)
	2014	43 (28.10%)
	2015	37 (24.30%)
	2016	44 (28.90%)
	2017	67 (45.00%)
	2018	22 (14.50%)
	2019	46 (30.30%)
	Total	**292 (27.49%)**

The number of days that could be considered as part of the "heat wave" condition was highest in Karimnagar and way higher than Ongole and moderately higher than Angul.

Association between ambient temperature and all-cause mortality

Karimnagar

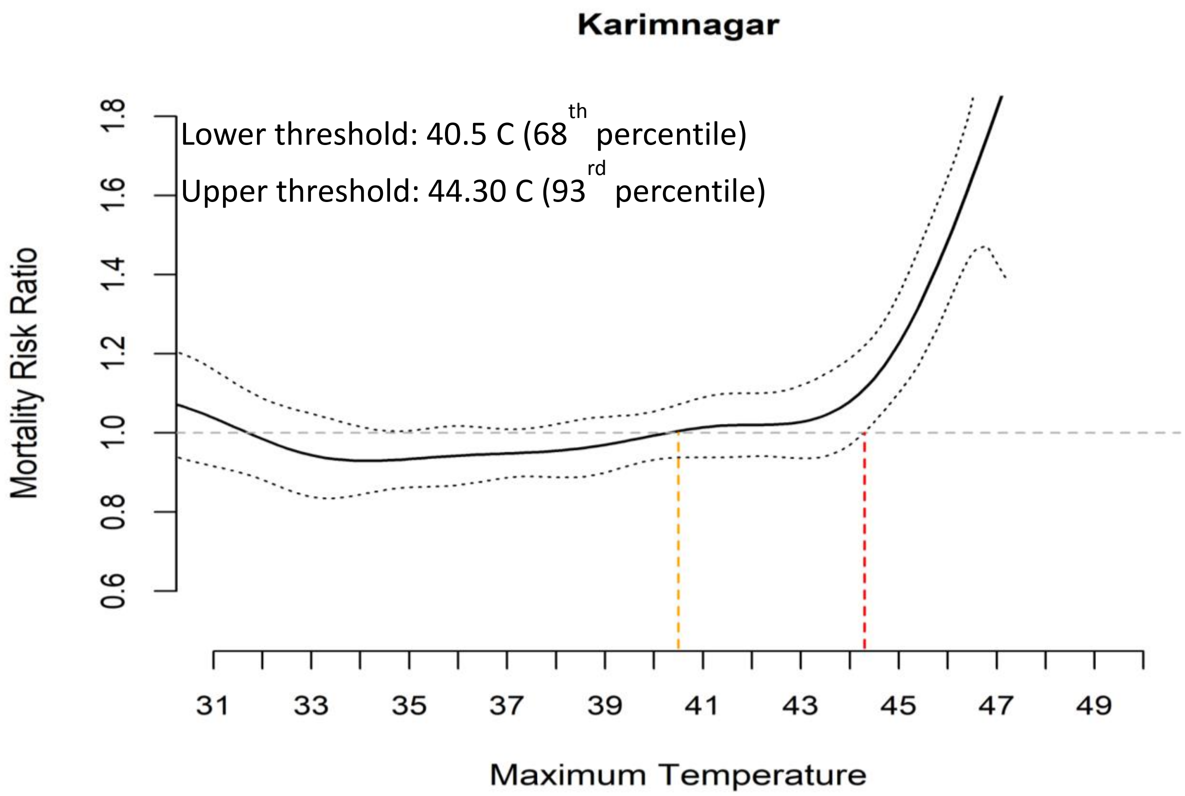

Figure 49: The thresholds (lower and upper) of maximum temperature where the fatal effects of ambient heat kick-in, Karimnagar, March to July, 2013 to 2019

The **lower threshold of** maximum temperature for Karimnagar was 40.5 C and the **upper threshold** was 44.3 C. These two thresholds correspond to 68th and 93rd percentile of maximum temperature. The rise of mortality above the upper threshold was found to be exponential, signifying little effect of mitigating measures, if any, beyond this temperature. No harvesting effect or plateauing effect was evident in Karimnagar.

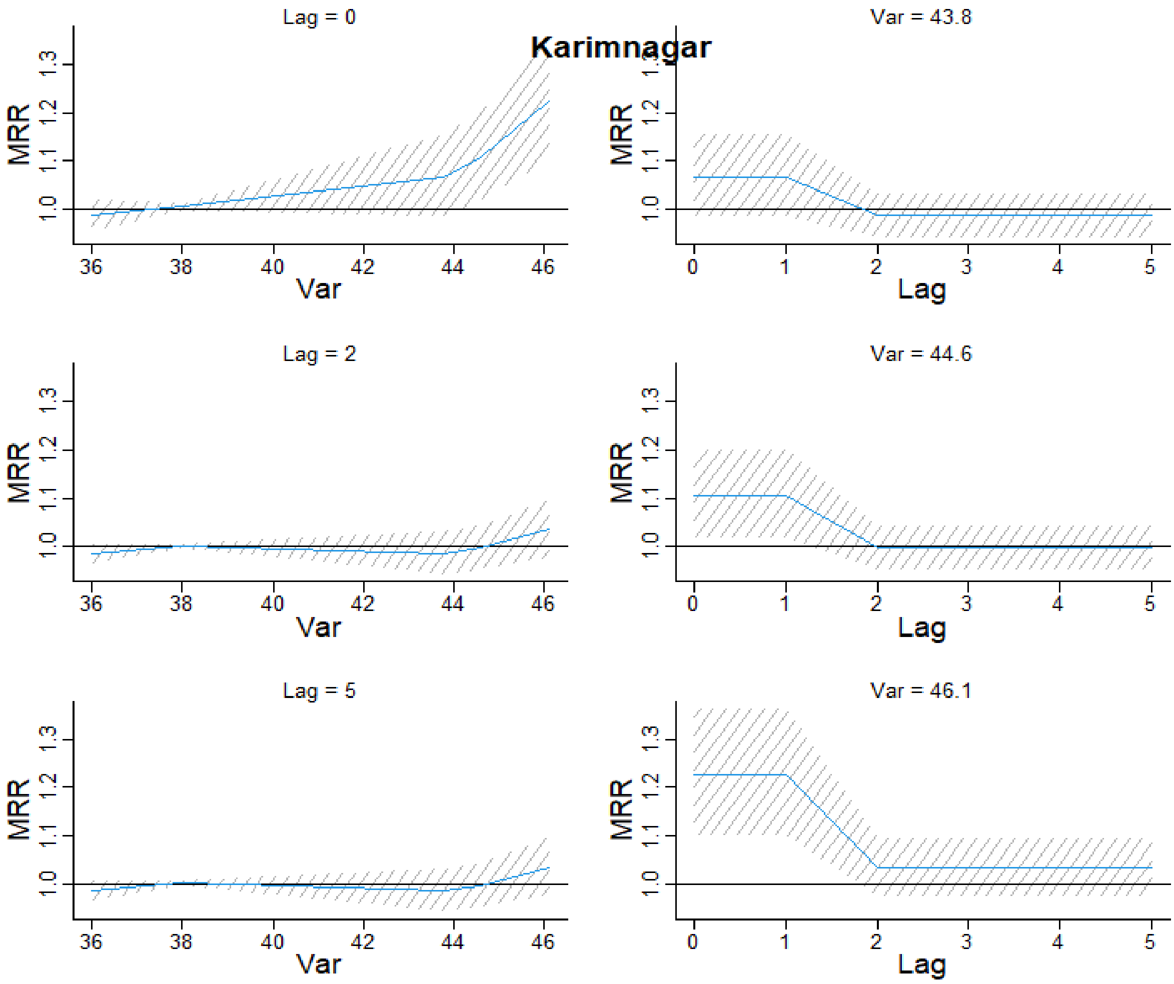

Figure 50: “Slice” graphs depicting the lack of lagged effect of the maximum temperature on all cause mortality, Karimnagar, March to July, 2013 to 2019

The slice graphs describe that there was no lagged effect of maximum temperature on all-cause mortality after one day. This was true for 90th percentile, 95th percentile and 99th percentile temperatures.

Ongole

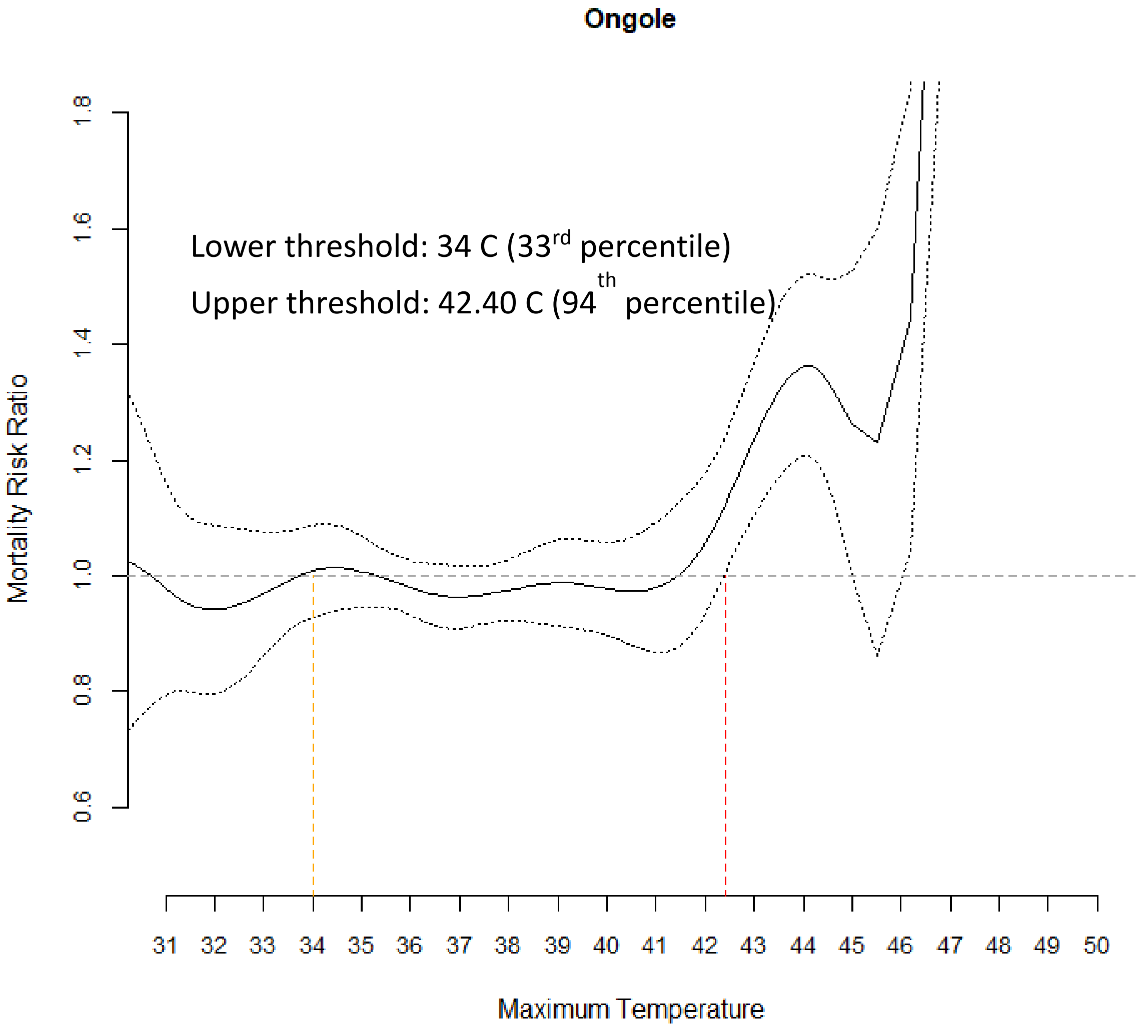

Figure 51: The thresholds (lower and upper) of maximum temperature where the fatal effects of ambient heat kick-in, Ongole, March to July, 2013 to 2019

The **lower threshold of** maximum temperature for Ongole was 34 C and the **upper threshold** was 42.4 C. These two thresholds correspond to 33rd and 94th percentile of maximum temperature.

We observed a significant **harvesting** effect between 44.5 C and 45.5 C. This is often observed as because the most vulnerable die as the temperature soars in the relatively lower temperatures bringing about an "apparent" dip in mortality at a higher temperature for the time being. The exponential rise after the 45 C in Ongole was also notable.

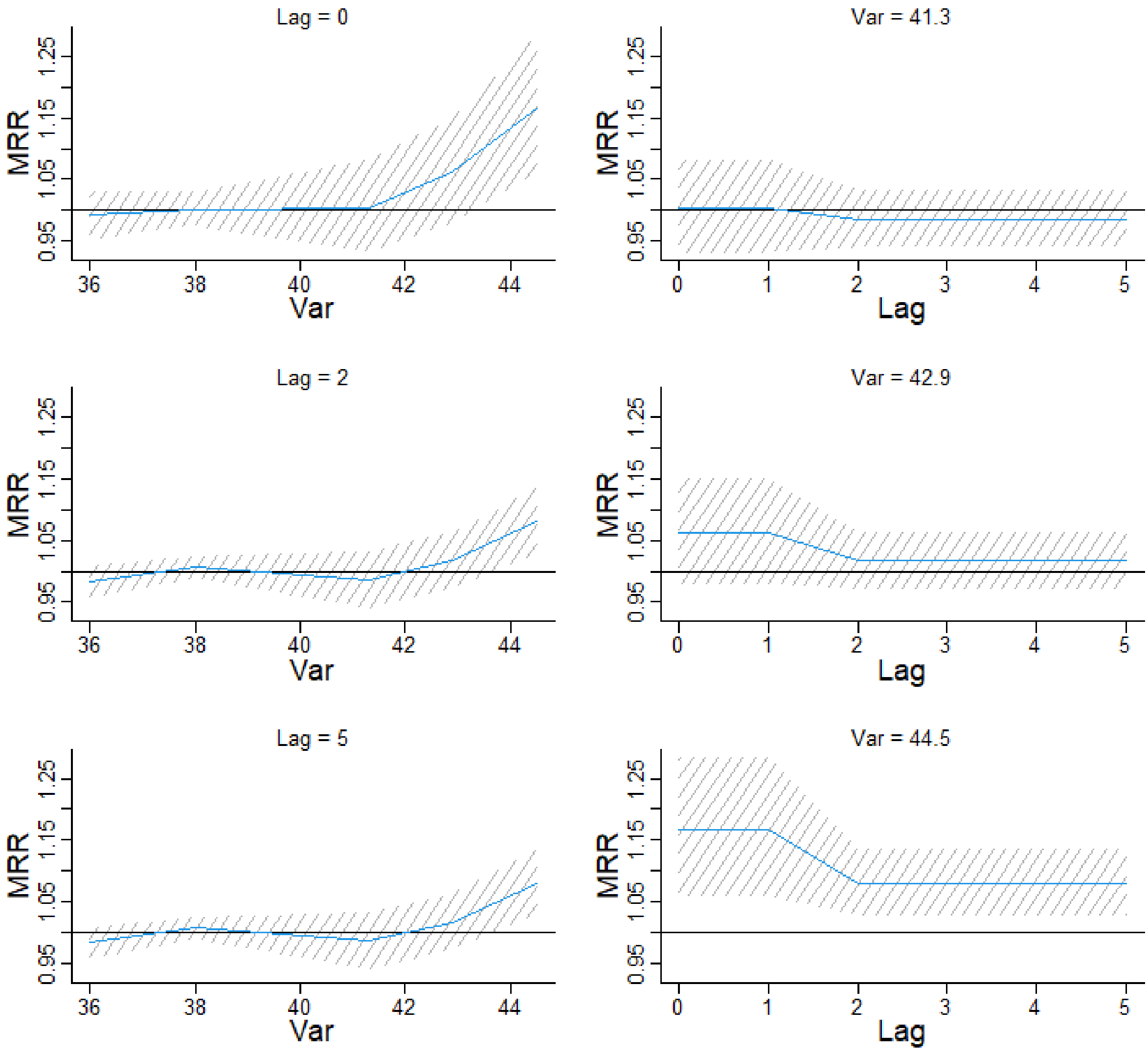

Figure 52: "Slice" graphs depicting the marginal lagged effect of the maximum temperature on all-cause mortality, Ongole, March to July, 2013 to 2019

We also observe a marginal lagged effect in Ongole for higher temperatures beyond 44 C. But the magnitude was negligible.

Angul

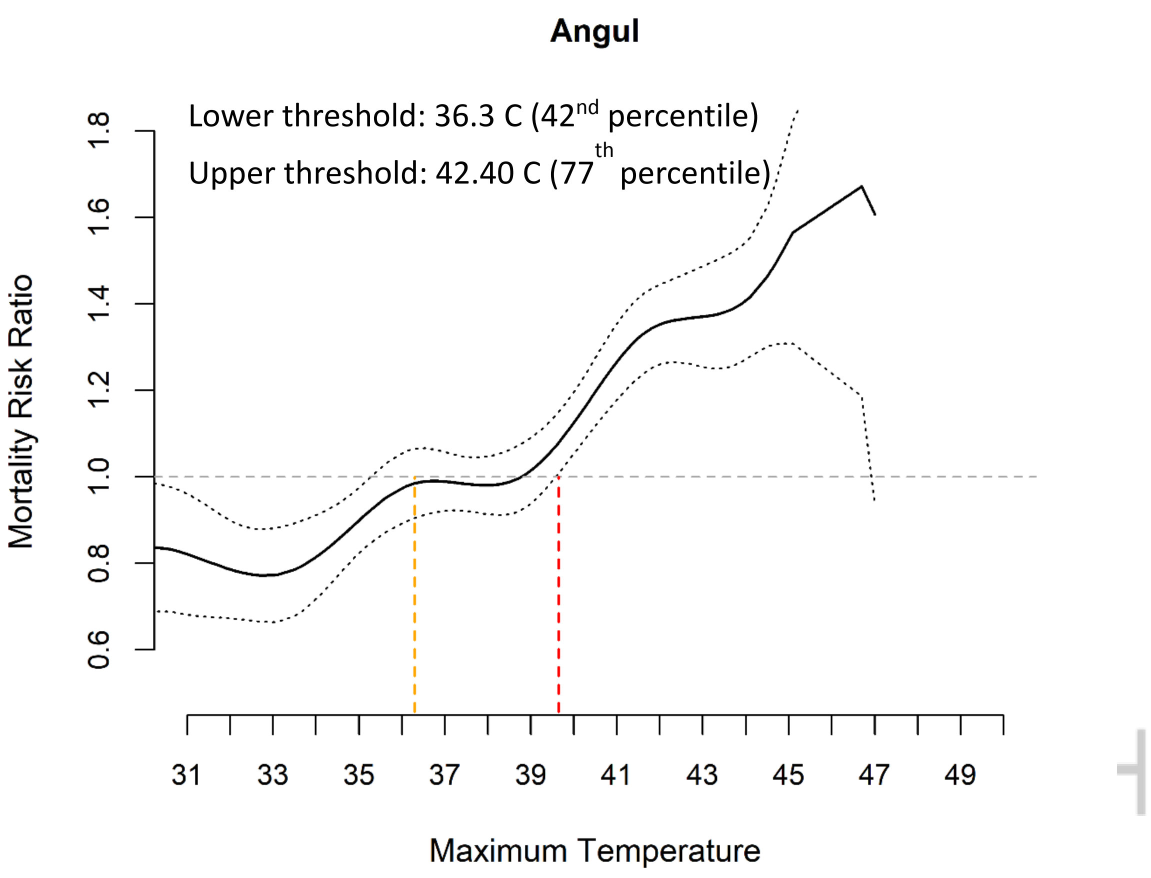

Figure 53: The thresholds (lower and upper) of maximum temperature where the fatal effects of ambient heat kick-in, Angul, March to July, 2013 to 2019

The **lower threshold of** maximum temperature for Angul was 36.3 C and the **upper threshold** was 42.4 C. These two thresholds correspond to 42nd and 77th percentile of maximum temperature for the city. The less steep rise in the Mortality Ratio beyond the upper threshold was notable as compared to the other two cities, so was the plateauing of the effect at very high temperatures. However, the plateauing might have been due to smaller sample size (relatively rare events of such high temperatures and death in that range). Additionally, Angul being a state in Odisha, the state which has already implemented heat action plan, this may have led to mitigation of the deleterious effects of heat in the district to some extent, resulting in flattening of the curve.

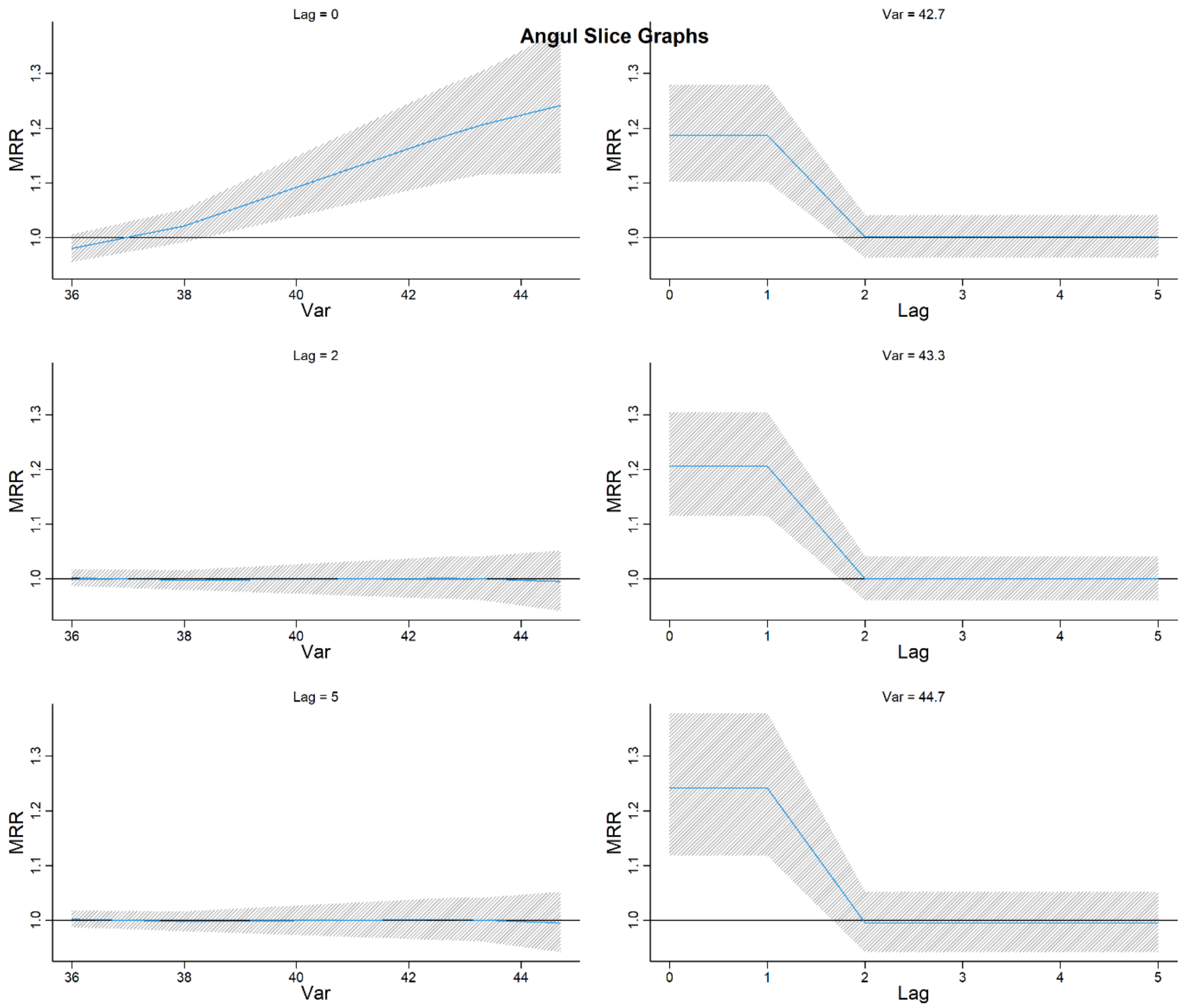

Figure 54: “Slice” graphs depicting the marginal lagged effect of the maximum temperature on all-cause mortality, Angul, March to July, 2013 to 2019

No lagged effect of heat was observed in Angul. However, the steep rise of mortality at lag 0 as temperatures soared was a significant feature.

Three city comparison of “thresholds” - the role of humidity

We observe that both the thresholds for Ongole and Angul were very similar and considerably lower as compared to the thresholds of Karimnagar. Probing deeper into the probable causes indicate that the considerable higher humidity adds to the deleterious effect of ambient heat in Ongole and Angul, hence we see the unfavourable impact of ambient heat in these two districts at a relatively lower threshold. Meanwhile, Karimnagar being dryer and yet hotter displays minimal effect on human health in relatively lower temperatures (when the maximum is between 35 and 40 C). Apart from the role of humidity, this may also signify that probably the heat resilience and adaptive capacity among the residents of such places have been built up over years and also evolutionally over generations perhaps. Even the more persistent heat wave-like conditions in Karimnagar is likely to add to the adaptation process. In contrast to that in more humid places like Ongole and Angul, the vulnerability to heat is compounded by relative humidity. From our explanatory models we observed that in these two cities humidity interacted with maximum day-time temperature in accentuating its harmful effects, contributing to around 25% of the “effect” of ambient heat on mortality, when the relative average humidity was more than the median for that respective city. Therefore, the deleterious effect of heat is felt at lower thresholds in these two cities as compared to Karimnagar. However, humidity, per se, did not have any independent effect on mortality which means humid days that were not hot enough did not affect health. But, the hot days that were more humid than the dryer hot days displayed greater lethality. However, creating a “heat index” that is temperature plus humidity did not explain the variability in outcomes better than inputting temperature and humidity separately. To conclude the hot weather warning system should include predictions of ambient heat as well as humidity – a humidity cut-off to be decided which can be 50th percentile or 66th percentile for that city from historical data as observed by our models.

Effect of Minimum Temperature

The same effect, as mentioned above for humidity, could be observed for the minimum temperature of the day. The minimum temperature of the day, if it is on the lower side, cools the physiological milieu of the human body when it is exposed to high day time temperature. Therefore, higher night time temperature exacerbates the heat assault on body as it gets less opportunity to cool down during a hot night. We could observe this moderating effect of minimum temperature of the days as we had observed in our previous study concerning the city of Bhubaneswar. However, as with humidity, minimum temperature of the day is not independently associated with mortality. Therefore it only has a role of an "effect modifier" of daytime heat.

Table 32: Summary of excess risk of death from certain "baseline" points as maximum temperature rises – the estimate of additional risk due to rising ambient temperature

	Angul	Ongole	Karimnagar
Increase in risk of death for each degree rise above Upper Threshold	20%	16%	13%
Increase in risk of death at certain key T_max points from the mean temperature	90th percentile (42.7 C): 7% 95th percentile (43.3 C): 17% 99th percentile (44.7 C): 43%	90th percentile (41.3 C):5% 95th percentile (42.9 C): 20% 99th percentile (44.5C): 52%	90th percentile (43.8 C): 6% 95th percentile (44.6 C): 20% 99th percentile (46.1 C): 72%

This table finally summarizes the excess risk of death from the baseline (in some cases it is the upper threshold and in other cases it is the mean temperature). Karimnagar again displays greater resilience among its citizens.

Limitation of Threshold Assessment

Some meteorological data (less than 10%) was missing in all the three cities for one or two years. However, as we looked into the immediate effect of heat this would not have introduced so much bias into the estimates.

The mortality reported may be a slight underestimation as not all deaths are registered real time in small towns/cities of India. Again, as the error would be non-differentially distributed on so called "hot" as well as "non-hot" days, the introduction of bias would be less probable because of that and whatever little it might impact that would be on the side of underestimation.

What this study added?

Quantification of heat related vulnerability and temperature threshold for range of geographic settings for four different cities representing four different Indian states.

Broad Recommendations / Potential Impact of the Study for policy:

As this study considered four different cities of the country and the findings of current analysis may allow policymakers to answer the questions about the severity of the issue and to develop strategies for coping mechanism. Hence the key implications of this work will be as below;

1) The findings of this study are not only helping to establish priorities for action among many urban local bodies' players, but also promote in developing a strategic framework for city specific Heat Action Plan which envisioned at averting and decreasing heat health hazards. Heat Action Plans are likely to be more effective in bringing about change at city level and simultaneously build capacity in the field and develop public awareness regarding heat vulnerability and its coping mechanism. Hence, city wise Heat action plans to be developed, implemented and then empirically evaluated based on data to estimate their effectiveness.
2) Second most important policy implication will be related to temperature threshold assessment as timely determination of the city wise temperature threshold is very much needed for actions especially developing heat action plan and warnings alerts. Hence Every city must carry out Threshold Assessment at the interval of every 5 years.
3) Analysis has also shown that, in all of the cities, there is a significant correlation between household vulnerability and adaptive capacity. Therefore, to decrease vulnerability, attention and efforts should be directed towards adaptive capacity.
4) It is better to consider inclusion of humidity and minimum temperature in the heat warning system.
5) Interior heat exposure may be reduced through medium and short-term solutions, as well as recommendations on how to keep indoor temperatures low during extreme heat.

6) Long-term urban planning should address building location especially keeping in view the air flow as most of the houses are surrounded by either 3 or 4 sides tall buildings.
7) People with comorbidities especially Diabetes and Hypertension should be provided extra support during extreme heat.
8) Introduce cooling methods (keeping in view the affordability) at home and workplace and encourage people to sleep on bare floors (with safety) during extreme heat season, especially people without ACs.
9) Ensure availability of healthcare facilities in a gap less than 5kms.
10) Ensure good quality and uninterrupted water availability during summer.
11) Provide IEC on consumption and avoidance of evidence-based food practices.
12) Create more green spaces within their locality (if space is available).
13) Collaborating with the labour department to reform work timings especially for people working outside (construction workers, drivers, etc.).

Policy implications from Threshold Assessment

1. Humidity and minimum temperature need to be included in the heat warning system. This will make the system more responsive and might ensure more compliance to its norms from the general population.
2. Measures to combat humidity at the collective level and individual level in high humidity zones should be tried and disseminated to the public. Mitigation measures to neutralize the harmful effects of humidity should be at the forefront of publicity measures.
3. Heat action plans to be developed, implemented and then empirically evaluated based on data to estimate their effectiveness. This is one of the main ideas behind devising a strategy for threshold assessment so that they are used as empiric evidence of effective anti-heat measures instituted by various agencies.
4. Mortality registration system at the city and higher levels needs to be strengthened to study the effect of various assaults on community health including heat, disasters and pandemic. This is a weakness of the vital registration system as it exists in India and often hampers real time data based policy making.

SHORT, MID AND LONG TERM GENERAL POLICY RECOMMENDATIONS

Plan Period	Policy Recommendations
Short-term (Less than 3 months- Especially during summer)	1) Measures should be taken up to build the adaptive capacity of vulnerable households 2) Humidity and minimum temperature should be included in the heat warning system. 3) Household who does not have access to ACs/Air-coolers should be encouraged to sleep on bare floors (taking safety precautions) during extreme heat season. 4) People with comorbidities especially Diabetes and Hypertension should be provided extra support during extreme heat. The proposed urban community clinics (or mobile community clinics) must lay down rules so as to prioritize access to care by the aging adults with hypertension or diabetes. The state should offer free healthcare for this section of senior citizens at the designated public healthcare centers. Vocational skills training for the allied health workers should be conducted to improve the quality of care given to the aging adults with comorbid conditions. 5) Well-planned information, education and communication (IEC) campaigns should be conducted on consumption and avoidance of evidence-based food practices especially during extreme heat. 6) Laborers involved in arduous outdoor physical activities should be protected from extreme heat. One immediate measure could be to revise the work timings of such laborers during day time. The timing can be rescheduled in 8 hours between 7 AM to 7 PM with a gap between 12 noon and 3 PM.
Medium-term (3 months to 3 years)	7) City-wise Heat Action Plans (HAPs) should be developed, implemented and then empirically evaluated on the basis of data to estimate their effectiveness. 8) Community clinics should be set up in high-risk pockets on the lines of 'Basthi Davakhanas' (in GHMC, 2018) and 'Mohalla clinics' (in Delhi, 2015). Free diagnostic services and essential medicines should be provided to the high-risk yet under-served urban populations. Potable community clinics can be set up where building permanent structures could be a challenge. Such healthcare facilities should be made available within a radius of 5 Km, especially in the heat vulnerable pockets.

	9) Energy-efficient cooling systems should be introduced both at home and workplaces. Examples include *Telangana Cool Roof Program (2019)* and *Ahmedabad Cool Roof Initiative (2017-18)*. These programs involved covering rooftops of buildings with materials such as plastic sheets, ceramic tiles or lime plaster to reduce the ambient temperature inside. A comprehensive 'Cooling Action Plan' should be devised by the respective states in convergence with India Cooling Action Plan, 2019. 10) Efforts must be placed to ensure that the urban households have access to adequate and good quality supply of quality water throughout the summers.
Long-term (More than 3 years)	11) Every city must carry out heat threshold assessment at a regular interval of 3-5 years. 12) Since majority of the residential houses are seen to be surrounded by tall buildings on 3 or 4 four sides, future urban planners should weigh in the challenges of consequential restricted air flow that exacerbates the adverse consequences of extreme heat. 13) Innovative ways should be adopted to create more green spaces in urban areas. Some examples include green roofs, urban gardens, mini-forests, and so on.

CITY-WISE POLICY RECOMMENDATIONS

S.N.	City	Policy Recommendations
1.	**Angul**	(1) Uninterrupted supply of electricity during summer months should be provided (preferably to all households or) at least to those households residing in high-risk pockets, i.e., closer to industrial/traffic junction. (2) Awareness programs should also aim to encourage women to wear summer appropriate clothes and use protection gears during extreme heat conditions. (3) Awareness should be created among all people in the city regarding the threats that emanate from the use of coal for cooking and how it makes women and children particularly more vulnerable to heat waves and extreme heat. (4) The state must ensure access to affordable, reliable, sustainable and modern cooking energy for all households, especially those residing in the high-risk zones of the city. (5) Urban health services should be strengthened. To begin with, the financial allocation for urban healthcare as a proportion of total allocation in healthcare should be increased. (6) Community clinics should be set up in *high-risk* pockets of Angul, on the lines of *'Basthi Davakhanas'* (in GHMC, 2018) and *'Mohalla clinics'* (in Delhi, 2015). The aim should be to provide free diagnostic services and essential medicines to the high-risk yet under-served urban population in Angul. Potable community clinics can be set up where building permanent structures could be a challenge. (7) A comprehensive 'Cooling Action Plan' should be devised for Angul City in convergence with India Cooling Action Plan (ICAP) – launched by the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India in 2019. (8) Providing adequate care to comorbid patients entails high risk of financial burden on relevant households (AHRQ, 2014). Numerous studies establish that elderly COVID-19 patients with *hypertension* or *diabetes mellitus* have an increased admission rate into the intensive care unit (ICU) and mortality (Sanyaolu et al., 2020; de Almeida-Pititto et al., 2020). Usually, the elderly people are devoid of any easy access to healthcare services. Hence, building a robust healthcare ecosystem for the elderly with designated comorbid conditions is extremely crucial, especially during COVID-19 pandemic. The *proposed* urban community clinics (or mobile community clinics) must lay down rules so as to prioritize access to care by the aging adults with *hypertension* or *diabetes*. The state should offer free

		healthcare for this section of senior citizens at the designated public healthcare centres in the city. (9) Vocational skills training for the allied health workers should be conducted to improve the quality of care given to the aging adults with comorbid conditions.
2.	**Kolkata**	(1) The state should devise policy to reduce meat consumption in the city. According to report of IPCC (2020), a reduction in meat consumption could be beneficial both for climate (through lesser greenhouse gas emission) and human health. Awareness programs should be conducted to encourage the local population to avoid red meat during summer months. Such programs should also aim to apprise the households how a reduction in meat consumption can potentially address the issue of global warming. The state should also alter its food procurement policies so as to ensure consumption of vegetarian diets in summer. One possible mechanism may be to impose an environmental tax on animal agriculture and provide farm subsidies to encourage plant agriculture, especially during peak summer months. (2) The Government of West Bengal had launched *'Yuvasree'* – a financial assistance scheme for the unemployed youth of the state in the year 2013. The motto of this scheme is to provide employment assistance to the unemployed youths of West Bengal for increasing their employment ability and skill. The state can budget under this program and provide reimbursement of local transport expenses incurred by the unemployed people in Kolkata city. Alternatively, public transportation passes may be issued as a cashless form of benefit. Use of better modes of communication for the unemployed people will aid in reducing their exposure and sensitivity to extreme heat. (3) Kolkata has been among the most water-abundant cities of India with high ground water reserves. Over the last few years though the ground water levels have plummeted in various parts of the city. This has been largely because the rich neighborhoods pump their own water despite having water connections supplied by civic bodies. While the rich exploit more water from the ground, the urban poor in the city (especially in the slums) may be left with limited access to public water sources and rare access to private ones. Efforts must be placed to ensure that the urban poor households in Kolkata have access to adequate supply of quality water throughout the summers. The state must effectively tax the richer households on water use and cross subsidize the urban poor households to ensure multiple sources

of water such as municipality piped water, community tanks, community tube wells, and so on.

(4) Providing adequate care to comorbid patients entails high risk of financial burden on relevant households (AHRQ, 2014). Numerous studies establish that elderly COVID-19 patients with *hypertension* or *diabetes mellitus* have an increased admission rate into the intensive care unit (ICU) and mortality (Sanyaolu et al., 2020; de Almeida-Pititto et al., 2020). Usually, the elderly people are devoid of any easy access to healthcare services. Hence, building a robust healthcare ecosystem for the elderly with designated comorbid conditions is extremely crucial, especially during COVID-19 pandemic. Healthcare centres must lay down rules so as to prioritize access to care by the aging adults with *hypertension* or *diabetes*. The state should offer free healthcare for this section of senior citizens at the designated public healthcare centres in Kolkata city.

(5) Vocational skills training for the allied health workers should be conducted to improve the quality of care given to the aging adults with comorbid conditions.

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3. **Ongole**

(1) Adaptive capacity to counter extreme heat is very low in Ongole. Hence, the state must, therefore, take up short-term measures for enhancing the adaptive capacity of the vulnerable households. Long-term strategies can be designed towards reducing the exposure and sensitivity of the vulnerable groups.
(2) Efforts must be placed to ensure that the urban households in Ongole have access to adequate supply of quality water throughout the summers.
(3) Well-planned information, education and communication (IEC) campaigns should be conducted on consumption and avoidance of evidence-based food practices especially during extreme heat.
(4) Energy-efficient cooling systems should be introduced both at home and workplaces.
(5) Tin sheds and asbestos roof should be replaced by Concrete roof
(6) Municipality/Corporation should try to arrange the accommodation away from industrial area.
(7) Govt. must take measures like build sheds and resting areas, plant more trees, keep available water on road side during summer.
(8) People with comorbidities especially *Diabetes* and *Hypertension* should be provided extra support during extreme heat. The healthcare institutions must lay down rules so as to prioritize access to care by the aging adults with hypertension or diabetes. The state should offer free healthcare for this section of senior citizens at the designated public healthcare centers.

		(9) The Health facilities should be made available within a radius of 5 Km., especially in the heat vulnerable pockets.
4.	**Karimnagar**	(1) Uninterrupted supply of electricity during summer months should be provided (preferably to all households or) at least to those households residing in high-risk pockets, i.e., closer to industrial/traffic junction. Electricity board should try to provide electricity by 24/7 without any interruption. (2) Well-planned IEC campaigns should be conducted on consumption and avoidance of evidence-based food practices especially during extreme heat. (3) Tin sheds and asbestos roof should be replaced by Concrete roof (4) Municipality/Corporation should try to arrange the accommodation away from industrial area. (5) Govt. must take measures like build sheds and resting areas, plant more trees, keep available water on road side during summer. (6) People with comorbidities especially Diabetes and Hypertension should be provided extra support during extreme heat. The healthcare institutions must lay down rules so as to prioritize access to care by the aging adults with hypertension or diabetes. The state should offer free healthcare for this section of senior citizens at the designated public healthcare centers. (7) Health facilities should be made available within a radius of 5 Km., especially in the heat vulnerable pockets. (8) Households who use first aid at home during heat emergency in Karimnagar are found to have less vulnerability to extreme heat as compared to those who take no treatment. Action research should be conducted to train the households how to provide first-aid treatment during events of heat exhaustion, heat cramps, and so on[4]. (9) More green spaces should be created in the urban areas of Karimnagar. Some examples include green roofs, urban gardens, mini-forests, and so on.

[4] Some such aids include: moving the person to a cooler area and out of direct sunlight; loosening the clothing; removing any sweaty clothing; applying cool, wet towels to the face, neck, chest, and limbs; applying ice to the underarms, wrists, and groin; fanning the person's skin; offering cool water or sports drinks every 15 minutes if the person is conscious; and so on.

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