Climate Change and Liveability of Cities: an Assessment of Possible Health Threats Associated With Increased Temperatures in Cities

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Abstract

Climate change is associated with extreme weather events such as heat waves, droughts, floods, hurricanes, storms, and wildfires globally. Within cities, the impacts of climate change are quite conspicuous as the percentage of urban dwellers is expected to reach about 70% by 2050. As the planet warms up, temperatures in cities are likely to increase more than in rural areas. These dual challenges severely impact urban residents. This paper reports on a study on the impacts of climate change on the health and liveability of a set of 15 cities, in industrialised and developing countries from around the world. The assessment, based on the literature, examined the average temperature, maximum temperature and relative humidity of each city, and this data has been correlated with their liveability. It was complemented by a survey focused on residents of 109 cities from Africa, Asia, Europe, Latin America, North America Oceania. The findings show that developing countries seem to be especially struggling to adapt to the threats caused by increasing temperatures. Moreover, cities in industrialised countries are not immune to climate change impacts. The paper also outlines some mitigation and adaptation measures, which can be implemented to improve the liveability in cities and the well-being of their populations, and to make them more sustainable.

1. Introduction

The current post-industrial era has brought about much prosperity to human society but is also associated with global climate change. Caused mainly by human activities, climate change is one of the main challenges currently facing humanity (Donkor et al., 2019). The burning of fossil fuels in industries and transportation releases a large amount of carbon-dioxide and other greenhouse gases in the atmosphere (WHO, 2018). This situation, in turn, traps heat in the lower atmosphere, increasing the average global temperature over time (WHO, 2018). Increasing average global temperature causes polar ice caps to melt, which then leads to a rise in the sea level. Climate change encompasses not only rising average temperatures but also frequent occurrences of extreme weather events, such as heavy rainfall, floods, heat waves, droughts and intense storms (Pereira et al., 2018).

Various studies have shown that increasing temperatures pose a serious threat to general public health and can also be directly related to high mortality (Mazdiyasni et al., 2017; Mitchell et al., 2016; Mora et al., 2017) and morbidity rates (Linares et al., 2017). This is especially true among vulnerable groups of people (Åström et al., 2011). Heat waves have a greater impact on people residing near cities. They cause a general thermal discomfort among people and can result in low productivity at work (Zander et al., 2015).

Table 1. List of large cities in developing and industrialised countries with average, maximum temperature and relative humidity (Climate Data, 2010; Weather Atlas, 2010)

A significant number of large cities around the world are located near coastlines. It is estimated that more than 600 million people live in coastal areas that are 10 meters or less above sea level. Moreover, nearly 40% of the world's population - or around 2.4 billion people - live within 100 kilometers of sea coastlines. Hence, sea level rise is a major danger resulting from climate change. As the concentration of people residing near coastal cities is ever increasing, they are prone to threats like coastal flooding, storms, and hurricanes (Chowdhury et al., 2021). These extreme events could impact the urban dwellers through loss of life, injuries, and damage to properties and infrastructures. Heavy rainfall that accompanies a storm can cause flooding in the cities.

Climate change is a major risk in the public health sector. There is an increasing number of inter-linkages between climate change and health, showing serious threats to human health (USGCRP, 2016). It is shown to either exacerbate pre-existing health conditions or introduce new ones. Table 2 shows some of the different impacts on public health

S. No.	City	Country	Population (in million)	Avg. Temperature (in °C)	Max. Temperature (in °C)	Highest Relative Humidity (in %)	Lowest Relative Humidity (in %)
1	Berlin	Germany	3.76	2.9 (January) 23.7 (July)	39.0 (June 2019)	88.0 (November, December, January)	65.0 (May, June, July, August)
2	Athens	Greece	3.15	9.5 (January) 27.8 (July)	48.0 (July 1977)	71.9 (November)	47.6 (August)
3	Madrid	Spain	6.64	5.0 (January) 24.0 (July)	40.6 (August 2012)	74.0(December)	38.0 (July)
4	Milan	Italy	1.35	1.9 (January) 23.8 (July)	37.2 (July)	86.0 (January, December)	74.0 (March, June, July)
5	Sao Paulo	Brazil	12.18	15.4 (July) 21.5 (January)	38.3 (March)	80.0 (January, March, April, December)	74.0 (August)
6	Rio de Janeiro	Brazil	6.32	20.6 (July) 26.1 (January)	43.2 (December 2012)	80.0 (March, April, May, October)	77.0 (July, August)
7	New Delhi	India	21.75	14.2 (January) 34.3 (June)	48.0 (June 2019)	73.0 (August)	33.0 (May)
8	Bangkok	Thailand	8.28	25.6 (December) 30.2 (April)	40.1 (March 2013)	79.0 (September)	66.0 (December)
9	Chennai	India	7.09	24.3 (January) 33.0 (May)	45.0 (May 2003)	78.0 (November)	57.0 (June)
10	Barranquilla	Columbia	1.21	26.6 (January) 28.5 (June)	41.1 (April)	82.9 (October)	71.7 (January)
11	Quezon	Philippines	1.86	25.3 (January) 28.9 (May)	36.6 (April 2019)	86.0 (September, October)	65.0 (April)
12	Ho Chi Minh City	Vietnam	8.99	25.9 (December) 29.5 (April)	41.7 (July)	85.0 (September)	70.0 (February, March)
13	Shanghai	China	24.28	4.3 (January)	40.9 (July 2017)	79.0 (June)	71.0 (December)

				28.0 (July)			
14	Dhaka	Bangladesh	8.91	18 (January) 29 (August)	40.2 (April 2014)	74.0 (August)	37.0 (February)
15	Sydney	Australia	5.23	22.3 (February) 12 (July)	45.8 (January 2013)	66 (February)	55.0 (September)

from climate change-related stressors.

Table 2. Impacts of climate change on public health (Paci, 2014; Smith et al., 2014)

Stressors	Health outcomes	References
Heat stress	• Heat-related mortality and morbidity • Increased cases of cardiovascular, respiratory, and neurological disorders	(Mazdiyasni et al., 2017) (Mitchell et al., 2016) (Linares et al., 2017)
Extreme weather events (flood, heavy rainfall, storm, and wildfire)	• Death, injuries, infectious diseases and mental health disorders	(Paterson et al., 2018) (Finlay et al., 2012) (Lane et al., 2013)
Vector-borne diseases	• Malaria, dengue fever, tick-borne diseases, chikungunya, West Nile virus and Leishmaniasis	(Campbell-Lendrum et al., 2015) (Ogden, 2017) (Baylis, 2017)
Food and water-borne diseases	• Water-borne diseases like cholera and gastro-intestinal infections like diarrhea	(Wu et al., 2014) (Cann et al., 2013) (Bhandari et al., 2020)
Increased air pollution	• Respiratory diseases like asthma, cardiovascular disease and pre-mature deaths	(Orru et al., 2017) (D'Amato et al., 2015) (Revi et al., 2014)
Food security	• Undernutrition	(Phalkey et al., 2015) (Wheeler and Von Braun, 2013) (Lloyd et al., 2011)
Mental stress	• Mental health disorders (Post traumatic stress disorder, anxiety, adjustment disorder and depression)	(Trang et al., 2016) (Dean and Stain, 2010) (Berry et al., 2010)

Cities around the world are also finding it very difficult to meet the demands for fresh water from their growing population. Some cities are already facing acute water shortages, which can also result in power failures. For instance,

in 2015, the city of São Paulo, Brazil faced one of its worst drought periods, causing blackouts in the city (Watts, 2015). Some health-related studies have shown that in developing countries, droughts increase the risk of the breakout of water-borne diseases like diarrhea. Society can also face problems related to food insecurity and a rise in food prices as the requirements increase and the supply decreases (Revi et al., 2014). Subsequently, this will result in a negative economic impact. This paper aimed to highlight the risks arising from climate change in cities. Specifically, this study conducted a comprehensive literature review, supported by a survey, focusing on 15 tropical and industrialised countries around the world. More importantly, special focus was given to the threats to people's health due to a continuous increase of temperature.

2. Methods

2.1 Data source

The research undertaken and which led to this paper, consisted of three main steps. First, a detailed literature review was done on the impacts of climate change, focusing on the continuous increase in the temperature in cities. A special attention was given to the impacts that climate change has on health and the liveability of residents in cities. The literature review was done using an electronic search strategy across various databases. PubMed, Science Direct, Google Scholar and Research Gate were identified to have reliable and scientifically accurate articles and journals. These databases were then searched extensively for the following keywords: climate change, health, cities, urban areas, liveability, and global warming. Moreover, reports from the World Health Organization (WHO), United Nations (UN), European Environmental Agency (EEA) and Inter Governmental Panel on Climate Change (IPCC) were also used to extract information. Only papers, journals and reports published after 2010 were included in this study to provide recent information.

Secondly, a survey was conducted to identify the climate risks of tropical cities that are suffering from the global impacts of climate change. The survey for the sampled cities took place for one month, i.e., from the first week of April 2020 to the first week of May 2020. Different cities were selected from both industrialised and developing countries. The choice of samples was focused on tropical and densely populated cities, with more than 1 million inhabitants. Seven cities were selected from Asia, four cities from Europe, three cities from South America and one from Oceania, making a total of 15 cities (Figure 1).

Climate and weather-related variables, such as temperature and humidity for the 15 selected cities were also separately searched using online search engines. The databases that were mainly used for this purpose were Weather Atlas, Climate-data and Time and date. The data from these sources were then cross verified with each other to maintain reliability.

Thirdly, a questionnaire was designed to assess possible threats of climate change to the liveability of cities, as perceived by urban residents from many countries. Twenty-five open- and closed-ended questions were divided into two categories 'demographic details' and 'climate change and liveability'. Final adjustments of the instrument were made based on feedback received from an international group of climate change scientists. Data were collected over approximately three weeks January – February 2021 through the online survey tool 'Google forms'. Statistical analysis and visualization of the obtained results were made in Microsoft Excel.

3. Results And Discussion

3.1 Literature review and survey on climate risks

Research has shown that urban areas are usually warmer than the surrounding rural areas (Macintyre et al., 2018). This is mainly due to the UHI effect, causing more hot days in metropolitan areas when compared to rural areas. Table 1 indicates that tropical cities of both developed and developing countries around the world are already experiencing high temperatures and high humidity in recent years. New Delhi recorded a maximum temperature of 48.0°C in June 2019. This follows a rise in temperature trend in the city, which recorded maximum temperatures of 42°C in June 2018, 44°C in June 2017, and 42°C in June 2016 (Timeanddate, 2017). A similar rise in temperature trend is observed in Berlin, which recorded maximum temperatures of 39, 32, 30, and 35°C in the month of June in 2019, 2018, 2017 and 2016, respectively. Although Shanghai's maximum temperature (40.9°C) was recorded in July 2017, comparison with other years shows a consistent pattern in temperature rise, e.g., 40°C in 2016, and 38 and 39°C in 2018 and 2019, respectively (Timeanddate, 2019). Heat waves during this period have affected several people. For instance, during the heat waves of 1994 and 2004, the citizens of Berlin city suffered from more heat related stress and mortality than those in the neighboring state of Brandenburg (Gabriel and Endlicher, 2011). People living in the cities are vulnerable, as climate change worsens the UHI effect. Constant change in climate has increased the intensity and frequency of temperature fluctuations, which intensifies the occurrence of heat waves and tropical nights (Lee et al., 2020), as supported by Table 1, which shows that the city of Berlin experienced hot summer days with temperatures reaching up to 39°C during summer of 2019. The humidity level also remained high during that period. During heat waves, cases of diarrheal diseases seem to peak in developing countries such as Bangladesh (Prince, 2017), along with respiratory and cardiovascular diseases (Dang et al., 2019).

Shanghai's population of 24.28 million inhabitants (Table 1) is exposed to the impacts of the UHI effect, and the temperatures are expected to rise further, causing an increased intensity of heat waves in the city's center when compared to its outskirts (Tan et al., 2010). Other densely populated cities like New Delhi, Ho Chi Minh City and Chennai are also highly exposed to the impacts of the UHI effect. According to Dang et al., (2019) and Ragettli et al., (2019), the main reasons for hospitalisation during hot summer months in Switzerland, South Korea, Vietnam and Bangladesh were respiratory and cardiovascular disorders and renal and infectious diseases. The deterioration of physical and mental health of the population has also been linked to the increasing temperatures. In Australia, an increase in hospital admission for mental disorders (e.g. anxiety) during heat waves has been documented (Nitschke et al., 2011). In Sweden, people with previous hospital admissions for a mental disorder were found to have the highest relative risk of death as the duration of the heat waves increased (Oudin Åström et al., 2013).

As specified in Table 1, Bangkok (Thailand) and Ho Chi Minh City (Vietnam) experienced an average temperature of 25.6°C to 30.2°C and 25.9°C to 29.5°C respectively, which are quite similar. However, the humidity for Ho Chi Minh City was relatively high when compared to Bangkok. These unusual climatic conditions could increase the rate of hospital admission due to heat waves. This assertion is supported by an earlier study that showed an increase of 2.5% in hospital admissions during periods of heat waves in Vietnam (Dang et al., 2019). Total ambulance calls increased by 18.8% in Brisbane, Australia during heat wave days when compared to non-heat wave days (Tong, 2013).

Further, according to Table 1, Rio de Janeiro and Madrid recorded the high temperatures of 43.2 °C and 40.6°C, respectively, in 2012. Rio de Janeiro has shown a trend in increasing temperature, recording maximum temperatures of 38°C in 2013, 39°C in 2015 and 40°C in 2015. This follows a similar rise in temperature trend in the city of Madrid, which records a maximum temperature of 39°C in 2013, 38°C in 2014 and 40°C in 2015. These cities have a population of around 6 million people, whose health is at risk because of climate change. The continuous increase in temperature could increase the mortality rate in these tropical cities.

Although Athens experienced a maximum temperature of 48.0°C in 1977, recent data have shown a consistent pattern in temperature rise like the other cities. Also, some studies have highlighted increased hospital admissions during heat wave days (Ragettli et al., 2019). Outdoor workers in tropical and sub-tropical cities (e.g. New Delhi, Chennai, Dhaka) are

particularly more vulnerable to heat strokes caused by high temperatures. Outdoor female workers' health is another issue that has come to the, especially during pregnancy, as it creates additional heat stress problems. Respiratory and cardiovascular diseases, secondary to exposure to poor air quality, were found to have a greater impact on women due to their greater propensity for higher particulate deposition in the lung tissue (Ylipaa et al., 2019).

3.2 Questionnaire on climate threats - Demographic profile

Residents of 109 cities from six regions, Africa (31.4%), Asia (21.4%), Europe (29.3%), Latin America (5.7%), North America (7.9%) and Oceania (4.3%) participated in the survey (Figure 2).

The demographic profile of the respondents is shown in Table 3. The gender distribution of the residents included 40.1% female, 57.7% male and 2.1% did not answer to this question; almost 65.50% of the respondents were between 29 and 58 years old; nearly 2.9% had a high school degree and 89% had received a postgraduate degree. Moreover, 36% were professionals and 1.4% were unemployed; 33.1% received monthly income of above 3000 € and 10.3% had income of 1000 to 2000 €; almost 48.9% of the respondents lived in flat and 15% lived in semi-detached house. The household participants of the respondents included 2 adults (52%), no children (50%) and 17% with 1 child (less than 18 years old).

Table 3: Demographic profile of the respondents.

Variable	N	%
Gender		
Male	57	40.1%
Female	82	57.7%
No answer	3	2.1%
Total	142	100.0%
Age (years)		
18-28	7	4.9%
29-38	24	16.9%
39-48	43	30.3%
49-58	26	18.3%
Over 58	39	27.5%
Education level		
High school or less	4	2.9%
Graduate	10	7.2%
Postgraduate	125	89.9%
Occupation		
Unemployed	2	1.4%
Retired	14	10.1%
Student	9	6.5%
Temporary Employee	3	2.2%
Administrative Staff	5	3.6%
Trained Professional	50	36.0%
Junior Management	5	3.6%
Middle Management	18	12.9%
Upper Management	23	16.5%
Consultant	7	5.0%
Monthly income (€)		
Below 500	21	15.4%
500 to 1000	24	17.6%
1001 to 1500	14	10.3%
1501 to 2000	14	10.3%
2001 to 2500	11	8.1%

2501 to 3000	7	5.1%
Above 3000	45	33.1%
Type of housing		
Flat	68	48.9%
Semi-detached house	21	15.1%
Detached house	42	30.2%
Adults in the household		
1	18	12.9%
2	73	52.5%
3	22	15.8%
4 or more	26	18.7%
Children (less than 18 years old) in the household		
None	71	50.4%
1	25	17.7%
2	20	14.2%
3	16	11.3%
4 or more	9	6.4%

3.2.1 Descriptive analysis of climate change impacts on cities liveability

Temperature increase on a global scale is a big environmental threat all over the world. Rapid urbanization has raised the city's emission levels and has an effect on the temperature of the atmosphere. However, the COVID-19 pandemic and associated worldwide lockdown have recently lowered pollution levels. There are significant impacts that has been observed in the major megacity of the world. For example, the lockdown due to COVID-19 pandemic in the cities caused the pollution level of the city significantly improved (Sahani et al., 2020). As shown in Table 4, 17.8% of the participants stated that they have full lockdown. The results also show that 2.4% of participants experienced no lockdown and 16.7% have partial lockdown.

Table 4 shows participants' awareness of the impact of climate change on the liveability in their city. Based on the findings of this study, 46% of the respondents were, to some extent, aware of climate change impacts on the liveability in their city, and only 28% of respondents were sufficiently aware of this issue. Also, 1.4% of respondents were not aware of such impacts. According to the results presented in Table 4, around 46% of participants in this survey had approximate knowledge about climate change that affects the quality of life of the city dwellers. Specifically, 22.3% stated that climate change does not pose a significant threat to the residents' quality of life, and 2.2% were not aware of this issue.

Individuals, communities, and governments react to climate change in a variety of ways, which are also influenced by public views of its causes, impacts, and broader implications (Demski et al., 2017). In the survey, we investigated respondents' opinions about rising temperature over the last decade, most of whom considered human activities and natural causes to be major contributors to climate change (49% and 2.2% respectively). Also, 44.5% of participants consider both of human activities and natural causes and 2.2% stated that there is no change in temperature of their

city. Therefore, it can be concluded that the more people have knowledge on the raising weather temperature and the factors causes. According to Kashef (2016), human activities are the main derivers of climate change and have a significant impact on many aspects of human settlements. Human activities and natural causes, for example, can influence human settlements through a variety of intermediary factors, including natural environmental change (Si et al., 2014), the socioeconomic system (Si et al., 2014), extreme weather/climatic events, and human health (Lo et al., 2019).

In the current survey, we considered basic descriptive for some of the phenomena that contribute to climate change in the city. These phenomes were displacements, flood, greater inequalities, higher vulnerability, health problems, increased food security problems, increased poverty. According to the survey, most of the respondents experienced higher vulnerability and health problems (23% and 22%, respectively). The findings revealed that only 3% of people reported increased food security problems due to the climate change impacts. The factors of displacements and greater inequalities included approximately equal percentages (10%). These findings are in line with Tiihonen et al. (2017) study as their results showed that increasing temperature caused by human activities can directly affect cities liveability.

In this survey, we discussed 7 items that could be positive steps to the reduction of climate change in cities. These items included buying organic foods, planting more trees, using public transport, participating in environmental campaigns, buying more energy-efficient devices, recycling waste and use less electricity. As the results of Table 4 show, 66.9% of the respondents stated that planting more trees is an effective way to decline climate change. The percentage of responses that included use public transport, buy more energy-efficient devices, recycle waste approximately were equal among participants (55%).

To determine the importance of different contributions to climate change, respondents were asked, "Which of the factors do you think has contributed the most to climate change?" These factors were aerosols, deforestation, greenhouse gases, land use, and land cover change, and capitalism. Table 4 demonstrates that most people (48%) determined that greenhouse gases have the highest effect on climate change. In the next level, land use and land cover change were considered 28.8% as the second factor which contributes to climate change. The lowest contributors were for aerosols and capitalism with 18.7% and 1.4%, respectively. Table 4 shows respondents´ attitudes regarding to how climate change threatens on personal health and safety of residents in their city. According to the findings of this study, 45% of respondents to some extent believed that climate change threatens the health of citizens and only 0.7% of people were not sufficiently aware of this issue. In the survey, we investigated the natural hazards that most people have experienced. The items mentioned included floods, dry spells, storm surges, droughts, wild/bush, fires, higher rainfall, heat, cyclones. Approximately 64% of respondents stated that they experienced floods, 56% dry spells and a lower percentage declared they experience droughts (0.7%) in their city.

Extreme weather conditions such as heat waves, droughts, and floods are expected to become more common and intense as a result of climate change (Donkor, 2020). These adjustments are likely to increase property and crop losses, as well as trigger costly societal disruptions (Béné et al., 2018). As shown in Table 4, 57% of the participants stated that poverty is the most important factor that leads to a direct socio-economic impacts of climate change. Following it, respondents regarded inequalities and marginalization to be the major socio-economic factor in climate change in their cities (51%).

In this survey, we considered six actions that can be taken to mitigate climate change impacts and make cities more liveable including: climate-resilient urban planning; enhanced economic development; environmental regulations to curve carbon emissions and pollution; promote renewable energy; sustainable public transportation; waste management through recycling/reuse. According to Table 4, most of the participants (76.8%) in this survey stated that climate-resilient urban planning is an essential action to address climate change impacts in cities. Besides, promoting

renewable energy (59%) was the second most important factor for people. Nearly, 46.5% of the respondents had the same attitude about reducing climate change through sustainable public transportation and waste management.

For the question of who the main responsibility should have to tackle climate change impacts in the city, most people declared that central government has the highest responsibility (79%). After that, individuals and stakeholders, and local government were considered (62%) (Table 4). Concerning the question of what institutions are working to reduce climate change impacts in the city, most of the respondents declared that environmental groups have the greatest responsibility (73.9%).

Table 4 exposes respondents awareness level of the socio-economic burden of public health hazards due to climate change. Based on the findings of this study, 30% of people had a moderate attitude and 21.4% of people were sufficiently aware of this issue.

Table 4. Factors associated with climate change and liveability of cities

Variable	N	%
Stage of lockdown at the height of the COVID-19 pandemic		
No lockdown	9	2.4%
Partial lockdown	63	16.7%
Full lockdown	67	17.8%
Does climate change impact the liveability in your city?		
Not at all	7	5.0%
Yes, to a limited extent	26	18.6%
Yes, to some extent	65	46.4%
Yes, to a great extent	40	28.6%
I don’t know	2	1.4%
Does Climate change threaten the quality of life of the residents of your city?		
Not at all	3	2.2%
Yes, to a limited extent	31	22.3%
Yes, to some extent	64	46.0%
Yes, to a great extent	38	27.3%
I don’t know	3	2.2%
Which of the following components of your city are most significantly impacted by climate change?		
Housing	51	35.9%
Telecommunications	13	9.2%
Transportation	42	29.6%
Waste management	53	37.3%
Water provision	83	58.5%
Drainage system	70	49.3%
Energy supply	56	39.4%
Food, agriculture	4	2.8%
Do you think the temperature in your city has been rising over the past decade?		
No, there is no change	3	2.2%
Yes, because of human activities	68	49.6%
Yes, because of natural causes	3	2.2%
Yes, both because of human activities and natural causes	61	44.5%
I don’t know	2	1.5%
Which phenomena related to climate change have you experienced on your city?		

Variable	N	%
Abnormal rainfall and drought	2	0.5%
Displacements	39	10.2%
Flood	2	0.5%
Greater inequalities	42	10.9%
Higher vulnerability	90	23.4%
More health problems	87	22.7%
Increased food security problems	1	0.3%
Increased in poverty	51	13.3%
I don’t know	2	0.5%
Which of the following do you think has contributed the most to climate change?		
Aerosols	1	0.7%
Deforestation	26	18.7%
Greenhouse gases	67	48.2%
Land use and land cover change	40	28.8%
Capitalism	2	1.4%
I don’t know	3	2.2%
How much do you think climate change threatens the personal health and safety of residents in your city?		
Not at all	1	0.7%
To a limited extent	26	18.6%
To some extent	63	45.0%
To a great extent	49	35.0%
I don’t know	1	0.7%
Which climate hazards do you experience on your city?	91	64.1%
Floods	80	56.3%
Dry spells	42	29.6%
Storm surges	1	0.7%
Droughts	25	17.6%
Wild/bush fires	1	0.7%
Higher rainfall	11	7.7%
Heat	4	2.8%
Cyclones	91	64.1%

Variable	N	%
Which of the following are the direct socio-economic impacts of climate change in your city?		
Poverty	81	57.0%
Overpopulation	34	23.9%
Unemployment	56	39.4%
Insecurity and crimes	44	31.0%
Inequalities and marginalization	73	51.4%
Which of the following actions should be taken to address climate change and make your city more liveable?		
Climate-resilient urban planning	109	76.8%
Enhanced economic development	49	34.5%
Environmental regulations to curve carbon emissions and pollution	80	56.3%
Promote renewable energy	84	59.2%
Sustainable public transportation	66	46.5%
Waste management through recycling/reuse	66	46.5%
Who do you think should have the main responsibility to tackle climate change impacts in your city?		
Individuals and stakeholders	88	62.0%
Environmental organizations/lobby groups	42	29.6%
Local government	89	62.7%
Central government	113	79.6%
Business and industry	75	52.8%
All of us	6	4.2%
Which of the following entities are taking initiatives to reduce climate change impacts in your city?		
Citizens themselves	69	48.6%
Environmental groups	105	73.9%
Private companies	30	21.1%
Regional government	54	38.0%
National government	63	44.4%
International organizations	52	36.6%
Which of the following activities can help decline climate change?		
Buy organic food	18	12.7%
Plant more trees	95	66.9%
Use public transport	79	55.6%

Variable	N	%
Participate in environmental campaigns	39	27.5%
Buy more energy-efficient devices	77	54.2%
Recycle waste	78	54.9%
Use less electricity	37	26.1%
What do you think is the level of socio-economic burden of public health hazards due to climate change in your city?		
None	2	1.4%
Uncertain	2	1.4%
Low	23	16.4%
Moderate	42	30.0%
High	41	29.3%
Very high	30	21.4%

4. Conclusion

The findings of this study emphasise that, after the recent deadly heat waves, there is clear pressure in many countries to introduce plans, and so their development was necessarily rapid. As such plans are being introduced by an increasing number of countries, we recommend that the contents of these plans be consistently developed as information on the effectiveness of interventions accumulates. More importantly, the notion of gradual acclimatisation to heat in elderly groups to build up their physiological defenses is a potentially valuable concern that has been given little attention. Although evidence supports the advice to stay in an air-conditioned setting, avoiding outdoor temperatures and strenuous exercise could deprive elderly people of the opportunity to train their sweat glands.

The bottom line is that we also need to take action to make our communities less vulnerable to the already ongoing impacts of climate change. Many communities have programs to address health issues that are climate sensitive. Based on the findings of this study, there are a few approaches for managing the health threats associated with extreme heat, as follows:

- By communicating heat wave risks and suggesting protective actions, heat wave early warning systems can protect individuals. These warning systems are much less costly than heat illness treatment and coping strategies.
- Encouraging people to hydrate during heat warnings and avoiding strenuous outdoor exercise.
- Easy access to public drinking fountains, swimming pools and spray pads, which can help keep individuals cool during periods of extreme heat.
- Urban forests might mitigate urban heat islands, including street trees and wooded areas, reducing local air temperatures.

Stricter mitigation policy should also be implemented, to reduce greenhouse gas emissions. Many studies have shown that lower greenhouse gases are related to lower mortality rates during extreme heat events, especially in tropical cities. Moreover, mitigation measures are also linked with health co-benefits. A case in point is how the promotions to use

cleaner alternatives such as public transportation, walking or cycling for daily commute can bring about reductions in climate-altering pollutants in the air, causing direct health benefits for people. Similarly, diets that restrict foods with high carbon footprints, such as meat and dairy products, not only reduce carbon emission but also offer health benefits by lowering the risk of cardiovascular diseases.

Adaptation measures from public health and health care services should also be pursued, especially in the tropical cities of low and middle-income countries. This helps to promote health and reduce the disease burden during increasing temperatures. Some public health interventions include infectious disease surveillance, early warning systems, vulnerability mapping and resilient health care services (Smith et al., 2014). It is suggested that outdoor activities should be reduced during those periods. Vulnerable groups of people should be especially protected. Finally, smart technologies for cooling can also be used to reduce indoor heat and improve the health and well-being of the urban population in developing countries. These include upgrading the housing infrastructure with cooling methods such as ventilations, fans and renewable air conditioning (Lundgren Kownacki et al., 2019). There are some limitations in this study as it covers a small number of cities around the globe. Moreover, the research only uses data gathered after 2010, hence providing a picture of current trends and limited insights on past trends.

Declarations

Conflict of interest: Walter Leal Filho, Liza Tuladhar, Chunlan Li, Abdul-Lateef Babatunde Balogun, Marina Kovaleva, Ismaila Rimi Abubakar, Hossein Azadi, Felix Kwabena Donkor declare that they have no conflict of interest.

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Figures

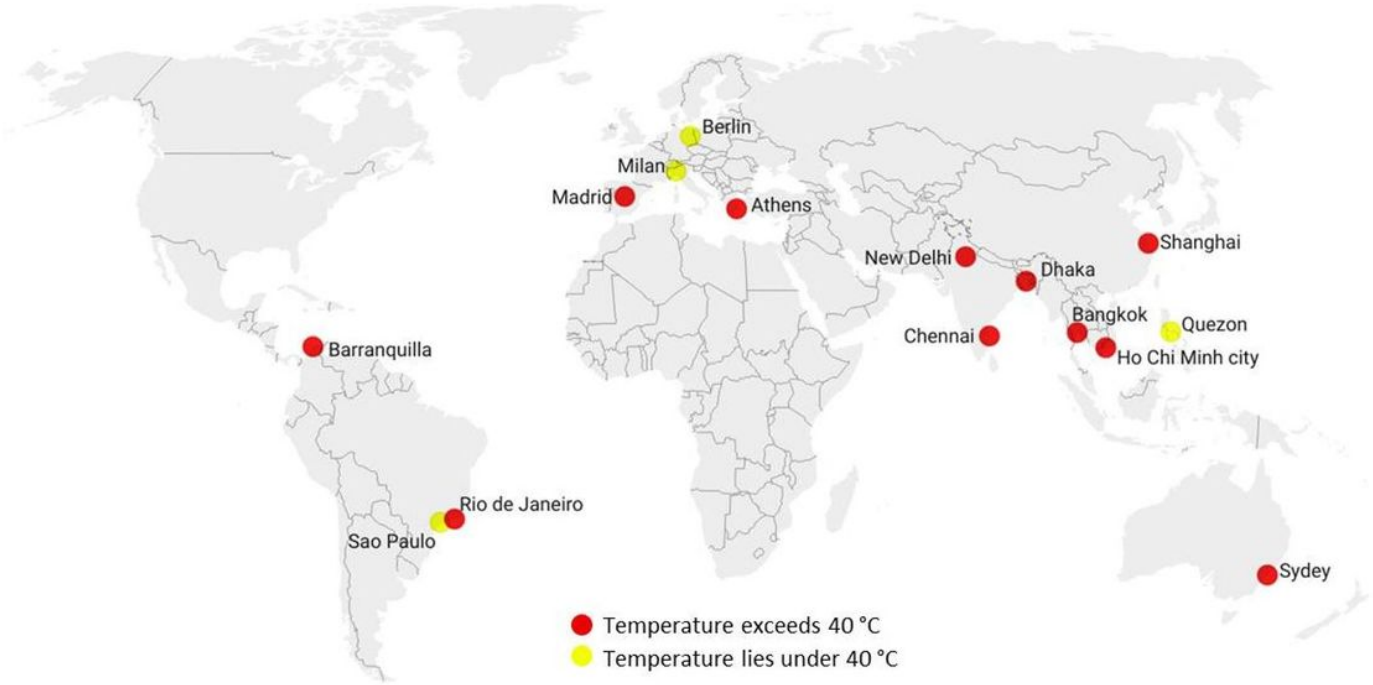

Figure 1

World map, highlighting the sampled cities (created with Datawrapper). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Cities of respondents (created with Datawrapper). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.