



Systematic Assessment on Extreme Heat Events and its Impact on Health

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ABSTRACT: Global warming condition and climate change expand the intensity and the frequency of extreme events. Among other extreme events, heat waves are now considered a major occupational and health hazards having significant cumulative association with health of living being around the world. In this paper, impact of extreme heat waves on the human health is carefully studied along with its other effects. It is interesting to observe that heat wave not only poses direct effect but also indirectly affect the system. Lot of studies has been done by the developed and modern countries which are carefully reviewed in this paper. Unfathomable analysis of this study is showing colossal acute association between extreme heat waves and mortality rate, which vary with diverse climate factors, sensitive population including elders and children. Paper also focused on advices and recommendations about general practices to public and clinical approaches that are anticipated as a solution to reduce health problems due to heat.

Keywords: Extreme Heat Wave, Heat Index, heat vulnerability, human health.

Abbreviation: HW, heat wave: HWs, heat waves.

I. INTRODUCTION

Critical variation in the atmospheric composition due to different anthropogenic activities, large number of change are observed locally and globally that affect the ecology of the system which later on poses serious threats on the health of the individuals. Global warming is one of the most drastic effects of this modernization that show lot of climate change around the world. Advancement in the technology no doubt make the life easy but due to mismanagement and irregularity done by the human beings natural composition of the environment is continuously changes due to which frequency of extreme events like drought, flood, thunder storms, high speed winds, high rain, Heat Wave (HW) and cold wave, etc. is continuously increased day by day. Out of these, HW is commonly and regularly observes events during particular months of the year especially in most of the heat conscious countries. Occurrence and strength of these heat waves in every year is the main concern of the researcher because of their significant effect on human health. Extreme heat waves are considered crucial and paramount hazards in environmental and occupational settings causing heat-induced mortality and morbidity and vector borne diseases [1-3]. Heat Waves (HWs) are one of the slightest considered and most underrated regular risks in the world. Numerous studies are now accessible and explored screening the connection between health related impediment and heat stress [2, 4]. Along with health impacts like heat cramps, heat exhaustion, dehydration, and heat stroke, these HWs also have impact on agriculture, ecosystems and national economy too. Many studies proved on the basis of occurrence and strength of HWs that HWs will be more intense in near future because of environmental and

behavioral factors. These factors may involve climate change, weather conditions, social, culture, physiological conditions, vulnerable and sensitive group among society that pose a many challenges to the society [5, 6]. It is observed on the basis of study done from 1969 to 2005 that HWs and number of hot days are increasing in India [7]. Trend shows that temperature up to 11°C increases per century in India [8, 9]. Occurrence of HWs in Northern India is found in the range between five and six per year [10, 11]. Understanding the characteristics of HWs is thus extreme important to design appropriate corrective measures and to save health and reduce mortality rate. In the coming section, definition of HW and concept of HI are studied for various countries to understand the basics of HW and HI. This clarification and understanding regarding details of HW and HI, will helps author to understand its importance. For the present study, several research papers are systematically reviewed to examine the association between heat waves and its impact on human body in the form of morbidity and mortality in an international as well national context.

II. HEAT WAVES

Heat waves now a day's very common climatic action that are very uncomfortable and poses an acute as well chronic effects. HW is classified by the Intergovernmental Panel on Climate Change as one of extreme weather events due to Climate [12]. There is no exact definition of heat wave and varied as per the different situation like geographical condition, etc. although it is generally assumed as prolonged period of excessive heat. It is not possible to propose exact definition of HW as it depends upon the threshold of an individual, duration of an event and climate information

of the area under observation. HW definition mainly have two aspects “physiological” and “sociological” which vary with the location of observation. People who live in tropical area are likely to have a different appreciation of heat than those live in plain or mountain area. Thus during the definition of HW, along with environmental factors like temperature, humidity, etc. social or cultural factors such as adaptation play an important role.

Common definition of heat wave is required to understand the global changes in extreme events. But due to physiological and sociological factor it is not possible to give common definition and hence researchers give basic condition and criteria to define a HW in particular region. Keep basic idea, different researchers used the 90th or other percentile of daily maximum temperature in their studies [13, 14]. Now the question arises that why HW is of concern in present scenario. HW is responsible to many type of health effects. Quantification of HW is very important because only then, it is possible to control and understand its effects. To quantify the HW, a mathematical term called Heat index is used, which quantify the effect of Heat wave.

III. HEAT INDEX

It is common observation that during summer season, it is not only the temperature but also humidity which bother heat toleration capability. Humidity makes summers more uncomfortable and unbearable, because higher the relative humidity, higher the temperature actually feels and it is responsible to increase the body core temperature. When relative humidity is high, mean amount of water vapors is high makes the weather sticky. Better sense of heat related health risk comes out if the effects of temperature and humidity combines to calculate Heat Index (HI), since heat alone is less dangerous than the sum of heat and humidity. Hence, considering all these points, to quantify the effect of HW,

HI is used in which both temperature and humidity are used. One of the common formula which is used by most of the researchers was developed by Steadman by using multiple regression analysis on the basis of meteorological data [15].

$$HI = -42.379 + 2.04901523xT + 10.1433127xRH - 0.22475541xTxRH - 6.83783x10^{-2}xT^2 - 5.481717x10^{-2}xRH^2 + 1.22874x10^{-3}xT^2xRH + 8.5282x10^{-4}xTxRH^2 - 1.99x10^{-6}xT^2xRH^2 \quad (1)$$

Where, the denoted terms in equation stand for HI: Heat Index in °F; RH: Relative Humidity in %, T: Ambient Dry Bulb Temperature in °F.

During the extreme events, on the basis of HI values, HI standard has been set up and HI alert will be categorized as extreme danger, danger, extreme caution and caution according to NOAA's National Weather Service [16, 17]. National Weather Service Heat Safety, www.weather.gov/om/heat/index.shtml and shown in Table 1 and Fig. 1.

The HI Table 1 and Fig. 1 shows that warmer temperature with lower humidity can produce less hazardous condition to health in comparison same temperature with higher humidity. The red zone in the side represent extreme danger where chances of heat stroke is predominant, which begins around 132°F at 100% humidity. However, at 75% humidity, the same level of danger happens at just 96°F, which indicate that temperature alone is less dangerous than sum of temperature and humidity. No doubts that extreme events like heat wave have number of hazardous effect like infrastructure performance, energy demand, water quality, building design etc. but its health effect is one of the main concern. Kiem *et al.*, (2010) [18] estimated that in Australia, more than one million people were affected due to HW and many more studies has been done which systematically proven the adverse effect of HW on health.

Table 1: Heat Index Table ([https://www.wrh.noaa.gov/psr/general/safety/heat/heatindex.png\(17\)](https://www.wrh.noaa.gov/psr/general/safety/heat/heatindex.png(17)))

Heat Index	Possible heat disorders for people in higher risk groups	Category
130°F or higher (55°C or higher)	Heatstroke/sunstroke highly likely with continued exposure	Extreme danger
105°F to 130°F (41°C to 55°C)	Sunstroke, heat cramps or heat exhaustion likely, with heatstroke possible with prolonged exposure and/or physical activity	Danger
90°F to 105°F (32°C to 41°C)	Sunstroke, heat cramps and heat exhaustion possible with prolonged exposure and/or physical activity	Extreme caution
80°F to 90°F (27°C to 32°C)	Fatigue possible with prolonged exposure and/or physical activity	Caution

Table courtesy of NOAA and US National Weather Services.

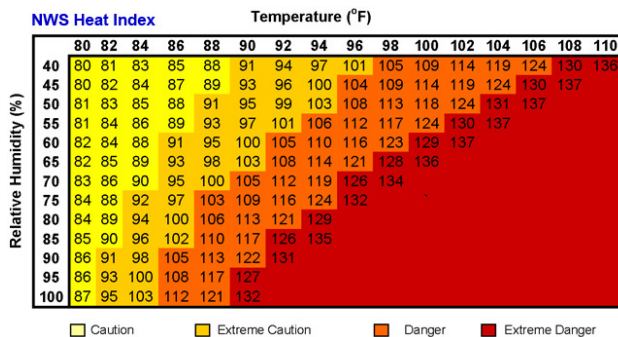


Fig. 1. Heat Index Chart (NOAA, [https://www.wrh.noaa.gov/psr/general/safety/heat/heatindex.png\(17\)](https://www.wrh.noaa.gov/psr/general/safety/heat/heatindex.png(17)))

Courtesy of NOAA and US National Weather Services.

IV. HEAT WAVES AND HEALTH IMPACTS

Extreme HWs affect majorly environment, agriculture and human health. Although HWs need to be considered important due to their significant direct and indirect impacts on health. The important direct health effects are diseases and disorders in respiration tract, digestive tract, kidneys and cardiovascular augmentation. In an extreme case, the inability of an individual to maintain body temperature via blood stream/flow or by sweating is most common reported reason leading to death. Indirect effects are also numerous which exploit at later stage or responsible due to complex impact pathway and can be in the form of degradation of water quality, producing toxins in surface and drinking water supply, favoring the growth of algae, poor air quality, increasing the risk of pollution and contaminants in the environment. HWs also affect the regular transportation of food and water supply. Cases of death and hospital admissions is observed on same day or have lagged effect depends upon intensity and exposure of HW different vulnerable groups. All these direct and indirect effects of heat waves ultimately leads to mortality, degradation of quality of environment, population and life style.

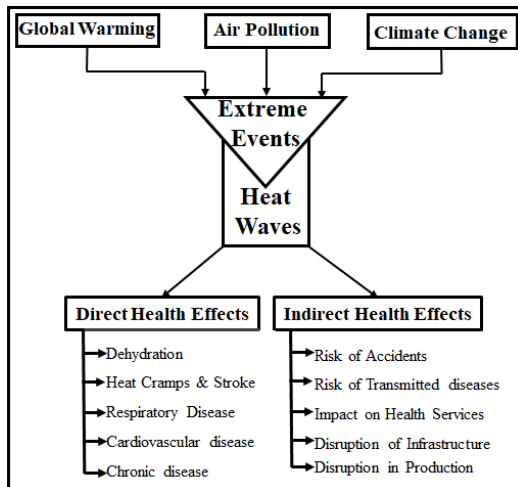


Fig. 2. Heat wave: its cause and direct and indirect impact on Health.

Extreme temperature significantly affected the vulnerable segment of population such as infants, elders, less privileged members of our society. Fig. 1

conceptualizes the major causes of heat waves and direct and indirect impact of extreme event on human health.

Exposure to HWs for certain period of time causes various heat-related diseases like heat stroke, heat syncope and heat cramps [19]. These diseases depend upon core body temperature and when it exceeds 103°F, multiple organ dysfunction may takes place which may further leads to death of a patient [20-22]. Heat wave is a disaster but unfortunately proper guidelines and best practices are still need more practice even in developed countries like Europe and United States. As shown in Table 2, there is high mortality rate in many developed nations including London, France, Switzerland, Germany due to extreme HWs from 1976 to 2003. VHWs in France led to 14,802 deaths in 2003 which took place in a short span of just 20 days. Likewise, heat waves in London and Germany in the same year caused more than 1000 deaths. In terms of percentage the mortality rate increased from 9.7% to 17% in London from 1976-2003 [23].

These short-term increase in death rates, is as similar as seen for very severe pollution incidents. A study conducted by Guo *et al.*, in 2017 [24], represents relationship between high heat waves and mortality from 18 countries by selecting 400 communities covering study period from 1972-2012 which is represented in Table 3. Table shows the time period when study was conducted, death rate in numbers and number of communities studied in 18 countries. Authors observed 26 million deaths in that particular study period where number of deaths and extreme annual heat wave days were different by community. The maximum number of communities were studied in United State from 1985-2006 where 7, 106,601 deaths were observed in just 20 years. Even in developed nation Japan there are more than 1 crore or 10 million deaths were observed in the period from 1972-2012.

Assorted studies have shown that, overall impact of heat waves episodes depends on a range of factors like the frequency or magnitude of heat waves, season, size of a population, number of sensitive people in a particular population, public health facilities and rejoinders [25]. Heat waves episodes are also correlated with various other environmental hazards like air pollution, forests fire, shortage of electricity and water source, which further have implication for human fitness achievement.

Table 2: Extreme heat waves and mortality rates in numbers and percentage increase as compared to previous year [23].

S.No.	Year	Location	Mortality rate in numbers and/or percentage increase
1.	1976	London, UK	9.7, 9.7 and 15.4 % increase in England, Wales and London
2.	1981	Portugal	1906 excess deaths
3.	1983	Rome, Italy	35% increase in deaths
4.	1995	London, UK	11, 11 and 23% increase in England, Wales, and London
5.	2003	Italy	3134 (15%)
6.	2003	France	14802 (60%)
7.	2003	Switzerland	975 deaths (6.9%)
8.	2003	Netherlands	1400 deaths
9.	2003	Germany	1410 deaths
10.	2003	London, UK	2091 (17%) Mortality in Londonregion

Table 3: Number of deaths due to extreme heat waves in 18 countries [24].

S.No.	Period	Country	No. of Community	No. of deaths
1.	1985-2006	United States	135	7, 106, 601
2.	1999-2008	Thailand	62	619, 432
3.	1990-2010	Spain	51	1, 054, 098
4.	1972-2012	Japan	47	10, 075, 406
5.	1986-2011	Canada	26	944,105
6.	1997-2011	Brazil	18	1, 101, 149
7.	1987-2010	Italy	10	248, 808
8.	1990-2012	United Kingdom	10	3, 513, 043
9.	1992-2010	South Korea	7	472, 421
10.	2002-2009	China	6	172, 703
11.	1984-2007	Ireland	6	316, 652
12.	1998-2013	Colombia	5	267, 736
13.	2001-2010	Moldova	4	18, 828
14.	2006-2010	Philippines	4	90, 917
15.	1988-2009	Australia	3	36, 984
16.	1994-2007	Taiwan	3	218, 302
17.	2009-2013	Vietnam	2	35, 655
18.	2004-2013	Iran	1	40, 824

In developing country like India, there are similar numbers of heat wave days observed per year within each type of heat wave definition. Data shows that at the end of May, 2018, Indian Meteorological Department in India, observed heat waves in many states. These states were east and west Rajasthan, east and west Madhya Pradesh, Haryana, Chandigarh, Delhi, South Uttar Pradesh, Uttarakhand. In Phalodi, a town in Rajasthan, highest heat waves were recorded on 19th May 2016, which is 51°C highest ever recorded temperature in India. Churu, other town in the state also recorded highs of 50.2°C the same day. The highest maximum temperature recorded on 27th May, 2018 was 47.2°C in East Madhya Pradesh [27]. Previous data from Indian Meteorological department Ministry of Earth Sciences, indicates 4,620 deaths in India which is caused by erratic heat waves conditions in the last four years. Out of these, 4,246 deaths were from Andhra Pradesh and Telangna alone. In 2016, this figure was 1,600 deaths due to massive heat waves, whereas it was 2,081 in 2015, 549 in 2014 and 1,443 deaths in 2013. It is well documented in different HW action plan that the primarily reason for these deaths are heat stroke and dehydration. These conditions lead to respiratory and renal failure, especially for sensitive population like infants and elderly people and patients who are suffering with heart and kidney disorders. Indian Meteorological Department has started issuing heat waves alerts to general public so that people can take necessary precautions to protect themselves from extreme weather.

V. DISCUSSION

Present research work explains how weather extremes are associated with significant public health concern [28-30]. Weather extremes like drought, heat waves, and precipitations can results into crop failure, tropical cyclone, floods, morbidity and mortality among the communities consistent with anthropogenic climate change [31]. Extreme temperatures in the form of heat waves in any area of the world are accountable for major directly-mediated weather-related mortality [32-37].

Two well-documented examples are Chicago heat wave in 1995 and the Paris heat wave of 2003 [38]. In both the cases, extreme heat waves and hot temperatures was responsible for high mortality rate and also caused economic disturbances, inconvenience, and discomfort to public. The morbidity and mortality caused by heat can have direct and indirect effects on the body [39], which includes minor to major illness of heat stroke. Exposure to heat causes stresses underlying physiological systems and results in different manifestations [40].

Many regions in India like west part, north-west, north-central, central and south-central area experiences extreme heat waves. Due to this drought are now common in hilly area also [41-43]. Pollution from industries and transportation also play role in ambushing the heat. Short of apposite greenery, insufficient trees, lack of shades in cities makes the situation unbearable scorching. Such conditions with high density of people, closely spaced residential areas, lack of proper ventilation leading to a phenomenon called "Urban Heat Island" effect, making these dwelling vicinity behave like an oven, absorbing abundant heat due to tin or plastic sheet roofs. Because of Heat Island effects, incidence of direct effects on human like heat strokes, dehydration and deaths increases. It happens majorly among underprivileged sections of our society like daily wages labours, riskshaw pullers, street hawkers/vendors and/or small shopkeepers as they are majorly exposed to heat waves [44]. For the proper management of HW, it is necessary to make some suitable monitoring strategy as mentioned in one of the research paper in case of respiratory symptoms [45].

VI. CONCLUSION

Frequency and intensity of HW increases as result of Global warming. Heat waves and related events are not well defined and different researchers define it on a national or local basis and on the basis of threshold of an individual, duration of an event and climate information of the area under observation. HW events in several countries are linked with increasing pollution level of air and water, health hazards, increase in

emergency hospital admission and public health services. For the protection of general public from heat, proactive steps and evidence-based strategies are much needed. The strategies to reduce mortality and protection to health need further research that will identify gaps, loopholes and safety measurements. Targeting high risk groups cannot be only solution to this problem but good primary health of population is also required. If primary health of a population gets improved, sensitivity of the population for extreme temperature decreases, automatically. To reduce the impact of heat, morbidity and mortality, Government should make some health action plan. Besides, public awareness and community outreach programmes should be there along with early warning system. Energy-intensive buildings should be designed more to keep that building artificially cool. At the same time, we must build our houses that remain cooler, energy efficient, green and sustainable. Other simple steps that can be easily followed to protect general populations and prevent deaths due to heat waves can be

- Planting more trees with wide canopies along roads to absorb heat.
- More green cover in low-income residential areas.
- Change working hours in school, offices and commercial activities.
- Proper information to general public regarding power cuts.

The better understanding and knowledge of the characteristics of heat wave effects on mortality is important to protect human health and life. These heat waves will be longer, frequent and more intense in the coming years. Our findings suggest that the effect of heat waves on mortality is dependent on intensity of heat not only on duration and risk of death increases during heat waves than usual climate.

Conflict of Interest. No.

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