Study on Heatwave Disaster Prevention and Control Planning System—Enlightenment of Major Countries in the World

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Abstract. Due to global warming, the frequency and intensity of extreme heatwave are increasing. Heatwave disaster will become one of the most serious disasters in the future. In order to reduce the impact of heatwave, comparative analysis, case analysis and induction are used to study the response measures of heat wave disasters in major countries in the world, which are divided into the following two parts: heatwave disaster monitoring and early warning system and heat-health action plan. From the perspectives of early warning standards, response measures and response agencies, the standard and complete framework of heat health action plan is proposed. Some suggestions are put forward to establish a perfect and effective heatwave response system.

Keywords: Heatwave disaster; Heat-Health action plan; Prevention and control system.

1. Introduction
Human activities have been the main cause of global warming since the middle of the 20th century[1,2]. In recent years, man-made greenhouse gas emissions have reached an all-time high, leading to more severe climate change and frequent extreme weather disasters. The frequency and intensity of extreme weather events such as droughts, floods, hurricanes and heatwaves are increasing[2]. Four of the world’s 10 most deadly natural disasters in 2015 were thermal disasters[3].

2. Introduction of Heatwave Disaster

2.1. Definition of Heatwave
Heatwave is a meteorological concept in a broad sense, which means that high temperatures, high humidity and long duration make people feel uncomfortable, may threaten public health and life safety, and increase energy consumption, weather processes affecting social productive activities[4]. At present, there is no uniform definition of heatwave. Heatwave are defined by the World Meteorological Organization and some countries based on parameters such as temperature, thermal index, and human physiological equivalent temperature, as shown in Table 1.
Table 1. Definition of heatwave (Source: compilation according to Ref. [5]).

| Country or organization | Defining parameters | Heatwave Definition |
|-------------------------|---------------------|---------------------|
| WMO                     | Maximum temperature per day | The maximum daily temperature is above 32 °C and lasts for more than 3 days. |
| US Canada Israel        | Daytime Heat Index   | A high temperature alert is issued when the daytime heat index exceeds 40.5 for 3 hours for two consecutive days or when the thermal index is expected to exceed 46.5 at any one time |
| Germany                 | Physiological equivalent temperature (PET) | When the body’s PET exceeds 41 °C, the thermal mortality rate increases significantly. Therefore, PET is higher than 41 °C for the heatwave warning standard. |
| China                   | Maximum temperature per day | A day maximum temperature of 35 °C is called high temperature, and a high temperature process for several days (more than 3 days) is called a heatwave |
| Netherlands             | Maximum temperature per day | The maximum daily temperature is above 25 °C and lasts for more than 5 days, with at least 3 days of maximum temperature above 30 °C |

2.2. Present Situation and Development Trend of Heatwave Disaster

World Health Organization (WHO) saying that 2015-2018 was the hottest four years on record and that the global average surface temperature in 2018 was about 1 °C above the pre-industrial baseline [4]. June 2019 was the hottest June on record for human weather, while Europe, South America, Africa and Asia were hit by heatwaves of varying degrees [3].

Since the 21st century, the frequency and duration of heatwave disasters have increased significantly, the intensity and scope of disasters have continued to expand, and the fatality rate has risen sharply, second only to earthquakes and tsunamis. More than 70,000 people were killed by extreme high temperature disasters in pan-europe in 2003. Heatwave have killed more than 150,000 people worldwide over the past 20 years [6].

2.3. Impact of Heatwave Disaster

The effects of heatwave include human health, production and living, natural environment and urban infrastructure, etc. Heatwave can contribute to air pollution, and environmental pollution can also pose a threat to people with asthma, cardiovascular disease, and sudden death when exposed to extreme heat [7]. Heatwave directly affects the urban infrastructure, such as melting the road surface, and damaging the power system (as shown in figure 1).

Figure 1. Effects of heatwave on the human body and urban systems (Source: Redrawn from Ref. [9]).
3. Global Heatwave Disaster Monitoring and Early Warning System

After realizing the increasingly serious effect of heatwave disaster, some countries and regions in Europe and America began to establish a more comprehensive disaster planning system on the basis of the Early Warning System. The research shows that the heatwave prevention and control planning system with integrated disaster warning system and disaster response system can reduce the impact of high temperature heatwave disaster in a short time [10-11].

3.1. Thermal Hazard Monitoring and Early Warning Systems

The Early Warning System of heatwave is established on the basis of the meteorological early warning system, but it cannot objectively show the severity of heatwave by directly using the existing meteorological forecasting system, it is necessary to set the early warning parameters and standards in the existing meteorological forecasting system, it is necessary to set the early warning parameters and standards for heatwave separately. Statistics of 14 heatwave hazard monitoring and warning systems and related parameters are shown in Table 2.

### Table 2. Global Heatwave Hazard Early Warning Systems.
(Source: compiled from Ref. [2-3,6-8,10-33])

| Country | Level | Heat wave monitoring and early warning | Early warning unit | Thermal hazard alert trigger criteria | Alert time | Monitoring and forecasting agencies |
|---------|-------|----------------------------------------|-------------------|--------------------------------------|-----------|-----------------------------------|
| India | City | Agricultural | Tmax | 1 day/≤30°C | 5-7 | 
| China | City | Shanghai Municipal | Tmax | For 3 consecutive days/≤35°C | 3 | 
| Germany | Regio n | German Ministry of Health | Physiological | Level 1: 30°C-32°C; Level 2: 32°C-34°C; Level 3: 34°C-36°C; Level 4: >36°C | 3-8 | 
| Sweden | Regio n | Swedish National Health Department | Tmax | Level 1: ≤20°C for 4 days; Level 2: ≤23°C for 5 days; Level 3: ≤30°C for 10 days; Level 4: ≤40°C for 10 days | 3-5 | 
| Greece | Regio n | Ministry of Health of the State of Greece | Tmax and Heat Index | Southern Greece: Tmin=29°C; Middle Greece: Tmax=24°C; Eastern Greece: Tmax=27°C | 3 | 
| France | City | National Institute for Health Monitoring | τ and Tmax combination | Average 3 days for Tmax and Regional thresholds | 2-4 | 
| Australia | Regio n | Australian government and health sector | PET and Tmin | PET=35°C for at least 3 days, and cooling to below 20°C a.m. if the threshold may change, depending on the weather in the previous few days | 0.5-3 | 
| UK | Country | National Severe Weather Warning Bureau | Tmin | For 2 consecutive days/≤30°C (regional average) | 2-3 | 
| Canada | State | National Institute of Public Health | Tmax and Tmin | The 3 days average =16-20°C or =21-33°C | 2-3 | 
| USA | City | High temperature | Tmax | For two consecutive days/≤21°C; ≤24°C on average for 3 days; ≤27°C on average for 6 days | 3-3 | 
| USA | Regio n | Napa County Department of Health and Public Services | Collic index | 3 consecutive days heat index≥84.3°C; high temperature index ≥105-119 | 5-7 | 
| USA | City | Department of Public Health | Collic index | 3 consecutive days≥58% | 3-7 | 
| Australia | State/ region | South Australian Socio-Economic Authority | Average daily temperature (JET) | For three consecutive days ADT≥32°C | 2-3 | 
| Southern Africa | Regions | National Weather Service | Tmax | The long-term average temperature (7 days)≥42°C | 2-3 | 

3.2. Standard Parameters for Early Warning System

A single early warning parameter, such as temperature, can not be used to accurately predict high temperature heatwave, so on the basis of a weather forecasting system, each early warning trigger standard system uses 2-3 different parameters to more intuitively predict heatwave. A Comparative Study of 17 out of 25 systems shows that the ‘early warning parameters’ and ‘warning trigger criteria’ of each system vary from region to region, most of the early-warning parameters are daily maximum temperature or average temperature. Some systems also consider night temperature or humidity, and use the early-warning parameters such as thermal index, hygrothermal index and physiological equivalent temperature. For example, the hot weather response system in Toronto, Canada uses the ‘wet heat index’ as an early warning parameter.
3.3. Early Warning System Classification
Most early warning systems use two to four warning levels, represented by numbers or colour changes (such as red, orange, yellow, and white). The Toronto early warning system is divided into two response levels: high-level extreme heat alarm and low-level general heat alarm, the triggering of different heat alarms is determined by the fatality rate of heat disaster.
In most systems, early warning standards are very broad at the national level, and the alert level for the whole country is only a reference value, which needs to be determined locally in accordance with its own climatic and social conditions. For example, the National Early Warning System in Britain and Canada is mainly to guide the establishment of local thermal early warning system. The early warning systems of countries such as France and Greece, which are divided into northern and southern France, and Greece, which is divided into northern, central and southern and insular areas. Warning standards are more targeted in smaller areas such as Philadelphia, Toronto, Rome and Shanghai.

4. Heat-Health Action Plan
The Early Warning System of high-temperature heatwave usually only runs in the period of high-temperature disaster, while the planning system focuses on the whole cycle of heatwave disaster. Meanwhile, the corresponding measures are formulated according to the different climate characteristics and the prevention and control targets in each stage. With the development of resilient city concept, the healthy development of city system and the physical and mental health of city residents are paid more and more attention, the ‘planning system for high-temperature heatwave disasters’ has been gradually integrated into the ‘Heat-Health Action Plan (HHAP)’.

4.1. Development of Global Heat-Health Action Plan
At the end of the 20th century, cities such as Philadelphia, Chicago and Toronto in North America were the first to formulate policies to deal with heatwave. In 1996, the ‘extreme high temperature response plan’ was established and implemented in Philadelphia, USA. After the outbreak of large-scale extreme heat disaster in pan-EEuropean area in 2003, many European and American countries began to draw up the heat disaster ‘Management Plan’, and made relevant laws at the national level to guide the development of national heat disaster management system. The Heatwave Plan for England, the First National Planning Guide, was adopted in 2004. In addition, Italy, Germany, Spain, Switzerland, Sweden, Belgium, Romania and other countries and regions have also developed hot health action plans [24].

4.2. Global Heat-Health Action Plan
The objective of the heat-health action plan is to respond to extreme heat conditions, including heatwaves and their associated thermal hazards, and to minimize their effects. The action plan consists of two components: a ‘thermal Hazard Early Warning System’ based on biometrics and weather forecasting systems; and a ‘thermal-health Action Plan’ aimed at reducing social risks [6]. Select and comb 11 representative ‘hot health action plans’ in the world, from the release level of Action Plans, major measures, target groups, implementation methods and other aspects of comparative analysis, the main content as shown in table 3.
4.3. Main Measures of Hot-health Action Plan

The ‘Hot-health Action Plan’ is divided into national and regional levels, and corresponding action plans are initiated for different levels of early warning, such as New Hampshire, the city of Phoenix, etc. In addition to the action plans of Greece, Lisbon and other countries and regions, most of the ‘Hot-health Action Plans’ are regularly evaluated and revised, ranging from several times a year to once every 2-3 years. The target groups for the implementation of the ‘Hot-health Action Plan’ include not only the National Public Health Departments, medical institutions, old-age institutions, the Department of Health and other health-related agencies, but also the people and special groups (such as the elderly, workers in special industries, etc.). In addition, all action plans have specific programmes for health system and high temperature vulnerable groups.

4.4. Planning Authority of Heat-health Action Plan

Most hot-health action plans are developed and implemented by the government. Action Plans in the United Kingdom, Toronto, Canada and Arizona in the United States also set up a special management committee responsible for the implementation and revision of the plan, and has accountability mechanisms for relevant government departments.
The ‘Hot-health Action Plan’ issued by Arizona State in 2016 is led by the State Department of Health. It is divided into five types of response plans according to the severity of the hot disaster. In 2001, the Toronto Government of Canada developed a ‘Hot-health Action Plan’, which was implemented by a government-appointed ‘heatwave emergency committee’ composed of representatives from various city departments and agencies [14].

4.5. Key Responses of Heat-Health Action Plan
Some state governments in the United States, such as Arizona and New York State, have also deployed contingency strategies to deal with urban heat disasters in order to prepare for the long-term changes of high-temperature heatwaves and propose countermeasures against urban heat island effect. France’s Hot-health Action Plan calls for each institution to have at least one cooling center during a hot disaster and to develop a mobile phone APP, the APP lists information about urban cooling centers that can direct residents to nearby service centers to avoid disasters, and calls people who are vulnerable to heat, such as people living alone, on a regular basis, to ensure a smooth passage through the heat hazard period. In addition to the general response.

5. Conclusion
Under the extreme climate change environment caused by climate change, heatwave disaster is becoming one of the frequent natural disasters that all countries need to pay attention to. The most effective way to avoid the effects of heatwave is to mitigate climate change by reducing greenhouse gas emissions and controlling the rise in global average temperatures, as well as to reduce local air pollution and heat island effects in cities. When the heatwave is coming, how to effectively prevent and control the disaster, reduce the social risk and improve the urban resilience is the key to build a complete ‘heatwave early warning system’ and ‘Heat Health Action Plan’ coordinated operation mechanism. Heatwave are closely related to regional climate, and heatwave warning systems and heat health action plans must be tailored to each country’s actual situation.

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