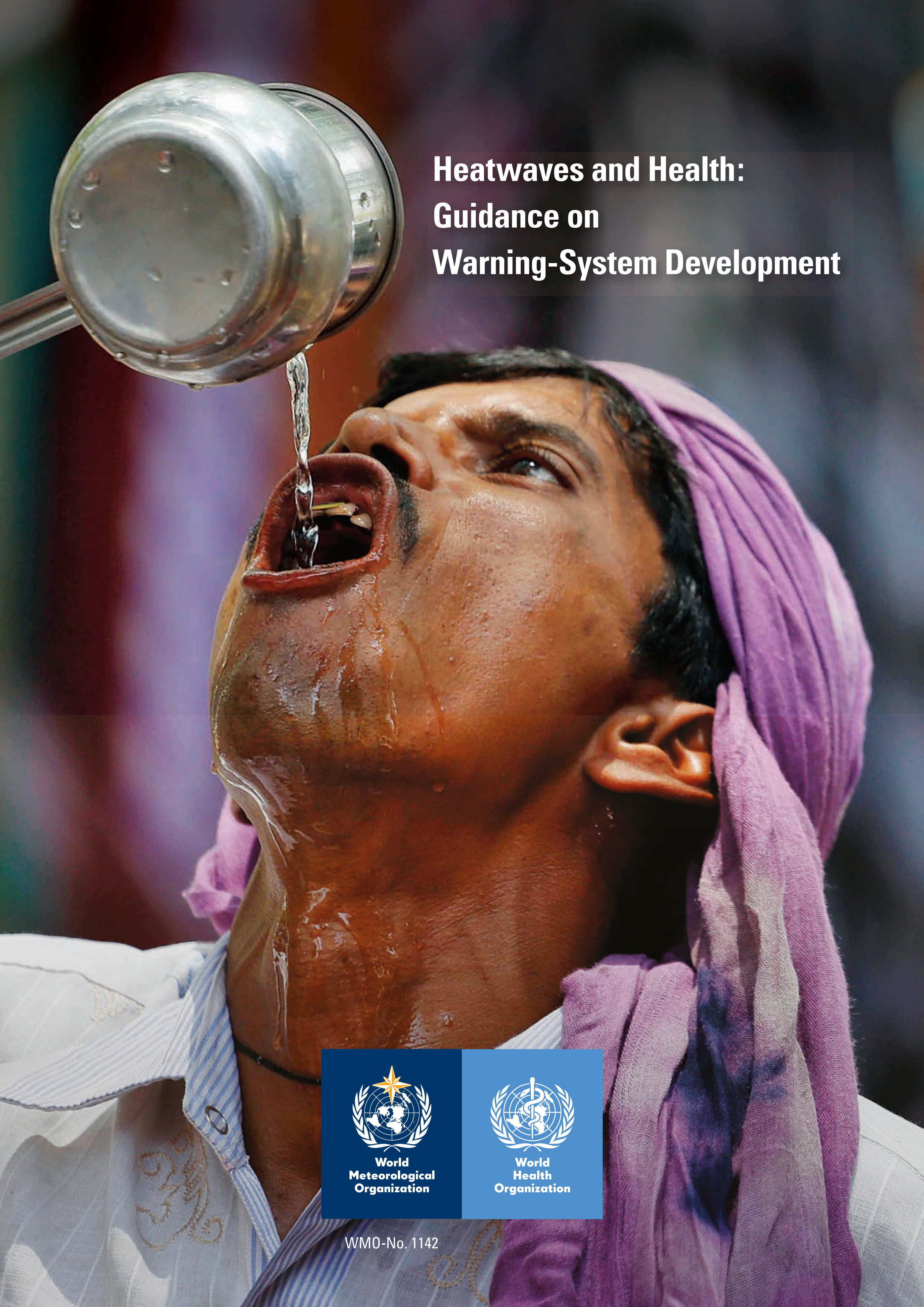

Heatwaves and Health: Guidance on Warning-System Development

World Meteorological Organization

World Health Organization

WMO-No. 1142

WORLD METEOROLOGICAL ORGANIZATION

WORLD HEALTH ORGANIZATION

Heatwaves and Health: Guidance on Warning-System Development

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World Meteorological Organization
Weather • Climate • Water

World Health Organization

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FOREWORD

Heatwaves are among the most dangerous of natural hazards, but rarely receive adequate attention. They often lack the spectacular and sudden violence of other hazards, such as tropical cyclones or flash floods. Even the related death tolls are not always immediately obvious. For example, the European heatwaves in the northern hemisphere summer of 2003 were responsible for the deaths of tens of thousands of people.

The Fifth Assessment Report (AR5) of Working Group I of the Intergovernmental Panel on Climate Change (IPCC), released in September 2013, stated that, over the previous 50 years, hot days, hot nights and heatwaves had become more frequent. Previously, in 2012, the IPCC Special Report on Extremes also indicated that the length, frequency and/or intensity of heatwaves would likely increase over most land areas in the twenty-first century. There is increasing recognition that heat-related risks might be reduced through systematic development of heatwave early warning systems, alerting decision-makers and the general public to impending dangerous hot weather. It is important that public-health measures and advice on how to avoid negative health outcomes associated with hot-weather extremes, are elaborated in advance. Considering the need for close coordination between meteorological and health services in this regard, the World Meteorological Organization (WMO) and the World Health Organization (WHO) took the initiative to jointly develop and disseminate guidance on Heat–Health Warning Systems (HHWSs).

Under the auspices of the WMO Commission for Climatology (CCl), WMO and WHO experts have compiled this Guidance. It considers who is at risk from heat, outlines approaches to assessing heat stress, presents the science and methodologies associated with the development of HHWSs, overviews heat-intervention strategies which are a necessary part of any truly integrated HHWS, considers the problem of communicating heat risk and how to evaluate HHWSs and draws attention to the essential elements of summer heat plans within which HHWSs are nested. The climate component of an HHWS is the responsibility of the National Meteorological and Hydrological Services (NMHSs) and WMO, while much of the responsibility concerning the societal response component lies with the health- and social-service sectors. It is hoped that the Guidance will act as a catalyst for bringing together key players from climate, health, emergency-response agencies and decision-makers, as well as the general public, for initiating action concerning the overall management of heat as a hazard.

Growing concerns over climate change have brought to the fore three important aspects: adaptation, disaster-risk reduction and the need for climate information and services to support these. HHWSs bring together these three facets and exemplify an effective demonstration of climate-risk management in practice. We expect this publication to enable NMHSs and health-sector agencies to provide effective climate services and save lives in vulnerable communities around the world.

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Heatwaves and Health: Guidance on Warning System Development was developed with the advice and leadership of scientists from around the world in the fields of weather, climate and health and related disciplines under the auspices of WMO and WHO. The experts involved brought the diversity of research, academic, intergovernmental and operational experience to this work. Both WMO and WHO would like to extend their appreciation to all those who participated in preparing this publication and to those whose contributions to the published literature relevant to heat and health added richness to the content.

WMO and WHO are grateful for the contributions and commitment of the lead editor, Glenn McGregor (Department of Geography, Durham University, Durham, United Kingdom), under whose leadership this Guidance has been developed. Mr McGregor has a longstanding association with the WMO Commission for Climatology (CCl), having led its Expert Team on Climate and Health from 2005 to 2010. He is President of the International Society of Biometeorology and Emeritus Editor of the International Journal of Climatology. We also acknowledge with appreciation the contributions by authors of the chapters and, particularly, the joint editors – Kristie Ebi (independent consultant, California, USA), Bettina Menne (Programme Manager, Climate change, sustainable development and green health services, WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany) and Pierre Bessemoulin (president of CCl, 2005–2010, Toulouse, France). The publication builds on the knowledge of several important projects such as EuroHEAT, implemented by the WHO Regional Office for Europe and co-funded by the European Commission. Outcomes of such initiatives have helped improve public-health responses to weather extremes and, in particular, the use of heatwaves as case studies for improving public-health responses.

We also appreciate the contributions of the chapter authors: Glenn McGregor (Chapter 1); Martin-Immanuel Bittner, Franziska Matthies, Paola Michelozzi, Sari Kovats and Bettina Menne (Chapter 2); Gerd Jendritzky and Larry Kalkstein (Chapter 3); Scott Sheridan, Christina Koppe and Larry Kalkstein (Chapter 4); Haleh Kootval (Chapter 5); Kristie Ebi (Chapter 6); Sari Kovats (Chapter 7); Robin Hicks and Bettina Menne (Chapter 8) and Glenn McGregor (Chapter 9); and to those who offered additional comments, contributions and reviews of the text: Peter Berry, Diarmid Campbell Lendrum, Kim Knowlton, Thomas Kosatsky and Virginia Murray.

PREFACE

Heat or hot weather that lasts for several days, often referred to as “a heatwave” can have a significant impact on society, including a rise in mortality and morbidity. Heatwaves also place an increased strain on infrastructure (power, water and transport). Clothes and food retailing, tourism and ecosystem services can also be affected, such that there may be socioeconomic “winners and losers” from heatwave events. In some instances, heatwaves may even trigger social disturbances at a number of levels. The impacts of heatwaves can be great and sometimes catastrophic, as manifested by the large number of heat-related deaths recorded across Europe in July and August 2003, and the Russian Federation in July and August 2010. While the effects of heat may be exacerbated in cities, due to the urban heat island (UHI) effect, the livelihoods and social well-being of non-urban communities can also be severely disrupted during and after periods of unusually hot weather.

In contrast to other extreme climate events, heatwaves have only recently become recognized as a significant threat to environment and society. Furthermore, the principles of risk assessment and management are being increasingly applied to a number of climate hazards. Consequently, and in accordance with the general aim of early warning systems, Heat–Health Warning Systems (HHWSs) have been developed in a number of countries. The broad purpose of an HHWS, which is an integral part of a wider Heat-Health Action Plan (HHAP), is to provide meteorological and/or climate-prediction-based information on the likelihood of forthcoming hot weather that may have an effect on health. This information is used to alert decision-makers and the general public to impending dangerous hot weather and for the implementation of a range of actions, as encapsulated in an HHAP, designed to reduce the effects of hot-weather extremes on health.

Since the implementation of the first HHWS in the city of Philadelphia, USA, in 1995, a large amount of international experience has been accumulated regarding the development of HHWSs. To date, however, this information has not been brought together in a single volume.

This Guidance has been developed jointly by WMO and WHO to outline for practitioners in both NMHSs and National Health Services (NHSs) the issues surrounding the general heat–health problem and present how an understanding of the biometeorology, epidemiology, public-health and risk-communication aspects of heat as a hazard can be used to inform the development of an HHWS as part of a wider HHAP. The Guidance places emphasis on the practical aspects of HHWSs at a generic level and is not intended to be prescriptive.

The Guidance has been produced to have global applicability. It has drawn on expert opinion and the acquired experience of a wide range of people and institutions involved in the development of warning systems and heat plans. In particular, it has been enriched by information contained in the US Environment Protection Agency’s *Excessive Heat Events Guidebook* and reports of the projects funded by the European Commission under its fifth (1998–2002) and sixth (2002–2006) framework programmes: Assessment and Prevention of Acute Health Effects and Weather Conditions in Europe (PHEWE), Climate Change and Adaptation Strategies for Human Health (cCASHh) and Improving Public Health Responses to Extreme Weather/Heat-Waves (EuroHeat).

Because the main focus of the Guidance is the development of an HHWS as the alert component of a wider HHAP, the chapters in this volume have been ordered to reflect this. Thus, background on the physical and physiological nature of heat and its assessment is presented initially, followed by material on the structure of HHWSs and associated science and communication issues that need to be taken into consideration when developing an HHWS. Later chapters provide the opportunity for readers to develop an appreciation of the relationship of an HHWS to a wider HHAP, such that, downstream of the development of the scientific and communication aspects of HHWSs, come issues of evaluating the performance of the warning system and consideration of the type of intervention strategies that could theoretically be implemented in advance of, or following, an HHWS-generated warning. Longer-term initiatives for managing heatwaves and health are presented at the end of the Guidance.

Readers are encouraged to read this Guidance in conjunction with the WHO publications *Heat/Health Action Plans* and *Public Health Advice on Preventing Health Effects of Heat*. We hope that the Guidance will be useful to decision-makers around the world; meteorological and health practitioners in NMHSs and NHSs, including the agencies that deal with the health effects of heat on people; the emergency-response and hazards communities; the media; and people whose living or working circumstances make heat and heatwaves an issue that needs to be addressed.

G.R. McGregor
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EXECUTIVE SUMMARY

Heatwaves are a pervasive natural hazard. Although there is no universally accepted definition, they are understood to be periods of unusually hot and dry or hot and humid weather that have a subtle onset and cessation, a duration of at least two–three days, usually with a discernible impact on human and natural systems. Because there is no absolute universal value, such as a given temperature that defines what is extreme heat, heatwaves are relative to a location's climate: the same meteorological conditions can constitute a heatwave in one place but not in another. Day- and night-time conditions are equally important for understanding the health effects of heatwaves, which may range from heat rash to heat cramps, heat exhaustion, heatstroke and death. At the individual level, poor thermoregulation or the inability to balance heat gains to, and heat losses from, the body are responsible for heat-related health outcomes.

In addition to thermoregulatory factors, demographic and socioeconomic characteristics may determine an individual's level of heat risk. These include age (being elderly or very young), having pre-existing disease, living alone, being socially isolated, homeless, not having access to heat–health information in a variety of forms, being immobile, suffering from mental illness or not being able to undertake self-care. Other factors such as deprivation and gender may also be important. People possessing multiple risk factors are at higher risk of heat-related illness and death.

One way to manage the risk of heat-related health effects is through the development of an HHWS. The overall aim of an HHWS is to provide meteorological and/or climate-prediction-based information on the likelihood of forthcoming hot weather that may have an effect on health. This information is used to alert decision-makers and the general public to impending dangerous hot weather and for the implementation of a range of actions, as encapsulated in an HHAP, designed to reduce the negative health effects of hot weather extremes. Typically, HHWSs are composed of a number of elements that include:

- Weather forecasts of high temperatures that may also include humidity;
- A method for assessing how future weather patterns may evolve in terms of a range of health outcomes;
- The determination of heat-stress thresholds for action;
- A system of graded alerts/actions for communication to the general population or specific target groups about an impending period of heat and its intensity and to government agencies about the possible severity of health impacts.

An HHWS is often part of a wider HHAP. HHAPs include not only the HHWS itself, but also the following:

- General public education and awareness-raising about heat;
- Preparedness in terms of specific training of stakeholders in, and responders to, periods of extreme heat;
- Specific guidance on actions to reduce personal levels of heat risk;
- Clear guidance on heat-risk governance and responsibility for the implementation of a range of strategies and the maintenance of critical hard and soft infrastructure (for example, air-conditioning in care homes and social/support networks);
- A plan outlining "the when, what, how and to whom" in relation to heat-related messages;
- A programme of evaluation in terms of whether the HHWS and HHAP are achieving their aims;
- A real-time health-surveillance system;
- Advice on longer-term strategies for reducing heat risk, such as through climate-sensitive building, urban design and town planning (WHO, 2008);
- Monitoring and evaluation of the effectiveness of interventions and how they could be improved.

HHWSs are frequently developed at the local/regional level because data availability, human and technical resources and heat–health associations are usually geographically specific. For this reason, the structure of HHWSs varies significantly among cities, regions and countries.

Of principal concern in an HHWS is how to assess the level of heat stress associated with the meteorological or climate forecast, translate this into an estimate of a likely health outcome and identify a critical heat-stress threshold for a graded plan of action.

A range of “simple” biometeorological indices and more “complex” human heat-budget models exist for the assessment of heat stress, the choice of which will depend on the material and human resources, including technical expertise, available to an NMHS and any scientific evidence indicating the best index for the given situation. While most HHWSs use either a single meteorological variable, such as maximum temperature, or a simple biometeorological index, such as the Heat Index or apparent temperature, some HHWSs use outputs from numerical human heat-budget models and airmass-based synoptic climatological approaches for assessing heat stress. Similarly, there are a number of climatological and epidemiological methods for determining action-threshold points.

Usually, HHWS thresholds are response-specific, that is, the threshold values are set at a level associated with a negative human response as indicated by the long-term relationship between some measure of heat stress (for example, the Heat Index) and mortality. In HHWSs based on a “simple index” of heat stress, the threshold for action is usually the index value at which mortality (or any other health outcome) starts to rise rapidly, with the type of action or level of alert being determined by the intensity and duration of the period of exceptional heat. In a synoptic-based HHWS, the threshold for action relates to the occurrence of an airmass type known to be associated with high levels of mortality. In the absence of health data, HHWS developers often assume that extreme heat-stress index values associated with the 95th to 99th percentile will precipitate a health response and thus use such values for identifying action thresholds.

Without an effective communication and dissemination strategy, the benefits arising from an HHWS, such as lives saved or hospital admissions reduced, may be minimal. It is imperative that the risk associated with extreme heat in general and an impending period thereof in particular, is communicated precisely and adjusted according to the target or vulnerable group. Consequently, bespoke messages, which may be action-threshold specific (health authority, emergency service, media, community action group) composed of clear, unambiguous language, are an essential “downstream” element of any HHWS. The same principles extend to the communication and outreach elements associated with wider HHAPs.

Where an HHWS is a fully integrated component of an HHAP, outputs from an HHWS are used to operationalize a set of heat-intervention strategies from the individual to societal level. These range from simple actions at the personal level, such as ensuring sufficient indoor ventilation or liquid intake to the initiation of community-based “buddy” systems and transport of the vulnerable to dedicated cooling centres. While there is a wide range of interventions, the local context, including human and financial resources and cultural practices, will determine which interventions are most likely to be effective and how information which supports efforts to reduce heat–health risks is best communicated.

In order to gauge the effectiveness of an HHWS and identify opportunities for improvement, it is necessary that HHWS developers, stakeholders and users critically examine system performance through a formal programme of evaluation. Identification of the objectives and methods of evaluation and who should be involved in their design and implementation should be an integral part of the early development phase of an HHWS. Evaluations fall into two broad types, namely process- and outcome-based, within which are many other types.

Although the level of activity associated with HHWS operation during the “heat season” – the time of the year when extreme heat events or heatwaves are likely – will be high, a base level of activity associated with a wider HHAP such as “heat education”, seasonal awareness and the development and testing of workable intervention strategies need to be sustained all year-round for reasons of HHWS efficacy and social acceptability.

HHWSs are dynamic and continually evolving in their level of sophistication. With rapid improvements in seasonal forecasting skill and the understanding of uncertainty associated with forecasts over the 10–90 day timeframe, opportunities exist for incorporating long-lead climate information of a probabilistic nature into an HHWS.

In some locations, the synergistic effects of heat and poor air quality are likely to contribute to increased mortality and hospital admissions. There will, therefore, always be a need to assess whether or how air-quality information needs to, or could be, integrated into an HHWS and, if so, how effective, integrated climate, air-quality and human-health observation networks could be commissioned.

HHWSs are just one aspect of the adaptive management of heat risk and should be considered alongside longer-term heat-management strategies, especially in burgeoning megacities, where the UHI effect is likely to result in added heat loads. In this respect, climate-sensitive building, urban design and city planning have a role to play in reducing possible future increases in severe heat events associated with climate change.

One of the recent initiatives of the United Nations System, the Global Framework for Climate Services (GFCS), identifies health as a priority alongside disaster-risk reduction, agriculture and water resources. HHWSs represent a crucial component of the GFCS Health Exemplar aimed to improve the management of climate-related risks.

CHAPTER 1
INTRODUCTION

1.1 HEATWAVES: THEIR PHYSICAL CHARACTERISTICS

Heat or hot weather that lasts for several days, often referred to as a “heatwave”, is a pervasive natural hazard that can exact a heavy toll on human systems, affecting health, livelihoods and infrastructure. Natural systems can also be severely affected by the impacts sustained beyond the duration of a heatwave. Although there is no universally acceptable definition of heatwaves (Perkins and Alexander, 2013; Robinson, 2001), they are understood to be periods of unusually hot and dry or hot and humid weather that have a subtle onset and cessation, a duration of at least two to three days and a discernible impact on human activities. During such periods of hot weather, not only do daytime temperatures reach high values but nocturnal temperatures and humidity levels may also rise well beyond their long-term mean. Heatwaves are relative to a location’s climate; the same meteorological conditions can constitute a heatwave in one place but not another. Similarly, not all heatwave events are the same as their spatial extent, and intensity may vary considerably across a region (Stefanon et al., 2012).

From a physical meteorology perspective, two broad types of heatwave events may be identified. Dry heatwaves are often associated with stable periods of weather that bring clear skies and large inputs of solar radiation. Hot and dry conditions may also be accompanied by windy conditions, which can increase heat stress. Dry heatwaves usually occur in locations with a continental or Mediterranean climate or where air is warmed adiabatically. Moist heatwaves are characterized by very warm, oppressive, humid conditions throughout the day and night, often with nocturnal cloud cover, a feature that prevents loss of heat accumulated throughout the day and thus little night-time relief. Such heatwaves are often a feature of mid-latitude temperate and maritime climates and may be endemic to some regions (Hunt, 2007). Based on these characteristics, heatwaves are more likely to occur in locations that possess a highly variable summer climate or a clear hot season and, accordingly, may result from a range of large-scale meteorological situations and climate-related mechanistic processes (Chang and Wallace, 1987; Choi and Meentemeyer, 2002; Grumm, 2011; Hunt, 2007; Kunkel et al., 1996; Palecki et al., 2001; Pezza et al., 2012; Zaitchik et al., 2006). Locations without a highly variable summer climate or a clear hot season are not immune from heatwaves, however. On occasions, unusual combinations of ocean, land and atmospheric conditions may provide the climatological context for short-term climate surprises and the occurrence of extreme temperature and humidity events. The timing of heatwave events may also be partly related to the general climate setting. For example, disastrous heatwave events in southern Asia appear to occur early in the summer before the arrival of the summer monsoon. One way to gauge the relationship between climate and the occurrence of heatwave events is to consider the climate types according to a standard classification of climate associated with heatwave events which have had a significant societal impact (Table 1).

Unlike many climate hazards, such as tropical cyclones, tornadoes, thunderstorms and floods, heatwaves are geographically diffuse and occur over large areas. The effects of periods of unusually hot weather may be exacerbated in large urban areas, however, because of the local heat island effect which occurs when heat from the sun is stored in the urban fabric during the day and is released slowly back into the environment at night with no cooling evaporation. As a result, nocturnal urban temperatures may be several degrees above those of regional temperatures during heatwave events. This has important implications, not only for urban inhabitants, but also for urban biophysical systems.

Table 1. Climate types associated with major extreme temperature events as identified in the EM-DAT International Disaster Database (http://www.emdat.be/)

Region	*Koppen-Geiger climate type**
North America	Cfa, Dfa, Dfb
Europe/North Africa	Csa, Csb, Cfa, Cfb, Dfa, Dfb
Asia	Aw, Bsh, Cwa, Cfa
Australasia	Csb, Cwa, Cfa, Cfb

*Climate type descriptions
where:

Aw	tropical wet and dry or savanna climate
Bsh	low-latitude steppe climate (arid and semi-arid)
Csa	Mediterranean climate
Csb	dry summer subtropical climate
Cfa	humid subtropical climate with uniform rainfall distribution
Cfb	maritime temperate climate
Cwa	humid subtropical climate
Dfa	hot summer continental climate
Dfb	warm summer continental or hemiboreal climate

1.2 SOCIETAL IMPACTS OF HEATWAVES

Heatwaves can have significant direct and indirect impacts on society (McGregor et al., 2007) and it is the vulnerable individuals or sectors of society that may experience the direct impacts. At the level of the individual, the health effects of heat are relative, due to a range of heat-risk factors. Although the main factors of vulnerability may vary geographically, depending on the social, economic and political setting, there are some commonalities across countries in terms of heat-risk factors, including being elderly, having pre-existing cardiovascular or respiratory disease, living alone, working outdoors or being involved in heavy labour indoors close to industrial heat sources. In some places, gender, the nature of a person's dwelling where they are temporally or permanently resident (in a hospital or care home), being urban and poor and having certain medical conditions such as diabetes, fluid/electrolyte disorders and some neurological disorders, may also play a role. As well as the elderly, younger adults and children may also be affected during heatwaves. For some members of the population, the synergistic effects of several heat-risk factors may prove fatal.

A direct societal impact of heat is death. Tens of thousands of deaths have been reported. Over the period 2000–2011, southern and eastern Asia and the European Region were particularly affected. Heat as a health problem is not new in some areas. Over the period 1990–1999, significant heatwave events also occurred in come countries of those regions: Orissa, India, in 1995 and 1998, resulting in an estimated 558 and 2 541 deaths, respectively; Pakistan in 1995 with an estimated death toll of 523; and Chicago, USA, in 1995 with 670 deaths reported. Regions other than those noted where heatwaves with significant impacts in terms of deaths have also occurred since 1990 include Mexico in April 1990 (380 deaths) and Australia in 1993, 1994 and 1995 and 2009 with the 2009 heatwave event in south-eastern Australia resulting in 300 excess deaths and widespread disruption.

Further to the direct effects, heatwaves can burden health and emergency services and also increase strain on physical infrastructure (energy, water, transport). Hospital admissions increase during heat events, although the level of increase may vary by heatwave intensity and by factors such as age. Increased demands for water and electricity may result in power shortages and even blackouts. If crops and livestock are badly affected during heatwave events, then issues related to food and livelihood security are likely to arise. Wider social impacts may include effects in sectors such as clothing and food retailing, ecosystem services, tourism and security.

1.3 CLIMATE VARIABILITY, CLIMATE CHANGE, HEATWAVES AND ADAPTATION

Climate variability is a well-known characteristic of climate and heatwaves represent one facet of that variability. With climate change and climate variability, the occurrence of heatwaves is likely to increase. Evidence is emerging from the analysis of long-term climate records of an increase in the frequency and duration of extreme temperature events (Fischer and Schär, 2010). Further, climate-change modelling studies indicate that summers such as that experienced across Europe in 2003 may well represent what the future holds for European society in the latter part of the twenty-first century (Beniston, 2004), while the 2003 European and 2010 Russian Federation heatwaves may be partly attributed to human-related external influences on climate (Otto et al., 2012; Stott et al., 2004). In general, society is faced not only with addressing current climate variability, but also with finding ways to adapt to future changes relating to heatwaves.

In adapting to new heatwaves in the future, a range of options from the short to medium to long term should be considered. Among a range of possible adaptations is the development of HHWSs – the focus of this publication. The implementation thereof, based on 3–10 day forecasts of unusually hot and stressful weather, together with an effective set of intervention strategies, is one way in which society can address the challenges posed by heatwaves and a changing heatwave climate.

1.4 PURPOSE OF THE GUIDANCE

The purpose of this Guidance, developed jointly by WMO and WHO, is to outline, for practitioners in both meteorological and health services, the issues surrounding the general heat–health problem and present how an understanding of the biometeorology, epidemiology, public-health and risk-communication aspects of heat as a hazard can be used to inform the development of an HHWS as part of a wider HHAP. The Guidance places emphasis on the practical aspects of an HHWS at a generic level and is not intended to be prescriptive.

Specifically, the Guidance outlines the factors associated with vulnerability to heat, the approaches to developing and assessing the effectiveness of an HHWS, the range of possible intervention measures and the essentials for effective communication of the risk of heat-related health effects and associated coping strategies. In so doing, this Guidance offers practical advice to NMHSs and NHSs on initiating the development of an HHWS and helps them build capacity in planning for extreme hot-weather events.

CHAPTER 2
HEAT AND HEALTH

Key messages

- Increases in heat load and a rising body core temperature can lead to a range of health effects, the worst of which is life-threatening heatstroke.

- There is ample observational evidence for the health impacts of periods of extreme heat as manifested by the high number of deaths during heat events such as the Chicago 1995, European 2003 and Russian Federation 2010 heatwaves.

- While all individuals are potentially exposed to heat, the level of risk can be modified dramatically through a range of heat-risk factors that determine the heat sensitivity of individuals. These include a mix of socioeconomic, personal, behavioural and medical risk factors.

2.1 INTRODUCTION

Heatwaves are an emerging public-health problem. A number of major heatwave events have occurred over the past decade, some of which have had devastating effects, such as that of Europe in 2003 and that of the Russian Federation in 2010 (Robine et al., 2008; Osborn, 2010). This chapter reviews the human physiology and the response of the cardiovascular system to anomalous heat and the impacts on health of hot weather and heatwaves, summarizes some of the key risk factors and provides indications for proper heat preparedness and response from a health perspective.

2.1.1 Human physiology and heat

When excessive heat exposure overwhelms the body's heat-dissipating mechanisms, core temperature rises. An increase of as little as one degree Celsius (1ºC) is immediately detected by thermoreceptors disseminated through the skin, deep tissue and organs (Benzinger, 1969; Knochel and Reed, 1994; Guyton and Hall, 2000; Bouchama and Knochel, 2002). The thermoreceptors convey the information to the hypothalamic thermoregulatory centre, which triggers two powerful responses to increase dissipation of heat: an active cutaneous vasodilatation by inhibiting the sympathetic centres responsible for vasoconstriction, and the initiation of sweating through cholinergic pathways (Benzinger, 1969; Knochel and Reed, 1994; Guyton and Hall, 2000; Bouchama and Knochel, 2002). The cutaneous vasodilatation results in marked increases in blood flow to the skin and cardiac output at the expense of other major vascular beds, such as splanchnic beds (Rowell, 1983). These cardiovascular adjustments to accelerate the transport of heat from the core to the periphery for dissipation to the surroundings constitute a major stress on the cardiovascular system, especially when impaired through pathological processes. Initiation of sweating results in the production of up to two litres per hour of sweat, rich in sodium and potassium (Knochel and Reed, 1994; Guyton and Hall, 2000). This poses additional stress on the cardiovascular system if the plasma volume is not properly restored – by intake of fluid, for example.

These two responses are complemented by the activation of mechanisms of reduction of heat gain (Knochel and Reed, 1994; Guyton and Hall, 2000). They comprise the inhibition of shivering and the reduction of heat generated by cellular metabolism, as well as behavioural adjustment: adaptation (reduction) of the level of physical activity, the donning of appropriate clothes (light, loose-fitting) and the search for a cool environment.

2.1.2 Acclimatization

Acclimatization is an adaptive response to a hot environment in which an individual “learns” to better tolerate exposure to excessive heat (Knochel and Reed, 1994; Guyton and Hall, 2000; Kinney et al., 2008). This adaptation may take two to six weeks and includes physiological adjustment of the cardiovascular, endocrine and renal systems. This results in increased maximal stroke volume, decreased maximal heart rate, expansion of plasma volume and higher glomerular filtration rate and hence less work for the cardiac muscles. Also, sweating is initiated at a lower temperature and in greater volume, but with sodium chloride content reduced, resulting in more efficient heat dissipation and less salt depletion and dehydration (Knochel and Reed, 1994; Guyton and Hall, 2000; Bouchama and Knochel, 2002). Physiological adaptation is lost after some weeks of non-exposure, however (Williams et al., 1967). Complete (long-term) acclimatization to an unfamiliar thermal environment may take several years (Frisancho, 1991). Long-term adaptation results in a lower rise in core temperature and a lower increase in heart rate at a given heat load (Hori, 1995).

Currently, it is still being debated whether there is a reduction of vulnerability in certain populations over several decades (Carson et al., 2006; Davis et al., 2003). The vulnerability of population groups may change over time (through well-targeted prevention programmes, for example). This has been shown in a recent study examining effects of high temperatures on the mortality of the elderly in Italian cities in relation to the implementation of public-health heat-prevention and response plans (Schifano et al., 2012). Regarding the general climatic background, US studies have shown that the effects of heatwaves on mortality and health in general are less pronounced in places with a generally warmer climate (Medina-Ramon and Schwartz 2007; Hajat and Kosatky, 2010). In contrast, the effect of heatwaves on mortality in Europe seems to be even more pronounced in warmer, more southern countries (Baccini et al., 2011).

2.2 HEAT, ILLNESS AND DEATH

Excessive heat can cause the development of heatstroke, heat exhaustion, heat cramps, heat syncope, heat oedema and heat rush (Table 2). Heat can cause severe dehydration, acute cerebrovascular accidents and contribute to thrombogenesis. It can further aggravate chronic pulmonary conditions, cardiac conditions, kidney disorders and psychiatric illness.

Only a few deaths and illnesses are directly caused by heat due to elevations in body core temperature for a prolonged period – deaths due to heatstroke – while many more are related to the worsening of existing health conditions mentioned above. The public-health significance of effects varies, depending on the extent of time the deaths are being advanced or antedated.

Table 2. Heat-related medical conditions, symptoms and management

Medical condition	*Signs and symptoms/mechanism*	*Management*
Heat rash	Small, red, itchy papules appear on the face, neck, upper chest, under breast, groin and scrotum areas. This can affect any age but is prevalent in young children. Infection with Staphylococcus can occur. It is attributed to heavy sweating during hot and humid weather.	Rash subsides with no specific treatment. Minimize sweating by staying in an air-conditioned environment, taking frequent showers and wearing light clothes. Keep the affected area dry. Topical antihistamine and antiseptic preparations can be used to reduce discomfort and prevent secondary infection.
Heat oedema	Oedema of the lower limbs, usually ankles, appears at the start of the hot season. This is attributed to heat-induced peripheral vasodilatation and retention of water and salt.	Treatment is not required as oedema usually subsides following acclimatization. Diuretics are not advised.
Heat syncope	This involves brief loss of consciousness or orthostatic dizziness. It is common in patients with cardiovascular diseases or taking diuretics before acclimatization takes place. It is attributed to dehydration, peripheral vasodilatation and decreased venous return resulting in reduced cardiac output.	The patient should rest in a cool place and be placed in a supine position with legs and hips elevated to increase venous return. Other serious causes of syncope need to be ruled out.
Heat cramps	Painful muscular spasms occur, most often in the legs, arms or abdomen, usually at the end of sustained exercise. This can be attributed to dehydration, loss of electrolytes through heavy sweating and muscle fatigue.	Immediate rest in a cool place is advised. Stretch muscles and massage gently. Oral rehydration may be needed, using a solution containing electrolytes. Medical attention should be sought if heat cramps are sustained for more than one hour.
Heat exhaustion	Symptoms include intense thirst, weakness, discomfort, anxiety, dizziness, fainting and headache. Core temperature may be normal, subnormal or slightly elevated (less than 40°C). Pulse is thready, with postural hypotension and rapid shallow breathing. There is no alteration of mental status. This can be attributed to water and/or salt depletion resulting from exposure to high environmental heat or strenuous physical exercise.	Move the patient to a cool, shaded room or air-conditioned place. The patient should be undressed. Apply cold wet sheet or spray cold water and use fan if available. Lay the patient down and raise his or her legs and hips to increase venous return. Start oral hydration. If nausea prevents oral intake of fluids, consider intravenous hydration. If hyperthermia is above 39°C or impaired mental status or sustained hypotension occurs, treat as heatstroke and transfer the patient to hospital.
Life-threatening heatstroke	Exposure to heat stress (heatwave, summer season and/or strenuous exercise) Body temperature rapidly increases to greater than 40°C and is associated with central nervous system abnormalities, such as stupor, confusion or coma. Hot, dry skin, nausea, hypotension, tachycardia and tachypnoea are often present.	Measure core temperature (rectal probe): if > 40°C, move to a cooler place, remove clothing, initiate external cooling: cold packs on the neck, axillae and groin, continuous fanning (or keep ambulance windows open) while skin is sprayed with water at 25–30°C. Position an unconscious patient on his or her side and clear airway to minimize risk of aspiration. Administer oxygen 4 l/min and isotonic crystalloid (normal saline) solution. Transfer rapidly to an emergency department.

Source: adapted and updated from Bouchama and Knochel (2002) and Knochel and Reed (1994) in Matthies et al., 2008; WHO, 2009)

2.3 OBSERVED IMPACTS OF HEATWAVES ON HEALTH

A range of methodological issues exists related to the establishment of the impacts of climate on health and, in particular, heatwaves (Xun et al., 2010), including, for example, the lack of a standard definition of the term "heatwave". The purpose of this section is not to address definition issues related to heatwaves, as this is dealt with elsewhere in this publication. Rather, evidence is presented from the literature that summarizes the general nature of the impacts of heatwaves on health in the form of changes in mortality and morbidity.

2.3.1 Mortality

That heatwaves have significant impacts on mortality is clear from observational evidence. For example, the heatwave that occurred in Europe in August 2003 was unprecedented (Schaer and Jendritzky, 2004) and caused the greatest impact on mortality ever recorded in Europe with more than 70 000 excess deaths across 12 European countries (Robine et al., 2008). Heatwaves have a greater impact on mortality than the reported number of deaths or cases certified as due to classical heat illness. It is possible to quantify the excess mortality if a baseline mortality is estimated, which, it is assumed, would have occurred in the absence of the heatwave (expected mortality). Attributable mortality is estimated by subtracting this expected mortality from the observed mortality during a pre-defined period. The expected mortality is calculated using a variety of measures, including moving averages, smoothing functions and averages from similar time periods in previous years. Estimates can be sensitive to the method used to calculate the "expected" mortality (Gosling et al., 2009; Whitman et al., 1997).

While numerous studies have assessed the impacts of heatwave events on mortality, they used different methods, which makes comparisons difficult. Where studies have considered the mortality excess by cause of death, the greatest impacts have been found to be from respiratory and cardiovascular disease (Rooney et al., 1998; Huynen et al., 2001; Wang et al., 2012; D'Ippoliti et al., 2010). Comparison of these estimates should be made with caution as not only the methods used to estimate the excess deaths were different, but also the exposures. Even during August 2003, countries were affected by extreme temperatures of different magnitudes and duration. Similar temperatures can have different impacts, depending on the duration of the event or the acclimatization status of the population, which is related to the time in the season when the heatwave occurred, as well as the long-term climate. In addition, there can also be variations in the magnitude of excess mortality over the years in one place (see also acclimatization section) owing to differences in heatwave characteristics and the affected population (for example, reduced pool of vulnerable persons depending on previous winter season, see below). This makes vulnerability assessments and also the evaluation of public-health measures important but methodologically difficult (Pengelly et al., 2007). Furthermore, the thresholds associated with excess mortality vary, depending on the geographical conditions, the degree of adaptation of the population and many other factors. This makes it necessary to have regionally specific warning regimes (Tong et al., 2010), depending on the local relationship between temperature and mortality, the aim of the HHWS and the interventions that are triggered during a warning situation (Matthies et al., 2008). Beyond the effect of clear and distinguishable heatwaves, there are also important continuous effects of elevated temperatures on mortality with implications for general summer preparedness: the temperature-mortality relation follows a U-shape with a regionally varying thermal optimum for minimum mortality and threshold for increasing mortality related to rising and falling temperatures (Keatinge et al., 2000; McMichael et al., 2008).

Heatwave timing appears to have a notable effect on the level of mortality. Heatwaves occurring early in the summer have been shown to be associated with greater impacts on mortality in the same population than later heatwaves of comparable or higher temperatures (Hajat et al., 2002; Kinney et al., 2008; Anderson and Bell, 2011). The impact of high temperatures later in the summer is sometimes diminished after an early heatwave. In Europe, heatwaves occurring in June result in relatively high mortality compared to later in the summer, while most high-mortality events in southern Asia appear to occur early in the summer before the summer monsoon.

Lower-than-expected mortality can sometimes be observed following a heatwave. It is likely that parts of the excess mortality during a heatwave are attributable to deaths brought forward by a matter of days or weeks (short-term mortality displacement, also referred to as the harvesting effect). Assuming there is a pool of people at elevated risk of dying ("high-risk pool") in a population at any given time, a hot episode increases the risk of dying for those individuals, decreasing the pool size. Heat also potentially increases the recruitment of individuals into the high-risk pool from the general population. The transitions from a healthy to a high-risk state and then to death are possible explanations of several phenomena observed in epidemiological studies such as:

- The short-term reduction in mortality soon after a severe heat episode, known as the "harvesting effect", due to the brief temporal advancement of death among those in the high-risk pool;

- The greatest mortality increases associated with heatwaves occurring early in the summer, when the size of the high-risk pool is largest (Basu and Samet, 2002);

- The greatest summer mortality following low-mortality winters that inflate the pool at risk of dying from high temperatures (Stafoggia et al., 2009).

Following the heatwave in Paris, France, in August 2003, no strong reduction in reported mortality was seen (Le Tertre et al., 2006). Undoubtedly, some short-term mortality displacement did occur during this event, but it is also clear that many persons died who would not normally have died in the following weeks. A study of a heatwave in Belgium, however, calculated that 15 per cent of the excess mortality was due to deaths brought forward (Sartor et al., 1995) and other proportions have also been reported in the literature (Gosling et al., 2009). To date, no robust methods have been developed that quantify this effect and the proportion of "harvesting" during acute episodes remains uncertain.

2.3.2 **Morbidity**

Few studies have investigated the impact of heatwaves on morbidity. Data on non-fatal outcomes are often not routinely collected on a daily basis. Some studies have therefore used data on the use of health services, particularly hospital admissions or emergency service activities, which are available as daily or weekly time series.

Heatwaves in the USA have been found to be associated with increases in emergency hospital admissions. The 1995 Chicago heatwave resulted in an 11 per cent increase in overall emergency hospital admissions and a 35 per cent increase in the over-65 age group (Semenza et al., 1999). Of these excess admissions, 59 per cent were for heat-related illness (dehydration, heat exhaustion and heatstroke) in persons with underlying chronic disease. In the United Kingdom, a small increase in hospital admissions was reported in Birmingham during the 1976 heatwave (Ellis et al., 1980) and no statistically significant excess was observed during the 1995 heatwave in London (Kovats et al., 2004). In 2003, a 16 per cent increase in admissions of individuals over 75 years of age was detected in London (Johnson et al., 2005). The same summer, at one Spanish hospital, approximately 40 per cent of the admissions during the heatwave period were identified as heat-related, but no heatstroke was diagnosed (Villamil Cajoto et al., 2005). In France, where the 2003 heatwave was most intense, many hospitals were overwhelmed and a number of heat-stroke cases were reported (Vanhems et al., 2003; Gremy et al., 2004; Lecomte and de Penanster, 2004). The prompt availability of hospital admission and/or emergency service data has also led to the idea of syndromic surveillance as a basis for rapid appraisal of developing heatwave situations (Claessens et al., 2006; Leonardi et al., 2006).

2.4 **FACTORS THAT INCREASE THE RISK OF HEAT-RELATED ILLNESS AND DEATH**

Some people are more at risk from heat-related illness than others. Conceptually, this can be understood in terms of varying levels of heat vulnerability within a population, which, in turn, is related to contrasts in individual or group exposure and sensitivity (Bassil and Cole, 2010). As exposure is largely a characteristic related to climate – and heat stress in particular – this is dealt with in the following chapter. This section addresses the main non-climatic heat-risk factors that influence sensitivity to heat, such as adaptation and socioeconomic status, added to which is a range of personal characteristics (Havenith, 2005), including age, fitness, gender, acclimatization, behaviour, body weight and the presence of co-existing illness or drug treatment. Alone or in concert, such heat-risk factors may well modify the level of sensitivity within the population to heat and, in combination with modifiers of exposure, determine overall vulnerability to heat.

2.4.1 **Adaptation**

The degree of adaptation to local climate is probably explained, in large part, by physical and social mechanisms regulating exposure to high temperatures. The details of this adaptation are complex and not completely understood, but include behavioural factors such as time spent outdoors, clothing, social/cultural adaptations (for example, the siesta in southern Europe) and the physical environment, including thermal properties and nature of the built environment (building design and city planning).

Given the strong influence of social and physical adaptations on population exposure to heat, it is not surprising that details of the association between outdoor (weather) temperatures and health effects differ between studies conducted in different countries or regions.

2.4.2 **Socioeconomic factors**

Socioeconomic factors may affect exposure to heat as determined by building type and place of residence but also have an important effect on individual sensitivity. Although indicators of socioeconomic status, including ethnicity, occupation and education, have been found to be associated with heat-related health effects, there are inconsistencies between studies. In the USA, there is good evidence that people of lower socioeconomic status are at increased risk of heat-related mortality (Basu and Samet, 2002). Some European studies report weak or no apparent effects of socioeconomic status (Stafoggia et al., 2006; Hajat et al., 2007). A study in Italian cities, however, which used level of education as an indicator, as is available on individual death certificates, found that excess mortality in Rome during the summer of 2003 was 5.9 per cent among people with the highest level of education and 17.9 per cent in persons with the lowest level of education. A similar pattern was observed for Milan (Michelozzi et al., 2005). Socioeconomic deprivation was found to be a risk factor for heatwave-associated excess mortality in Paris, but not for the rest of France (Rey et al., 2009) and also in Barcelona, Spain (Borrell et al., 2006).

Excess mortality has also been observed to be greater in single persons (those not married or cohabiting) (Vandentorren et al., 2006). This may indicate that persons with less social support are more at risk. This is partly corroborated by studies that have reported increased social contact as a protective factor (Vandentorren et al., 2006; Bouchama et al., 2007). The effects of social isolation or the role of social networks in coping with hazards is not straightforward and requires further in-depth, qualitative research (Kovats and Hajat, 2008). Epidemiological data from Europe also suggest that patients living in nursing homes are at increased risk during heatwaves because of their high dependency level (Kovats and Hajat, 2008). Overall, socioeconomic factors have a complex interaction with morbidity and mortality of individuals and populations since they interact with other determinants of health (lifestyles) and access to, and performance and effectiveness of, health-care systems.

2.4.3 **Physiological factors and age**

Advanced age represents one of the most significant risk factors for heat-related deaths in developed countries as a consequence of an increasingly larger proportion of the elderly in their populations. When compared to young adults, the elderly have reduced thermoregulatory responses: sweating rate, skin blood flow and cardiovascular function (Kenney and Munce, 2003; Kenny et al., 2010). Ageing is also associated with physiological changes in renal function and water and electrolyte homeostasis that increase the risk of renal failure (Flynn, 2005). Changes in renal function may also lead to hyperkalaemia and, consequently, to cardiac rhythm disturbances. In addition, in older individuals, reduced water intake (as found for bedridden subjects or those experiencing an impaired thirst stimulus) may lead to hypernatremia that increases the risk of coronary and cerebral thrombosis and central nervous system dysfunction (Kenny et al., 2010).

All these physiological changes related to ageing may be exacerbated in the presence of chronic cardiovascular and renal conditions and pharmacological therapy (Flynn, 2005). Dehydration decreases plasma volume and venous return and thus cardiac output. It also slows the sweating rate (Knochel and Reed, 1994). This is a common cause of hyperthermia and death in both extremes of age, namely babies and children less than four years old and the elderly or cognitively impaired, all of whom rely on adults to provide an adequate liquid intake (Knochel and Reed, 1994; Guyton and Hall, 2000). Factors that promote excessive fluid loss such as diarrhoea or febrile illness in the paediatric population and pre-existing renal or metabolic disease and the taking of diuretics in the elderly, may increase the risk of heat-related injury and death (Knochel and Reed, 1994). Adverse health effects due to dehydration, starting with mild symptoms, can begin with a loss of fluid equivalent to approximately 3 per cent of body weight (Nadel, 1984).

2.4.4 **Medical conditions**

As described above, a robust cardiovascular system is essential for maintaining a normal body temperature during heat stress (Rowell, 1983). The inability to increase cardiac output because of cardiovascular disease or heart medication that depresses the myocardium will therefore increase susceptibility to heatstroke and/or cardiovascular failure and death (Kilbourne et al., 1982; Vassallo and Delaney, 1989; Semenza et al., 1996).

Inability to dilate the cutaneous circulation and increase the skin blood flow because of peripheral vascular diseases, for example, as a consequence of diabetes, atherosclerosis or use of certain medication such as sympathomimetics, also increases the risk of severe heat illness (Knochel and Reed, 1994; Martinez et al., 2002). While cardiovascular failure is a prevalent cause of death during heatwaves, any chronic medical condition must be considered a potential risk factor for heatwave-related illness and death, as demonstrated recurrently in epidemiological studies in Europe and North America (Kilbourne, 1999; Semenza et al., 1999; Hemon and Jougla, 2004; Michelozzi et al., 2005).

People with pre-existing respiratory disease are also at higher risk but the extent of the effect remains unclear (Ayres et al., 2009). Heat may produce an exacerbation of symptoms among people with asthma, rhinosinusitis, chronic obstructive pulmonary disease (COPD) and respiratory tract infections. Acute respiratory episodes are associated with airway and systemic inflammation, as well as cardiovascular co-morbidity, and may be triggered by exposure to heat. During an extreme heat event, subjects with COPD may hyperventilate, thus increasing the possibility of dynamic hyperinflation, leading to dyspnoea and to mechanical and cardiovascular effects (Michelozzi et al., 2009).

Increasing the volume and effective evaporation of sweat is the main mechanism for heat dissipation during a heatwave (Knochel and Reed, 1994; Guyton and Hall, 2000). Dehydration, drugs with anticholinergic properties, ageing, and chronic disease, such as diabetes, scleroderma and cystic fibrosis, which affect the number and/or function of sweat glands, can considerably increase the risk of hyperthermia and heatstroke (Buchwald and Davis, 1967; Kilbourne et al., 1982; Knochel and Reed, 1994; Kritikou-Pliota et al., 2000; Martinez et al., 2002). Other risk factors include a lack of mobility (especially being confined to bed), mental or neurological disorders and other chronic disease of the respiratory or cardiovascular system (Vandentorren et al., 2006; Medina-Ramon et al., 2006; Bouchama et al., 2007).

Some studies have also suggested that the level of dependency might be a direct risk factor for heatwave-associated mortality as impaired cognitive functioning, immobility and inability to self-care might affect the adoption of appropriate protective behaviour and/or seeking assistance (Belmin et al., 2007).

2.4.5 **Gender**

Some studies have shown differences in mortality impacts between men and women. In terms of numbers of heatwave deaths, these are greater in women than in men, given the higher number of women in all age groups. Women have higher core body and skin temperatures and may be less tolerant to heat than men (Havenith, 2005). A study where men and woman were matched on physical characteristics (size, body fat, etc.) found that the differences were minimal. In some cases, the effects on gender are age-specific. In certain countries in Europe, for example, the effects are greater on women in the elderly age groups (D'Ippoliti et al., 2010). In short, the role of gender as a risk factor remains unclear and has only been assessed for a limited number of developed-country situations. In some countries, where the division of labour is strong with men or women undertaking strenuous tasks in outdoor or indoor heat or where cultural factors as expressed through dress lead to higher personal heat loads, there may well be clear gender effects.

2.4.6 **Medication**

Medication is frequently associated with the high morbidity and mortality observed during heatwaves (Kilbourne et al., 1982; Kaiser et al., 2001). Medication can affect the body's usual cooling mechanisms and potentially cause increased health problems in a number of ways (WHO, 2009), namely by:

- Altering central thermoregulation and therefore physiological and behavioural responses;
- Changing cognitive alertness, leading, for example, to increased drowsiness and reduced heat-avoidance behaviour;
- Changing blood pressure and cardiac output, affecting cooling by vasodilation or increasing dizziness and fainting;
- Inhibiting normal sweating mechanisms for cooling by evaporation due to anti-cholinergic effects blocking the parasympathetic nervous system;
- Altering renal function and electrolyte balance, with increased risks from dehydration and drug toxicity or overhydration and electrolyte imbalance (Table 3).

Heat exposure can also increase medication toxicity and/or decrease its efficacy: dehydration and changes in blood-volume distribution associated with excessive heat exposure and the thermoregulatory response can influence drug levels, the kinetics and excretion thereof and, hence, pharmacological activity (Weihe, 1973; Michenot et al., 2006). Enhanced toxicity needs to be considered, especially for drugs with a narrow therapeutic index, such as digoxin or lithium. High ambient temperatures can adversely affect the efficacy of drugs, as most manufactured drugs are licensed for storage at temperatures up to 25°C (Crichton, 2004). This is particularly important for emergency drugs used by practitioners such as antibiotics, adrenalins, analgesics and sedatives.

2.4.7 **Behaviour**

Behaviour has a principal effect on exposure, but may also affect sensitivity. People who overexert during work or leisure may become dehydrated and therefore susceptible to heat illness and death. Similarly, very young or very old people may be at increased risk due to inadequate fluid intake or inadequate behaviour such as neglecting protective measures. That behaviour is important has been demonstrated in studies showing that protective actions such as dressing lightly, using cooling techniques (taking extra showers/baths, visiting air-conditioned places), increasing social contact and having home air-conditioning, tend to reduce the risk of death during a heatwave (Vandentorren et al., 2006; Bouchama et al., 2007).

Table 3. Medication and its mechanisms in relation to increasing risks to heat

Medication	*Mechanism*
Anticholinergics	Can affect central thermoregulation, reduce cognitive alertness and prevent or reduce sweating (many of the drugs below have anticholinergic effects).
Antipsychotics	Can inhibit the sweating mechanism and reduce systolic blood pressure, central thermoregulation, cognitive alertness and vasodilation.
Antihistamines	Can inhibit the sweating mechanism and reduce systolic blood pressure.
Anti-Parkinson's disease agents	Can inhibit the sweating mechanism, reduce systolic blood pressure and cause dizziness and confusion.
Antidepressants	Reduce sweating; some can decrease centrally induced thermoregulation and cognitive alertness.
Anxiolytics and muscle relaxants	Reduce sweating and increase dizziness, decrease cardiac output and therefore reduce cooling by vasodilation, and worsen respiratory symptoms.
Antiadrenergics and beta-blockers	Can prevent dilation of the blood vessels in the skin, reducing the capacity to dissipate heat by convection.
Sympathomimetics	Vasodilators, including nitrates and calcium channel blockers, can worsen hypotension in vulnerable patients.
Antihypertensives and diuretics	Can lead to dehydration and reduce blood pressure; hyponatremia is a common side effect and can be worsened by excess fluid intake.
Antiepileptics	Can reduce cognitive alertness and increase dizziness.
Other drug classes such as antiemetics, anti-vertigo drugs, gastrointestinal drugs, urinary incontinence drugs	Also have anticholinergic effects.

Source: adapted from WHO, 2011

2.5 SUMMARY

This chapter has provided an introduction to the physiology of heat and the effects of heat on health and outlined a range of factors that may influence heat vulnerability through determining heat sensitivity and, ultimately, the level of heat risk. Increasing heat load and rising body core temperature invokes physiological mechanisms, such as vasodilation and sweating, the purpose of which are to reduce heat load. In a situation where such mechanisms are ineffective, body core temperature will continue to rise, resulting in a range of progressively worse health outcomes. The most drastic of these is heatstroke, which can be fatal. While all individuals are potentially exposed to heat, the level of risk can be modified dramatically through a range of heat-risk factors that determine the heat sensitivity of individuals. These include a mix of socioeconomic, personal, behavioural and medical risk factors.

CHAPTER 3
ASSESSMENT OF HEAT STRESS

Key messages

- Heat is a complex phenomenon resulting from the interaction of solar radiation, atmospheric temperature, atmospheric moisture and wind speed or ventilation.

- Periods of extreme heat that have an effect on human health are often referred to as heatwaves. Although there is no universally accepted definition of heatwave, they are generally understood to be periods of extreme day- and night-time temperatures (greater than local 95th percentile values) with a duration of two days or more.

- Levels of heat stress can be assessed using a range of empirical biometeorological indices, often based on single or combined measures of temperature, atmospheric humidity and wind speed, or the output from numerical human heat-budget models. The choice of method chosen for assessment will very much depend on data availability and the resources available.

- Biometeorological index or heat-budget model values, together with health data, can be used to identify threshold values beyond which the effects of heat on health increase rapidly. Such threshold values, identified as part of an HHWS, are often used as a basis for issuing warnings to the public about impending periods of health-threatening heat. In the absence of health data, extreme biometeorological index or heat-budget model values, associated with the 95th to 99th percentile, are often used as action-threshold values in an HHWS.

In the previous chapter, the thermophysiology of heat and the nature of heat-risk factors were described and it is clear that there is a close relationship between human health and the thermal component of the atmospheric environment. This chapter focuses on the thermal environment and briefly describes the nature of heatwaves, factors that influence exposure to heat and methods for assessing heat stress.

3.1 HEATWAVES

Although there is no generally accepted definition of a heatwave (Souch and Grimmond, 2006; Robinson, 2001), heatwaves in a health context can be considered as periods with sustained heat load or excessively hot weather that result in one of a number of heat-related health outcomes including mortality, morbidity and emergency service call-out (Kovats and Jendritzky, 2006). During heatwaves, there is usually a gradual increase in mortality/morbidity with greater heat load, rather than a sudden increase above a clear threshold. Some intense and extreme events, however, produce sharp, very short-term, increases in heat-related health effects (Braga et al., 2002; Dessai, 2002; Kan et al., 2007). While most studies focus on daytime conditions, there is emerging evidence that nocturnal conditions can also play an important role in generating heat-related health effects, a result of the cumulative build-up of heat load with little respite during the night (Rooney et al., 1998). Heat intensity and duration, but also time of the year, repetition, time between adjacent events and acclimatization of individuals are important determinants of the health outcomes of heatwaves. From a cause-effect perspective, one approach to heatwave definition is that based on the physiological response (strain) to environmental stress in the form of exposure to heat as outlined in section 3.3.2.

The intensity, duration and timing of heatwaves can influence the risk of heat-related mortality. In the EuroHEAT study of the health effects of heatwaves in a number of European cities, it was found that, in prolonged heatwave events, mortality was 1.5–5 times higher than for heatwaves of short duration, with the highest increases for prolonged heat events found in Athens (Greece), Budapest (Hungary), London, Rome and Valencia (Spain), in persons of the 75+ age group

(D'Ippoliti et al., 2010; Michelozzi et al., 2009). Other studies have also confirmed the importance of heatwave duration on health outcomes (Montero et al., 2012; Rocklov, 2012).

Hot days occurring in the early part of any year may have a greater effect on health than those occurring later on (Hajat et al., 2002; Paldy et al., 2005). The impact of high temperatures later in the summer sometimes diminishes after an early heatwave, either because of so-called mortality displacement (Gosling et al., 2009) or within-season acclimatization. Some late-summer or hot-season events may be so intense and long, however, that the health effects are far greater than earlier events. For example, the European heatwave event of August 2003 in Germany resulted in approximately twice the number of total deaths recorded for six preceding heat events that occurred earlier in the summer.

3.2 **EXPOSURE**

In the case of heatwaves, exposure can be thought of as the location of people or activities in places that can potentially be affected by heat. A consequence of exposure might be a range of detrimental effects, including illness, death and damage to, or loss of, infrastructure and ecosystem services (Cardona et al., 2012). In contrast to other climate hazards, heat is quite diffuse and may occur over a wide area. Heat is also a complex phenomenon as it is the result of the interaction of temperature (sensible heat), humidity and direct or diffuse radiation load. In the case of people, direct exposure to heat or a heat source may occur if someone is undertaking an activity directly in the sun or near a non-natural heat source such as a furnace. For indoor environments, such as houses and offices, heat is usually a result of the synergistic effects of temperature and humidity, as direct exposure to radiation load does not usually occur in such sheltered environments.

It is worth noting that exposure and vulnerability are different, as the latter refers to the propensity of exposed people or activities to experience detrimental effects. As discussed in Chapter 2, vulnerability is not a product of physical factors but is related to a range of cultural, social, environmental, political and economic contexts (Cardona et al., 2012). While it is possible for a person or activity to be exposed to heat, it does not necessarily follow that they will be vulnerable.

Single meteorological variables, simple biometeorological indices or the output from numerical human heat-budget models (see section 3.4) are used to assess heat stress (McGregor, 2012). The requisite data for heat-stress assessment usually comes from first-order weather stations (often at airports) or from climate stations in rural areas not explicitly established for weather and health purposes. The representativeness of information on heat stress derived from such locations needs to be borne in mind when assessing exposure (WMO, 2011). Given this, analyses and forecasts of heat load based on data from standard weather and climate stations can only be considered an estimate of the actual heat load, particularly in the case of cities and indoor environments.

Because temperatures are generally higher in urban areas, exposure to heat may be greater in large cities due to the UHI effect, which may amplify the regional heat load during heatwave events. UHI is caused by many factors, including less radiant heat loss in the urban canopy layer, changes in the energy and water balances and lower wind velocities compared to rural environs (Arnfield, 2003). Accordingly, local and regional climates can be modified significantly by urbanization and other land-use changes.

It is possible that UHIs could be important for health in heatwave events for which there are clear urban/non-urban temperature differences. For example, during the 1995 Chicago heatwave, when air temperatures reached 38°C (Kunkel et al., 1996), the UHI effect raised night-time temperatures by a further 2°C. In the Athens area, the difference between urban and non-urban areas can amount to 4.6°C in the summer months. In London, the August 2003 heat event resulted in urban rural temperature differences of 8–9°C (GLA, 2006). Although there may be general differences in urban and non-urban temperatures, there may be large intra-urban variations in climate because of the heterogeneity of urban surfaces. This makes identifying "hot spots" in cities, where exposure could be high, difficult (Wolf and McGregor, 2013; Wolf et al., 2013). Moreover, UHIs are highly dynamic in time and space and therefore hard to quantify either spatially or temporally for individual heatwave events. When estimating the health effects of extreme temperatures within a city, housing type and socioeconomic factors are likely to be important. Theoretically, heat exposure in large urban areas and associated health effects should be greater because of the UHI effect and elevated heat risk (Reid et al., 2009). To date, there has not been a systematic investigation of this issue, although Hajat et al. (2007) present some evidence for London having higher heat-related death rates than other urban areas in the United Kingdom.

Because indoor environments can have significant health effects (Spengler, 2012) there is growing interest in the nature of indoor climates for a range of dwelling and building types, especially in the context of climate change and projected increases in extreme temperature events. A number of factors appear important for determining indoor thermal loads and, thus, heat exposure, including building thermal mass and orientation, as well as forced or passive ventilation. Despite the importance of indoor climates for health, especially during heatwaves, little is known about indoor thermal loads and their actual health effects (Bokenes et al., 2011; Jendritzky et al., 2012; White-Newsome, 2012). This is because there are few systematic observation programmes of indoor climate and health. Such programmes are required in order to place observed indoor temperatures in the broader context of the thermal range 19–24°C associated with indoor comfort (Ormandy and Ezratty, 2012). More often than not, in the absence of observed indoor temperatures, indoor climates are inferred from estimates or measurements of outdoor heat load based on standard weather- and climate-station data. This makes the evaluation of indoor climate-related health effects problematic. The European 2003 heatwave event provided clear evidence of the effects on health of the indoor environment. In France, for example, the risk of death was increased by living in buildings with few rooms, poor insulation or a large number of windows. Living on upper floors, especially the top floor, or having the bedroom under the roof also increased mortality risk (Kovats and Hajat, 2008; Vandentorren et al., 2006). An adaptation strategy often proposed for managing indoor climate and thus reducing exposure to heat is that of air-conditioning, which has been found to be a strong protective factor in some countries, such as the USA (Basu and Samet, 2002) and Portugal (Nunes et al., 2011). Yu et al. (2012), however, raise the possibility of a reduction in thermal adaptability with prolonged use of air-conditioning.

An atmospheric characteristic that is not often addressed when considering exposure is poor air quality and how this might combine with heat stress to challenge individuals. As hot weather and poor air quality sometimes coincide, it can be difficult to separate the effects of the two exposures. Two pollutants are particularly relevant during heat episodes: ozone and particulate matter with diameter less than 10 micrometres (PM10). Ozone levels are highest outdoors, while PM10 also penetrates indoors. One possibility is that the effects of heat and air pollution are essentially equivalent to the effect of the two exposures occurring separately (an additive effect). Alternatively, it is plausible that there might be a greater-than-additive effect of simultaneous exposures to air pollution and heat (a synergistic effect). On days with high ozone and PM10 levels, larger heatwave effects on total and cardiovascular mortality, especially among the elderly, have been observed (Analitis et al., 2014). For some European locations, there is increasing evidence of a synergistic effect of high temperatures and ozone exposure on mortality, as recorded in the EuroHEAT project (WHO, 2009). Alternatively, the higher PM10 effects during summer may be associated with open windows and more outdoor activities, the so-called ‘‘ventilation’’ hypothesis (Chiusolo et al., 2011).

3.3 THERMAL ASSESSMENT PROCEDURES

Because air temperature alone has not been considered a good indicator of the human thermal environment or heat, thermal indices – most of them two-parameter indices – have been developed to describe the complex conditions of heat exchange between the human body and its thermal environment. For warm conditions, indices usually consist of combinations of dry-bulb temperature and different measures for humidity. Comprehensive reviews of such simple biometeorological indices can be found in Fanger (1970), Landsberg (1972), Driscoll (1992), Parsons (2003) and Blazejczyk et al. (2012).

Without claiming to be complete, a set of available and operationally applied thermal-assessment procedures is reviewed below. They are currently being utilized by various national and local weather services around the world and can easily be evaluated by the potential user based on the need to describe thermoregulatory processes and heat load as described in Chapter 2 and section 3.2.

3.3.1 Simplified biometeorological indices

3.3.1.1 *Heat Index*

The Heat Index (*HI*) combines air temperature and relative humidity (*RH*) to determine an apparent temperature – how hot it actually feels. When the relative humidity is high, the evaporation rate of water is reduced. This means that heat is removed from the body at a lower rate, causing it to retain more heat than it would in dry air. Heat Index is widely used in the USA and is effective when the temperature is greater than 26ºC (80ºF) and relative humidity is at least 40 per cent.

$$Heat\ Index\ (HI) = -42.379 + 2.04901523(T_f) + 10.14333127(RH) - 0.22475541(T_f)(RH) - (6.83783 * 10^{-3})(T_f^2) - (5.481717 * 10^{-2})RH^2 + (1.22874 * 10^{-3})(T_f^2)RH + (8.5282 * 10^{-4})(T_f)(RH^2) - (1.99 * 10^{-6})(T_f^2)(RH^2) \quad (1)$$

where:

T_f air temperature in degrees Fahrenheit

RH relative humidity expressed as a whole number

3.3.1.2 *Humidex*

Humidex was devised by Canadian meteorologists and first used in 1965 to describe how hot, humid weather feels to the average person (Smoyer-Tomic et al., 2003). *Humidex* combines temperature and humidity into one number to reflect the perceived temperature.

$$Humidex = (air\ temperature) + \hbar \quad (2)$$

where:

$\hbar\,(\hbar umidity) = (0.5555)(e - 10.0);$

$e\ (water - vapour\ pressure) = 6.11 * exp^{(5417.7530*((1/273.16)-(1/dewpoint)))}$

The range of *Humidex* values and the associated degree of comfort is given below:

Less than 29	no discomfort
30 to 39	some discomfort
40 to 45	great discomfort; avoid exertion
Above 45	dangerous
Above 54	heatstroke imminent

An extremely high *Humidex* can be defined as one that is above 40. In such conditions, all unnecessary activity should be curtailed. If the reading is in the mid- to high 30s, then certain types of outdoor exercise should be toned down or modified, depending on the age and health of the individual, physical fitness, type of clothes worn, and other weather conditions.

3.3.1.3 *Net effective temperature*

Net effective temperature (*NET*) is routinely monitored by the Hong Kong Observatory, China (Li and Chan, 2000) and takes into account the effect of air temperature, wind speed and relative humidity. *NET* is calculated as follows:

$$NET = 37 - (37 - T)/(0.68 - 0.0014(RH) + 1/(1.76 + 1.4v^{0.75})) - 0.29T(1 - 0.01(RH)) \quad (3)$$

where:

T	air temperature (°C)
v	wind speed (m/s)
RH	relative humidity (%)

NET has a higher value when the temperature is higher, but its value will be lower with higher wind speed and relative humidity. Taking acclimatization into account, it is believed that people at a particular place will feel cold or hot when the value of *NET* is equivalent to the lowest or highest of 2.5 per cent of all values. In Hong Kong, China, a cold (or very hot) weather warning is issued when *NET* is forecast to be lower (or higher) than the 2.5th percentile (97.5th percentile). This procedure is also used in Portugal.

3.3.1.4 ***Wet-bulb globe temperature***

Wet-bulb globe temperature (*WBGT*) combines temperature and humidity into a single number (Budd, 2009) and is also affected by wind and radiation. It is measured by a simple three-temperature element device. The first temperature (T_g) is measured by a black-globe thermometer, usually consisting of a 150-mm black globe with a thermometer located at the centre. The black-globe temperature represents the integrated effects of radiation and wind. The second thermometer measures the natural wet-bulb temperature (T_{nwb}). It consists of a thermometer whose bulb is covered with a cotton wick that has been wetted with distilled water from a reservoir. Evaporation from the wet bulb cools the thermometer. The natural wet-bulb thermometer, like the black-globe thermometer, is not shielded from wind or radiation and represents the integrated effects of humidity, wind and radiation. The final temperature element is the (shaded) air temperature (T_a). It is measured by a thermometer shielded from radiation, generally by being placed in a weather screen. It is the standard temperature normally quoted in weather observations and forecasts.

The three elements T_g, T_{nwb}, and T_a are combined into a weighted average to produce *WBGT*.

$$WBGT = 0.7 * T_{nwb} + 0.2 * T_g + 0.1 * T_a \tag{4}$$

WBGT is widely used by researchers as an easily measured general heat-stress index in occupational medicine (ISO, 1989).

Instead of measuring *WBGT*, the Australian Bureau of Meteorology (BoM) uses an approximation based on standard measurements of temperature and humidity to calculate an estimate of *WBGT* under moderately sunny and light-wind conditions. Real variations of sunshine and wind are not taken into account. The formula is likely to overestimate *WBGT* in cloudy or windy conditions or when the sun is low or below the horizon. Under clear, full-sun and low-humidity conditions, the approximation underestimates *WBGT* slightly. The simplified formula is:

$$WBGT = 0.567 * T_a + 0.393 * e + 3.94 \tag{5}$$

where:

T_a	air temperature (°C)
e	water-vapour pressure (hPa)

3.3.1.5 ***Apparent temperature***

Apparent temperature (*AT*) is defined as the temperature at the reference humidity level, which produces the same amount of discomfort as that experienced under the current ambient temperature and humidity. Basically, *AT* is an adjustment to the ambient temperature (*T*) based on the level of humidity. Absolute humidity with a dewpoint of 14°C is chosen as a reference (adjusted a little with temperature). If the humidity is higher than the reference, then *AT* will be higher than *T* and, if the humidity is lower than the reference, then *AT* will be lower than *T*. The amount of deviation is controlled by the assumptions of the Steadman (1984) model. *AT* is valid over a wide range of temperatures and includes the chilling effects of the wind at lower temperatures.

A simple hot-weather version of AT, known as *HI* (see equation 1), that focuses on *T* and *RH*, is used by the US National Weather Service (NWS).

The formula for AT used by BoM is an approximation of the value provided by a mathematical model of the human heat balance. It can include the effects of temperature, humidity, wind speed and radiation. Under Australian conditions, the effect of full sun produces a maximum increase in AT of about 8°C when the Sun is at its highest elevation in the sky. Two forms are given, one including radiation (equation 6(a)) and one without (equation 6(b)). The non-radiation version includes the effects of temperature, humidity, and wind:

$$AT = T_a + 0.348 * e - 0.70 * ws + 0.70 * Q/(ws + 10) - 4.25 \quad (6(a))$$

$$AT = T_a + 0.33 * e - 0.70 * ws - 4.00 \quad (6(b))$$

where:

T_a dry-bulb temperature (°C)
e water-vapour pressure (hPa)
ws wind speed (m/s) at an elevation of 10 m
Q net radiation absorbed per unit area of body surface (W/m^2)

It should be noted that there are three different versions of AT (equations (1), 6(a) and 6(b).

3.3.1.6 ***Excess Heat Index***

The Excess Heat Index (*EHI*) is a new index developed by (BoM) (Nairn and Fawcett, 2013), which considers the relationship of maximum and minimum temperatures averaged over a three-day period to a climate reference value (95th percentile) of observed daily temperature (single-day average of maximum and minimum temperature in a common 9 a.m. to 9 a.m. period) to identify and characterize heat events. Positive, contiguous three-day-average daily temperature departures from the 95th percentile reference value indicate a significant excess heat event or heatwave. *EHI* takes the following form:

$$EHI_{sig} = (T_i + T_{i+1} + T_{i+2})/3 - T_{95} \quad (7(a))$$

where: T_{95} is the 95th percentile of daily temperature (T_i) for a climate reference period, calculated using all days of the year. Daily mean temperature (*DMT*) is defined as

$$DMT = (T_{max} + T_{min})/2 \quad (7(b))$$

across the 24-hour period, where the maximum temperature typically precedes the minimum temperature in the 9 a.m. to 9 a.m. (local time) observation period. *DMT* T_i on day i is in °C. The units of EHI_{sig} are °C. Expressed in this way, EHI_{sig} is, in effect, an anomaly of the three-day daily mean temperature with respect to the climatological 95th percentile of the daily mean temperature. EHI_{sig} has been recently applied to an assessment of the changing nature of heatwaves (Perkins et al., 2012).

3.3.2 **Heat-budget models**

Heat exchange between the human body and the thermal environment (Figure 1) can be described in the form of the energy balance or heat-budget equation. The thermal comfort of an individual is the result of a response to the balance between heat gains and losses. This is often expressed in the form of the human energy balance as described by heat-budget models. The human heat budget can be written as:

$$M - W - [Q_H(T_a, v) + Q^*(T_{mrt}, v)] - [Q_L(e, v) + Q_{SW}(e, v)] - Q_{Re}(T_a, e) \pm S = 0 \quad (8)$$

where:

M	metabolic rate (activity)
W	mechanical power (kind of activity)
S	storage (change in heat content of the body)

skin:

Q_H	turbulent flux of sensible heat
Q^*	radiation budget
Q_L	turbulent flux of latent heat (diffusion water vapour)
Q_{SW}	turbulent flux of latent heat (sweat evaporation)

respiration:

Q_{Re}	respiratory heat flux (sensible and latent)

and where the meteorological input variables to the heat budget include:

T_a	air temperature
e	water-vapour pressure
v	wind velocity
T_{mrt}	mean radiant temperature, including short- and long-wave radiation fluxes, in addition to metabolic rate and clothing insulation

In equation 8, the appropriate meteorological variables are attached to the relevant fluxes but the internal (physiological) variables, such as the temperature of the core and the skin, sweat rate and skin wetness, which all interact in determining heat exchange conditions, are not explicitly modelled by the heat budget.

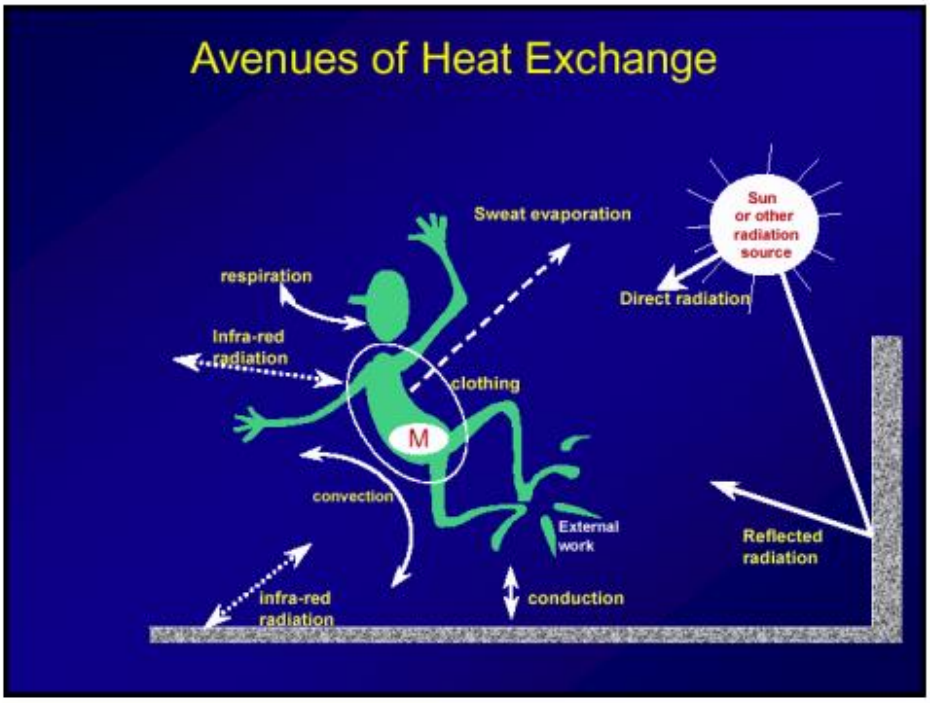

Figure 1. The human heat budget

Source: Havenith, 2005

A range of heat-budget-based indices exist which represent physiological response (strain) to heat (McGregor, 2012). Five of the more widely used indices are presented below.

3.3.2.1 ***Standard effective temperature***

Standard effective temperature (*SET**) is defined as the equivalent air temperature of an isothermal environment at 50 per cent *RH* in which a subject, while wearing clothing standardized for the activity concerned (this contrasts with the original *ET** approach of Gagge et al. (1971), describing total heat loss from the skin), has the same heat stress (skin temperature T_{sk}) and thermoregulatory strain (skin wettedness *(w)*) as in the actual environment. *SET** uses skin temperature T_{sk} and skin wettedness (*w*) for the limiting condition. The values for T_{sk} and *w* are derived from the Pierce "two-node" model of human physiology (Gagge et al., 1971; 1986). For outdoor application, *SET** has been enhanced to *OUT_SET** (Pickup and de Dear, 2000).

3.3.2.2 ***Predicted mean vote***

To predict actual thermal sensation, Fanger (1970) assumed that the sensation experienced by a person was a function of the physiological strain imposed on him by the environment. This he defined as "the difference between the internal heat production and the heat loss to the actual environment for a person kept at the comfort values for skin temperature and sweat production at the actual activity level". He calculated this extra load for people involved in climate-chamber experiments and plotted their comfort vote against it. Thus, he was able to predict the comfort vote that would arise from a given set of environmental conditions for a given clothing insulation and metabolic rate.

The final equation for optimal thermal comfort is fairly complex. ISO Standard 7730 includes a computer program for calculating predicted mean vote (*PMV*) on the ASHRAE 7-level thermal sensation scale (ISO, 1994).

3.3.2.3 ***Perceived temperature***

Fanger's *PMV* equation (1970), including improvement of the description of latent heat fluxes with the introduction of *PMV** (Gagges et al., 1986) is generally the basis for the operational thermal assessment procedure entitled Klima-Michel-model (Jendritzky et al., 1979), which is used by the German National Weather Service (Deutscher Wetterdienst (DWD)). The output parameter is perceived temperature (*PT*) (Staiger et al., 1997), which takes into account a certain degree of adaptation, given various clothing ensembles. *PT* is defined as the air temperature of a standard environment that would produce the same thermal stress as in the actual environment. At DWD, this procedure is run operationally, taking acclimatization quantitatively into account by using the health-related assessment of the thermal environment (*HeRATE*) approach (see sections 3.3.4.1 and 4.3.2). To date, DWD is the only NMHS running a complete heat-budget model on a routine basis. The output is used for various applications in human biometeorology.

3.3.2.4 ***Physiological equivalent temperature***

Physiological equivalent temperature (*PET*) (°C) is based on a complete heat budget model of the human body (Höppe, 1984; 1999). *PET* provides the equivalent temperature of an isothermal reference environment with a water-vapour pressure of 12 hPa (50% at 20°C) and light air (0.1 m/s), at which the heat balance of a reference person is maintained with core and skin temperature equal to those under the conditions being assessed. For the reference person, a typical indoor setting is selected with work metabolism of 80 W added to basic metabolism and a heat resistance of clothing of 0.9 clo[1]. The influence of humidity on *PET* is restricted to latent heat fluxes via respiration and via diffusion through the skin. The *PET* assessment scale is derived by calculating Fanger's (1970) *PMV* for varying air temperature in the reference environment using the settings for the *PET* reference person. Hence, *PET* is comfort-based.

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[1] This is the amount of insulation that allows a person at rest to maintain thermal equilibrium in an environment at 21°C (70°F) in a normally ventilated room (0.1 m/s air movement). Above this temperature the person so dressed will sweat, whereas below this temperature the person will feel cold. Clothing insulation may be expressed in clo units: 1 clo = 0.155 K·m²/W.

3.3.2.5 *Universal Thermal Climate Index*

The Universal Thermal Climate Index (*UTCI*) is a new index for the thermo-physiological assessment of the atmospheric environment. The procedure has been developed under the umbrella of CCl and was presented at a joint WMO/WHO/European Union Cooperation in Science and Technology (COST) Symposium on *UTCI* in Geneva in 2009. *UTCI* was achieved via a multidisciplinary collaboration of numerous scientists from 22 countries with different expertise in the relevant disciplines. It made use of the scientific progress achieved in the last three decades, both in thermophysiology and heat-exchange modelling, including clothing (Fiala et al., 2012; Havenith et al., 2012). The *UTCI* model is a multinode, multilayered thermophysiological numerical representation of the human body (Jendritzky et al., 2012). The output from the *UTCI* model is an equivalent temperature. This is related to a strain index that represents the synergistic behaviour of metabolic rate, core temperature, skin wettedness, blood flow and sweat rate (Broede et al., 2012). All aspects of *UTCI* have been comprehensively published in a special issue of the *International Journal of Biometeorology* (McGregor, 2012(a)) and there are numerous applications in the various fields of human biometeorology. The quite demanding data inputs required to run the *UTCI* model are just the same as with the above-mentioned, simpler heat-budget models. For this reason, the *UTCI* application as an index for establishing heat load will most likely be restricted to those NMHSs that collect the requisite climate data and have the scientific capacity to run the *UTCI* model (McGregor, 2012(b)). The European Centre for Medium-Range Weather Forecasts (ECMWF) recently completed a feasibility study demonstrating the utility of forecasting *UTCI* up to 10 days on the global scale (Pappenberger et al., 2014). These forecasts could be used by NMHSs with lesser capacity as a basis for their regional or local health-warning systems.

3.3.3 **Holistic approaches**

Another commonly used approach for evaluating heat response is the synoptic approach (see Chapter 4). This involves the classification of days into holistic airmasses or weather types, which encompass not only temperature but also measures of humidity, cloud cover, pressure and wind (Sheridan and Kalkstein, 2004). The underlying philosophy of this approach is that humans and animals react to the suite of atmospheric conditions surrounding them, as described by a range of weather variables. An airmass-based evaluation considers, a priori, that the umbrella of air encompassing humans plays the major role in our physiological and behavioural reactions to weather. Application of this approach in a number of predominantly mid-latitude locations has demonstrated that high mortality levels are predisposed to specific airmass or weather types. If, on a short-term basis, such airmass types could be forecast, then estimates of how the population might react to a given airmass situation, in terms of health outcomes, could be made. Operational heat–health warning systems based on the synoptic approach are described in Chapter 4.

3.3.4 **Adaptation considerations**

All the indices cited above are absolute: a particular meteorological variable is considered to have the same impact on the human body, no matter where or when it occurs. There is much value to absolute indices as they provide a measure of intensity for any extreme weather event: meteorological stress. Humans and other organisms also respond to weather in a relative way: we respond differently to the weather, depending on the frequency of the particular extreme episode. This is due to the ability to adapt, at least to a certain level. Thus, a temperature of 42°C with a relative humidity of 10 per cent will have a much different effect in Rome than it will in Cairo (Egypt). In addition, such conditions in Cairo during May would elicit a different response than the same conditions occurring in mid-July. Thus, there is growing interest in relative biometeorological indices that have the capability of taking human differential response into account. Two such indices are presented below.

3.3.4.1 *Health-related assessment of the thermal environment*

Health-related assessment of the thermal environment (*HeRATE*) is a conceptual model of short-term acclimatization based on findings in adaptation studies (Koppe, 2005; Koppe and Jendritzky, 2005). The procedure modifies absolute thresholds of a selected thermal index by superimposition of the (relative) experience of the population in terms of the index over the previous weeks. The time series of the daily weights of the past are derived from Gaussian filtering. The absolute part is weighted by 2/3 and the relative part by 1/3. In this way, *HeRATE* combines an approach that accounts for the short-term adaptation of human beings to the local meteorological conditions over the past four weeks with *PT* in order to assess the thermal environment in a health-relevant way. This procedure aims at modifying a constant threshold above which negative impacts on human health would be expected by means of a variable part. By including short-term adaptation, this system can be applied to data from different locations and at different times of the year without further modifications. Based on the constant part only, such thermal conditions are classified as heat load or cold stress if they fulfill some minimum requirements.

HeRATE is used operationally by DWD in all applications of *PT* (see section 3.3.2.3).

3.3.4.2 ***Heat Stress Index***

Another approach to account for relative response is the Heat Stress Index (*HSI*) of Watts and Kalkstein (2004), a comprehensive summer index that evaluates daily relative stress for locations based on deviations from the norm. It is based on *AT* (*HI*, section 3.3.1.1) and other derived meteorological variables, including cloud cover, cooling degree-hours and consecutive days of extreme heat. Statistical distributions of meteorological variables are derived for 10-day periods of the annual cycle so that percentile values for each parameter can be determined. The daily percentile values for each variable are then summed and a statistical distribution is fitted to the summed frequencies. The daily *HSI* value is the percentile associated with the location of the daily summed value under the summation curve. Each day's *HSI* value varies between 0 (coolest) and 10 (most stressfully hot), hence a stressful value of 9.8 yields different meteorological values for cities in different climates.

3.3.4.3 ***Excess Heat Index-acclimatization***

This index is similar in structure to *EHI* (section 3.3.1.6) but compares three-day averaged maximum and minimum temperatures with averaged temperatures over the previous 30 days (Nairn and Fawcett, 2013). In making a comparison with the previous 30 days, the Excess Heat Index-acclimatization (EHI_{accl}) takes into account possible short-term acclimatization, similar in principle to what is achieved by *HeRATE* (section 3.3.4.1).

EHI_{accl} takes the form of:

$$EHI_{accl} = (T_i + T_{i+1} + T_{i+2})/3 - (T_{i-1} + .. + T_{i-30})/30 \tag{9}$$

where T_i is *DMT* (see section 3.3.1.6, equation 7(b)). Expressed in this way, EHI_{accl} is an anomaly of three-day *DMT* with respect to the previous 30 days. It provides a short-term temperature anomaly index in contrast to the long-term anomaly index represented by *EHI* (section 3.3.1.6). The units of EHI_{accl} are °C. The magnitude of EHI_{accl} provides a proxy of the level of heat stress as represented by the size of the temperature anomaly in comparison to the 30-day average.

3.3.4.4 ***Excess heat factor***

The excess heat factor (EHF) combines the previously presented EHI_{sig} and EHI_{accl} indices and therefore includes, in effect, an acclimatization component (as expressed in EHI_{accl}). EHF provides a measure of the intensity, load and duration of a heatwave event. Positive values of EHF indicate the occurrence of a heatwave event. EHF takes the following form:

$$EHF = EHI_{sig} * \max(1, EHI_{accl}) \tag{10}$$

As noted by Nairn and Fawcett (2013), combining indices that separately represent excess heat (EHI_{sig}) and heat stress (EHI_{accl}) gives a heatwave measure that has a strong signal-to-noise ratio. This is because low EHF values record low-impact heatwaves. As the values of EHI_{sig} and EHI_{accl} grow, their product increases as a quadratic response to increasing heat load.

3.4 SUMMARY

Heat stress can be assessed using simplified biometeorogical indices, composed of one, two or multiple meteorological variables, or heat-budget models – numerical models that attempt to describe, in mathematic terms, the body's heat gains and losses. The choice of method for assessing heat stress will depend on the resources available to HHWS developers. Daily biometeorological index or heat-budget model values, along with health data (daily mortality counts, for example) are applied to the identification of threshold values beyond which the health effects of heat increase rapidly. Observed and forecast threshold values are often used as a basis for action within an HHWS.

CHAPTER 4

HEAT–HEALTH WARNING SYSTEMS: DEFINITION AND METHODOLOGY

Key messages

- An HHWS is the weather-based alert component of a wider HHAP.

- HHWSs are designed to alert decision-makers and the general public to impending dangerous hot weather and to serve as a source of advice on how to avoid negative health outcomes associated with hot weather extremes.

- The operation of an HHWS includes weather forecasting, the determination of whether an “action trigger”, such as a threshold temperature or biometeorological index value having significance for health effects, is likely to be exceeded in the near future, and the issuance of watch/warning messages to stakeholders in the heat–health field.

- HHWSs are best developed to suit local conditions in terms of the data available for analysing historical heat–health relationships, weather-forecasting capacity and human resources dedicated to running an HHWS. For this reason, operational HHWSs vary in their nature from location to location.

Catalysed by a number of serious heat events, the development of HHWSs, as part of broader HHAPs (Matthies et al., 2008) at a variety of levels of governance, has been rapid over the last decade. This chapter reviews the nature of HHWSs with emphasis placed on system structure and mechanics.

4.1 WHAT IS A HEAT–HEALTH WARNING SYSTEM?

Interest in the development of HHWSs has been quite recent: before the intense event of 2003, for example, very few systems existed in Europe (Lowe et al., 2011).

In the context of this Guidance, a heatwave is defined as an unusually hot period (relative to the local climate) that can lead to a negative health outcome for humans. An HHWS is designed to alert decision-makers and the general public to impending dangerous hot weather and to serve as a source of advice on avoiding negative health outcomes associated with hot-weather extremes (WHO/WMO/UNEP, 1996). In effect, an HHWS is the weather-based alert component of a wider HHAP. The operation of an HHWS includes weather forecasting, the determination of whether an action trigger, such as a threshold temperature or biometeorological index having significance for health effects, is likely to be exceeded in the near future and the issuance of watch/warning messages to stakeholders in the heat–health field. The identification of vulnerable population groups, interaction with stakeholders, the design and operationalization of heat-intervention strategies, the implementation of longer-term heat-mitigation procedures, such as public education and urban planning and design, and evaluation of HHWS effectiveness, are all components of a wider HHAP.

Although an effective HHWS can employ one of a number of measures of heat stress and its nature may vary according to local population, political systems and available resources, several aspects should be universal to all HHWSs.

First, all systems should consider local meteorology, demographics and urban structure (Sheridan and Kalkstein, 2004; Kalkstein et al., 2008). A one-size-fits-all set of systems may not properly accommodate all locations, especially if developed within countries that span different cultural and climate zones. For example, in the USA, a system was designed in the 1990s to call a warning of excessive heat whenever *AT* was forecast to exceed 41°C for three consecutive hours on two consecutive days, no matter where it occurred (NOAA (National Oceanographic and Atmospheric Administration), 1995). Such a system does not take into account the relative, rather than the absolute, nature of weather's impacts on a particular area.

Second, all systems should be based on thresholds that are related to actual heat–health outcomes. HHWS trigger mechanisms should be geared to the point where human health actually deteriorates. This threshold varies greatly from place to place and also depends on the scope of the system. It can also vary within a place: the heat–health relationship may be more acute earlier in the summer season than later on in the season at the same place, for example.

Third, HHWS nomenclature should be clearly understood by the public, local stakeholders and decision-makers. Thus, on a national level, a standardized terminology, together with understandable criteria and messages, helps significantly with communication. This also applies at the local level, where messages may need to be tailored to reflect community characteristics – senior citizens or particular ethnic groups, for example.

Fourth, all systems should be paired with an effective notification and response programme. These "mitigation plans" include lines of action defined by multiple stakeholders or agencies, interaction with the media and messages to the public as to how they should react to extreme weather.

Finally, all systems should be evaluated to determine their effectiveness. The evaluations need to incorporate the effectiveness of mitigation activities, as well as the appropriateness of the warning determinant itself (see Chapter 7).

4.2 THE FRAMEWORK FOR DEVELOPMENT

Figure 2 displays the typical sequence of events within the development of an HHWS. Most HHWSs begin with the establishment of certain thresholds of human-health tolerance to extreme weather. Exceeding these thresholds triggers the issuance of a warning or alert. The benchmark for issuing a warning varies from place to place, based upon differential local health responses to extreme weather. In some cases, however, prior to HHWS development, correlations between negative human-health outcomes (morbidity, mortality, heat load on the body) and extreme weather are developed to permit an estimate of those health outcomes based on forecast data. A variety of ways exists for establishing climate and health relationships with associated advantages and disadvantages (Gosling et al., 2009).

In some places, it is the NMHS that is responsible for issuing advisories and warnings for heat. In others, the local public-health agency takes responsibility for warning issuance, having taken advice from their NMHS about forthcoming conditions.

Forecasts issued by NMHSs are therefore used as the primary input into an HHWS and associated HHAP. In some cases, forecasts are used as input into algorithms that attempt to estimate the degree of negative health impact of the weather. If the expected negative impact is above a predefined level or if a situation is identified that has been associated with negative health outcomes during the calibration period, the responsible agency (whether it is the NMHS or a local health department) issues a warning or alert. Although the meteorological input varies among systems, thresholds in all cases are determined, beyond which expected human-health problems increase. Beyond that point, information is disseminated to various stakeholders so action can be taken, as outlined in a wider HHAP.

Usually, there are two or three separate warning categories: a low-level announcement to warn the population of impending stressful weather; a higher-level issuance that tells people that the weather might be dangerous to their health; and the highest-level warning or alarm, at which time a variety of intervention measures are put into place by the community (see Chapter 6). In all cases, warnings must be disseminated rapidly to the public and responsible stakeholders or the effectiveness of the HHWS is greatly diminished (WMO, 1999).

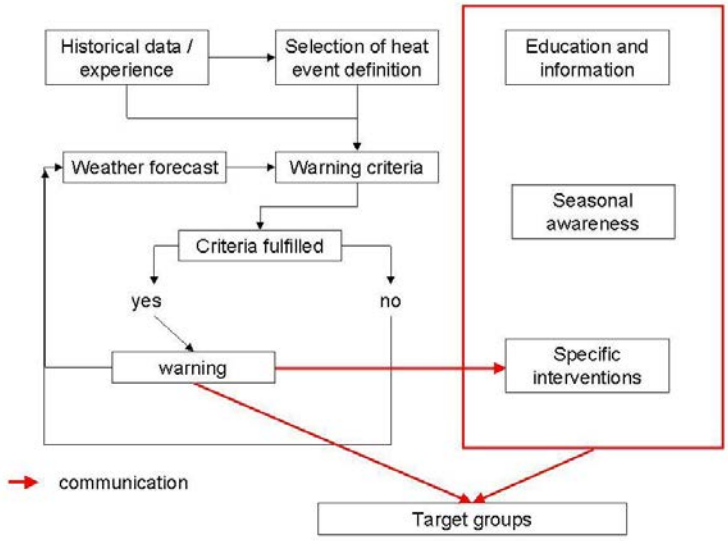

Figure 2. Flow diagram demonstrating the operation of a typical Heat–Health Warning System within a wider Heat–Health Action Plan (elements in the red box)

4.3 METRICS OF HEAT-EVENT DETERMINATION IN HEAT–HEALTH WARNING SYSTEMS

A number of methodological decisions must be made when an HHWS is developed. Because many of these systems have been initially employed at the individual city or country level, the range of methods currently utilized in HHWSs is wide. Just as there is no universal quantitative definition of “heat event” or “heatwave”, neither is there a single method by which heat situations, that may adversely affect human health, are identified and incorporated into an HHWS. Current systems generally incorporate one of several broad categories: single-metric, heat budget, synoptic or other[2] (see section 3.3).

4.3.1 Single- or few-parameter methods

Of all of the methodologies, utilization of the single metric of temperature or a modified form of apparent temperature (see section 3.3.1) is perhaps the most common type of system. *T* or *AT* methods are the sole approach in all systems in at least 13 countries: Belarus, Belgium, France, Greece, Hungary, Latvia, the Netherlands, Poland, Portugal, Romania, Spain, Switzerland and the United Kingdom (WHO, 2009). As all these systems are initiated at the federal level, the entire country is under a similar system, although the thresholds may vary from location to location. The only exception to this is Hungary, where only the city of Budapest is covered by an HHWS.

Further, across Canada and the USA, a significant number of systems exists that are based on *HI* or *Humidex* thresholds (Sheridan and Kalkstein, 2004). These systems have various levels of importance, depending upon the local climate and susceptibility to heat events. In some cases, they have been replaced by synoptic-based systems; in other cases, the two run side-by-side. In Italy, *AT*-based thresholds are utilized in a number of cities and, in some cases, may operate in conjunction with synoptic-based models (Accetta et al., 2005; Kirchmayer et al., 2004).

Despite its simplicity, there are a number of different ways in which temperature can be incorporated into an HHWS (Pascal et al., 2013). The most straightforward is the exceedance of a maximum temperature threshold on a given day. The threshold may be based on a historical critical mark (arbitrarily obtained on occasion) or on comparison with negative health outcomes within the historical record. Single-day thresholds are climate-specific, ranging from 30°C in Belarus to 38°C in Greece (WHO, 2009). Though not the only part of the HHWS, a warning

[2] It should be noted that, in general, the European systems reviewed here are “top–down”, in that the structure is most often set at the national level. In comparison, while national guidelines exist in North America and Australia, there is significant decentralization of the HHWS process and, thus, a wider diversity of systems.

threshold is reached in Phoenix, Arizona, USA, when the forecast temperature exceeds a smoothed curve of the season cycle of record daily maximum temperatures, with a threshold as high as 45°C in July.

Other permutations exist. In a number of HHWSs, a threshold must be exceeded on a number of days before any warning is called. In Latvia, warnings are issued if the maximum temperature exceeds 27°C for six consecutive days or exceeds 33°C on one day (WHO, 2009). In the Netherlands, to meet warning criteria, the temperature must exceed 25°C on five consecutive days and exceed 30°C on one day (Koppe et al., 2004). The Watch Warning System for Heatwaves (ICARO) index, which signals the potential for warnings to be issued in Portugal, is based on an exceedance of 32°C for two consecutive days (Paixao and Nogueira, 2002).

Recognizing the importance of overnight temperatures, a large number of systems (including Belgium, Montreal (Canada), England, France, Poland, and Spain) utilize thresholds for both maximum and minimum temperature in determining warnings (WHO, 2009; Kosatsky, pers. comm.). Thresholds vary from 15°C in parts of England to 25°C in parts of Spain for minimum temperatures, with maxima from 28°C in England to 41°C in Spain (WHO, 2009). In Budapest, a daily mean temperature is used as a threshold (Paldy, pers. comm.). Similar to the maximum temperature thresholds, there are also considerations of duration built into maximum and minimum thresholds; Belgium, England and France (two days), as well as Montreal and Poland (three days), all require thresholds to be exceeded on multiple consecutive days before a warning is considered (WHO, 2009; Henderson and Kosatsky, 2012).

In addition to temperature thresholds, there are a number of HHWSs that employ one of several *AT* metrics. *AT* is a single variable that accounts for temperature, as well as other meteorological factors, most typically humidity. These metrics could be beneficial in areas with very variable levels of atmospheric moisture, making the temperature alone perhaps less representative of the "oppressiveness" of the weather than in locations where the humidity is relatively consistent from day to day. Thresholds of maximum *AT* are utilized throughout Italy, where the thresholds are adjusted by location, time of year and duration of heat event (de'Donato et al., 2004; Kirchmayer et al., 2004). *AT* is also used in Queensland, Australia, with regionally varying thresholds (35°C in Brisbane, 37°C in Amberly, for example) that must occur on at least two consecutive days (Queensland Health, 2004). *HI*, which incorporates temperature, humidity and wind speed, is commonly utilized throughout all HHWSs in the USA that are not based on the synoptic methodology, as well as in Switzerland. Official thresholds are set at a maximum heat index of 41°C and a low of 27°C over two consecutive days for all regions of the USA, although each region is permitted to adjust these values to reflect local climatology (NWS, 1992). *Humidex* is in use throughout all Canadian locations that do not incorporate the synoptic methodology (Marshall, pers. comm., 2006). Thresholds in Canada are set to the exceedance of a maximum *Humidex* of 40 on two consecutive days. Thresholds of the Temperature-Humidity Index are utilized in Romania (WHO, 2009). Table 4 summarizes the characteristics for a range of HHWSs, from which it is clear that system structure varies widely between locations.

Table 4. A selection of operational Heat–Health Systems showing the varying nature of system structure, heat-event definition and type of threshold used for triggering warnings (✓ indicates the presence of the system element but detail on the nature of this is lacking)

Country	*Threshold*	*Thresholds based on historical mortality*	*Excess mortality forecast*	*Duration of heat event included*	*Seasonality or adaptation included*	*Regionally variable thresholds*	*Human expertise*
Australia (Queensland)	*AT*			2 days		✓	✓
Belarus	*T*						
Belgium	*Tmax/Tmin/*Ozone			3 days			
Canada (Toronto region)	Airmass	✓	✓	✓	✓	✓	✓
Canada (Montreal)	*Tmax/Tmin*			✓			
Canada (all others)	*Humidex*			✓			
China (Hong Kong)	*NET*						
China (Shanghai)	Airmass	✓	✓	✓	✓		✓
France	*Tmax/Tmin*	✓		3 days		✓	✓
Germany	*PT*			2 days	✓	✓	✓
Greece	*Tmax*			✓			
Hungary (Budapest only)	*Tmean*	✓					
Italy	Airmass/*Tapp*	✓	✓	✓	✓	✓	
Republic of Korea	Airmass	✓	✓	✓	✓	✓	✓
Republic of Korea (Seoul*)	Airmass	✓	✓	✓	✓	✓	✓
Latvia	*Tmax*			✓			
Netherlands	*Tmax*			✓			
Poland	*Tmax/Tmin*						
Portugal	*Tmax*	✓	✓	✓		✓	✓
Romania	*ITU*						
Slovenia	Forecaster						✓
Spain	*Tmax/Tmin*	✓				✓	✓
Switzerland	*HI*						
United Kingdom (England and Wales)	*Tmax/Tmin*			✓		✓	
USA (synoptic**)	Airmass	✓	✓	✓	✓	✓	✓
USA (all others)	*HI*			2 days		✓	✓

where:

T	temperature	*HI*	Heat Index
AT or Tapp	apparent temperature	*PT*	perceived temperature
Tmax	maximum temperature	*ET*	equivalent temperature
Tmin	minimum temperature	*ITU*	Temperature Humidity Index
Tmean	mean temperature		

* *Seoul has been subdivided into five regions based upon unique climatology and health response. This represents the only subdivided urban HHWS currently in operation.*

** *Seattle (Washington), Portland (Oregon), San Francisco and San Jose (California), Phoenix and Yuma (Arizona), Dallas and Houston (Texas), Minneapolis (Minnesota), Chicago (Illinois), St. Louis (Missouri), Dayton, Columbus and Cincinnati (Ohio), Philadelphia (Pennsylvania), Washington (DC), Baltimore (Maryland), New Orleans, Monroe, Shreveport, and Lake Charles (Louisiana), Little Rock and Fort Smith (Arkansas), Memphis (Tennessee), Jackson and Meridian (Mississippi)*

4.3.2 Heat budget

A more complex approach to the determination of HHWS thresholds is based on a heat-budget model. This method, applied on a county level across Germany, is based on the perceived temperature (°C) (see section 3.3.2.3). *PT* is evaluated within a broader framework known as the Health Related Assessment of the Thermal Environment (*HeRATE*) approach (see section 3.4.4.1).

Based on these adaptations, four different levels of heat stress have been determined: slight, moderate, strong and extreme. These levels vary over time and place (Figure 3). Exceedance of a strong or extreme heat load is the warning threshold utilized, although a warning is also issued if the threshold for a strong heat load is not reached but *PT* is higher than 34°C.

4.3.3 Synoptic-based systems

Synoptic-based systems are currently implemented in four countries – Canada (3), China (1), Italy (4) and the USA (28) and are being developed for the Republic of Korea (Lee et al., 2011). In the USA, a number of systems are created as single or “stand-alone” systems, with one centralized location serving as a reference for an entire forecast area affiliated with one NWS office; in other cases, where two or more major cities are in close proximity, or there is significant mesoclimate variability, multiple parallel systems are run. In Canada, the three systems in place are entirely within metropolitan Toronto, with different algorithms for each location. In Italy, all synoptic systems run alongside the *AT* systems discussed above.

Synoptic-based systems were first developed based on the Temporal Synoptic Index which has been replaced by the Spatial Synoptic Classification (SSC) (Kalkstein et al., 1996(a); Sheridan, 2002). SSC incorporates temperature, dewpoint, wind direction, wind speed, cloud cover and pressure, measured four times per day. This information is used to determine which one of seven airmasses (or a transitional type) is represented by the ambient atmospheric conditions. The classification is based on a set of typical conditions for each airmass. These vary from location to location and from season to season in a cohesive spatial and temporal manner (Bower et al., 2007).

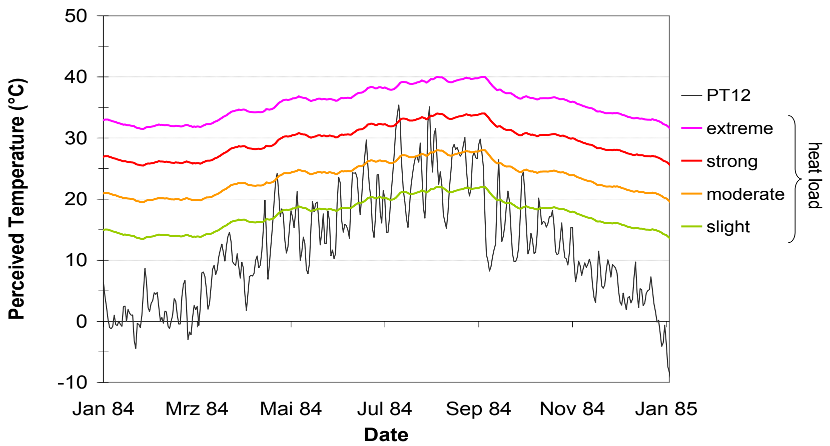

Figure 3. Example of the thresholds used in the German Heat–Health Warning System: a warning is issued when the thresholds of a strong or extreme heat load are exceeded.

Source: Modified from http://www.umweltbundesamt.de/sites/default/files/medien/515/publikationen/umid0309-e.pdf

The standardized mean summer mortality for each airmass is determined and those airmasses with statistically significant mortality greater than the normal are identified. Most often, two particular airmasses are deemed "offensive", with respect to higher mortality values: dry tropical (DT) characterized by low atmospheric moisture content and large insolation amounts and moist tropical plus (MT+), a hybrid type with high humidity and nocturnal temperatures often associated with extensive cloud cover (Figure 4).

In many cases, airmasses with mean overall increase in mortality are also associated with a higher standard deviation in mortality. To further refine mortality predictions, within-airmass algorithms have been developed to account for differences in airmass character from day to day, as well as for time of season and persistence. It is these forecast algorithms that then predict mortality for input into the decision-making process as to whether a heat warning should be called.

4.3.4 Other methodologies

While the above three methodologies comprise the bulk of all present day HHWSs, other methods are in operation. In Slovenia, no official methodology is utilized; rather, the forecasters assess the situation, based on experience (Cegnar, pers. comm., 2006). Similarly, in a number of systems currently in use, including those in Canada, France, Germany and the USA, the institution that is responsible for issuing the warning has some leeway in adjusting the thresholds discussed above, upwards or downwards, to account for factors not included within the particular approach (WHO, 2009; NWS, 1992).

4.4 HOW WARNING THRESHOLDS ARE DETERMINED

As the above section shows, a number of different means are utilized to define a "heat event". Similarly, there are a number of ways in which the precise threshold levels which instigate issuance of a warning are determined.

4.4.1 Determining thresholds

A number of HHWS thresholds are response-specific; that is, the threshold values are set at a level associated with a negative human response (WHO/WMO/UNEP, 1996). Although it is widely recognized that the health impacts of excessive heat are wide-ranging, including significant increases in morbidity as measured by hospital admissions (Semenza et al., 1999) or other metrics, mortality data are most commonly used in HHWS threshold determination (Sheridan and Kalkstein, 2004). The reasons for this are straightforward: mortality data, unlike all other information on morbidity, are the most regularly collected and standardized; unlike hospital admissions (reporting based on severity can vary and may also depend on the health system), are binary in nature and are available for the longest period of time. All synoptic-based systems in the USA are based on 24 years of mortality data (Sheridan and Kalkstein, 2004); the French system is based on 33 years of mortality data (Pascal et al., 2006).

While raw-total mortality is what is initially obtained, a number of different methods of analysis have been undertaken. Given that heat exacerbates other ailments and that the official definition of a "heat-related death" has long been known to underestimate heat's true impact, analysing only official "heat-related deaths" has not generally been a basis for an HHWS. As a number of studies have identified the elderly as the most vulnerable subset of the population, some HHWSs are based solely on the mortality data of those aged 65 and older (Toronto: Kent et al., 2002). Others, such as the Italian systems (Michelozzi et al., 2005), are based on all non-accidental mortality. Most, however, are based on total, all-cause mortality, including all US synoptic-based systems and the French system (Sheridan and Kalkstein, 2004; Pascal et al., 2006).

Long-term mortality data are generally reduced to a "baseline" or normal daily value, standardized to account for demographic changes over time (Sheridan and Kalkstein, 2004). Within-season adjustment is also necessary, especially in places that have a typical temporary out-migration during parts of the summer, such as Italy in August (Michelozzi et al., 2005). From this baseline, daily "anomalous mortality" can be calculated and correlated with weather conditions. As noted by Gosling et al. (2009), a number of methods exist for calculating baseline and excess mortality, which bear implications for understanding climate–health associations and for making comparisons between different locations and thus HHWSs.

There are a number of different means by which anomalous mortality data are evaluated. In all synoptic-based systems, the airmasses that are associated with statistically significant anomalous mortality are identified; the algorithms defined above further refine this connection. In most cases, a predicted number of excess deaths is forecast, although, in Toronto, the historical data are utilized to predict the likelihood (in per cent) of excess mortality occurring. The threshold is then exceeded in situations where at least one excess death is predicted; in Toronto, the threshold is when an excess death is at least 65 per cent likely (Sheridan and Kalkstein, 2004).

In other locations, different thresholds of the thermal metrics are set. In France, thresholds are set to correspond with temperature levels that have been associated with a mean 50 per cent increase in mortality in urban areas and a 100 per cent increase in rural areas (Pascal et al., 2006). After some adjustments, the French system uses thresholds that correspond to the 99th percentile of the regional distribution of minimum and maximum temperature. In Portugal's ICARO system, a threshold is set at the equivalent of a 31 per cent rise in mortality for an announcement and at the equivalent of a 93 per cent rise in mortality for an alert (Nogueira et al., 1999).

In some HHWSs, no mortality component has been utilized in the determination of warning thresholds. A notable example is Germany, where the heat-budget model evaluates the thermal stress on a typical human and bases thresholds on the different levels of stress. Though not explicitly based on a mortality response, a clear correlation with mortality has been established (Koppe, 2005).

In many other cases, however, the thresholds have been somewhat arbitrarily set. In a number of HHWSs, the threshold is set to a percentile. In Belgium, for example, the 95th percentile of summer maximum temperature is the threshold (SPF, 2005). The thresholds of other systems are based on historical values, such as the US *HI* threshold of 41°C or the Canadian *Humidex* threshold of 40°C. While all these thresholds are set to capture only the most extreme days, it should be noted that they have not been developed from, nor are they related to, any specific health response.

Hajat et al. (2010) have presented a useful analysis of the comparison of the prediction capacity of different approaches (synoptic, epidemiological, temperature humidity index, physiological classification) for identifying hot days that have significant health effects. They found little agreement between approaches regarding days identified as being "most dangerous" and concluded that the triggering of heat alerts and associated intervention strategies varies significantly.

One other important distinction among HHWS thresholds is their seasonality. Much research has shown that heat vulnerability varies throughout the season, with higher vulnerability earlier in the warm season (Smoyer, 1998; Kalkstein, 2002; Basu and Samet, 2002; Dessai, 2002; Kysely, 2004) and some warning systems account for this differential variability. As mentioned above, the *HeRATE* system in Germany accounts for short-term acclimatization within its calculation of the threshold perceived temperature (Koppe, 2005). Similarly, airmass character within the synoptic-based systems varies seasonally. Because "time of season" is typically utilized in predictive algorithms for these systems, synoptic-based systems account for intraseasonal acclimatization (Sheridan and Kalkstein, 2004). While other thresholds can be made to be variable, those of most *AT*- or *T-based* HHWSs do not vary over the course of the year.

4.4.2 **Defining and determining different levels of warnings**

Most HHWSs have more than one level of warning and there is little consistency in the nomenclature for the different warning levels. The "alert" level in England, for instance, means that a heatwave is expected within three days but, in Belgium, signifies that the heatwave has already started. In some systems, the different levels of warnings have no names at all and are referred to as "Level 1", "Level 2", "Level 3", etc. or as "green", "yellow", "orange" and "red" (WHO, 2009). Because the purpose of warnings is to effect behaviour change during heatwave events, it is critical that careful consideration is given to how warnings are communicated and what the

Table 5. Heat–Health Warning System levels based on the time until the event or magnitude during the event

	Examples of nomenclature	*Description*
Pre-alert levels (temporal)	Seasonal vigilance	Activated during the whole summer season, though no heat event is forecast.
	Outlook	A heat event is expected during the next 3–5 days.
	Watch (warning)	A heat event is expected within the next 24–48 hours.
Alert level (severity)	Heat alert Heat advisory Warning Severe weather warning	Moderate heat event occurring or imminent
	Excessive heat warning Extreme heat alert Heat emergency Maximum mobilization Extreme weather warning	Significant heat event occurring or imminent

implications might be of using different approaches (using different types of staged or hierarchical warnings, different terminology and different visuals for communication) (see Chapter 5).

There are several ways to distinguish warning levels. One way is based on the time until the event (Table 5). In some HHWSs, the lowest level of alert is active during the whole operating season of the HHWS. This level indicates that there is no risk of a heatwave and is often used to raise the general awareness of the potential danger of heat for human health and to provide the general public with information on how to behave in case of a heatwave, as well as to educate health-care professionals. Some HHWSs have one or more pre-alert levels, which is/are activated when a heatwave is forecast to arrive during the next few days.

The severity of a heatwave can determine the level of alert. Heatwave levels are either graded according to the intensity of the heatwave, the duration or, in some cases, a combination of both. In some HHWSs, soft limits are used to increase the level of warning in case an “emergency” or very severe situation occurs or the predicted level of mortality increase is used for increasing the warning level. In Belgium, apart from the duration, ozone concentration also determines the level of alert (SPF, 2005).

4.4.3 **Other considerations with warnings**

One significant concern in the development of HHWS thresholds is the frequency with which warnings are called; that is, to define at which point heat stress conditions become “sufficiently hazardous” to human health in a given population to warrant a warning (Kovats and Koppe, 2005). What “sufficiently hazardous” means depends on the scope of the HHWS. If the aim of a system is to prevent as much heat-related mortality as possible, a low threshold has to be defined (T1 in Figure 4, for example,). In this case, a lower threshold may be chosen and, while the number of lives that could be saved could be very large (amount a in Figure 4), the cost would be high and warning fatigue may set in. Another possibility would be to define only very severe situations as “sufficiently hazardous” (threshold T3 in the example). The aim of such a system is to prevent only the mortality peaks during very extreme conditions. As such conditions are very rare and might occur only once in several years, the total number of lives saved with such a system is smaller (amount c in Figure 4), although any mitigation costs would be less.

Current systems vary significantly. Many of the synoptic-based systems, operating on the principle of statistically significant increases in mortality, identify increases in mortality of between 5 per cent and 10 per cent as targets for warning issuance. A long-term analysis of 50 years’ worth of historical data suggests that, were warnings issued based solely on the system output, the synoptic-based Toronto system would have a mean of 4.5 warnings per year (1.4 higher-level extreme alerts, 3.1 lower-level alerts), with variability from 0 to 19 in any particular year (Kent et al., 2002). On the other hand, the higher-threshold French system, with a required 50 per cent or 100 per cent rise in mortality, results in less than one warning per year (Laaidi et al., 2004).

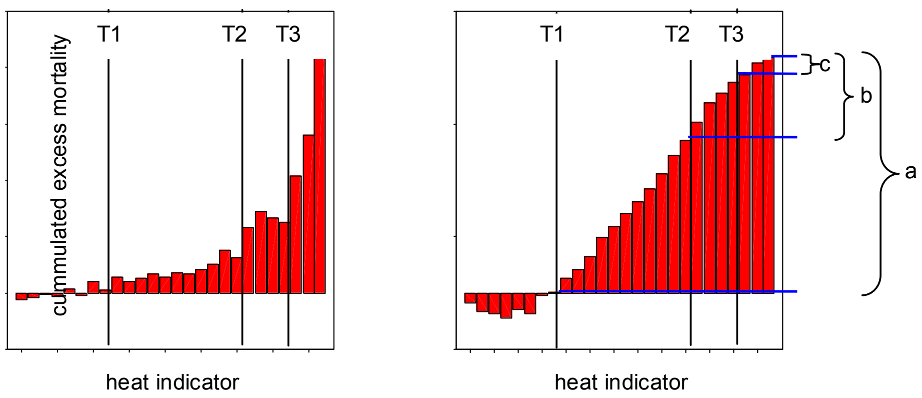

Figure 4. Example of the relationship between temperature and excess mortality during summer (left) and cumulative excess mortality (right): T1–T3 thresholds; a, b, c – amount of mortality that can be prevented when applying the different thresholds in case of a 100 per cent effective Heat–Health Warning System.

Source: Koppe, 2005

Another cost-related concern involves the period of time during which the HHWS is active. Most systems operate only during the time of the year in which heatwaves are most likely to occur, in order to reduce costs. This period certainly varies across the different climate zones. In the northern hemisphere middle latitudes, systems generally run until the end of September (Canada, Germany, Italy, USA) or October (Spain). A more important concern, because of the significance of early-season heatwaves, is the beginning of the heat season. The operating season starts in Germany in April; the Canadian and USA synoptic systems in May; and most other systems in June (WHO, 2009; Sheridan and Kalkstein, 2004). In order to determine the operational time frame for an HHWS, analyses are required to define when the statistical relationship between temperature and health effects transition from inverse to positive. This approach to identifying the HHWS season will be best suited to places with a clear winter excess mortality such as in mid-latitude countries. For subtropical countries with distinct monsoon climates, the period preceding monsoon onset is sometimes critical in terms of heat-related health effects and is therefore the time of year when it will be most necessary for the HHWS to be "turned on".

4.5 ISSUANCE OF WARNINGS

HHWSs differ in the way warnings are issued. Some systems issue a statement only when the pre-alert or alert level is reached. Other systems issue statements daily, whether a pre-alert or alert level is reached or not; such statements may relate to general information about the heat season such as preparedness or be composed of "good weather" messages. More details on the communication aspects of warnings can be found in Chapter 5.

Similarly, the number of warnings issued per day varies within the systems between once (generally in the morning) and three times (morning, noon, afternoon). In some HHWSs, the warnings are explicitly cancelled if the weather forecast changes or when the heat event is over. Other systems simply "cancel" their warnings by not renewing them. In Canada, a "deactivation notice" is issued (Peter Berry, pers. comm.).

Several significant spatial issues arise concerning the warning systems currently utilized in HHWSs. First and foremost is the spatial cohesiveness across different regions. In a number of systems, such as in France (Figure 5), the threshold is defined to account for climatological differences (InVS, 2005), in order to define a more cohesive warning region when heat events occur – although, on any given day, the spatial variability in the meteorological forecast may not always coincide with these different thresholds. Another concern is in the areas where different jurisdictions cross. In Europe, although many countries have individual systems, there is at present no international cohesiveness signifying that those living on either side of a border region may be subject to different levels of warning. In Canada and the USA, it is where one forecast region ends and another begins (often not coinciding with significant political boundaries) that concern is raised. No published work has evaluated this concern.

Another issue involves the distinctions that are made within a given region, particularly between urban and rural areas (Sheridan and Dolney, 2003). Since the sources of many HHWS messages (media, health agency, etc.) tend to be located in larger urban areas, in addition to the fact that the UHI results in urban areas being warmer (Oke, 1979), many people not located in cities do not perceive that the message is addressed to them. At present, a number of systems are aimed at broader areas, such as the county *(Land)* level in Germany or the *département* level in France (InVS, 2005). In other areas, such as China, a system is only in place for Shanghai and does not therefore cover adjacent rural areas (Tan et al., 2004). In a number of forecast offices in the USA, urban areas are placed under warnings more often than rural areas.

Urban HHWSs often cover the entire city on the assumption that responses within the comprehensive urban area are somewhat similar. Recent collaborative work between the National Institute of Meteorological Research (NIMR) of the Korea Meteorological Administration (KMA) and the University of Miami, Florida, USA, have shown the importance of dissecting very large urban regions into smaller areas and developing HHWSs with unique thresholds within each of the areas (Kalkstein and Sheridan, 2011; Kalkstein et al., 2011; Lee et al., 2013). At present, 14 distinct airmass-based HHWSs are in operation for the largest cities in the Republic of Korea and are utilized by KMA for important guidance in the issuance of heat advisories and warnings for these urban areas.

The most unique aspect of the systems is the regional intra-urban HHWS that has been developed for Seoul to better serve its very large population. The city was divided into five distinct regions with a separate HHWS and associated password-protected website for each. This was accomplished by determining homogeneous climatic regions within this extensive city, utilizing meteorological data from 25 different stations and, through a clustering procedure, five meteorologically homogeneous areas. Mortality algorithms were developed separately for these regions and thus five individual HHWSs are now operational, whereby a warning can be called in one section of the city but not in another.

There are two important advantages to this intra-urban differentiation. First, those sections of the city which are most vulnerable to heat-related health problems have been isolated. Second, Seoul can marshal intervention resources to the appropriate sections of the city, based upon intra-urban health responses to heat. Not all major metropolitan areas would require such a specific delineation but Seoul is unique because of its local relief within the urban area and its vast geographical extent.

Finally, most HHWSs do not explicitly account for indoor conditions (see section 3.2), as warning criteria are based on outdoor meteorological observations and forecasts. Much of the susceptible population, however, spends most of their time indoors. The potential danger of indoor thermal stress can either be assessed by setting the thresholds for the heat warnings based on the relationship between health and outdoor temperature or by including information about the relationship between outdoor and indoor thermal environment. In Germany, there is qualitative information about the thermal stress indoors for a realistic worst-case residential building, based on the modelled relationship between outdoor meteorological conditions and indoor heat stress (Becker and Pfafferott, 2007). In some countries where vulnerabilities are well understood (absence of air-conditioning, for example), the warnings and associated messaging do take indoor conditions into account to some degree.

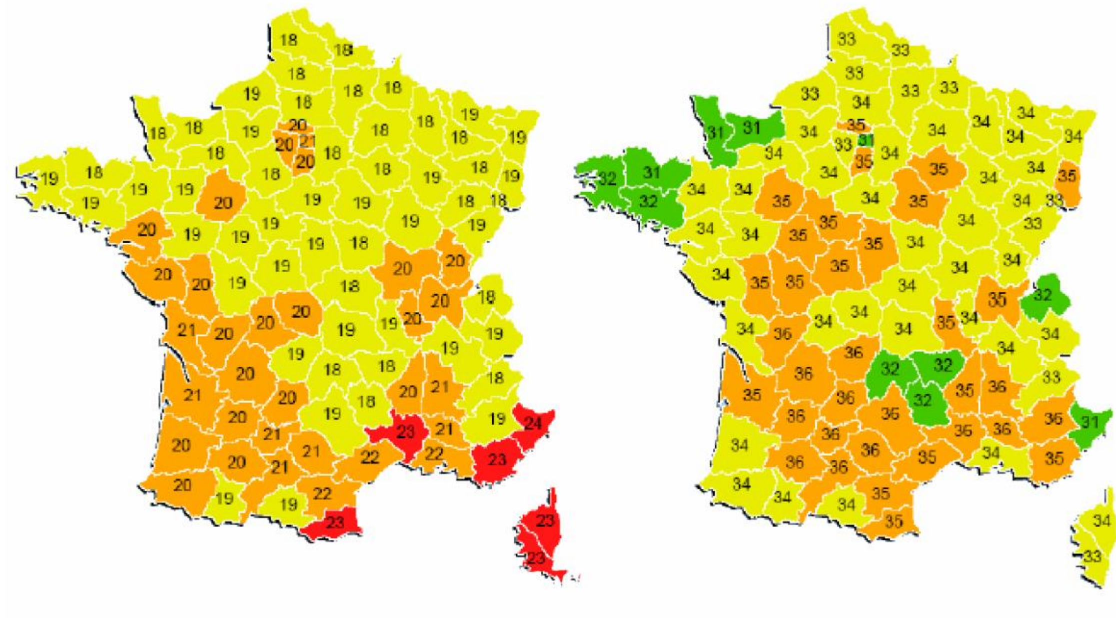

Figure 5. Thresholds of minimum temperature (left) and maximum temperature (right) in France

Source: InVS, 2005

4.6 THE FUTURE OF PRESENT-DAY HEAT–HEALTH WARNING SYSTEMS

Due to climate change, an increase in the number of heat events is very likely (IPCC, 2007; IPCC, 2012). HHWSs are an important adaptation strategy and may help mitigate the impacts of an increased number of heat events in the future.

As HHWSs are constructed based on a historical relationship between health impacts and the thermal environment, consideration will always have to be given to the stability of this historical relationship with changes in climatic patterns (the so-called issue of relationship stationarity). It can be assumed that populations adapt to climate change, not only because of the implementation of the HHWS, but also through acclimatization (physiological adaptation). In addition to a changed exposure to heat (section 3.2), there are also several socioeconomic and individual risk factors (see Chapter 2) that may change during the coming decades. It is therefore necessary to adapt the warning system to actual climatic conditions and general adaptation status of the population and to define the thresholds for issuing warnings in a way that accounts for changing vulnerability patterns. Indeed, research on trends in the heat–health relationship in the USA (Davis et al., 2004) has shown decreased vulnerability from the 1970s to the 1990s, though future scenarios suggest an increase in heat vulnerability in the future with increasing elderly populations (Hayhoe et al., 2004).

A warning system that is based on a “historical” percentile of minimum and/or maximum temperature, for instance, will issue more warnings in a warmer world than it was originally supposed to, leaving the population more inclined to ignore warnings. While revising an HHWS and changing the thresholds upon which warnings are issued, however, the aim of the system must be considered: is it to protect individuals at risk or to avoid peaks in overall mortality? Has the vulnerability of individuals at risk changed? Has the number of individuals at risk changed – or both?

Another issue is that of air-conditioning. With rising temperatures, the use of air-conditioning will increase in order to reduce the individual’s exposure thereto in countries that can afford it. Thus, on the population level, a reduced exposure to heat will alter the relationship between outdoor thermal environment and health impacts. Those with no access to air-conditioning or improved housing or those who work outdoors will not have any reduced vulnerability and may indeed be more exposed if the heat generated by air-conditioning warms the environment further. It is questionable whether it makes sense to include such considerations while evaluating and adapting existing HHWSs, as changes in the thermal stress/mortality relationship at the population level may not be representative of the individual level. In the case that increased use of air-conditioning or improved housing is found not to be lowering vulnerability and associated health effects within a particular population group, a review of community response measures as part of an HHAP would be appropriate.

In some HHWSs, large heat events are used to recalibrate the warning procedure. It is important that warnings are issued on the occasion of a heat event and that there is a set of effective intervention measures. No adjustments may be necessary to forecast heat-related mortality more accurately, as it is unlikely to increase the effectiveness of the system. Moreover, due to the rarity of very extreme events, statistical relationships may be significantly altered by these “outliers”, which may result in making warning algorithms less useful for more “ordinary” heat events.

Whether or not to combine heat warnings with air-quality warnings should also be considered. The probability of having high ozone levels in a heat event is relatively great as there is some evidence of the synergistic effect on mortality of high temperatures and ozone levels (Analitis et al., 2008(a)) but heat and ozone warnings often address different target groups. While heat warnings often address the elderly and frail who spend most of their time indoors, where ozone levels are low – even if they are high outside – ozone warnings in general target population groups with outside activities. Furthermore, while heat warnings attempt to minimize behaviour that may put the individual at risk, ozone warnings attempt to minimize behaviour such as driving vehicles that will collectively increase ozone levels. Furthermore, systems that advise the public on high ultraviolet (UV) radiation levels may also lead to confusion about how to respond on high-risk days. Current practice points to a preference for the non-inclusion of air-quality warnings in an HHWS but, as the picture becomes clearer about the synergistic effects of heat and poor air quality on health, this situation may change. Certainly, there is the possibility that the impacts of heat and poor air quality on health may be climate- or location-dependent, such that there may be value in integrating air quality with heat warnings in some locations but not in others.

Despite the strides made in the development of sophisticated HHWSs, inherent weaknesses remain, some of which can be addressed, but not others. For example, no system can forecast precisely the degree of negative health outcomes, such as mortality level, because there are so many additional non-meteorological variables or confounding factors that impact death rates. Thus, the mortality/weather relationship does not correspond well to a dose/response relationship. This, of course, is not an issue exclusive to HHWSs as attempts to develop weather- and climate-based early warning systems for other health outcomes, such as UV radiation exposure or vectorborne disease, have varying levels of success and inherent problems (McGregor, 2012).

Little has been done to develop specific warnings for particularly vulnerable groups, such as the elderly, obese or very young. Although messages often mention that these individuals are more susceptible to heat problems, systems are often designed for the population at large. For this reason, some HHWSs are being planned for target groups. In the desert region of the south-western USA, for example, many poor people have only “evaporative coolers” available to deal with excessive heat. These work on the principle that evaporation will cool the air coming into the house during very dry conditions and are ineffective when the weather becomes more humid. Plans are therefore being developed for a specialized evaporative cooler warning system to warn individuals that their coolers have become ineffective because of more humid conditions (Kalkstein and Kalkstein, 2004). On the other hand, many systems have been based on heat–health responses that focus on urban areas, and many mitigation plans focus predominately on urban residents. Some research has indicated that rural population responses may be as extreme as urban ones (Sheridan and Dolney, 2003). Thus, while it may be desirable to target specific population subgroups, they should not lead to confusion amongst the general population or make certain subgroups feel they are not vulnerable to heat. In the context of an HHAP, the implementation of different response strategies for different subgroups may be feasible only in more developed countries which have more sophisticated communication systems.

4.7 SUMMARY

The overall aim of an HHWS is to alert decision-makers and the general public to impending dangerous hot weather and to serve as a trigger point for the implementation of advice on how to avoid negative health outcomes associated with hot weather extremes. Typically, HHWSs are composed of a number of elements which include weather forecasting, a method for assessing how future weather patterns may play out in terms of a range of health outcomes, determination of heat-stress thresholds for action, a system of graded alerts/actions for communication to the general population or specific target groups about a pending period of heat and its intensity and to government agencies about the possible severity of health impacts.

An HHWSs is often part of a wider HHAP, which not only embraces the HHWS itself but also education and awareness-raising, heat-event preparedness and guidance on heat-avoidance actions and heat-risk governance, a communication plan, a programme of evaluation, a health-surveillance system and advice on longer-term strategies for reducing heat risk. The structure of HHWSs varies significantly between cities, regions and countries because human and technical resources and heat–health associations are usually geographically specific.

Lastly, when entering into the development of a warning system, the various “do’s and don’ts” (lessons learned from the experiences of those who have worked with or helped to develop early warning systems for a wide range of societal concerns) need to be considered, in order to assist governments and other decision-makers in preparing effective warnings and in aiding the media and the public in interpreting and using such warnings (Glantz, 2004).

CHAPTER 5

COMMUNICATING HEAT–HEALTH WARNINGS AND HEAT-RELATED INFORMATION TO STAKEHOLDERS AND THE PUBLIC

Key messages

- Warning is the process by which people are made aware in advance of actual or potential harm. The way in which warnings are communicated is one of the critical determinants of the success of an HHWS as part of a wider HHAP.

- It is imperative that the risk associated with an impending period of anomalous heat is communicated precisely and adjusted for the target group.

- Warning messages need to be composed in clear, unambiguous language.

- A well-honed communication plan is also necessary for the general communication and outreach elements associated with heat-intervention strategies, which are part of a wider HHAP.

- Knowing the factors that influence human response to warnings can assist with the development and implementation of communication and education strategies for both an HHWS and an HHAP.

- Messages need to be elaborated jointly by different agencies or communities (health services, weather services, etc.).

As outlined above, the purpose of an HHWS is to detect when adverse, health-damaging, hot weather is likely to occur and to assess the likely health consequences of a period of extreme heat. HHWSs are, therefore, the starting point of a set of activities designed to maximize the number of people who take appropriate and timely action against potential harm during extreme heat events. One such activity is the communication of warnings about an impending heat event to stakeholders and the public. Warning is the process by which people are made aware in advance of actual or potential harm, hence the way in which warnings are communicated is one of the critical determinants of the success of an HHWS as part of a wider HHAP. This chapter considers the elements of warning and the factors associated with effective communication and dissemination of heat warnings and heat-related information.

5.1 ELEMENTS OF WARNINGS

5.1.1 The need to warn

The public expects to be warned of any natural phenomena that endanger life and property. In the case of excess heat, communicating the risks of hot weather and heatwaves and how to respond are recommended elements of a summer and heatwave-prevention strategy based around an HHWS and an HHAP. Warning in good time allows proper action to be taken, depending on the type and severity of the warning. Weather warnings concerning heat incorporate a high degree of urgency and severity of expected conditions. They are intended to alert the public in a manner that attracts attention. Heat warnings, like all other meteorological warnings, are usually issued when conditions are forecast to exceed predetermined criteria (see section 4.3), are amended or updated as required and are given priority in dissemination over other routinely produced weather products.

5.1.2 The decision to warn

Issuing timely warnings is a high-priority challenge for the staff of an NMHS. Responding to the challenge requires a thorough understanding of the many factors influencing a successful decision to warn. Such factors include (but are not limited to) knowledge of conceptual models and atmospheric conditions favourable for hazardous weather to occur, as well as expertise in interpreting datasets from radar, satellites and numerical weather prediction (NWP) models. Effective decision-making in relation to managing any climate risk is made up of a number of elements. Awareness of the situation – the anticipation of how events are likely to develop – plays an important role in decision-making. Furthermore, it implies the sensitivity to respond to developments that may occur if the conditions change. An essential element of a successful warning decision is a plan with which all staff must be familiar and which will be the basis for training and drills. The plan should also be used for reference during a similar severe event, regardless of personnel on duty. Other components of the plan, which should be understood by the operational personnel, include contact information for key officials and the media, content of the warning, frequency of issuance, and dissemination methods.

5.1.3 Content of a warning

The actual content of a warning message that is delivered to members of the public is of critical importance in guiding people and leading them to take appropriate action to protect themselves from the hazard. The wording of warnings is crucial to the effectiveness of the service. Important points to be kept in mind when composing a warning are:

- Clear definition of the components of the message;
- Simplicity of the message;
- Personalization of the message and description of the actions required;
- Prioritization of the order of importance of the information;
- Use of plain language;
- Inclusion of a statement of recommended action;
- Ensuring that shortening of the message by broadcasters does not distort its meaning.

The point about recommended action is especially important. An effective warning message should recommend ways that the public can achieve protection, including safety rules or guidelines for appropriate action. These recommended actions should be worked out in agreement with disaster managers, following established regulations. A message that effectively describes a danger but offers no suggestions for protection simply tends to be denied or reinterpreted by recipients. The public could generate protective actions for themselves based on misinterpreted folklore or an incorrect understanding of the threat that would increase their level of likely injury.

5.1.4 Language

To influence the recipients of the warning, care should be taken to ensure that the language and vocabulary used are appropriate to the region or country, the culture and user needs. Warnings should be issued not only in the official language of a country but also, where necessary, in other commonly used languages. The use of technical terminology and jargon depends on the recipients. Whereas highly technical terms and abbreviations are to be avoided for the general public, they can be used in communicating with other decision-makers and governmental agencies if they have been agreed upon in advance. In all cases, the use of clear, concise, simple words is the most effective way of conveying meaning and avoiding confusion. The fact that the public may see or hear a warning only once adds to the need for clarity and simplicity.

5.1.5 Criteria for issuing warnings

Criteria and thresholds need to be defined as part of the warning system. When exceeded, these thresholds will automatically lead to the issuance of a warning. Criteria and thresholds may differ from region to region in the world and even within the same country. The frequency of exceeding thresholds is a factor for consideration when selecting them. For example, while summer temperatures of 40ºC may be considered normal in some countries, the same temperatures in a mid-latitude country with a temperate climate may present serious challenges to the authorities and risks to members of the public if they are unprepared (see section 4.4.1).

5.2 DISSEMINATION OF WARNINGS TO THE PUBLIC

5.2.1 Effective dissemination and communication

Forecasts and warnings are highly perishable products and should be disseminated rapidly to the public in order to be of value. Resources available to an NMHS dictate, to a large degree, the level of sophistication of technological application for disseminating the information. In both developed and developing countries, technology is advancing and is becoming more affordable and accessible. The question thus becomes how to disseminate the information in the most effective way to the intended audience. In order to carry out this function effectively, the staff responsible need to be well trained in aspects of preparing the information for presentation via various mass media such as radio, television and print, as well as via the Internet, and the message dissemination itself. Warnings and forecasts need to be not only understandable but also attractive so as to elicit sufficient interest and motivation for the user to read, listen to or look at and take action upon. This requires NMHS staff to have effective communication skills, which can be gained through specialized training. In addition, skills relating to interacting with, and rendering service to, the media are important, such as writing effective press releases and holding interviews, press conferences and press briefings. Needless to say, communication with the press is enhanced if journalists have a background in the general subject area.

5.2.2 Media for dissemination

Each medium of communication has its advantages and disadvantages. Television and radio reach the population at large and are ideal for the distribution of time-critical information such as warnings. Radio can reach a wide audience rapidly in an emergency situation, whereas television has the advantage of presenting the information in graphical format. Newspapers, while useful for providing detailed and graphic information and being a powerful medium for public education purposes, are not suitable for the dissemination of warnings. Whatever medium of dissemination is used, it should be remembered that more and more information, including warnings, is becoming available to the public and it is essential that it is clear and easily understood by users.

In addition to the mass media, NMHSs use the Internet to disseminate weather forecasts and warnings. It is a versatile tool because an NMHS can display large amounts of easily updated information. This may include raw data, forecasts and warnings and educational information. The Internet allows an NMHS to display its information in an attractive format, including visual graphics and animations, which may attract and motivate users. Where required, information can target specific or specialized users who are provided with forecasts via a password.

In some NMHSs, the public can call and speak directly to a staff member but this may result in overloading service lines at critical times. Restricted-use, unlisted, hotline numbers are normally available, which permit urgent communication to take place between the NMHS and government authorities or emergency managers. Additionally, weather messages recorded on automatic telephone answering devices are effective in reducing the number of telephone calls to the forecast office.

The telephone paging system is another method that allows quick, simple messages or alarms about time-critical weather information to be sent to a list of individuals, including emergency managers. Weather information is also made available through arrangements between NMHSs and mobile telephone providers, who disseminate it to individuals subscribing to the service. This may take the form of a Wireless Application Protocol, a standard for transmitting interactive content over mobile phone networks. The subscriber receives web pages on the display of a mobile phone. The Short Messaging System (SMS) is also a popular modern way of receiving weather information.

Press conferences or briefings are a useful method of effectively obtaining wide coverage of important events such as high-impact weather, including expected hot or cold spells. Whatever method is used, an effective dissemination system must provide appropriate information to emergency management officials and the general public in a reliable and timely manner. As communication facilities are liable to break down from time to time, back-up methods have to be available so that the most urgent messages – such as warnings – can be distributed without interruption.

Very often, the challenge facing an NMHS within severe funding constraints is to provide the most cost-effective dissemination system. Often, the use of “off-the-shelf” technologies is the most cost-effective and efficient approach for preparation and dissemination of forecasts and warnings. In ensuring back-up capability when the primary dissemination system fails, particularly during high-impact or hazardous events, partnership arrangements to pool resources with the media and emergency services can be an effective approach.

5.2.3 Evolving and emerging communication technologies

The rapid development of information technology has placed considerable demands on NMHSs in terms of providing improved weather products and enhanced information.

Advances in information and communication technologies have raised expectations in the broad area of health. This has resulted in the development of eHealth as a tool that enables cost-effective and secure use of information and communication technologies in support of health and health-related fields, including health-care services, health surveillance, health literature, education, knowledge and research. The 58th World Health Assembly (2005) urged WHO Members to consider establishing and implementing national electronic public-health information systems and to improve, by means of information, the capacity for surveillance of, and rapid response to, disease and public-health emergencies (WHO, 2005(b)).

5.2.3.1 *Implications for the design, packaging and delivery of weather information*

Text messages such as SMSs are an efficient means of transmitting short and timely messages to users with mobile phones, either on demand or as an emergency alert. Mobile communication systems already have the capability to transmit and receive graphics, voice and text in a similar way to television. The trend towards the mass use of different kinds of mobile devices to receive weather products and information will increase the need for:

- More compressed, compact weather warnings, including heat warnings;
- More time- and location-specific information.

To facilitate the delivery of weather information to next-generation mobile devices, new standards for data and protocols will be required, as well as more efficient means of data packaging. One example of a possible solution is the use of Extensible Markup Language (XML), an open standard for data exchange between different computer systems over the Internet.

A Web service is a distributed computing technology over the Internet, similar to XML in many respects and used for the exchange of data between computer systems. It is based on the client-server application model.

Meteorological content remains essential in exploring such new opportunities. The new communication systems support the vision of giving target groups the information they need in the most expedient and informative way. The system is a tool to deliver the message in ways that are easily understood and used, but the limitations on information interpretation, such as probabilistic statements and dealing with uncertainty, should also be made known (WMO, 2008).

5.3 COORDINATION WITH USERS

In the broadest sense, coordination should be pursued with all sectors that are users of the meteorological information and whose mandate makes coordination with them essential to the effectiveness of their work. To ensure effective warning, coordination is required within the hazards community and with the media. For maximum effectiveness, warning systems need to be linked to organizations responsible for response actions. This holds true at local and national levels. The key to success is involvement of the local population and strong support for coordination by the local political leadership.

Where meteorological hazards are concerned, the regular flow of reliable and authoritative warning information to the public, political leaders, responsible officials and affected institutions is vital.

5.3.1 Coordination with the hazards community

An emergency plan of an NMHS for dealing with hazardous weather should be carefully coordinated with corresponding plans of agencies having emergency-response responsibilities. The plan should be practised regularly to ensure that all staff members are familiar with their responsibilities, that its technological components are fully operational and that it fits in smoothly with the overall emergency-response effort. Experience in many countries shows that time and effort invested in the development, maintenance and exercise of a good emergency plan will invariably yield substantial dividends when a real emergency occurs.

The maintenance of a regular flow of authoritative and factual information can pose a particular challenge during catastrophic events, even when a functioning communication system exists. This is generally due to difficulties in obtaining and confirming information or in coordinating the many players involved in emergency response. These constraints can delay the release of official statements and may sometimes create an information vacuum. This vacuum may be filled by media personalities or external experts who are less constrained in their comments and who may, inadvertently, contribute to public confusion.

5.3.2 Coordination with the media

Coordination with the media is essential for the timely and accurate dissemination of warnings. The various media are often in competition with one another to obtain the earliest story or a new angle. In order to ease this competition and promote a consistent message, conference calls or hotlines involving the major media outlets are of prime importance. It is important to arrive at agreements with the media during severe weather such as heatwaves:

- Warnings should not be modified except in format;
- Warnings should be issued directly to the public as soon as possible and as close to verbatim as possible;
- Warnings should not be disseminated after expiry time;
- Viewers and listeners should be urged to monitor the development of the weather conditions.

5.3.2.1 *Media accounts, everyday life and risk signature*

The extent to which media accounts or stories shape people’s behaviour is clearly a key question for risk-communication practice. Research suggests that different risks have the capacity to engender specific patterns of understanding and response. This is often referred to as “risk signature”, which may be understood in terms of people’s practical reasoning, in specific circumstances, about the material nature and potential social impact of a given risk. In this sense, the signature is neither a wholly objective nor a wholly subjective attribute of the risk. Rather, it is about how the material characteristics are articulated in social terms. The differences in the structure of media accounts reflect the degree to which understandings can be grounded in terms of everyday experience. Media accounts will play an important role in shaping understanding, according to the extent to which everyday experience can be called upon to provide a compelling account (WHO, 2006). The media should be considered as both mirrors of public perception and, at the same time, as contributing to public perception. Systematically analysing those two functions should help us to take stock of public perception of risks in the policymaking process.

In particular, the tendency toward panic reactions in response to catastrophic risks is something that should concern those involved in both industry and public health. The economic losses caused by overreaction or misplaced reaction can be huge, as can the loss of human life. Often, the risk-management response is in proportion to the media coverage of the issue rather than the actual risk to human health. Policymakers and regulators are not consistent in how they address risk and society does not treat equivalent risks with the same degree of intervention. For example, deaths from road-traffic accidents are not regarded in the same way as deaths from food-poisoning and do not precipitate the same degree of media coverage and reactionary risk management.

5.3.2.2 *Media monitoring*

In modern society, the mass media represent one of the most important means of communication between governments and citizens and between information producers and consumers. The mass media are important for profiling the issues and problems with which public opinion is interested and concerned. The potential for the media to play a critical role in communicating information about extreme weather-related health issues is, therefore, immense. Communication via the media, particularly related to environment and health, remains a weak area, however, and continues to frustrate public-health advocates. A lack of communication skills and resources and poor channels of communication between information sources and media and the private and public sectors can often make a bad situation worse (WHO, 2006). It is critical that the media are monitored in terms of the role they play in conveying general and specific information relating to the association between extreme weather events and health-related outcomes.

5.3.3 Aspects peculiar to heat–health risk communication

Early involvement of the media is recommended in order to initiate rapid communication when a heat hazard is forecast or detected. Experience shows that this is not always the case. For example, the WHO Fifth Futures Forum, while dealing with case studies requiring rapid response, such as the heatwave in France and Portugal in the summer of 2003, concluded that failures in communication were found to be the key features of the crisis (WHO, 2004). Experience has elicited elements that contribute to success in risk communication. Some key considerations, based on best practice examples, are provided below.

5.3.3.1 *Trust*

The overriding goal is to communicate with the public in ways that build, maintain or restore trust. The media play a role in determining the level of trust the public displays. There is, therefore, an increasing need to gain a better understanding of the interplay of public perceptions and the media, communication strategies and policy initiatives and to investigate how public authorities can earn both trust and legitimacy when communicating about uncertainty and health risks (WHO, 2006).

5.3.3.2 *Timely warning*

The parameters of trust are established in the first official announcement. The timing, candour and comprehensiveness of the message may make it the most important of all communications.

5.3.3.3 *Transparency*

Transparency needs to be the first order of the day. Maintaining public trust throughout an event requires transparency (communication that is candid, easily understood, complete and factually accurate). Transparency characterizes the relationship between the event managers and the public. It allows the public to view the information-gathering, risk-assessment and decision-making processes associated with response to extreme events. Governments should release information to their own populations and to other governments and international agencies. Commitment to transparency on its own is insufficient. Equally important, for example, is is the need to ensure that those in the front line of public communication – namely science and health journalists – have adequate tools and skills to perform their task and to discern when a commitment to transparency is not being observed (WHO, 2005(b)).

5.3.3.4 **The public**

Understanding the public is critical to effective communication. It is usually difficult to change pre-existing beliefs unless these are explicitly addressed and it is nearly impossible to design successful messages that bridge the gap between expert and public without knowing what people think. Early risk communication is directed at informing the public about technical decisions (known as the "decide and tell" strategy). Today, risk communicators teach that crisis communication is a dialogue. It is the job of the communicator to understand the public's beliefs, opinions and knowledge about specific risks. This task is sometimes called "communications surveillance". The public's concerns must be appreciated, even if they seem unfounded.

5.3.3.5 ***What the individual can do***

Risk-communication messages should include information about what members of the public can do to ensure their own safety. It is important to agree with the media at the beginning of the heat season the key messages to announce and what key health professionals should do in order to avoid adverse health impacts during heatwaves. The content of specific behavioural and medical advice varies across public-health response plans and cultures (WHO, 2011). Passive dissemination of advice may not be sufficient to reach those people most at risk and active identification and care of vulnerable people should be an integral part of any public-health response plan.

5.4 **COMMUNITY OF PRACTICE**

In order to establish an effective HHAP for dealing with warnings, especially for mitigating the effects of extreme weather events such as heatwaves, NMHSs with which HHWSs are usually associated, should work closely with governmental authorities at policy- and decision-making levels. This is important as it affects the allocation of resources by any government responding to the possible effects of expected high-impact weather. Despite efforts in this direction, work still needs to be done before this is achieved on a wide scale. Developing communities of practice is a way to integrate the meteorological community and user communities at national, regional and local levels to work together to remove the gaps between the provision, understanding and use of information. For example, the conceptual framework put together by the US Environment Protection Agency (EPA) for an "Air Quality and Health Community of Practice", comprising the weather-forecasting community, the atmospheric observation community, the hazard-alerting community, public-health officials and local and regional air-quality managers (Figure 6) could well be applied in the case of the development of a heat–health community of practice approach to heat-risk management.

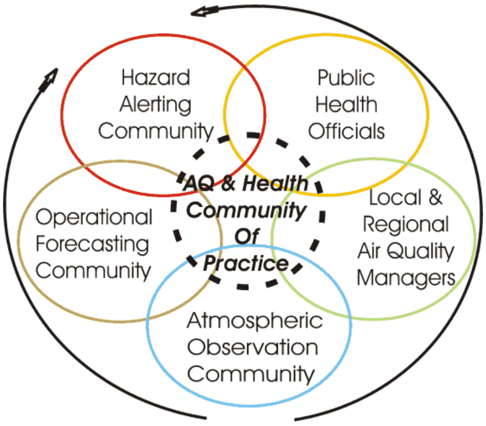

Figure 6. Example of an "Air Quality and Health Community of Practice" structure

Source: Gary Foley, EPA, USA

5.5 PUBLIC EDUCATION AND OUTREACH

Public education and outreach programmes are a critical part of a wider HHAP. They aim to strengthen the links between NMHSs and users of their products and services so that individuals, communities and organizations can make effective use of them. This applies equally to warnings and services associated with an HHWS. While public education and outreach programmes associated with heat should be developed, together with partners such as public-health and educational authorities, emergency management agencies and the media, NMHSs can develop education and outreach programmes specific to the weather and climate dimensions of an HHWS. In this regard, it is worth drawing a distinction between public education and outreach programmes and campaigns as follows:

- Public education refers to products and services associated with learning about weather, climate and water, specifically heat (and cold), primarily within the formal education system;
- Outreach refers to products or services about weather, climate, water and heat that involve short-term contact with members of the public and other users of the services of the NMHS with the intention of providing information and raising awareness and interest.

5.5.1 Critical factors

The following are critical success factors for establishing a public education and outreach programme, whether it is focused on the weather and climate elements or the health effects of heat:

- Understanding the needs of the target audience through a clear understanding of their behaviour and attitudes;
- Establishing an implementation plan based on clearly defined needs, goals, objectives and target audience;
- Involving the target audience in the planning, implementation and governance of the programme;
- Using the right people – fully committed and with the appropriate range of knowledge and skills;
- Making material widely available, using hard copy but also modern technology distribution;
- Ensuring high-level support from key decision-makers and management;
- Ensuring adequate funding and realistic consideration for sustainability and continuity of activities;

- Coordinating initiatives to build upon or create synergies with existing initiatives;
- Learning from successful initiatives and examples of public education and outreach programmes;
- Ensuring evaluation and feedback to help improve the public education and outreach programme.

5.5.2 **Target audience**

A target audience is a group of people whose behaviour or attitudes the public education and outreach programme is attempting to change. In this case, the target audience needs to be divided in such a way that the people in each segment have essentially the same characteristics. When considering the target audience, four groupings are commonly used: geographical location, demographic characteristics, occupation, and behaviour pattern. The following are the various audiences that might be targeted by a public education and outreach programme addressing heat–health services:

- Health and social practitioners;
- Schools and other academic institutions;
- General public;
- Particularly vulnerable sectors of society;
- People involved in recreational or economic activities;
- Media;
- Hazards community; and
- Governmental authorities.

To date, few studies have specifically focused on the public response to heat warnings but those that have been conducted have revealed a range of factors that may determine the public's perception of heat as a hazard and their subsequent response to warnings (Kalkstein and Sheridan, 2007; Sheridan, 2007). Research on the evaluation of the effectiveness and use of the UV Index is relevant to understanding perception of heat risk (Borner et al., 2010; Carter and Donavon, 2007; Dixon and Hill, 2007; Morris et al., 2011).

Having identified the target audience, it is worth obtaining basic information that will help to provide a picture of the target audience and the community in which it resides:

- Why do people in a target audience behave as they do and what might make them change?
- What are the cultural and ethnic characteristics of the audience?
- What is important to the target audience?
- Does the audience believe there is a problem that needs addressing?
- What is the knowledge base of the audience?
- How does the audience receive and share information?
- Who are the opinion leaders and information disseminators in the audience?

A key component for the success of any public education and outreach programme is to work in partnership with others. Agencies such as education ministries, universities, training institutions, professional bodies and trade associations can make a valuable contribution to ensuring a programme is relevant and has the desired impact on the target audience. Educating the media is one way to educate the public. The media will, however, tend to focus on the impacts of a hazard and on the warning and will pay less attention to the need to understand what a warning can and cannot do for society. Cooperative programmes between the media and the NMHSs can help improve public education.

On the social side, it should be remembered that several generations that coexist within society will have different histories of exposure to heat hazards. It is important to remind the public constantly about hazards and their potential impacts.

5.6 **SUMMARY**

Communication links the biometerological and weather-forecasting science components of an HHWS with the societal risk reduction components of an HHAP. A well-honed communication plan is therefore crucial for the success of an HHWS, especially in terms of how weather-forecast-based heat warnings are translated into action. It is imperative that the risk associated with an impending period of anomalous heat is communicated precisely and adjusted according to the target group. Consequently, bespoke messages about a forthcoming extreme heat event, which may be action-threshold specific (health authority, emergency service, media, community action group) composed of clear, unambiguous language, are an essential element of any HHWS. Such messages need to be developed by NMHSs. The same communication principles extend to the communication and outreach elements associated with heat-intervention strategies which are part of a wider HHAP and discussed in the next chapter. Lastly, understanding the factors that influence human response to warnings – and therefore the effectiveness of an HHWS – can inform communication and education strategies.

CHAPTER 6
INTERVENTION STRATEGIES

Key messages

- Intervention strategies refer to actions taken to reduce the health risks associated with extreme heat events; they contribute towards building resilience.

- Intervention strategies can be applied at the individual to community levels and developed for specific target groups.

- WHO, the US Centers for Disease Control and Prevention (CDC) and Public Health England (PHE) have all developed action plans to be taken during periods of extreme heat.

- Although often focused on a heat event, intervention strategies also extend to the longer timescales of urban design and planning such that the way in which buildings and towns are designed and planned can have a marked impact on managing heat exposure.

This chapter outlines a range of intervention strategies that can be implemented in order to reduce the health risks associated with heat-related events and help build resilience at the individual to community levels. The strategies presented in this chapter are based on "developed-country" experiences, mainly due to lack of documented information on formally instituted HHAPs and intervention actions emanating from developing countries. That said, some aspects of the developed-country strategies are also relevant to developing countries, given the universal nature of the generic impacts of heatwaves on human health.

6.1 HEAT INTERVENTION

The intervention measures instituted by the community and the actions taken by individuals when heat warnings are issued by an HHWS determine the extent of a heatwave's impact. These measures are highly variable from one locale to the next and depend on available resources, the political structure and the awareness that heat is a major health problem. The basic goals of intervention strategies during a heatwave are to help individuals:

- Maintain their core body temperature within a healthy range through appropriate changes in behaviour and activities;

- Recognize, in themselves and in others, the signs and symptoms of heat stress; and

- Know what actions to take to reduce heat stress.

Interventions may be passively communicated through mass media (see Chapter 5) or have active elements, such as warning providers of health or welfare services or transporting individuals at risk to cooling centres (Kovats and Ebi, 2006). The interventions implemented depend on the local context, including cultural practices, human and financial resources and other factors. As discussed in Chapter 5, stakeholders need to be involved in the design of intervention strategies to incorporate local knowledge of effective measures to reduce heat stress.

Most publications on preventing heat-related illness are written from the perspective of temperate, high-income countries. People in tropical countries have acclimatized to their warmer temperatures through clothing, housing design and cultural habits (siestas during the heat of the day, for instance). Population growth, development and globalization have changed clothing, behaviour and housing construction and created large urban slums, thus increasing vulnerability to heatwaves in regions that had been considered relatively heat-tolerant. Further, increases in global mean surface temperature are resulting in regions and communities reporting temperatures that are close to the temperature limits to which humans can physiologically adapt: even tropical countries may experience heatwaves.

Interventions can be categorized by individual- and community-level responses (including responses by employers). The timing of which interventions to implement should be tied to the levels of warning used in the HHWS, with educational messages provided early on.

6.2 INDIVIDUAL-LEVEL RESPONSES

One goal of an HHAP is to build the capacity of individuals and communities to self-manage their responses through effective and timely strategies. Many of these strategies are implemented following the issuance of a warning from an HHWS. Examples of comprehensive advice for individual actions following an HHWS warning are provided in Boxes 1 and 2 adapted from PHE (2013) and CDC (2012) respectively, on preventing heat-related illnesses. Beyond this population-level advice, both PHE and CDC offer specific advice for vulnerable groups or sectors. For example, PHE provides specific advice for care-home managers and staff and health- and social-care professionals (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/201039/Heatwave-Main_Plan-2013.pdf). Examples of target groups for which CDCs provide tailored advice include people aged 65 and older, babies and children, people with chronic medical conditions, low-income groups, outdoor workers and athletes (http://www.bt.cdc.gov/disasters/extremeheat/specificgroups.asp). Similarly, WHO (2011) has provided detailed information on specific responses to heat for various target groups, plus heat-related medical advice and treatment practices for medical professionals. WHO also extends its advice to urban designers and town planners in an attempt to raise awareness that long-term intervention strategies to do with the nature of the built environment can also assist with managing the heat–health problem. Box 3 provides a summary of the main topics addressed in this WHO publication.

Electric fans

Used appropriately, electric fans can help reduce heat stress but, when used inappropriately, can exacerbate heat stress. Fans do not actually cool the air. As long as the air temperature is less than an individual's skin temperature, moving air can decrease heat stress by increasing the exchange of heat between the skin surface and the surrounding air and by increasing the rate of evaporation from the skin (EPA, 2006). If the dry-bulb temperature is higher than 35ºC, the hot air passing over the skin can make an individual hotter. When the weather is very hot and dry, using a fan alone when body core temperatures exceed 38ºC actually increases heat stress, because of the limits of conduction and convection. When the temperature is more than 35ºC and the relative humidity is 100 per cent, air movement can make an individual hotter. Thus, fans need to be used with caution and under specific conditions. Generally, the use of fans should be discouraged unless they are bringing in significantly cooler air. Gupta et al. (2012) have provided a review of the use of fans as a heat-intervention measure and concluded that systematic research is required to establish, beyond the anecdotal level, the effectiveness of these devices for reducing the health effects of heat.

6.3 COMMUNITY-LEVEL RESPONSES

Community involvement is critical for the timely dissemination of information and for ensuring the health and safety of particularly vulnerable individuals. This can start with educational campaigns before the heatwave season begins. Where medical care is generally available, a coordinated response can be developed across ambulance and emergency services, hospitals and other organizations providing care. The specific organizations to be included will depend on the medical care infrastructure. In the USA, for example, fire departments are often called out when there is a medical emergency.

Box 1. Public Health England: advice on preventing heat-related illnesses

Stay out of the heat: keep out of the sun between 11.00 a.m. and 3.00 p.m. If you have to go out in the heat, walk in the shade, apply sunscreen and wear a hat and light scarf; avoid extreme physical exertion and wear light, loose-fitting cotton clothes.

Cool yourself down: have plenty of cold drinks, and avoid excess alcohol, caffeine and hot drinks; eat cold foods, particularly salads and fruit with a high water content; take a cool shower, bath or body wash; sprinkle water over skin or clothing or keep a damp cloth on the back of your neck.

Keep your environment cool: keeping your living area cool is especially important for infants, the elderly or those with chronic health conditions or who can't look after themselves; place a thermometer in your main living-room and bedroom to keep a check on the temperature. Keep windows that are exposed to the sun closed during the day and open at night when the temperature has dropped. Close curtains that receive morning or afternoon sun. Care should be taken with metal blinds and dark curtains, as these can absorb heat – consider replacing them or inserting reflective material between them and the window space; turn off non-essential lights and electrical equipment – they generate heat. Keep indoor plants and bowls of water in the house as evaporation helps cool the air. If possible, move into a cooler room, especially for sleeping; electric fans may provide some relief, if temperatures are below 35°C*.

Longer term: consider putting up external shading outside windows; use pale, reflective external paints; have your loft and cavity walls insulated – this keeps the heat in when it is cold and out when it is hot; grow trees and leafy plants near windows to act as natural air-conditioners

Look out for others: keep an eye on isolated, elderly, ill or very young people and make sure they are able to keep cool; ensure that babies, children or elderly people are not left alone in stationary cars; check on elderly or sick neighbours, family or friends every day during a heatwave; be alert and call a doctor or social services if someone is unwell or further help is needed.

If you have a health problem: store medicines below 25°C or in the refrigerator (read the storage instructions on the packaging); seek medical advice if you are suffering from a chronic medical condition or taking multiple medicaments.

If you or others feel unwell: try to get help if you feel dizzy, weak, anxious or have intense thirst and headache; move to a cool place as soon as possible and measure your body temperature; drink some water or fruit juice to rehydrate; rest immediately in a cool place if you have painful muscular spasms (particularly in the legs, arms or abdomen – this occurs in many cases after sustained exercise during very hot weather) and drink oral rehydration solutions containing electrolytes. Medical attention is needed if heat cramps last more than one hour; consult your doctor if you feel unusual symptoms or if symptoms persist.

* NOTE: At temperatures above 35°C, fans may not prevent heat-related illness and can cause excess dehydration. The advice is to place the fan at a certain distance from people, not aiming it directly at the body and to have regular drinks. This is especially important in the case of sick people confined to bed.

Source: adapted from *Heatwave Plan for England 2013* (PHE, 2013):
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/201039/Heatwave-Main_Plan-2013.pdf

An agency should be designated with authority to coordinate response activities and disseminate information. For example, in Victoria, Australia, the state-level Department of Health is the lead agency, which issues alerts to state and Commonwealth government departments, departmental programme areas, hospitals, local government, health and community service providers and peak bodies through its Requests and Incidents Emergency Management System (Victoria Government, 2011). In England, responsibility lies with PHE, which is an executive agency of the Department of Health.

Notwithstanding which particular agency is responsible for actioning an HHAP, public officials should, at least:

- Inform the public of the anticipated heatwave and how long it is forecast to last;
- Communicate clear messages of the dangers of heatwaves, emphasizing that health protection is the first priority. Where possible, postpone outdoor or sporting activities during the heat of the day, including at schools. Work with utilities to prevent suspensions of water and electricity service;

- Inform care-givers and those responsible for particularly vulnerable populations of the risks and appropriate responses. Additional emergency medical personnel may be assigned to address any increase in demand for services. Cooling centres can be opened to provide relief and transportation thereto can be provided for the most vulnerable;

- Provide access to additional sources of information, such as media broadcasts, toll-free numbers, websites and hotlines to report concerns about individuals who may be at risk; and

In preparation for a heatwave, public agencies, health- and social-care providers and employers can assess which individuals are at particular risk and identify what extra help they might need. Elderly adults living alone are likely to need at least daily contact, whether with care workers or volunteers. People with mobility or mental health problems, who are on certain types of medication or living in accommodation that is hard to keep cool, will probably need extra care and support.

As an example of the type of community-level actions employed, Box 4 provides a description of the interventions used in the Philadelphia HHWS, one of the earliest systems to be developed (Kalkstein et al., 1996(b)), while Tables 7 and 8 compare the intervention activities of Philadelphia and Toronto and those applied in the USA and Europe, respectively. From a consideration of the material in Box 3 and Tables 6 and 7, it is clear that coordination between various stakeholders is important, along with outreach to vulnerable populations, such as the homeless. In some cases, a list of high-risk individuals has been developed. If resources are restricted, some communities have identified the areas where most of the vulnerable people live. A number of utilities suspend electricity disconnections during a heatwave, thus providing necessary utility service to non-paying customers during the worst of the heatwave. The level of implementation of some generic intervention strategies appears to vary between major geographical regions, reflecting a contrast in social, economic and possibly cultural circumstances.

While many of the examples provided in this chapter are for large cities, which often have significant resources at their disposal to implement comprehensive and sometimes quite sophisticated intervention measures, small communities are often the norm in many parts of the world. Such communities may possess less financial and human capacity for implementing the full range of possible responses to a heat event and their approach to extreme events will necessarily be different. Box 5 provides an example of how a small rural community in Manitoba (Canada) reduces impacts on health from extreme heat.

6.4 **OUTDOOR WORKERS**

Outdoor workers are the focus here as they are often neglected in discussions about the health effects of heat, although this situation is changing as the effects of heat on worker health, productivity and justice in the workplace are being recognized (Dash and Kjellstrom, 2011; Hanna et al., 2011; Kjellstrom et al., 2013; Kjellstrom and Crowe, 2011).

The International Labour Organization and others have established standards for occupational heat exposure. The basis of the regulations is to maintain core body temperature below 38ºC. Because core body temperature varies with the level of physical activity, recommended exposure levels are often categorized by workload, as shown in Box 6.

According to the Occupational Safety and Health Administration (OSHA) of the *US Department of Labour Technical Manual*, these threshold limit values (TLV) are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C. They are also based on the assumption that *WBGT* of the resting place is the same or very close to that of the workplace. Where *WBGT* of the work area is different from that of the rest area, a time-weighted average should be used.

TLV in Box 6 apply to physically fit and acclimatized individuals wearing light, summer clothing. If heavier clothing that impedes sweat or has a higher insulation value is required, the permissible heat-exposure TLV in Table 6 above must be reduced.

Box 2. US Centers for Disease Control and Prevention: tips for preventing heat-related illness

- Drink more fluids (non-alcoholic), regardless of your activity level. Don't wait until you're thirsty to drink. Warning: If your doctor generally limits the amount of fluid you drink or has you on water pills, ask him how much you should drink while the weather is hot.
- Don't drink liquids that contain alcohol or large amounts of sugar – these actually cause you to lose more body fluid. Avoid very cold drinks, because they can cause stomach cramps.
- Stay indoors and, if at all possible, stay in an air-conditioned place. If your home does not have air-conditioning, go to the shopping mall or public library – even a few hours spent in an air-conditioned place can help your body stay cooler when you go back into the heat. Call your local health department to see if there are any heat-relief shelters in your area.
- Electric fans may provide comfort, but when the temperature is between 35°C and 38°C (95°F and 99°F) fans will not prevent heat-related illness. Taking a cool shower or bath, or moving to an air-conditioned place is a much better way to cool off.
- Wear lightweight, light-coloured, loose-fitting clothing.
- Never leave anyone in a closed, parked vehicle.
- Although any one at any time can suffer from heat-related illness, some people are at greater risk than others. Check regularly on:
  - Babies and young children;
  - People aged 65 or older;
  - People who have a mental illness;
  - Those who are physically ill, especially with heart disease or high blood pressure.
- Visit adults at risk at least twice a day and watch them closely for signs of heat exhaustion or heatstroke. Babies and young children, of course, need much more frequent watching.

If you must be out in the heat:

- Limit your outdoor activity to morning and evening hours.
- Cut down on exercise. If you must exercise, drink two to four glasses of cool, non-alcoholic fluids each hour. A sports beverage can replace the salt and minerals you lose in sweat. Warning: if you are on a low-salt diet, talk with your doctor before drinking a sports beverage. Remember the warning in the first tip above.
- Try to rest often in shady areas.
- Protect yourself from the sun by wearing a wide-brimmed hat (also keeps you cooler) and sunglasses and by putting on sunscreen protection factor of 15 or higher (the most effective products carry "broad spectrum" or "UVA/UVB protection" on their labels).

Source: adapted from Health Studies Branch, National Center for Environmental Health, Center for Disease Control and Prevention: http://emergency.cdc.gov/disasters/extremeheat/heattips.asp

Most heat stress in outdoor workers can be prevented by:

- Engineering controls, such as general ventilation, evaporative cooling and spot cooling;
- Changing work practices, such as providing plenty of drinking water;
- Scheduling heavy work during the cooler parts of the day or reducing the physical demands during the hottest part of the day;
- Alternate work and rest periods, with rest periods in a cool area;
- Wearing appropriate clothing; and
- Educating employees about the hazards of heat stress.

Tips from OSHA on reducing heat stress in employees (OSHA, 1999), are provided in Box 7 and are similar to the advice provided to the general public.

Box 3. Topics covered in *Public Health Advice on Preventing Health Effects of Heat: New and Updated Information for Different Audiences* (WHO, 2011)

- Information for the general public during heatwaves
- For health authorities, medical professionals and care providers: risk factors for heat illness and mortality
- For medical professionals and care-providers: health conditions that create high risk of health effects from heat
- For medical professionals: adverse effects of medication during hot weather
- For medical professionals: considerations regarding drinking advice during hot weather and heatwaves
- Information for general practitioners
- Information for retirement- and care-home managers
- For medical professionals: mild and moderate heat illnesses and their management
- For medical professionals: management of life-threatening heatstroke
- For the general public and care-home managers: reducing indoor temperatures during hot weather
- For health authorities: information on protecting health from vegetation fires during heatwaves
- For the public: information on protecting health from vegetation fires during heatwaves
- For health authorities, care-home managers and employers: standards for occupational safety during heatwaves
- For health authorities and city planners: interventions in the built environment for the protection of health from effects of heat
- For health authorities: communicating “heat”

Source: adapted from http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Climate-change/publications/2011/public-health-advice-on-preventing-health-effects-of-heat.-new-and-updated-information-for-different-audiences

Box 4. Philadelphia Hot Weather–Health Watch/Warning System

The city of Philadelphia and other agencies and organizations institute a series of intervention activities when a heatwave warning is issued. Television and radio stations and newspapers are asked to publicize oppressive weather conditions, along with information on how to avoid heat-related illnesses. In addition, these media announcements encourage friends, relatives, neighbours and other volunteers (“buddies”) to make daily visits to elderly persons during the hot weather. Buddies are asked to ensure that the most susceptible individuals have sufficient fluids, proper ventilation and other amenities to cope with the weather. A “heatline” is operated in conjunction with the Philadelphia Corporation for the Ageing to provide information and counselling to the general public on the avoidance of heat stress. The heatline telephone number is publicized by the media and by a large display seen over much of the centre of Philadelphia. When a warning is issued, the Department of Public Health contacts nursing homes and other facilities boarding persons requiring extra care to inform them of the high-risk heat situation and to offer advice for their protection. The local utility company and water department halt service suspensions during warning periods. The Fire Department Emergency Medical Service increases staffing during warnings in anticipation of increased demand. The agency for homeless services activates increased daytime outreach activities to assist those on the streets. Seniors’ centres extend their hours of operation of air-conditioned facilities during warning periods.

Box 5. How a small rural community in Manitoba (Canada) reduces impacts on health from extreme heat.

Developing a Heat Alert Response System (HARS) in the Assiniboine Regional Health Authority (ARHA), a rural community in Manitoba, required that health officials addressed challenges common to smaller communities and utilized existing strengths. Establishing a temperature-mortality relationship was not feasible due to the large geographic area, low population density and limited number of deaths during extreme heat events. Despite this, mortality curves of other neighbouring communities including Winnipeg and Brandon and historical temperature data for the ARHA provided sufficient evidence to demonstrate heat–health risks and support development of an HARS. With support from the provincial and regional Medical Officer of Health, multiple partners such as Meals on Wheels, Disaster and Emergency Preparedness officials, aboriginal health regional officials, municipal government officials (Mayor, Chief Administrative Officer, local Emergency Management Office), service-providers for seniors, and Manitoba Housing, were engaged to help with this task.

Development of the ARHA HARS and prioritization of community-response measures was informed by an assessment of vulnerability through consultation with community groups. Findings revealed that, during the heat season, ARHA experienced an influx of transient visitors (golfers, campers, children attending specialty camps) and efforts were needed to protect these individuals, as well as permanent residents, from extreme heat events. Stakeholder consultations also revealed challenges with providing cooling options because of a limited number of easily accessible air-conditioned buildings. In addition, issuing timely alerts was found to be difficult because of weekly media deadlines and limited local media coverage. Response measures were therefore developed to specifically address these challenges. They focus on:

- Integrating HARS into the ARHA Disaster Emergency Response Plan to ensure a robust and coordinated response;
- Adjusting other municipal plans to include heat;
- Ensuring that residents of long-term care facilities have access to air-conditioning in common rooms;
- Establishing an alternative meal plan (cold plates) during alerts in long-term care facilities;
- Implementing alternative work hours, whereby staff work evenings or nights to avoid intense heat during the day-time,
- Working collaboratively with Manitoba Health to issue heat alerts and warnings to residents, schools, daycare centres, recreational groups, volunteer support groups, sporting events and transient populations (campers, for example);
- Providing notifications to businesses using refrigerated products so that they can activate business continuity plans in case of a heat emergency;
- Contacting municipal department heads to encourage appropriate preparations (fill fuel tanks, check emergency response equipment such as fans, generators, back-up communications capability);
- Notifying transportation service providers of the potential need to transfer people to and from cooling facilities;
- Putting volunteers on stand-by to assist at cooling facilities and with drinking-water distribution.

Source: adapted from Peter Berry, Climate Change and Health Office, Health Canada

Table 6. Summary response and intervention elements in Philadelphia and Toronto

Programme elements	*Philadelphia*	*Toronto*
Prediction		
Ensure access to weather forecasts capable of predicting heatwave conditions 1–5 days in advance.	✓	✓
Risk assessment		
Coordinate transfer and evaluation of weather forecasts by heatwave programme personnel.	✓	✓
Develop quantitative estimates of the heatwave's potential health impacts.	✓	✓
Use broad criteria to identify heat-attributable deaths.	✓	✓
Develop information on high-risk individuals.	✓	
Develop an accessible record on facilities and locations with concentrations of high-risk individuals.	✓	✓
Notification and response		
Coordinate public broadcasts of information about the anticipated timing, severity and duration of heatwave conditions, as well as availability and hours of any public cooling centres.	✓	✓
Coordinate public distribution and broadcast tips on how to stay cool during a heatwave and of heat-exposure symptoms.	✓	✓
Operate phone lines that provide advice on staying cool and recognizing symptoms of excessive heat exposure or that can be used to report heat-related health concerns.	✓	✓
Designate public buildings or specific private buildings with air-conditioning as public cooling shelters and provide transportation.	✓	✓
Extend hours of operation of community centres with air-conditioning.	✓	
Arrange for extra staffing of emergency support services.	✓	
Directly contact and evaluate the environmental conditions and health status of known high-risk individuals and locations likely to have concentrations of these individuals.	✓	✓
Increase outreach efforts to the homeless and establish provisions for their protective removal to cooling shelters.	✓	✓
Suspend utility shut-offs.	✓	✓
Reschedule public events to avoid large outdoor gatherings when possible.	✓	
Mitigation		
Develop and promote actions to reduce effects of urban heat islands.	Not evaluated	

Source: adapted from EPA, 2006

Box 6. Recommended threshold limit values for heat exposures

Permissible heat exposure threshold limit workload* values

Work/rest regimen	*Light*	*Moderate*	*Heavy*
Continuous work	30.0°C	26.7°C	25.0°C
75% work, 25% rest, each hour	30.6°C	28.0°C	25.9°C
50% work, 50% rest, each hour	31.4°C	29.4°C	27.9°C
25% work, 75% rest, each hour	32.2°C	31.1°C	30.0°C

* Values are in °C, wet-bulb globe temperature.

Source: adapted from OSHA (1999), Chapter IV

Table 7. Public-health measures in USA and European HHWSs

Measures, strategy	*Level of implementation**	*Comments*
Media announcements (radio, television)	+++	Provide general advice on heat stress avoidance to general public.
Bulletin or web page	+++	May be restricted access to relevant professionals or accessible by everybody.
Leaflet	++	General advice and advice for nursing-home managers: often distributed at beginning of the summer via health centres, and places where vulnerable people may be.
Telephone helpline	++	Either a dedicated telephone service is opened (Heatline in Portugal) or people are encouraged to phone a pre-existing general health advice line (NHS Direct in the United Kingdom).
Opening of cooling centres	++	There is some evidence that cooling centres are not used by high-risk individuals but by low-risk individuals.
Alert to hospital emergency rooms, ambulance services	+	Used to improve operational efficiency (need to deploy extra staff): needs to be based on local information and carefully evaluated.
Home outreach visits to vulnerable persons	+	Important but usually expensive: use pre-existing networks of volunteers (buddy system in Philadelphia) or professionals (social workers). Requires a registry of vulnerable people.
Evacuation of vulnerable persons from their homes to cooling centres	+	Using a registry of vulnerable people who are visited at home and evacuated, if necessary.
Outreach to homeless	+	High-risk group in southern USA (11 homeless people died in heatwave in Phoenix, July 2005).
Electricity companies cease disconnection for non-payment	+++	Utility companies have initiated and financially supported HHWSs in the USA. Most important where population relies heavily on air-conditioning (as is the case in the USA).
Water companies cease disconnection for non-payment	+	
Fan distribution	++	Fans are effective when they circulate cooler air, but not above temperatures ~37ºC.

+ rarely implemented, ++ often implemented, +++ implemented very often

Source: adapted from Kovats and Ebi, 2006

Box 7. Tips on reducing heat stress

- Encourage workers to drink plenty of water – about one cup of cool water every 15 to 20 minutes, even if they are not thirsty – and to avoid alcohol, coffee, tea and caffeinated soft drinks that dehydrate the body.
- Help workers adjust to the heat by assigning a lighter workload and longer rest periods for the first five to seven days of intense heat. This process needs to start all over again when a worker returns from vacation or other absence.
- Encourage workers to wear lightweight, light-coloured, loose-fitting clothing. Workers should change their clothes if they get completely saturated.
- Use general ventilation and spot cooling at points of high heat production. Good airflow increases evaporation and cooling of the skin.
- Train first-aid workers to recognize and treat the signs of heat stress and ensure that all workers know who has been trained to provide aid. Train supervisors to detect early signs of heat-related illness and permit workers to interrupt their work if they become extremely uncomfortable.
- Consider a worker's physical condition when determining fitness to work in hot environments. Obesity, lack of conditioning, pregnancy and inadequate rest can increase susceptibility to heat stress.
- Alternate work and rest periods, with rest periods in a cooler area. Shorter, more frequent work-rest cycles are best. Schedule heavy work for cooler times of the day and use appropriate protective clothing.
- Monitor temperatures, humidity, and workers' responses to heat at least hourly.

Source: adapted from OSHA (1999)

6.5 SUMMARY

The interventions outlined in this chapter have been presented as actions that fall into a spectrum of activities that can be implemented from the pre- to post-event continuum. Clearly, there is a wide range of interventions that can be applied in the reduction of the health risk arising from severe heat events. It is the local context, however, including human and financial resources, cultural practices and other factors, that will determine which interventions are most likely to be effective, and how the information would best be communicated.

CHAPTER 7

EVALUATION OF HEALTH WARNINGS AND HEALTH-PROTECTION MEASURES

Key messages

- Evaluation of an HHWS is important for determining whether it is meeting its aims and objectives.

- Evaluations can be either process- or outcome-focused. Process evaluations assess what goes on during a heat event such as the development of a warning or the implementation of an intervention, whereas outcome evaluations assess the results, impact or outcomes of a warning or intervention such as whether lives are saved or admissions to hospital are prevented.

- Notwithstanding the type of evaluation undertaken (process or outcome), key performance criteria for evaluating an HHWS include simplicity, acceptability, timeliness, sensitivity and specificity.

This chapter focuses on the evaluation of an HHWS or alert system component of an HHAP and not on the evaluation of other parts of an HHAP or policy (such as housing or treatment). Some of the general principles of evaluating health interventions and common methods used are also discussed. At the end of the chapter, some general qualitative criteria are proposed against which an HHWS can be assessed.

7.1 WHAT IS EVALUATION?

Evaluation is the process of judging the worth or value of something (Wimbush and Watson, 2000). In general, there are two types, namely process and outcome evaluations (Table 8). An example of an outcome evaluation is when a public-health intervention is evaluated, based on estimates of the lives saved (premature deaths avoided) and other criteria such as acceptability or reduction of health inequalities. For a process evaluation, the emphasis is placed on the “working parts” of a system that lead to the initiation of an intervention.

Evaluation type aside, evaluation, in general, should aim to:

- Ensure that the intended outcomes of the HHWS are benefitting the health of the target population (effectiveness);

- Determine whether the HHWS is cost-effective (efficiency);

- Establish whether the HHWS is acceptable to the target population (humanity).

The key stages of an evaluation are outlined in Box 8.

The agency responsible for the development and delivery of an HHWS can have different reasons for undertaking an evaluation, which need to be addressed when defining its objectives. For example, a policymaker may be most concerned with cost-effectiveness of the system; health practitioners may be most concerned that people and organizations are working together effectively; and community organizations will want to know that the warnings are reaching the intended vulnerable individuals.

It is important to involve all stakeholders while developing and implementing the warning systems. The stakeholders’ perspective will also help define the aims and objectives of any HHWS evaluation. It is also important to consider evaluation and monitoring when the HHWS is set up so that the appropriate information can be collected. It is often difficult to do this retrospectively.

Table 8. Characteristics of outcome and process evaluations

	Outcome evaluation	*Process evaluation*
Objective	To assess the results/impact/ outcomes of a programme/intervention	To assess what goes on during a programme/ intervention
Research questions	How many lives were saved/hospital admissions avoided by intervention/programme? What is the cost-effectiveness of the intervention?	What was the quality of programme delivery? Did the warnings reach health- and social-care staff and the intended target group(s) in the community? How were the warnings received? What contextual factors are important in facilitating or hindering the issue of warnings? What are the possible unintended consequences of the HHWS?
Methods	Quantitative, qualitative Formal assessment of epidemiological data such as daily mortality or of intermediate endpoints such as changes in knowledge or behaviour	Qualitative Data collected by interviews or telephone surveys, face-to-face interviews with key participants and providers Contextual analyses
Limitations	Can be very difficult to identify to obtain data needed at the appropriate resolution. Can be difficult to attribute any health benefit to the HHWS with confidence. Ethical issues for experimental studies; cannot deny part of the population heat–health protection measures unless there is real uncertainty about their effectiveness.	Need to identify key players in advance Small numbers of people Cannot provide definitive answers.

Source: adapted from Kovats and Ebi (2006); Matthies et al. (2009)

Monitoring and review of systems should be set up and continue as long as the HHWS is operational. Monitoring for routinely recorded data about inputs and outputs in the HHWS, including any agreed performance standards, should also take place. It may also be helpful to collect baseline data (about the impact of heatwaves on the population, for example), so that a comparison can be made once the HHWS is operational. Sections 7.2 and 7.3 provide more detail on process- and outcome-based evaluations with the key characteristics and differences summarized in Table 8. A useful insight into some of the issues associated with evaluation is provided by Kovats and Bickler (2012), who note that evaluation of clinical and mortality outcomes is difficult because the outcome measure of heat-related mortality is not directly observed but has to be estimated retrospectively. Moreover, because the determinants of heat-related illness vary with the type of outcome (such as heatstroke) and there may be contrasts in the determinants of

Box 8. Evaluation framework

Evaluation should include the following steps:

1. Clear rationale and overview of the purpose of the evaluation
2. Consideration of methods required to evaluate the system or programme
3. Clear set of aims and objectives of the system and for the evaluation
4. A list of indicators required to measure effectiveness of the system
5. Clarification of how the results of the evaluation will be used and explicit plans to disseminate and act on the results of the findings

Source: Morgan (2006)

heat-related mortality and heat-related hospital admissions, evaluations of interventions are difficult (Kovats and Bickler, 2012). Despite the difficulties associated with HHWS evaluation, there is some evidence in the literature of attempts to establish the worthiness of an HHWS from a range of perspectives (Basil and Cole, 2010; Ebi et al., 2004; Toolo et al., 2013).

7.2 PROCESS EVALUATIONS

Process evaluations concentrate on examining the process of an intervention. In the context of an HHWS, this would be the operation of the warning system at all stages, from the meteorological forecast to issuing alerts to all the relevant institutions. It may also include the activities (interventions) undertaken by health- and social-care professionals that are linked to heatwave alerts. The process evaluation determines if all actors have an understanding of their roles and responsibilities and are able to undertake them during a heatwave. It would also identify any barriers to communication or cooperation that exist within the system. Successful interventions require information- and data-sharing between the relevant health and meteorological agencies. A key barrier in effectively implementing a warning system is often the lack of clear lines of communication between individuals and institutions (see Chapter 5).

A process evaluation of any complex system is recommended. HHWSs often involve quite a complex information cascade and it is important to check that every person who should be doing something understands their role and responsibilities. It may be that key messages only reach senior staff and not the persons (nurses, community workers, etc.) who are actually required to take action.

It is also important to know if the "acute measures" linked to a warning are implemented in a timely and appropriate manner. This is particularly important for heatwave interventions, as they are short-lived and activities should be implemented immediately or within 24 hours.

It is important that the result of any evaluation is disseminated to the participants in the HHWS. Regular process evaluations will build awareness and confidence in the system.

Key process-evaluation questions include:

- What is the frequency and type of heat alerts over a specific period?
- What is the effectiveness of the cascade of information to health and related professionals?
- What actions were taken in response to the various levels of alert and the barriers and facilitators to action?
- What were the outcomes and how did these differ across the "high-risk" or targeted groups?

For persons responsible for actions in the HHWS, key process-evaluation questions include:

- Who possesses awareness and knowledge of the written HHAPs?
- Is the HHWS delivered as widely as intended?
- Is there good communication between agencies?
- Are roles and responsibilities understood?
- What are the barriers (financial, information, etc.) to implementing relevant activities?

A good training exercise is to conduct a desktop simulation exercise where key people role-play as if a heatwave had actually occurred, which helps them to understand their roles and responsibilities.

Evaluations have often found that there is a need to define role and responsibilities, as well as to improve inter-agency cooperation.

7.3 OUTCOME EVALUATIONS

The outcome evaluation is the assessment of the effectiveness of the HHWS in terms of heat deaths avoided. Evaluation of intermediate endpoints (such as changes in behaviour) can also be undertaken.

Such evaluations generally focus on mortality as the outcome measure, although other endpoints could be used (emergency hospital admissions, contact with primary-care services or helplines). Outcomes must be shown to be sensitive to the effects of hot weather on the population in question, which requires complex epidemiological analysis.

The epidemiological methods for quantifying the temperature-mortality relationship are described in the climate and health literature. It is possible to compare this relationship before and after the introduction of an HHWS. Population mortality should become less sensitive to temperature extremes over time but there are difficulties in attributing this change to the HHWS as other factors (widespread air-conditioning, for example) may have also changed over time. Analysis of deaths on hot (heatwave) days with and without warnings during a single summer may also provide some indication of the effectiveness of the HHWS but there are possible ethical issues associated with this approach. A third approach is to compare interventions more formally in different areas. It would be unethical to provide no heat–health protection in a given area but, given the level of uncertainty around effectiveness for specific interventions, it would be appropriate to compare different strategies in different areas within a given city or district and even randomly allocate interventions at the community level.

Evaluating the "trigger" indicators

There are a variety of statistical techniques to test the robustness of the weather–health predictive model, as well as the meteorological forecasts themselves. In all cases, the model should be tested on independent data (years not originally included in the model). The test should not include years when the HHWS is operational, as this could alter the original weather–health relationship.

For HHWSs, which focus on the short range (0–3 days), one precondition for effectiveness is that the indicator used for triggering the warning can be forecast accurately. A skilful forecast of the warning indicator (such as maximum temperature) will minimize the number of false and missed alarms and so the confidence in the HHWS will be high. The forecast error of an NWP model depends on the model itself (model dynamics and physics), the weather situation, the region for which the forecast is made and the parameter that is forecast, as well as the lead-time of the forecast. Air temperature is a surface parameter with relatively high forecast accuracy. The forecast error is higher for dewpoint temperature, wind speed and radiation. With increasing lead-time, the accuracy of the forecast decreases.

It can therefore be expected that the accuracy of heat warnings that depend on air temperature as the trigger meteorological parameter for lead-times up to three days is quite high. Forecasting heat indicators that also require, for example, dewpoint temperature, wind speed and/or radiation as input, have lower forecast accuracy. Heat warnings based on such indicators should therefore not be given with lead-times longer than 48 hours. Procedures for undertaking a performance assessment of the weather prediction component of an HHWS can be found in the WMO publication *Guidelines on Performance Assessment of Public Weather Services* (WMO, 2000).

7.4 PUBLIC WARNINGS AND ADVICE

As outlined in Chapter 5, a communication and public education strategy is an essential part of any warning system. Public-health messages should be disseminated to all age and risk groups to increase awareness of symptoms of heat-related illness. In the USA, the most susceptible individuals are socially isolated, elderly and may have a mental illness or disability that causes cognitive/behavioural problems. An understanding of knowledge, attitudes and perceptions about "thermal behaviour" is needed before the most appropriate messages can be developed and issued.

Qualitative research methods are required to address the effectiveness of methods of communication, as well as the specific message. Focus groups or face-to-face interviews have been used to elicit useful responses. Investigation of the knowledge, attitudes and behaviour of high-risk groups and their carers can focus on questions about their understanding of the risks associated with heatwaves and the needed responses, as well as their experience of actual heatwave measures. It may be that weather perceptions are different in older adults and the very old. As outlined in Chapter 5, this relates to the concept of different "risk signatures".

Some specific research questions relating to the communication of messages and information include:

- How do people currently access and use weather information in their day-to-day lives?
- What are the key differences for different age groups, and men and women?
- How do people value, and how might they use, precise "early warning" information on heatwaves?
- What currently affects their behaviour during a heatwave (financial issues, morbidity that limits movement, etc.)?

If a programme of research on the effectiveness of public warnings and advice is planned as part of any evaluation exercise, it should be borne in mind that many persons at high risk of heatwave-related mortality are less likely to participate in focus groups or interviews, either by phone or in their own homes. Care should therefore be taken in the way study participants are selected to ensure that the sample is not too heavily biased towards low-risk individuals. Ethical approval should be obtained before interviewing people at home, especially vulnerable individuals. Some of the issues and outcomes associated with surveys of public perception and response to heat warnings are outlined in Sheridan (2007).

7.5 CRITERIA FOR EVALUATING A HEAT–HEALTH WARNING SYSTEM

The following criteria are suggested for the evaluation of an HHWS. They can be used for planning, implementing and ongoing evaluation to promote the best use of public resources through development of an effective and efficient HHWS.

Simplicity

The simplicity of a system refers to both its structure and ease of operation. An HHWS should be as simple as possible, while still meeting objectives. Factors to consider include:

- Type of information required to issue a warning;
- Number of people and agencies involved in issuing a warning;
- Time spent maintaining the system;
- Time spent issuing a warning.

Acceptability

The acceptability of a system reflects the willingness of individuals and organizations to participate in it. Factors to consider include:

- Interaction between agencies;
- Participation of agencies other than the one issuing the warning;
- Completeness of response in participating agencies.

Timeliness

Are the warnings timely with respect to the different response activities? Are there any delays in the steps of the HHWS?

Sensitivity

The sensitivity of the warning is the number of times a warning is issued and the forecast meteorological conditions actually occurred. Typically, evaluators are interested in how often a warning was not issued but adverse meteorological conditions actually occurred.

Specificity

The specificity of the forecast (the prediction of heat-attributable mortality) should be estimated, as well as the accuracy of the meteorological forecasts on which they depend, in order to avoid false positive forecasts of heatwave mortality, which will undermine the credibility of the system.

7.6 SUMMARY

HHWSs are implemented at the local level and therefore vary widely in structure, partner agencies and the specific interventions that are deployed during a heatwave or the summer season. Activities related to HHWSs may also change from year to year in response to events and the changing priorities of partner agencies. Heatwaves are rare events and the impact of each one is different. Heat-related deaths are also non-specific and difficult to identify. For all these reasons, HHWSs are extremely difficult to evaluate in terms of outcomes in the formal public-health sense. There are many types of evaluation and it should be acknowledged that different stakeholders may have different requirements for the evaluation of a system. Furthermore, stakeholders should be involved in the evaluation and the objectives and methods of the evaluation should be incorporated into the set-up of HHWSs.

CHAPTER 8

PLANNING FOR HEAT EVENTS AT THE INTRASEASONAL-TO-SEASONAL SCALE

Key messages

- Planning for extreme heat events is an ongoing process not restricted to the “heat season”, that is, the time of the year when extreme heat events or heatwaves are likely.

- The wider plan that embraces all elements for managing the health risks of heat events is generically referred to as an HHAP.

- An HHAP not only embraces an HHWS, but also education and awareness-raising, heat-event preparedness and guidance on heat-avoidance actions and heat-risk governance, a communication plan, a programme of evaluation, a health-surveillance system and advice on longer-term strategies for reducing heat risk.

- Preferably, a lead agency should be identified in the planning for extreme heat events; the governance of heat as a health hazard is therefore an important issue.

- As weather-forecasting and climate-prediction technology develops, planning for a forthcoming heat season will be assisted by the availability of long-lead, probabilistic-based forecasts of periods of extreme heat.

This chapter discusses the pre-season and intraseasonal considerations that might be employed to maximize the benefits of an HHAP and presents information about a number of existing HHAPs. Also discussed is the possibility of using seasonal climate-prediction models and medium-term weather-forecasting models as integral components of an HHWS. The purpose of predicting heat events at these timescales would be to provide health authorities with some advance notice of a heatwave event beyond the typical weather forecast timescale of three to five days or information about how many heat events and their severity are likely in the upcoming “heat season”, that is, the time of year when extreme heat events or heatwaves are likely. This latter advice is analogous to early-season tropical cyclone (hurricane, typhoon) predictions for emergency agencies and malaria early warning systems for public-health services.

8.1 PLANNING FOR THE NEXT HEAT SEASON

Planning for the next heat season should consider not only heatwaves but also a number of risks that are frequent in the heat season. These include an increased risk of food- and waterborne diseases; risks associated with recreational waters; risks related to tourism and seasonal migration; potential water scarcity; and risks to health from excessive sun exposure.

A combination of heat-season and heatwave activities seems useful, particularly in countries where hot weather is expected over several months. This may be increasingly applicable to northern European countries as a result of global climate change.

A precondition for the implementation of an effective HHAP and heatwave prevention is cooperation between institutions as outlined in previous chapters. Planning with the meteorological institutions and health and social services is essential. This includes the establishment of information flows and decisions on responsibilities, which are normally addressed in countries where heat plans exist. In countries where no HHAP exists – although there is a meteorological component of warning in most countries – no decision-making structures might be available. Incorporating an HHAP into national disaster-preparedness planning might be advisable but depends on the country’s requirements. This issue needs to be explored at country level, due to the differences in responsible authorities and administrative structures.

Health-system and social-service delivery planning are essential. Activities include:

- Summer-holiday planning and sufficient coverage of nursing staff in hospitals and nursing homes during that period;
- Contingency plans for well-trained staff to be available during heat-alert periods and emergency situations;
- Curricula for training health professionals in relation to the prevention and treatment of heat–health effects.

Exploring financial incentives and eventual legislation might be needed in some countries. The actual cost of heat prevention depends on the activities foreseen and the organization of the health system and collaborating sectors. Lack of funding and personnel, as well as problems with communication, are the most common barriers to the efficient implementation of heat-prevention activities.

8.2 HEAT–HEALTH ACTION PLANS

A range of HHAPs have been developed, the nature of which depends on the significance of heatwaves relative to other health concerns (Bittner et al., 2013; Lowe et al., 2011). Because HHWSs are nested in wider HHAPs, this section presents some of the imperatives associated with the development of HHAPs and describes the nature of HHAPs for a limited number of locations/regions.

Achieving the implementation of a Heat–Health Action Plan and common features of effective Heat–Health Action Plans

Heatwave–health effects are largely preventable, assuming exposure and sensitivity to heat can be identified, controlled and minimized. While the HHWS forms the alert-system component of a wider HHAP, its effectiveness can be rendered suboptimal if no action is taken in response to the issuance of warnings. Thus, an HHAP which encompasses and directs all preventive measures to be taken to protect the population from the effects of heatwaves is critical.

A number of core elements have been identified that are essential to the efficacy of HHAPs in achieving a reduction in heat-related health impacts. These are outlined in Box 9.

As well as ensuring the presence of key elements, the process to be followed in developing an HHAP needs to be given careful consideration. To this end, WHO has suggested a number of possible steps to be followed in the development of HHAPs. These are listed in Box 10 and build on general guidance for their development as outlined in WHO (2008). As the suggested steps are generic, there will be a need to adapt them to the local situation and general political context. Details related to each of the steps can be found in WHO (2011).

Box 9. Core elements of Heat–Health Action Plans

1. Agreement on a lead body (to coordinate a multi-purpose collaborative mechanism between bodies and institutions and to direct the response if an emergency occurs)
2. Accurate and timely alert systems (HHWS)
3. A heat-related health information plan (about what is communicated, to whom and when)
4. A reduction in indoor heat exposure, including medium- and short-term strategies and advice on how to keep indoor temperatures low during heat episodes
5. Particular care for vulnerable population groups
6. Preparedness of the health- and social-care system (staff training and planning, appropriate health care and the physical environment)
7. Long-term urban planning (to address building design and energy and transport policies that will ultimately reduce heat exposure)
8. Real-time surveillance and evaluation

Source: adapted from WHO, 2008

Box 10. Ten possible steps to developing a Heat–Health Action Plan

1. Set up a national or subnational steering group and technical working group/writing team
2. Evaluate the health vulnerability to heat
3. Draft the heat–health action plan based on the analysis carried out
4. Consult on the first draft
5. Consult on the nearly final draft
6. Secure ministerial approval for pilot-testing the plan
7. Pilot-test the plan at either the regional or national level
8. Evaluate the findings from the pilot test and use the results to improve the plan
9. Define the implementation process at the national level
10. Gain final ministerial approval and implement the plan

Further details available at: http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Climate-change/publications/2011/public-health-advice-on-preventing-health-effects-of-heat.-new-and-updated-information-for-different-audiences

Source: adapted from WHO, 2011

Effective plans have a range of common features, which include:

- An HHWS that has clear activation thresholds. These should set out what levels of action are to be initiated and who is responsible for each one. This includes the establishment of clear and reliable lines of communication. There may be one or more activation thresholds corresponding to either simple “warning or no warning” status or multitiered levels of raised awareness, alerts and warnings. The optimal HHWS should neither miss heatwave events nor give false alarms;

- Effective public-awareness campaigns that operate prior to each season and incorporate clear action statements that are repeated periodically through the season and particularly at the onset of a heatwave event;

- Effective cooperation between the relevant health agencies and providers to ensure that adequate resources are available and health systems are not over-burdened;

- Clear intervention strategies that are understood by participating agencies and a supportive public. Examples might include the participation of neighbours to check on those at risk as a first line of action, followed by the intervention of health practitioners and paramedics at their home or location so that only those with health emergencies are transported to hospital (see Chapter 6 for the range of interventions).

In the following subsections, a brief description of an HHAP for a number of locations is presented in order to illustrate their different features. A useful overview of HHAP typology for Europe is provided in WHO (2008) and Lowe et al. (2011). Bittner et al. (2013) have reviewed the current state of preparedness for heatwaves across Europe by assessing the level of development of country-level HHAPs.

8.2.1.1 *Philadelphia Excessive Heat Plan*

Philadelphia was the first city in the USA to introduce a heat–health watch warning system (referred to as the Philadelphia Hot Weather–Health Watch Warning System (PWWS)) as part of an Excessive Heat Plan in 1997. In this system, local city staff work with the NWS to determine when a heatwave is imminent.

PWWS was prepared by the Managing Director's Office of Emergency Management, in conjunction with key stakeholders and has four operational strategies, namely:

- Education and pre-season preparedness, which focuses on pre-heat season activities put in place to prepare agencies to respond to excessive heat events;

- Public notification and warning, which covers various public notification, alerts and warning procedures for excessive heat events;
- Excessive heat response, which details and coordinates response plans of Philadelphia, non-profit, and private agencies, including access to a "Stay Cool Interactive Map", designed to assist citizens in identifying cool locations;
- Utilities' response that encompasses the roles and responsibilities of utility companies that provide services in Philadelphia during an excessive heat event.

Prior to the development of PWWS, NWS had been issuing heat warnings based on a standard threshold of *HI* (*AT* – see Chapter 3). PWWS introduced the synoptic method (Kalkstein et al., 1996(b)) as described in Chapter 4, involving airmass classification and correlation with mortality to improve the sensitivity of alerting in heatwave conditions.

Following the issue of an alert, the Philadelphia Health Department contacts news organizations with tips on how vulnerable individuals can protect themselves. People who do not have air-conditioning are advised to seek relief from the heat in shopping malls, seniors' centres and other air-conditioned spaces. The system also relies on local "block captains" appointed by the local city council, who are asked to check on elderly neighbours. Other elements include the use of field teams to maintain home visiting, the activation of a telephone-based service whereby nurses assist callers who might experience heat-related health problems, and a city-sponsored outreach effort that encourages the public to visit older friends (see Box 4).

Following its successful operation, similar tailor-made systems are progressively being implemented for the 50–60 cities in the USA with a population of more than 500 000 and a co-located local meteorological office. Ebi et al. (2004) have undertaken an estimation of the benefits and costs of PWWS.

8.2.1.2 **Plan Canicule *of France***

The French *Plan Canicule* (Heatwave Plan) includes an HHWS that is integrated into three activation levels:

- Level 1: seasonal vigilance, continuously activated from 1 June to 31 August, to review operational meteorological and health information;
- Level 2: when the risk of a heatwave has been forecast or a heatwave is underway, specific actions relevant to the heat and health situation are undertaken by the prefectures or regions. These actions are adapted to the relevant *département* (the level of government between the region and the commune), taking into account local meteorological and health information, and include television and radio dissemination of information and media calls for remedial and preventive actions to be undertaken by the public;
- Level 3: During a heatwave that has important health impacts and is prolonged over a large region or when exceptional conditions (drought, electricity blackout) also occur, decisions and actions are undertaken at the level of the first minister.

The plan is centred on five pillars:

1. The establishment of protection measures for people at risk in care facilities and institutions, which include:
    - Regular access to air-conditioned buildings as an effective means to combat heatwave situations and the risk of hyperthermia for elderly people;
    - The installation of at least partial air-conditioning in all care establishments, homes of the elderly, residences and especially units of long-duration care; and
    - The testing of "Code Blue" alarms in aged persons' establishments on the day before, together with staff training in crisis management.

2. Implementing an alert, based on the assessments conducted by Météo-France and the Institute for Public Health Surveillance (InVS). InVS relies primarily on, and monitors, the forecasts received from Météo-France and proposes an alarm alert if the meteorological thresholds – which vary from region to region – are exceeded. Other information, including some of a qualitative nature, is also taken into account, such as other weather conditions, air pollution and social events. Through common briefings, InVS provides Météo-France with health information that could indicate potentially aggravating factors. Moreover, InVS notifies the emergency services, including fire and rescue services (*Service départemental d'incendie et de secours*), emergency medical services (*Service d'aide médicale d'urgence*), and the prefects of the *département* concerned are provided with relevant information through the Operational Inter-ministerial Crisis Management Centre (Centre opérationnel de gestion interministérielle des crises). InVS has the responsibility to inform the ministry in charge of health, which informs the prefects of the *départements* concerned for which an alarm has been issued. In the affected *départements*, the prefect decides on the measures to be adopted within the framework of the heat-management plan;

3. Identifying people at risk in the community, especially isolated individuals, and establishing mechanisms to notify them through local councils and social services in the event of an alert being issued;

4. Solidarity vis-à-vis those at risk and isolated;

5. At the national and local levels, dissemination of information is undertaken, aimed at the general public, health professionals, carers of infirm and elderly people and health establishments. During the summer, the population receives advice on protection from heat in line with the actions associated with Level 1. The weather chart of vigilance issued by Météo-France each day at 6 a.m. and 4 p.m. takes into account the heatwave phenomenon. In the event of an alert, recommendations from the ministry in charge of health are disseminated via radio and television.

Fouillet et al. (2008) evaluated the possible impact of *Plan Canicule* in a comparative analysis of heat-related mortality for heat events in 2003 and 2006 in Paris. They conclude that the lower-than-expected mortality during the 2006 heat event may be interpreted as a decrease in population vulnerability, together with increased awareness of the risks associated with extreme temperatures, implementation of preventive measures and the establishment of a heat-warning system.

8.2.1.3 ***Heatwave Plan for Victoria, Australia***

The Heatwave Plan for Victoria, Australia, adopts slightly different strategies to protect those at risk, in Melbourne and regional Victoria. The Victorian system relies on a combination of public messaging, alerting local councils and working with other organizations such as ambulance services, police and fire services, health services, general practitioners and community and residential care-providers.

Victoria's heatwave actions include:

- Pre-season planning and preparation, including public messaging advising on how to prepare for hot weather and possible power failures, as well as preparations involving ambulance services, local councils and health services and providers;

- Issuing and responding to a heat–health alert, involving notification of the relevant services and providers, together with the release of public-health messages to the broader community via media releases and the Health Department's website;

- In the event that a heatwave becomes an emergency, as the result of power and public transport failures, concurrent bushfires or extreme demand on health services, an emergency management response is initiated with Victoria police being the control agency. Hospitals, residential care facilities for the elderly and Ambulance Victoria also implement their plans and responses;

- After an emergency-level heatwave, services and providers implement recovery arrangements according to a State Emergency Recovery Plan and support affected individuals, families, neighbourhoods and communities in the immediate and longer term. The Victorian Department of Health uses a heat–health surveillance system to track and report on the human-health impact of heatwaves over the summer through the collection of morbidity and mortality data.

The HHWS component of the Heatwave Plan employs a single level of alert. A heat–health alert is issued if the mean of the forecast maximum temperature plus the following night's forecast minimum temperature is expected to exceed 30ºC in the Melbourne area (30ºC also in five forecast districts, 32ºC in three others and 34ºC in Mallee district). These thresholds were determined, based on climate and health relationships with some consideration of acclimatization (Nicholls et al., 2008). The forecast districts are publicly well known as they are the same areas used in public weather forecasts and in defining total fire ban districts on days of heightened wildfire danger. BoM issues seven-day forecasts of maximum and minimum temperatures for over 70 localities across Victoria. Box 11 provides the links for a range of resources related to the development, implementation and evaluation of the Victoria Heatwave Plan.

Box 11. Victoria Government heatwave planning resources

Background on heatwaves:
http://www.health.vic.gov.au/environment/heatwaves.htm

Heatwave plan for Victoria
http://www.health.vic.gov.au/environment/heatwaves-plan.htm

Information on heatwave planning
http://www.health.vic.gov.au/environment/heatwaves-planning.htm

Evaluation of the Victorian Government heatwave framework
http://docs.health.vic.gov.au/docs/doc/Evaluation-of-the-Victorian-Government-heatwave-framework

8.2.1.4 *England Heatwave Plan*

The England Heatwave Plan was developed in response to the August 2003 heatwave event, which resulted in over 500 excess deaths in London over a 10-day period. The core components include a Heat–Health Watch System that operates from 1 June to 15 September, based on forecasts from the United Kingdom Met Office that trigger levels of response from the Department of Health and other bodies.

Advice and information is issued by PHE directly to the public and to health- and social-care professionals, particularly those working with groups at risk, both before a heatwave is forecast and when one is imminent. Identification of individuals most at risk by primary-care teams and social services is also undertaken. These persons have priority for receiving advice on preventive measures and possibly assessment for extra care and support during heatwaves. Involvement of available help from the voluntary sector, families and others to care for those most at risk is encouraged. This is determined locally, based on existing relationships between statutory and voluntary bodies. The use of the media to disseminate advice to people quickly, before and during a heatwave is emphasized. The plan outlines responsibilities of participants at each of the five levels – Long-term planning; Heatwave and summer preparedness programme; Heatwave is forecast – alert and readiness; Heatwave action; and Major incident – emergency response. The threshold temperatures for triggering action vary by region, thus taking into account relative adaptation to heat. Details on the Heatwave Plan for England, including advice on actions for preventing heat-related illness, can be found at: https://www.gov.uk/government/uploads/system/uploads/ attachment_data/file/201039/Heatwave-Main_Plan-2013.pdf

8.2.1.5 *Research projects relevant to Heat–Health Action Plans*

A number of research projects have assisted with the understanding of heat–health relationships and the development of the components of HHAPs across Europe. Because of their importance for advancing the understanding of the association between heat (and cold) and health and the development of policy responses to extreme heat events, a summary of these projects is presented in Box 12.

8.3 GOVERNANCE OF HEAT AS A HAZARD

Responsibility for the issue of heat as a health hazard usually falls primarily with the government department of health, at either the national or local level, depending upon the size of the country and the extent of areas where heatwaves are a problem within a country. If separate initiatives concerning development of heat–health plans have occurred at a local level in several places within a country, then achieving a higher level of national consistency should be a preferred objective. Such coordination might come from either a national health agency, emergency-management authority or perhaps from national bodies that are associated with the various heat–health plans. In some cases, a country's NMHS might assist in coordinating the meteorological data and forecasts required.

At the local level, hospitals, ambulance providers and medical practitioners might be the motivating stakeholders in developing heat–health plans, since the occurrence of heatwaves will impact their workloads. Advance notice of a heatwave will assist in resourcing hospitals and other care providers and will allow for greater preparedness ahead of the event.

NMHSs contribute to the heat–health plans largely through the provision of meteorological data and forecast information that are used in the development and operation of the plans. In the developmental stages of an HHWS, climate data are used in conjunction with mortality data or similar indicators of adverse health impacts to develop thresholds.

Emergency management authorities provide a framework for the management of heat–health plans in relation to other natural and man-made disasters. They may ensure consistency of intervention strategies between responses to different disasters. These authorities might also allocate public (government) funding to support the development and maintenance of HHAPs in conjunction with preparation for other hazards.

8.4 SEASONAL CLIMATE-PREDICTION MODELS AND HEAT–HEALTH WARNING SYSTEMS

HHWSs commonly use forecasts of expected meteorological parameters such as temperature, humidity and wind speed with a time span to give advance warning of up to about five days. Many systems work in the 12–48 hour time frame but have an awareness phase at longer lead-times, where numerical guidance material suggests the possibility of heatwaves with varying confidence. This section discusses the possibility of using longer-period climate modelling – often referred to as seasonal climate prediction – to give greater lead-times of the possible onset of a heatwave event.

Seasonal climate-prediction models

There are a growing number of statistical-empirical and dynamical models for predicting seasonal climate (Barnston et al., 2010; Goddard et al., 2010; Stockdale et al., 2010; Graham et al., 2011) with seasonal climate predictions being produced by a range of organizations (Table 9). Seasonal predictions are used in conjunction with other information to create seasonal climate-outlook products related to, for example, temperature and rainfall over a specified period of time, often one to three months ahead. Outlooks are based on trends in regional sea-surface temperatures, ocean circulation and longer-term patterns in the atmospheric circulation, such as El Niño-Southern

Box 12. Major research projects related to the science and policy of the health effects of extreme climate events, including heat

Climate Change and Adaptation Strategies for Human Health (cCASHh)

The cCASHh project investigated the ways in which climate change affects health by carrying out a combination of impact and adaptation assessments for a selection of climate-related health outcomes, namely heat and cold; extreme weather events, including floods; infectious diseases transmitted by insects and ticks; and infectious diseases transmitted in the water supply or through food (water- and foodborne diseases). cCASHh provided “now and how” strategies for health threats from climate change. The analysis of the health impacts of the European 2002 floods and 2003 heatwave assisted, especially with the design of new policies and the improvement of measures, to address morbidity and mortality due to flooding and heatwaves. cCASHh also noted that, if improvements are not undertaken quickly enough in those risk areas where no recent disasters or emergencies have occurred, then levels of awareness and preparedness will be low. A major conclusion of the cCASHh project was that any comprehensive long-term strategy for minimizing the risks associated with global climate change requires the combination of planned adaptation (now and how) and mitigation. Further international burden-sharing is needed to distribute the costs of adaptation according to the vulnerability of countries to climate change (Menne and Ebi, 2006; WHO, 2005).

Assessment and Prevention of Acute Health Effects and Weather Conditions in Europe (PHEWE)

PHEWE investigated the association between meteorological variables during the warm season and acute health effects (mortality, hospital admissions) in 17 large European cities for the purpose of using understanding of the association between heat and health outcomes to develop preventive strategies. Specific issues investigated included health-related threshold levels of a range of weather variables, form of the weather dose-health response curve, latency time between weather exposure and effect, specific airmasses associated with health effects and the interaction between weather and particulate matter or gaseous air pollutants. Experimental HHWSs were also set up for six of the 17 cities (Michelozzi et al., 2007). A number of results have been published from this project demonstrating clear geographical variations in the weather-dose–health-response relationship and the potential synergistic effects on health of heat and air pollution, for example, Analitis et al. (2008) and Michelozzi et al. (2009).

Improving Public Health Responses to Extreme Weather/Heatwaves (EuroHEAT)

The general aim of the EuroHEAT project was to improve public-health responses to weather extremes and, in particular, to heatwaves. EuroHEAT reviewed the literature and administered a questionnaire to health officials in charge of HHAPs in 2005 in order to establish the nature of existing HHAPs in Europe and to identify models of good practice for national/local preparedness planning. Major findings from the EuroHEAT project were: the adverse health effects of heatwaves are largely preventable; prevention requires a range of actions at different levels from health-system preparedness coordinated with meteorological early warning systems to timely public and medical advice and improvements to housing and urban planning. An outcome of EuroHEAT was the production of guidance for the development and implementation of HHAPs at the national and regional levels in Europe to prevent, act upon and contain heat-related health risks (Matthies and Menne, 2009; WHO, 2008; WHO 2009).

Oscillation and persistent, shorter-term anomalies in the ocean–atmosphere system. Such predictions over timescales of one to three months do not define specific dates for any specific weather event such as heatwaves, but indicate the likelihood of temperature and rainfall varying significantly from normal. Although the skill of seasonal climate models and associated outlooks often varies seasonally and for different regions (Doblas-Reyes et al., 2013), they offer considerable potential for making seasonal-level assessments of the risk of hydrometeorological hazards, including heatwaves.

While many of the climate risk assessments based on seasonal climate prediction products are made at the continental or regional scale, increasingly, with the assistance of statistical or dynamical downscaling, particular hazards or smaller regions can be focused on. Examples of the type of products applicable to the heatwave issue are presented in Figures 7 and 8.

Table 9. Officially designated WMO Global Producing Centres of Long-Range Forecasts; Lead Centres of Long-range Forecasts and other centres providing global seasonal forecasts

Officially designated WMO Global Producing Centres (GPCs)	
GPC	**Web address**
Bureau of Meteorology (BoM), Australia	http://www.bom.gov.au/climate/ahead
China Meteorological Administration (CMA)/Beijing Climate Centre (BCC)	http://bcc.cma.gov.cn/
Climate Prediction Center (CPC), NCEP, NOAA, USA	http://www.cpc.ncep.noaa.gov/
European Centre for Medium-Range Weather Forecasts (ECMWF)	www.ecmwf.int
Japan Meteorological Agency (JMA)/Tokyo Climate Centre (TCC)	http://ds.data.jma.go.jp/gmd/tcc/tcc/index.html
Korea Meteorological Administration (KMA)	http://www.kma.go.kr/
Météo-France	http://www.meteo.fr
Met Office (United Kingdom)	http://www.metoffice.gov.uk/research/seasonal/
Meteorological Service of Canada (MSC)	http://www.weatheroffice.gc.ca/saisons/GPC_Montreal_e.html
South African Weather Services (SAWS)	http://www.weathersa.co.za/
Hydrometeorological Centre of the Russian Federation	http://wmc.meteoinfo.ru/season
Centre for Weather Forecasts and Climate Studies/National Institute for Space Research (CPTEC/INPE), Brazil	http://clima1.cptec.inpe.br/gpc/
Lead Centres of Long-range Forecasts (LCs)	
LC	**Web address**
WMO Lead Centre for Long Range Forecast Multi-Model Ensemble (LC-LRFEMME) jointly coordinated by KMA and NOAA/NCEP	http://www.wmolc.org/
WMO Lead Centre for Standard Verification System of Long Range Forecasts (LC-SVSLRF) jointly coordinated by BoM and MSC	http://www.bom.gov.au/wmo/lrfvs/
Other leading centres providing global seasonal forecasts	
International Research Institute for Climate and Society (IRI), USA	http://portal.iri.columbia.edu/
APEC (Asia-Pacific Economic Cooperation) Climate Centre (APCC), Republic of Korea	http://www.apcc21.org/eng/index.jsp

Source: http://www.wmo.int/pages/prog/wcp/wcasp/clips/producers_forecasts.html)

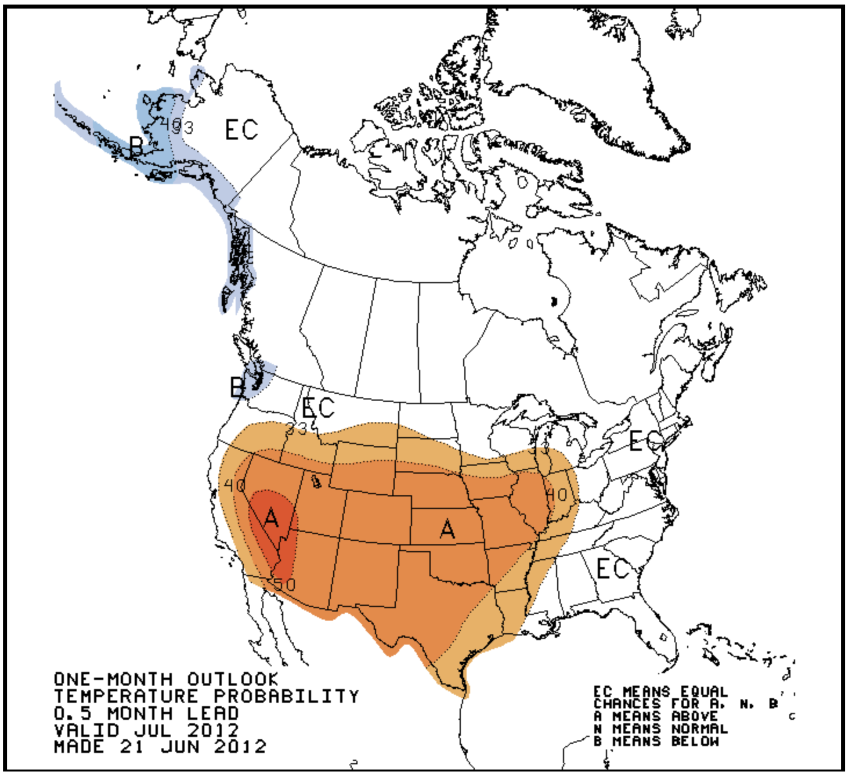

Figure 7. Example of a one-month-ahead outlook of temperature probability: this type of product could be usefully applied to developing guidance as to the likelihood of anomalous temperature conditions developing for a given region.

Source: http://www.cpc.ncep.noaa.gov/products/predictions/30day/, NOAA/NWS/NCEP/CPC

8.5 USING MEDIUM-RANGE TO SEASONAL CLIMATE PRODUCTS WITHIN HEAT–HEALTH WARNING SYSTEMS AND HEAT–HEALTH ACTION PLANS

There is considerable opportunity for agencies and authorities to apply assessments of the likelihood of heatwave occurrence to strategic decision-making related to preparations ahead of a heat season, such as financial, infrastructure and human resource management, and to expand public awareness-raising activities.

It should be noted that the probability of a heatwave event depends on the likely occurrence of both daily maximum and daily minimum temperatures above the long-term mean. While a product that indicates the probability of the maximum temperature being above normal provides some guidance, in some areas – perhaps in drought-affected regions – higher-than-mean maximum temperatures might be associated with below-mean minimum temperatures. Also, the short-term variability of temperature in a particular season might be different from the long-term average.

Consequently, an indication of the likelihood of above-average temperatures might not correspond to an increased likelihood of heatwaves. Notwithstanding this issue, temperature and other output from medium-range to seasonal climate models could be used to calculate a range of health-relevant biometeorological index values, such as those presented in section 3.3 or developed as part of the WMO-CCI ClimPACT Project (WMO, 2013). Availability of index values based on a range of seasonal climate-prediction models (multimodel approach) would facilitate the calculation of index-value probabilities and thus provide valuable information for heatwave-related decision-making.

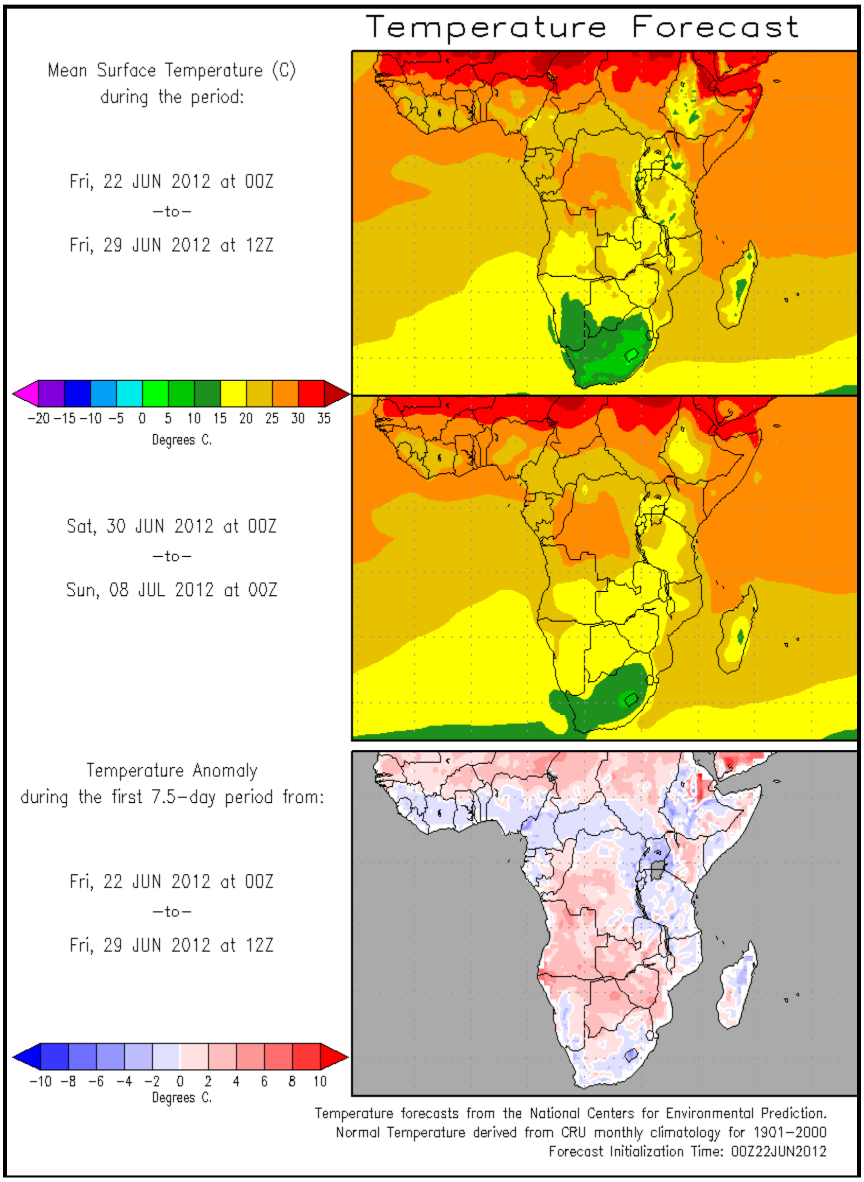

Figure 8. Climate outlooks for temperature over Africa (June 2012 in this example) show the 0–7 day and 8–15 day means, plus the departure of the first seven-day mean from the Climate Research Centre 100-year climatology. The underlying data are the direct products of the various operational forecast models run by NCEP, NWS and NOAA. Such outlooks could be used for assessing the likelihood of a period of excessive hot weather.

Source: http://wxmaps.org/pix/temp10.html, NOAA/NCEP/NWS

8.6 SUMMARY

HHAPs are composed of a number of elements, including an alert system or HHWS, which operates on the timescale of a heatwave event, and a number of longer-term elements, such as education, seasonal awareness and the development of workable intervention strategies. A number of HHAPs have been developed at a variety of scales and for different countries. Consequently, each HHAP is quite unique in many ways. That aside, a fundamental imperative in developing an HHAP is the issue of heat governance, that is, “who” has responsibility for heat as a hazard at the broad national or regional, as well as at the institutional, level. Although HHWSs, as components of HHAPs, use weather-forecast data at lead-times of three to five days, improved seasonal climate-prediction services and products offer the possibility of developing heat-risk awareness at longer monthly and seasonal timescales.

CHAPTER 9

LONGER-TERM INITIATIVES FOR MANAGING HEATWAVES AND HEALTH

Key messages

- Heatwaves have emerged as an important hydrometeorological hazard and will remain so, given projected changes in the frequency of extreme heat events associated with human-induced climate change.

- As part of a wider HHAP, HHWSs constitute an important adaptation strategy for managing the health risks associated with extreme heat events.

- HHWSs will continue to develop with advances in science and technology and the application of urban design and planning principles to the management of heat. The pace and degree of HHWS development, however, will depend on the availability of the requisite location-specific human and financial capital.

9.1 FUTURE DEVELOPMENT OF HEAT–HEALTH WARNING SYSTEMS

As science and technology progress and climate services are delivered, so will the development and application of HHWSs advance. Among current operational HHWSs, the level of sophistication varies. Some HHWSs rely on manual data feeds, while others are semi- if not fully automated. With time and adequate resources, those agencies that run “manual” HHWSs will gain access to the requisite technology to facilitate development of fully automated systems. Notwithstanding technological developments, human intervention will remain a key component of HHWSs. While technology will bring about improvements in data acquisition and flow and thus the technical development of HHWSs, consensus decision-making by HHWS operators, stakeholders and end-users will remain essential to the effectiveness of HHWSs now and in the future.

Scientific impediments to the effectiveness of HHWSs are the reliability of meteorological forecasts and the robustness of the meteorological or biometeorological index threshold values used to trigger warnings.

If the last decade can be taken as a guide to the next, then major improvements in forecast accuracy, possibly out to 10 days, can be expected. Because heatwaves are usually associated with stable atmospheric circulation regimes, such as blocking, improvements in the forecasting of atmospheric circulation regime, transition will assist immensely with the credibility of HHWSs as far as the underlying meteorological science is concerned. Moreover, ensemble forecasts of critical meteorological variables will help quantify the uncertainty associated with weather forecasts over a number of timescales.

The robustness of threshold values for triggering warnings is often dependent on the length of the historical climate and health record used to derive the threshold. More often than not, it is the shortness of health records that compromises threshold robustness. To achieve greater confidence in the reliability of threshold values as predictors of inflection points in climate and health relationships, HHWS developers must work closely with the relevant agencies to secure daily meteorological and health data for as long a period as possible. Key players in both NMHSs and NHSs should work closely together to ensure that data required for HHWS development are homogenous and relevant. Surmounting the problems of forecast accuracy and threshold robustness are therefore essential if good science is to underpin the future development of HHWSs.

With advances in human heat-balance modelling and requisite data for heat-balance models being available on a routine basis, the incorporation into HHWSs of complex biometeorological indices that aim to portray the exchange of heat between a reference person and the ambient environment is a likely future development in some locations.

There is a vast array of empirical biometeorological indices and a number of human energy-balance models. A common characteristic of these is their non-universality such that they may not be transferable to a wide range of environments. Development of a Universal Thermal Climate Index (*UTCI*), as has been achieved in the EU COST 730 project Towards a Universal Thermal Climate Index *UTCI* for Assessing the Thermal Environment of the Human Being (Jendritzky et al., 2012), may provide the possibility that many HHWSs in the future could, assuming no capacity- or capability-related limitations, be based on a standard descriptor of heat stress. Future developments might also include adjustments of meteorological and biometeorological thresholds based on assumptions about intraseasonal acclimatization.

In some political and social contexts, the unavailability of health data may be an overriding factor that restricts the derivation of critical meteorological or biometeorological index threshold values and thus the development of HHWSs. Consequently, HHWS developers must work towards developing a method for the prediction of health-relevant meteorological thresholds in data-sparse areas. Addressing this scientific challenge will assist with the development of HHWSs globally. In situations where there is basic meteorological information but no health data, a percentile-based threshold (90th, 95th) could be contemplated as a warning trigger value. Recent research has even indicated that thresholds as low as the 85th percentile for maximum temperature might be applied as a generic threshold (Honda et al., 2007).

Much remains unknown about the impact of the possible synergistic effects of heat and poor air quality on health. What is clear from research on this topic is that there may be no universal truism about heat, air quality and health. This is because the relative importance of heat or air quality for health outcomes during very hot weather may vary geographically. Notwithstanding the scientific debates surrounding this issue, a possible development could be the incorporation of air-quality information in HHWSs. To achieve this, spatially and temporally integrated air-quality, meteorological and health-monitoring networks will need to be established.

9.2 SEASONAL FORECASTING

Seasonal forecasting refers to predictions of meteorological variables 10–90 days in advance. If reliable, such forecasts have the potential to assist in decision-making for public-health responses to severe climate events (McGregor, 2012; McGregor et al., 2006). This is because high levels of natural all-cause mortality at the summer weekly, monthly and seasonal timescales have been found at some locations to be associated with anomalous heat at the same timescales. Variations in intraseasonal-to-seasonal mortality are most likely to be associated with summer climate variability, because periods of anomalously warm weather have a fundamental effect on mortality through increasing, for example, the physiological risk factors associated with heat-related health outcomes. Based on this, advance warning of forthcoming periods of anomalous hot weather might be possible. Already there are encouraging signs that fully coupled ocean–atmosphere multimodel predictions of summer temperature at the intraseasonal-to-seasonal timescale are improving for areas that have a history of heatwave-related problems. Hence, the potential exists to incorporate seasonal climate information into public-health-sector decision-making. For mutual benefits to accrue in the areas of the application of climate information in the public-health sector, enduring partnerships, based on a firm interdisciplinary knowledge base, will need to be built between the climate and health communities, as well as the associated research and operational communities.

9.3 URBAN DESIGN AND PLANNING

During periods of hot weather, nocturnal temperatures in urban areas may rise several degrees above their rural counterparts because of the UHI effect. As a result, urban inhabitants will not benefit from the relief that night-time normally offers.

The principal causes of UHI are the storage by day of solar energy in the urban fabric and release of this energy into the atmosphere at night and the fact that evaporation from urban surfaces as a cooling process is very limited. Given this, strategies for tackling the root causes of UHI – and thus stressful night-time temperatures – need to focus on controlling the absorption and release/escape of heat from the urban fabric and tipping the balance between the apportionment of available natural energy between heating and cooling of the urban atmosphere. Policies designed to reduce UHI may need to balance the requirement to manage heat at the building, neighbourhood and city scales, taking into account the nature of building development (new versus existing) and being aware of what is achievable in reality. Climate change has implications for the planning and design of current and future urban spaces from the local to city scale. Urban designers and planners need to acknowledge this and, in so doing, base design criteria on data that describe the current and projected future climate.

Because anthropogenic heat, for example from air-conditioners, could become an important future source of extra heat in the atmosphere for some major urban areas, strategies focused on managing heat emissions and the location of heat ejection to the atmosphere from infrastructure will become an important issue for planners.

In developing UHI mitigation strategies and applying the philosophy of climate-sensitive urban design, it must be borne in mind that UHI is a city-scale phenomenon and the outcome of the combination of a vast range of urban microclimates. As the built components of the urban system occur at different scales (individual building to industrial park to major industrial zone, etc.), any physical alteration of these will have climate impacts at different scales. Consequently, the link between UHI management policy and urban-climate scale needs to be acknowledged (Table 10). Perhaps focusing on the ways in which climate at the individual-building to neighbourhood scale can be managed will eventually have a cumulative effect at the larger city scale. While the choice of strategies for local climate modification through invoking a range of building-design and urban-planning strategies is considerable (Hales et al., 2007), the degree of benefit (the intensity of cooling and improvements to human thermal comfort) depends on a multitude of factors (Coutts et al., 2013).

9.4 CLIMATE CHANGE

Climate change is not only likely to bring about changes in the frequency and duration of heatwaves in “core” heatwave regions but also an alteration of the geographical distribution of heatwave disasters (IPCC, 2012; 2013). Heatwaves could very well occur in locations where there is no previous history of occurrence because of the poleward shift of the mean summer maximum and minimum isotherm and an altered pattern of atmospheric and land-surface moisture due to atmospheric-circulation changes. This has implications for national governments in terms of reviewing their natural disaster response plans and the incorporation within these of national HHAPs.

Table 10. The link between policy and urban climate scales in London, United Kingdom

Physical scale	*Policy scale*	*Urban-climate scale*
Individual building/street (façade and roof construction materials, design and orientation)	Building regulations and building control Urban-design strategy Local development framework	1–10 m Indoor climate and street canyon
Urban design (arrangement of buildings, roads, green space)	Urban-design strategy Area action plan Local development framework	10–1 000 m Neighbourhood scale, suburban variations of climate
City plan (arrangement of commercial, industrial, residential, recreational and “natural” space)	Subregional spatial strategy Regional spatial strategy	1–50 km City/metropolitan scale UHI form and intensity

Source: GLA, 2006

As society responds to climate change through adaptation, climate and health relationships may change. Consequently, HHWS developers will need to continually review the sensitivity of their systems, not only in response to societal adaptation, but also to short-term changes in social and health policy. Accordingly, appropriate adjustments to system trigger points and also intervention strategies will be needed.

9.5 HEAT–HEALTH WARNING SYSTEMS IN THE WIDER CONTEXT OF CLIMATE SERVICES

WMO has defined climate services as:

The dissemination of climate information to the public or a specific user. They involve strong partnerships among providers, such as NMHSs, and stakeholders, including government agencies, private interests, and academia, for the purpose of interpreting and applying climate information for decision-making, sustainable development, and improving climate information products, predictions, and outlooks (http://www.wmo.int/hlt-gfcs/).

Among a number of candidate sectors for the application of climate services, health is a priority. This is because weather and climate variability and extremes have both direct and indirect impacts on human health. Climate conditions affect a range of ecosystem services which support population health and can at times challenge the operation of health systems and related services. The availability of health-relevant climate information therefore has the potential to improve decision-making in the health sector. Placed in this context, this HHWS Guidance provides a worthy example of how information from the climate and health communities can be exchanged and blended in order to achieve a better understanding of the drivers and management of heat-related health risks.

ACRONYMS

APCC	APEC Climate Centre
APEC	Asia-Pacific Economic Cooperation
ARHA	Assiniboine Regional Health Authority (Manitoba, Canada)
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
AT	apparent temperature
BCC	Beijing Climate Centre (China)
BoM	Bureau of Meteorology (Australia)
cCASHh	Climate Change and Adaptation Strategies for Human Health (WHO)
CCl	Commission for Climatology (WMO)
CDC	Centers for Disease Control and Prevention (USA)
CMA	China Meteorological Administration
COPD	chronic obstructive pulmonary disease
COST	Cooperation in Science and Technology (EU)
CPC	Climate Prediction Center (USA)
CPTEC	Centro de Previsão de Tempo e Estudos Climáticos (Brazil) - (Center for Weather Forecasts and Climate Studies/National Institute for Space Research (CPTEC/INPE))
CRED	Centre for Research on the Epidemiology of Disasters
CSIS	Climate Services Information System (WMO/GFCS)
DMT	daily mean temperature
DRR	disaster risk reduction
DT	dry tropical airmass
DWD	Deutscher Wetterdienst (German Meteorological Service)
ECMWF	European Centre for Medium-Range Weather Forecasting
eHealth	Health care practice supported by electronic processes and communication
EHF	excess heat factor
EHI	Excess Heat Index
EM-DAT	Emergency Events Database EM-DAT (CRED)
EPA	Environmental Protection Agency (USA)
ET	equivalent temperature
EU	European Union
GLA	Greater London Authority (United Kingdom)
HACC	Home and Community Care (Queensland, Australia)
HARS	Heat Alert Response System (Manitoba, Canada)
HeRATE	Health Related Assessment of the Thermal Environment (DWD)
HHAP	Heat–Health Action Plan
HHWS	Heat–Health Warning System
HI	Heat Index
HSI	Heat Stress Index
ICARO	Watch Warning System for Heatwaves (Portugal)

ICD	International Classification of Diseases
INPE	Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research), Brazil
InVS	Institut de Veille Sanitaire (French Institute for Public Health Surveillance)
IPCC	Intergovernmental Panel on Climate Change (WMO-UNEP)
IRI	International Research Institute for Climate and Society (USA)
ISO	International Organization for Standardization (Organization internationale de normalization)
ITU	Temperature Humidity Index (Romania)
JMA	Japan Meteorological Agency
KMA	Korea Meteorological Administration
LC-LRFMME	WMO Lead Centre for Long Range Forecast MultiModel Ensemble (jointly coordinated by KMA and NOAA-NCEP)
LC-SVSLRF	WMO Lead Centre for Standard Verification System of Long Range Forecasts
LDEO	Lamont-Doherty Earth Observatory (USA)
Météo-France	French National Meteorological Service
Met Office	National Meteorological Service (United Kingdom)
MJO	Madden-Julian Oscillation
MSC	Meteorological Service of Canada
MT+	moist tropical plus airmass
NET	net effective temperature
NCEP	National Centers for Environmental Prediction (NOAA)
NHS	National Health Service (WHO)
NIMR	National Institute of Meteorological Research (KMA)
NMHS	National Meteorological and Hydrological Service (WMO)
NIMR	National Institute of Meteorological Research (KMA)
NMS	National Meteorological Service (WMO)
NOAA	National Oceanographic and Atmospheric Administration (USA)
NWP	numerical weather prediction
NWS	National Weather Service (NOAA)
OFDA	Office of Foreign Disaster Assistance (USAID)
OSHA	Occupational Safety and Health Administration (USA)
OUT_SET	outdoor standard effective temperature
PET	physiological equivalent temperature
PHE	Public Health England
PHEWE	Assessment and Prevention of Acute Health Effects and Weather Conditions in Europe
PM10	particulate matter with diameter less than 10 micrometres
PMV	predicted mean vote
POAMA	Predictive Ocean Atmosphere Model for Australia
PT	perceived temperature

PWWS	Philadelphia Hot Weather-Health Watch Warning System (USA)
RH	relative humidity (%)
SAWS	South African Weather Services
SET	standard effective temperature
SMS	Short Messaging System
SPF	Secours populaire français (People's Aid, France)
SSC	Spatial Synoptic Classification
TCC	Tokyo Climate Centre
TLV	threshold limit value
UHI	urban heat island
United Kingdom	United Kingdom of Great Britain and Northern Ireland
UNEP	United Nations Environment Programme
USA	United States of America
USAID	US Agency for International Development
UTCI	Universal Thermal Climate Index
UV	ultraviolet radiation
WBGT	wet-bulb globe temperature
WHO	World Health Organization
WMO	World Meteorological Organization
XML	Extensible Markup Language

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