World Health Organization
Country Office for Thailand

# Development of framework on heat-health warning system in Thailand

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DEPARTMENT OF HEALTH

# Executive Summary

Heat impacts, especially heatwaves, are found globally, be it in France, Spain, India or Pakistan and they have caused a large number of illnesses and deaths. In Thailand's case, the problems are not as prominent but the data from the Department of Disease Control shows an increasing trend in morbidity and heat events, hence the public health sector's necessity for preventive plans. This study investigated the issue, and compiled data on health impacts from heat stress and the heat-health warning systems of other countries in order to propose a system that is suitable to Thai context, and hence more effective.

The Health Impact Assessment Division, the Department of Health has developed a criteria and made suggestions on the heat-health warning system for Thailand for the purpose of surveillance and warning. The approach taken was literature review, secondary data analysis and expert justification. The literature review section included the review of epidemiological researches on health impacts from heat and other related factors, threshold temperature development and heat-health warning criteria. As for the secondary data analysis, it is aimed to propose the threshold temperature and develop a predictive model for health impacts from heat in Thailand, using health and environmental data 10 teras backward (from 2006 to 2015) from the Meteorological Department and the Bureau of Policy and Strategy, the Ministry of Public Health. Suggestions on the system and criteria and preventive measures for general public and risk groups were also presented.

By studying the threshold temperature of each region, it is found that the number is between 38.23 to 39.97 Degree Celsius, which the minimum hazardous temperature. From this threshold temperature, along with the reviewed data from other countries and expert meeting, the heat-health warning criteria for Thailand is as follows.

| No | Risk Degree | Temperature (degree Celsius) |
|---|---|---|
| 1 | Surveillance level | less than 38 |
| 2 | Alert level | 38.1 – 40.0 |
| 3 | Warning level | 40.1 – 43.0 |
| 4 | Danger level | over 43 degree Celsius for three consecutive days or more, or over 45 degree Celsius |

For maximum efficiency, the heat-health warning criteria and system requires practicality and context suitability; therefore, the developed criteria must undergo pilot testing in the regional and national scale. In the long term, related parties should hold meetings for creating an operational plan together, bearing in mind the importance of risk communication, preventive knowledge and skills training, detection of heatstroke’s early signs, first-aids treatment and etc. For the system to achieve sustainability, the risk groups - elders, children, pregnant women, people with pre-existing conditions and outdoor workers, along with the caregivers of these groups, must get special attention and care.

# Preface

Climate change from natural anomalies and human actions hugely affect human life nowadays, being one of the five factors of disability-adjusted life years (DALY) in Southeast Asia and worldwide. A health consequence of climate change, both direct and indirect, is heat-related and this affects the healthcare system in all public health organizations, locally and globally. There have been attempts to deal with the situation, which include development of risk factor and hazard surveillance system, climate-related health warning systems, reinforcement of the healthcare and environmental health system for prevention, treatment and restoration, body of knowledge and technology development, healthcare personnel capacity development on the understandings and preventive measures of climate change, greenhouse gas reduction and promotion of knowledge and understanding among local people.

In the global scale, heat-related impacts, especially from heatwaves as in Spain, France, India and Pakistan, can be catastrophic. In Thailand's case, the problems are not as prominent but the data from the Department of Disease Control shows an increasing trend in morbidity and heat events, hence the public health sector's necessity for preventive plans. A heat-health warning criteria and system are of utmost importance for dealing with the problems from climate change effectively.

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# Acknowledgment

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# Chapter 1

# Introduction

## 1.1 Project background

High ambient temperatures are hazardous in escalating morbidity and mortality of heat-related illness in many countries. However, the mortality during a heat wave or high temperature is preventable and recognized as a high priority for the World Health Organization. There is a common misperception that heat-related morbidity and mortality are addressed in relation to temperature climates. In fact, ambient temperatures higher than normal can cause significant mortality even in tropical regions, as demonstrated in India and Pakistan during worse heat wave event in 2015. The effects are more severely among the vulnerable groups such as the elderly, children, pregnant women and people with chronic conditions as they have insufficient capacity to respond to temperature increases. To mitigate heat-related morbidity and mortality, heat-health warning system will be developed and implemented as early detection to improve decision making in public health response and public concern for heat-health behaviour changes. Thailand is located in sub-tropical region and unavoidable consequences of climate change and high temperature effects. According to health information system of the MOPH, the number of heat stresses morbidity is substantially increasing from 2010 – 2013, which is 1,020, 1,241, 1,810 and 2,742 cases, respectively. However, this figure may be underreported. With this reason, MOPH Thailand with the collaboration of WHO Thailand and the technical expert (Dr. Kristie Ebi) has been implemented "the qualitative assessment of the risks of heat stress in Thailand" in 2015. The results of this project have been recommended to enhance capacity for risk management of heat related illness in Thailand by developing a heat-health warning system applicable for Thai population. Therefore, a framework of heat-health warning system should be developed in order to prevent the health impact of high temperature in Thailand, especially the most vulnerable group.

## 1.2 Objectives

**General:**

To develop a framework of heat-health warning system in Thailand

**Specific:**

1) To identify the heat-health temperature threshold in Thailand.

2) To develop heat- health warning criteria in Thailand.

3) To develop heat-health intervention and response, and propose health protection measures in specific risk group of population.

## 1.3. Methodology

1.3.1 Documentation review was to search epidemiological research studies investigating the effects of heat on health and associated factors, threshold temperature, and the warning criteria for heat-related illness protection measures and health care in the general population and the vulnerable groups to heat, including the heat-health warning systems and mechanisms.

1.3.2 Working group meeting was conducted on 6 June 2016 to develop the scope of work, a detailed work plan, output of this project.

1.3.3 Gathered metrological data (i.e. daily temperature, relative humidity, wind speed and rain fall) and health data (i.e. morbidity and mortality) dating back 10 years from 2006 to 2015 (except for the illness between 2010 to 2015) from the Department of Meteorology and the Office of Policy and Strategy, Ministry of Public Health

1.3.4 Analysed of data, it is intended to propose the threshold temperatures and to develop the models to predict the health effects of heat in Thailand by using environmental and health data.

1.3.5 Drafted a framework of Heat-Health warning system including a level of heat-health warning, heat health intervention and response, and proposed health protection measures in specific risk group of population.

1.3.6 Conducted expert consultation meetings on 2nd August and 9th September 2016 to consider and discuss the elements of framework of Heat-Health warning system and providing recommendation for improvement.

1.3.7 Hold the meeting with relevant agencies to present the draft framework of Heat-Health warning system for public review on 28 September 2016.

1.3.8 Revised and finalized the key findings for further propose to Ministry of Public Health and other Ministries for adoption and implementation.

1.3.9 Developed a web-based early warning system including risk area mapping, health protection measures.

1.3.10 Make a final report

## 1.4 Project outcome

A framework of heat-health warning system in Thailand which can be used as a guideline to warning on heat during a hot season. It will be proposed to MOPH and other ministries for adoption and implementation as an early warning to raise awareness in a wide range of societal concern and improve decision making in preparing effective guidance on heat-avoidance and mitigating heat-related illness among Thai population especially in vulnerable groups.

# Chapter 2

# Literature Review

## 2.1 Definition of Terms

The **American Conference of Industrial Hygienists (ACGIH)** provided the following definition for *heat stress*.

"Heat stress is the net (overall) heat burden on the body from the combination of the body heat generated while working, environmental sources (air temperature, humidity, air movement, radiation from the sun or hot surfaces/sources) and clothing requirements"

**Adverse health impact**s from heat refer to the impacts caused by exposure to the temperature higher than the body's tolerance. Once the body is exposed to heat or generates heat but is unable to stabilize its temperature or acclimatize to heat, both direct and indirect impacts in the body may occur and give rise to heat-related illnesses or conditions such as exhaustion, dizziness, rash, edema, heat cramps and heat syncope. These illnesses or conditions are caused by risk factors such as individual's condition, sex, behavior and socio-economic factors.

**Heat-related mortality** refers to death from unknown causes occurred inside or outside the place of residence such as houses, hospitals, temples, buildings, farms, forests, mountains or other public places that may have heat-related factors or the temperature above the baseline (38.5 Degree Celsius). The conditions are consistent with symptoms caused by heat, which are heat rash, swollen hands and feet, heat exhaustion, cramps, hyperventilation and heat stroke (Bureau of Epidemiology).

## 2.2 Adverse health impacts from heat

Adverse health impacts can be categorized as follows, physical health impacts, mental health impacts, effects, well-being impacts, occupational health impacts and mortality.

### 2.2.1 Physical Health Impacts

Physical health impacts from heat can be further divided into acute and chronic impacts. Acute exposure to high degree of heat can cause heat-related illness or death from heatstroke, but in case of chronic exposure, the risks of suffering from other illnesses and injuries would increase.

***<u>Heat-related illness</u>***

Acute health impacts occur when the body is not able to stabilize the core temperature or acclimatize to heat, resulting in the following heat-related illnesses, arranged from lower to higher severity – heat rash, heat edema, heat cramps, heat syncope, heat exhaustion and heatstroke (Details on heat-related illnesses, signs, symptoms/mechanisms and management are shown in Table 1).

- ***Heat rash***

Heat rash or prickly heat results from unevaporated sweat on the skin that is persistently wetted, causing the sweat to accumulate and clog in the papules, which become expanded and red from infection. In severe cases, it can cause itchiness and pain. It is commonly found in places with a high level of heat and humidity.

- ***Heat edema***

Heat edema is swelling of the legs from heat which causes the blood vessels to expand and thus, the body fluid moves to the legs by gravity. A significant risk factor is salt imbalance in the body. In case of salt loss is lower than average, the increased level of salt would draw the fluids to the legs.

- ***Heat cramps***

Heat cramp is the acute muscle shrinkage and contraction in the legs, arms and stomachs, causing severe pain. It results from excess loss of sweat, which is compensated by water so the body loses salt from the blood and muscles. Drinking a large amount of water without compensating salt dilute the salt's concentration and the level of sodium in the muscles is reduced, resulting in cramps.

- ***Heat syncope***

Heat syncope is caused by the body's inability to acclimatize to heat when the temperature rises rapidly. The body tries to excrete excess heat by increasing the blood circulation to the skin, causing the decreased amount of blood to other organs, especially the brain, and eventually fainting.

- ***Heat exhaustion***

Heat exhaustion is not as dangerous as heatstroke. It is a preceding sign of rapid heatstroke occurrence. It usually occurs when individuals become stressed due to prolonged heat and water loss, causing the core temperature to exceed 38 Degree Celsius for several hours. It is primarily caused by the significant loss of water or important salts through perspiration. Those suffering from heat exhaustion still perspire and experience loss of strength, fatigue, dizziness, headache, nausea and extreme fluid loss, but still have consciousness intact.

**Table 1 Heat-related illnesses, their signs and symptoms/mechanisms and management**

| Illness | Signs and symptoms/mechanisms | Management |
|---|---|---|
| Heat rash | - small red papules on the face, neck, upper chest, and groin, and below the nipple line<br>- found in all ages but most common in children<br>- Possible infection from Staphylococcus when the body sweats excessively in hot and humid weather | The rash disappears with no treatment needed by staying in air-conditioned environment, showering regularly and wearing lightweight clothes so that the affected area can dry. Topical anti-histamine and disinfectant drugs help reduce itchiness and prevent infection. |
| Heat edema | - leg swelling, usually at the ankles<br>- found since the beginning of summer<br>- caused by blood vessel expansion, resulting in water and salt congestion. | No treatment is needed since the swelling disappears after the body acclimatizes. Diuretics should not be used. |
| Heat syncope | - brief loss of consciousness or dizziness after rise up from the lying position<br>- commonly found in patients with heart and coronal artery disease or those using diuretics before the body can acclimatize<br>- caused by fluid loss.<br>- Blood vessel expansion reducing the blood flow back to the heart, causing the decrease in blood flow from the heart | The patient should lie down in cool places with feet and hip elevated to increase the blood flow back to the heart. Other causes of fainting must be ruled out. |
| Heat cramps | - muscle pain resulted from muscle shrinkage usually occurs at the legs, arms or stomach at the end of an exercise session<br>- caused by the loss of fluids sand salts from excessive perspiration and muscle weakness | Immediate rest in cool places, muscle stretching and gentle massage are recommended. Drinking fluid with salt to replace fluid lost may be necessary. Doctor consultation should be considered if the cramp persists for more than 1 hr. |
| Heat exhaustion | - symptoms: thirst, weakness, dis-ease, dizziness, fainting and headache, weak pulse, hypotension during position shift, rapid shallow breathing, and no change in | The patients should be moved to cool and shady, or air-conditioned area. Remove their clothing then wrap them in a water-soaked sheet or spray cool water on them with |

| Illness | Signs and symptoms/mechanisms | Management |
| --- | --- | --- |
| | consciousness<br>- normal core temperature, or decreased or increased (less than 40 ฎegree Celsius)<br>- caused by salt loss from being in high heat or excessive exercise can be the cause. | extra cooling effect from an electric fan. The patient should be in a lying position with their legs or hip elevated to increase the blood flow back to the heart. In case of nausea which causes the inability to drink, they might have to be feed intraveneously. If the body temperature rises above 39 Degree Celsius, the mental state changes constantly, or hypotension persists, use the same treatment as heatstroke and send the patients to the hospital. |
| Life-threatening heatstroke | - symptoms and signs: exposure to stress from heat (heatwaves, summer and/or excessive exercise), rapid body temperature increase above 40 Degree Celsius, and abnormalities in the central nervous system such as confusion, lethargy or coma, dry and heated skin, nausea, hypotension, fast heartrate and continuous rapid breath | Constantly check the patients' core temperature (rectal measurement). If it is above 40 Degree Celsius, move them to cool places, remove their clothing and begin cooling the body such as by compressing an ice pad around the neck, armpit and groin. Use electric fan to blow on their face xontinuously (or open the ambulance's windows) and spray cool water at 25 to 30 Degree Celsius. Lie the unconscious patients on their side and be careful not to let them choke. Provide oxygen at 4 litres/minute as well as salien solution, then send the patients to the hospital as soon as possible. |

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

## ***Increase of illness or injury risk related to stress caused by heat***

Studies found that there were many illnesses that correlated with extreme heat. The impact might not be instant and apparent at the time of maximum temperature but it could cause several chronic illnesses or aggravate pre-existing conditions such as heart and coronary artery disease, respiratory diseases or kidney disease. Prolonged exposure to heat results in the rise of the core temperature, causing the blood to flow more to the skin and the amount of blood flow to vital organs such as heart and lungs is lessened. This increases the stress to these organs as well as to the hematologic system, causing increase in platelets and red blood cells and, as a result, the blood viscosity. In extreme cases, it can cause dehydration and hypertension. Increase of heart and respiratory rate to regulate more heat results in exposure to environmental threats such as air pollution or allergenic pollens

Also, many studies found that heat-related stress correlated with the number of IPD admission or mortality from heart and coronary artery, brain, circulatory and respiratory diseases in Australia, Europe, USA and China, but a study in Denmark indicated that heat-related stress only correlated with IPD patients suffering from respiratory disease.

Risk of kidney disease from dehydration is also increased by heat-related stress. In extreme heat, excessive sweat evaporation causes the body to dehydrate and lose salts, especially sodium and chloride, which reduces the amount of fluids outside the cells. This causes stress to the kidney's function, acutely and chronically, eventually leading to kidney disease. Pre-existing illnesses such as diabetes, hypertension or renal calculi increase the chance of kidney failure.

Another impact is fatigue which increases risks of accidents or injuries, possible due to the fact that heat-related stress causes fainting, confusion, loss of concentration or mental stress.

There is only a few number of studies on the impacts of heatwaves on illnesses, since non-fatal illnesses are not recorded on a regular basis; therefore, the data comes from the service system i.e. hospitalization or ER attendance records which are stored in daily or weekly sequence

As for heatwaves in the US, it is found that it correlated with the number of hospital admission in Chicago in 1995. The number of ER patient admission increased by 11 percent, especially among those of 65 years old onward, the increase was 35 percent. 59 percent of these patients who had heat-related illnesses (dehydration, heat exhaustion and heat syncope) suffered from chronic diseases. In the UK, it is reported that the number of hospitalization increased slightly during the heatwave in Birmingham in 1976 and in London in 1995 (no statistical significance). In 2003, patient of age 75 increased by 16 percent in London. in the same year, a hospital in Spain reported that 40 percent of its patients had heat-related conditions, but no cases of heat syncope were diagnosed, and in France, the most severe heatwave was recorded in that year. Hospitals were crowded with patients and some of them suffered from heat syncope. These statistics brought about the development of symptom observation system, which was the fundamental foundation for the quick assessment during heatwave.

### 2.2.2 Mental health impacts

Hansen et al. studied the mental health impacts from heat-related stress during heatwaves in Australia from 1993 to 2006 and found that it might increase mental health risks, as seen from the noticeable increase of IPD patients with amnesia, and mental/mood disorder. A study conducted during heatwaves in England and Wales indicated that heat-related stress also correlated with the increase rate of aggressive behaviour and suicide. Workers were also found to be mentally stressed, causing decreased outputs and obstruction in their daily routines.

### 2.2.3 Well-being impacts

Heat-related stress impacts individuals' well-being by obstructing their personal activities such as work, travelling and recreation. Most people are not able to work properly and feel unwell, as a result of exhaustion or stress from fatigue. Manual labourers have problems concentrating and staying active and tenacious, causing impacts on their physical capacity and overall work performance as well as indirect impacts on their life satisfaction and quality.

### 2.2.4 Occupational health impacts

A study in India found a correlation between heat-related stress and mortality in labourers of 20 to 50 year old. This group of people is exposed to heat during prolonged working hours and the risk is especially high in those with lower incomes such as manual labourers and farmers who work without heat protection for a long period of time.

Physically fit outdoor workers are at risk of heat-related illnesses and injuries because they are not cautious in preventing dehydration and heat exposure. As for their mental health, it is found that prolonged heat exposure causes mental stress and these workers develop chronic mental problems, namely depression and anxiety.

## 2.3 The relationship between climate change, heat and health

Climate change results in the rise of the temperature at the Earth's surface; as a result, heat-related events become more frequent and hazardous, which would eventually affect human's health as follows.

### 2.3.1 The body's heat-regulating mechanism

When the body is exposed to the external heat (from the environment) or the internal one from its metabolism, causing excessive heat at above 37 Degree Celsius, its thermoregulatory system starts working promptly to regulate the temperature to 37 Degree Celsius. The mechanisms include increasing heart rate to increase blood flow to the skin and vasodilation at the skin to transfer heat. At the same time, the body would excrete sweat, as the evaporation would draw the heat out.

Bodily and environmental heat transfer can be done in three ways. 1) Radiation is the transfer of heat from inside the body to outside (or from the environment to the body) in the form of electromagnetic waves without using a conductor. 2) Convection is the transfer of heat through moveable conductors which are air and water. And, 3) Conduction is the process of transferring heat when in contact with cooler or hotter unmoveable objects such as metals. Another mechanism for heat transfer is evaporation, as mentioned. However, this mechanism is not as effective when relative humidity is above 80 percent because it almost reaches it saturation point, and when it reaches 100 percent, the sweat does not evaporate altogether, making this mechanism ineffective.

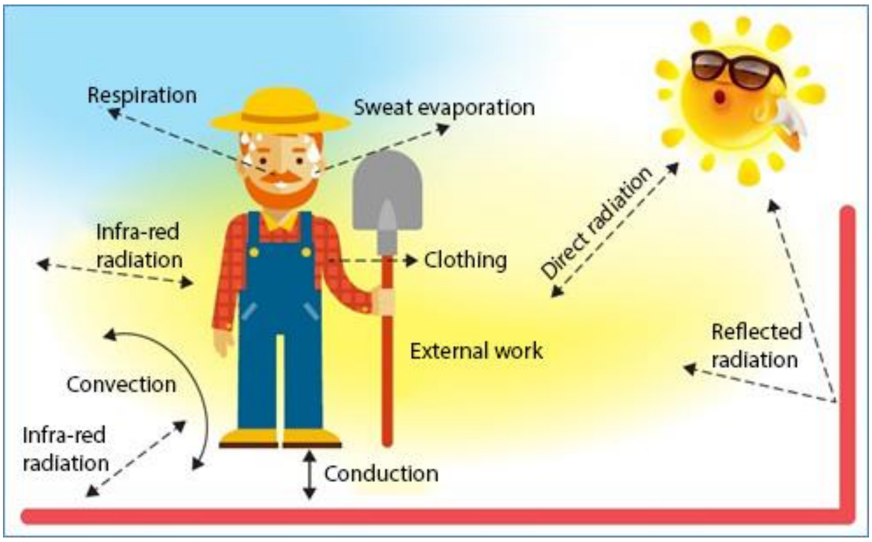



**Figure 1** - Heat-regulating mechanism
(Source : Adpated from Havenith, 1999)

### 2.3.2 Heat acclimatization

Human body is capable of adapting to heat after prolonged and repeated exposure and this is called heat acclimatization. Such mechanism could take two to six weeks in which the physiological systems, namely cardiovascular, coronary artery, endocrine and kidney. As a result, the stroke volume and glomerular filtration rate increase, while the plasma volume decreases, reducing the cardiovascular workload eventually. Moreover, the higher level of perspiration in lower temperature with lower salt excretion reduces the efficiency in heat regulation and salt loss. On the early days of high heat exposure, the body responds by increasing the temperature and heart rate, causing uneasiness. As the exposure continues, the body begins to acclimatize using the function of the heat-regulating system to increase the perspiration rate and transfer excess heat. The body would continue to do so until salt loss, blood circulation, heart rate and body temperature reduce to a stabilized level. It takes approximately one week for physically fit individuals to acclimatize themselves to heat and they will become more tolerant to heat. Even so, this process stops after a few weeks after the discontinuation of exposure. Complete acclimatization may occur, but would take many years. The core temperature and heart rate reduce at a certain level of heat exposure.

It is found that those who live in places with higher level of heat and humidity near the equator are more tolerant to heat because their body has acclimatized to heat automatically. Human in general starts to feel uneasy in the temperature range of 17 to 31 Degree Celsius. Other factors obstructing the acclimatization are, for instance, extreme heat exposure, old age, physical impairments, obesity, alcohol addiction or certain drugs usage.

The risk groups include elderly people, socially-isolated individuals, children and infants and individuals with obesity. In hot weather, smokers and drinkers are at risk of hyperthermia. Moreover, people with chronic illnesses such as lung and heart disease, and insomnia or insufficient rest would have more difficulties acclimatizing to heat as well.

## 2.4 Current situation on heat and health in Thailand

Extremely hot weather, caused by climate change, results in heat-related illnesses and deaths and this has caused losses and heath costs all over the world, be it in France, England, India or Pakistan. It can cause death within 24 hours if there is no prevention or immediate treatment. From 1970 to 2015, 149,657 deaths from heat are reported, especially in Europe where heat waves occured around 60 times, causing 134,397 deaths. In 2016, India faced the highest temperature in history at 51 Degree Celsius, higher than the record of 50.6 Degree Celsius in 1956, which was considered life-threatening.

Major risk groups are infants and small children (five years old or less), pregnant women, people of over 65 years old, people with psychiatric conditions, people with chronic diseases - kidney disease, heart disease and cancer, bed-ridden patients without self-care capacity, outdoor workers – farmers, construction workers, soldiers, workers in factories with high temperature, socially-isolated people and homeless people. The main factors are the extremely hot weather and acclimatization to heat or changing weather.

In terms of economic and environmental impacts, heat is responsible for the income loss among labourers due to the decreased outputs, drought and smog.

**In Thailand,** the change in temperature and relative humidity which are health risk factors has increased significantly, as seen from the records of the past five years. The maximum temperature shows the tendency to increase especially in 2016, as in Figure 2.

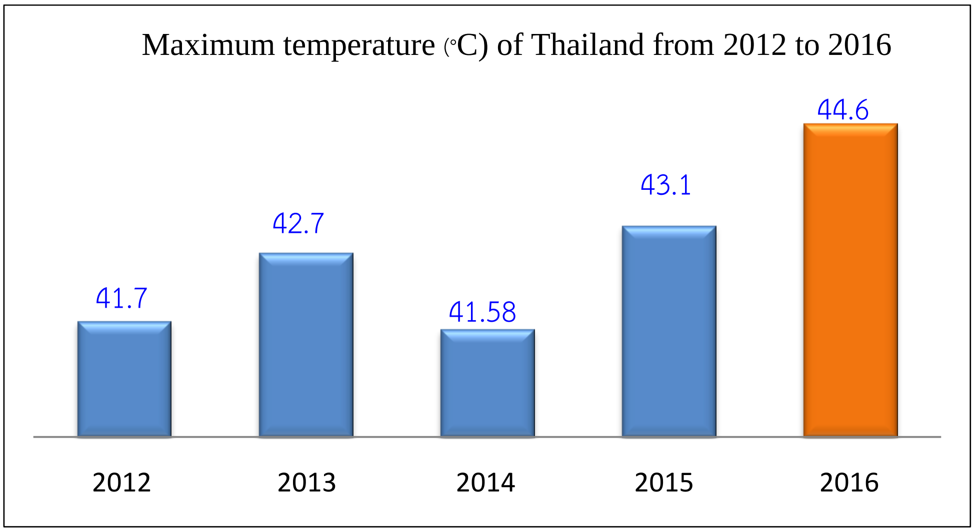
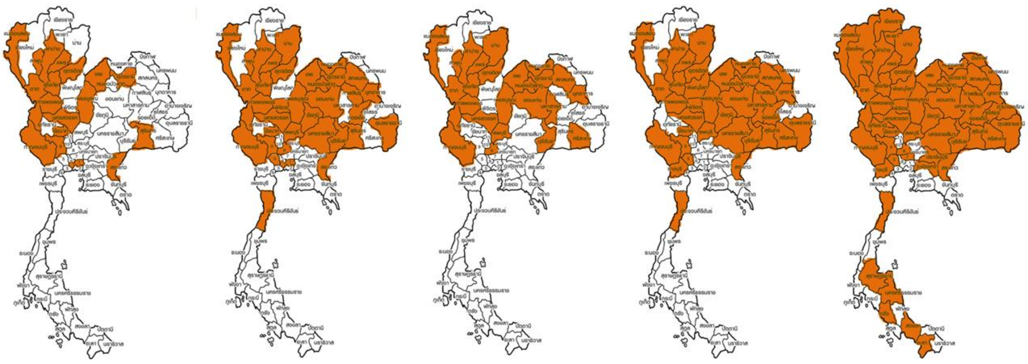



**Figure 2** - Maximum temperature (°C) of Thailand from 2012 to 2016

Taken the maximum temperature change in each province into consideration, it is found that every province shows the tendency in temperature rise and the number of provinces surpassing 40 Degree Celsius increases every year. In 2016, April has the highest average maximum temperature at 44.6, measured on April 28, 2016 at the Mae Hong Son's Meteorological Station, surpassing the record of 44.5 in Uttaradit in 1960. 2016 is also the year when El Nino is the most extreme in history. 51 provinces recorded temperature higher than 40 Degree Celsius (Figure 3).

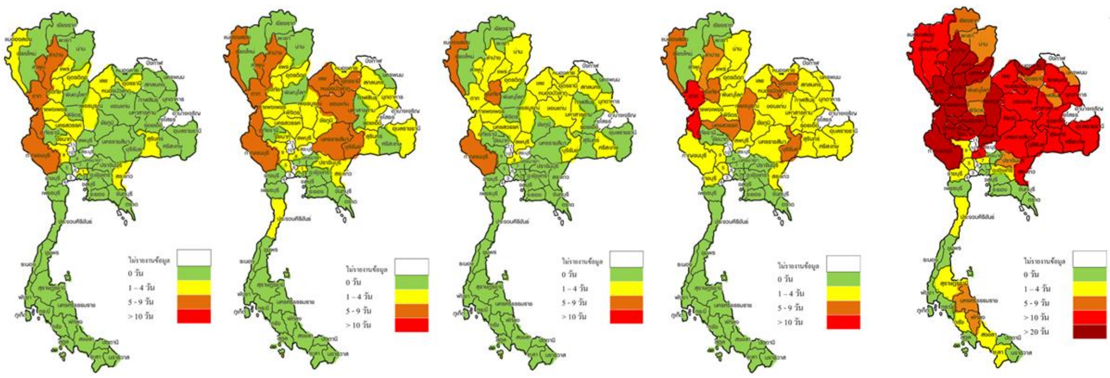


2012 18 provinces | 2013 36 provinces | 2014 24 provinces | 2015 37 provinces | 2016 51 provinces

**Figure 3** – The trend in maximum temperature change in Thailand from 2012 - 2016

**Source**: Department of Health, 2016

Also, more provinces have higher number of 10 and 20 consecutive days with the maximum temperature than 40 Degree Celsius, especially in the northern and central regions, as in Figure 4 -



2012 2013 2014 2015 2016

**Figure 4** - The trend of the number of days with maximum temperature higher than 40 Degree Celsius in Thailand from 2012 - 2016

**Source** : Department of Health, 2016

**Health event** is found that the morbidity and mortality rates from heat-related illnesses increase as well. From 2012 to 2016, the morbidity rate increase from 0.77 per 100,000 in 2013 to 5.28 in 2016 (Bureau of Policy and Strategy, Ministry of Public Health). Every year, April, the month of summer, has the highest morbidity rate, especially in the North and South. Occupational groups with the highest morbidity rate are farmers of 60 years old onwards, general labourers and students, respectively (Figure 6).

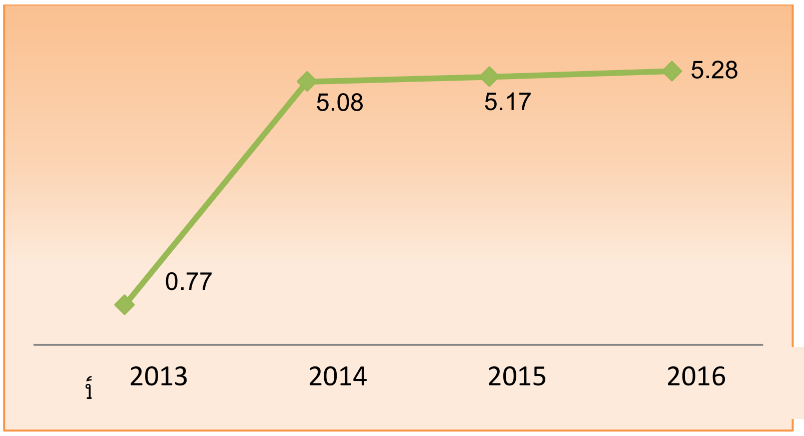



**Figure 5** - Morbidity rates of heat-related illnesses from 2013 - 2016

**Source**: GIS Health, Bureau of Policy and Strategy

## 2.5 Epidemiological studies showing heat-related health impacts

There are many studies studying mortality caused by heat by using heat exposure indicators and mathematical modeling.

### 2.5.1 Heat exposure indicators

Mortality and meteorological data have been used to identify heat-related health impacts. Most of the meteorological data come from the local meteorological stations, as the representative of the heat exposure of the populations living in or nearby the area, but there are several studies that measured the meteorological variables by themselves. The maximum, minimum and daily average temperatures are commonly used. Relative humidity, heat from radiation and wind speed are also taken into account to determine the value of heat-related stress, based on the physiological mechanisms related to heat. Other variables are as follows.

1) Apparent temperature – it is the temperature taken into consideration along with the air temperature and humidity. Many studies reported that daily apparent temperature had a strong correlation with adverse health impacts. Case studies in Seoul, Beijing, Tokyo and Taipei showed that it correlated with mortality with the critical temperature from 25.2 to 33 Degree Celsius.
2) Heat index is used along with heat and humidity. The United States National Oceanic and Atmospheric Administration uses heat index to predict and issue warnings to the public.

Metzger et al. (2009) found a linear correlation between the maximum heat index and mortality of the same day in New York from 1997 to 2006. Also, the non-linear correlation between mortality and maximum temperature one, two and three days before death, and it predicted the highest mortality rate at between 35 to 38 Degree Celsius.

3) Humidity index is the combination of relative humidity and temperature. Air Quality and Health uses humidity index to issue public warnings when the heat and temperature reach the hazardous point. Jackson et al. (2010) found the correlation between the maximum humidity index and mortality among elderly people (65 years old onward) in the state of Washington from 1980 to 2006.
4) Wet-bulb globe temperature (WBGT) is widely used in the international scale. In the occupational health context, WBGT is used to measure heat-related stress at work. Developed and approved for validity since 1950, it is the combination of different numbers concerning human's exposure to climate, humidity, air movement and heat radiation. It is concluded that Liljegren et al.'s (2008) is the most appropriate for outdoor WBGT and Bernard and Pourmoghani's (1999) for indoor, based on the assumption that there is no heat radiation indoor. A number of research found that WBGT was easy to interpret in terms of the correlation between the exposure size and the responses so it is used extensively to find the correlation between health impacts and work performance.

Certain studies use heat index by calculating from meteorological data and physiological variables such as metabolic rate or clothing. Recently developed from heat-regulating physiology model to show the physiological response to heat, the indicator Universal Thermal Climate Index (UTCI) can reflect human's capacity to transfer heat. The variables affecting the UTCI are air temperature, sun radiation, humidity and wind speed. UTCI was used in the studies of current thermal comfort and climate change in Hong Kong.

The heat indices mentioned above are only the examples of indicators that are developed and employed in research. A review study on indicators found that there were more than 40 indicators developed since 19th century, many of which attempted to show the exposure to heat-related stress by combining physiological and environmental variables related to heat. However, no variables are suitable in all circumstances. The most used in the past decades is WBGT. It is the universal standard measurement tool for occupational heat exposure and it is also used for recommendation by the American Conference of Governmental Industrial Hygienists for occupational heat exposure, determined by working and resting hour restriction at the different WBGT levels in order to prevent adverse health impacts from heat on the workers.

### 2.5.2 Methodology for the evaluation of adverse health impact related to stress from heat

The correlation between adverse health impacts and stress from heat is reported in a number of epidemiological studies, which use diverse heat stress variables and mathematical models. Some studies examined the increase in mortality when the temperature exceeds the threshold, or mortality at a specific percentile of the temperature. Some studied the correlation only between mortality and temperature, or the change in impact as a result of certain factors such as high humidity, wind speed, air pressure, cloud cover and synergistic air pollutants.

### 2.5.3 Statistical modelling of heat-related mortality: a time series research and statistical model

In environmental epidemiology, sequential study is the most well-known and employed approach. Time-series regression is suitable for studying impacts from heat exposure at a certain period of time, from one to several days, by comparing the cardinal numbers of daily mortality to the temperature of the same day or previous days, known as "lagged days". The design for a time series study is for estimating the value of the change in mortality in relation to the temperature with the control of confounding variables, namely the long-term mortality trends, seasons, air pollution and influenza outbreaks. This is similar to the one used for epidemiology of air pollution, measuring of correlation degree between air pollution and daily mortality. For instance, studies on temperature-related mortality found a non-linear correlation, that is, it has a U- or V-like shape; whereas, air pollution-related mortality has a linear one.

The techniques for statistical modeling of time-series research are developed by using various methods, from the simple linear regression to more complex methods. The cardinal number of daily mortality can leniently be treated as having a Poisson distribution, in which additional calculation methods may be required to rule out long-term mortality trends (e.g. population growth or technological changes), seasonal variation that has daily health impacts and climate variation.

Widely-used techniques for non-linear regression analysis in time-series research include generalized linear model (GLM), generalized additive model (GAM) and generalized estimating equation (GEE). All of which allow variable adjustment in both the linear and non-linear model for daily temperature or results from trends and seasons that might confound the analysis.

Some research employed GLM with parametric regression splines such as natural and cubic slines, in which a single spline function of time is used to create the trend in inconsistent seasonal change, in hope that it would help control the possible occurrence confounding results.

As for GAM, it is used extensively in short-term impacts of heat-related stress on mortality. It is more flexible than GLM, since it can be used to determine non-parametric correlation by using nonparametric smoothing such as Loess smoothing to adjust the confounding factors such as temperature group, season, results from days in the week, or climate and pollution variables that change daily. Dependent variables in GAM are the natural logarithm of expected mortality and the coefficients in regression equation is the natural logarithm of the rate ratio. One problematic issue about GAM is the collinearity of non-linear function and the difficulty in determining the category of smoothers and the amount of degrees of freedom in temporal adjustment. Moreover, nonparametric smoothing in GAM may give a deviated estimation and underestimate the actual variation.

GEE is the expansion of GLM and us used to analyze the impacts from air pollution. Later studies used GEE to analyze health impacts from heatwaves. Baccini et al. (2008) used GEE to determine the condition-responsive correlation of heat-related mortality in 15 European cities. GEE is suitable for a longitudinal study when mortality is leniently independent from the hot season each year, while mortality within the hot season of the same year is correlated.

## 2.6 Temperature threshold determination

**Temperature threshold** refers to the degree or level of temperature or other related figures and if exceeded, it can cause adverse impacts on human's health. There are many adverse health impacts from heat such as increased morbidity and hospital admission rate. In most countries, mortality rate is chosen because it is stored consistently and systematically, and can be tracked many years backward, unlike morbidity such as hospital admission which can vary, depending the health information system. After raw data on mortality is obtained, analysis method must be considered, for it can be extremely various and diverse. If heat causes relapse of several illnesses, heat-related mortality would be highly underestimated, resulting in the inefficiency of the heat health warning system. Later studies clearly showed that elder people were the most vulnerable; therefore, some systems use the mortality of people over 65. Italy uses all types of mortality data, except that from accidents.

Furthermore, long-term mortality is often adjusted to basic mortality or daily mortality in normal circumstances by considering the change in the population structure. Sometimes the variation within the season also has to be adjusted, especially in the regions with temporary migration during summer such as the month of August in Italy. From this basic mortality data, deviant mortality rate can be calculated and the climate correlation can be determined in many ways in order to understand the correlation between health and climate and to compare between different locations and their heat health warning systems.

Deviant mortality data evaluation can be analyzed in many ways. In synoptic-based systems, each one takes into account the types of air mass related to significantly abnormal mortality, which leads to prediction of further mortality. In Toronto, for instance, data from the past was used to predict the chance (in percentage) of the increase in mortality. Threshold determination occurs when there is one death more than the normal amount and the chance must be above 65 percent.

Each country has a different temperature threshold. For France, the threshold is the temperature correlated with average death that increases by 50 percent in the urban area and 100 percent in the rural area. After statistical adjustment, the threshold is at percentile 99 of the minimum and maximum temperature of the region. In Portugal, the threshold is determined from death that increases by 31 percent. At that point, announcements begin to be issued and at more than 93 percent, warnings are issued.

Some systems do not use mortality to determine the threshold. Germany uses heat balance model that determine the threshold that causes heat-related stress into different levels. Even with no mortality data taken into account, the threshold has a significant correlation with mortality.

There are other ways of determining the threshold. Many systems make determination based on the percentile. Belgium has sets the maximum temperature in summer at percentile 95 as the threshold temperature. Other systems refer to previous data, for instance, the USA determines the HI threshold at 41 Degree Celsius. Canada sets the Humidex at 40 Degree Celsius. It should be noted that these figures are made for determining the days with abnormally high heat level, not indicating health impacts.

The development of warning system development in Melbourne, Australia used the maximum and minimum daily temperature as the threshold. It is found that when the average between the maximum and minimum temperature at night of the same day exceeded 30 Degree Celsius, the mortality rate of people of 65 years old or over increased from the normal level by 15 to 17 percent. Moreover, when the daily minimum temperature was higher than 24 Degree Celsius, the mortality rate of the same day increased from the normal rate by 19 to 21 percent. It only took a day of threshold temperature exceeded to affect the mortality rate instantly. Therefore, the warning system that solely used that temperature level, which was meteorological data that was easy to collect, yielded good results in terms of warning. However, the correlation between the daily maximum temperature and mortality rate was not found. This might be due to the fact that the arrival of cool wind pattern caused a rapid temperature decrease so the temperature of certain days remained not too high until the evening.

In France, the determination is done by the ability (defined as the sensitivity and specificity) in identifying the period of time in which excess mortality occurs. It is estimated by comparing the three-day moving average mortality of one and three preceding year, then the excess mortality threshold is determined as 50 percent in big cities and 100 percent in others. Each city has the threshold determined by related parties as to have a consensus on the number of alarm and acceptable false alarms. The next thing to be determined is the percentile of the thermal indicators. During the process, the threshold can be adjusted as appropriate to each city (Pascal et al., 2013).

India often encounters problems from a large number of heat-related deaths so a warning system was set up. The Department of Meteorology indicates that heatwave is said to have occurred when the excess maximum temperature is 5 to 6 Degree Celsius higher (than the average at 40 Degree Celsius or lower) and for hazardous heatwave, it is 7 Degree Celsius or more, or when the excess maximum temperature is 4 to 5 Degree Celsius higher (than the average at over 40 Degree Celsius), it is 6 Degree Celsius or more. In any case, if the temperature reaches or surpasses 45 Degree Celsius, it can be said that heatwave has occurred.

Hajat et al. (2010) compared the predictive ability of several methods which were synopic, epidemiology, humidity-heat index and physiological categorization to identify the day that has a significant correlation between heat and health. It is found that each method yielded different results in identifying the most hazardous weather for issuing warnings and that affected the intervention measures of each method significantly.

Another factor affecting the threshold is season. A large number of research shows that the vulnerability to heat differs throughout the season. The highest is at the beginning of summer. Certain warning systems have taken this fact into account. For instance, the HeRATE system of Germany employs short-term acclimatization as a part of the critical apparent temperature calculation. In the same manner, air mass in synoptic-based systems also differs by seasons and since time is the predictive variable, the system would take into account the acclimatization occurred within the season. Nevertheless, No change is found throughout the year in temperature- and temperature-occurrence based systems.

# Chapter 3

# Determination of threshold temperature and Heat -health warning criteria

## 3.1 Data and data sources

To develop threshold temperature of Thailand, Meteorological data and health data has been collected in the period of 10 years from 2006-2015 (excluding illness data from 2010-2015) from the Department of Meteorology. and Bureau of Policy and Strategy, Ministry of Public Health; including

1. Daily temperature and climate related factors include maximum temperature, minimum temperature, average temperature, relative humidity, rainfall and wind speed which classified by province
2. Daily mortality and morbidity which classified by province and age group as follow;

| | |
|---|---|
| Mortality data | C349-Malignant neoplasm of unspecified part of bronchus or lung (I00-I99-Diseases of the circulatory system , I20-I25 Ischemic heart diseases ,I60-I69-Cerebrovascular diseases , J00-J99-Diseases of the respiratory system , J40-J47-Chronic lower respiratory diseases, N19-Unspecified kidney failure and total mortality in C349, I00-I99, J00-J99 and N19 |
| **Morbidity** (2010 - 2015) | T67.0-Heatstroke and sunstroke, T67.1-Heat syncope , T67.2-Heat cramp , T67.3-Heat exhaustion, anhidrotic , T67.4-Heat exhaustion due to salt depletion , T67.5-Heat exhaustion, unspecified , T67.6-Heat fatigue, transient , T67.7-Heat edema , T67.8-Other effects of heat and light , T67.9-Effect of heat and light, unspecified , C349-Malignant neoplasm of unspecified part of bronchus or lung , I00-I99-Diseases of the circulatory system , J00-J99-Diseases of the respiratory system , and N19-Unspecified kidney failure |

## 3.2 Mathematical Modeling to Predict Mortality and Morbidity

To create mathematical models to predict mortality and morbidity, the researcher has parsed groups of diseases (both morbidity and mortality) separately into provinces, regions (by the criteria of the Department of Administration, Ministry of Interior), and age-groups: 0-4 years, 5-14 years, 15-59 years and 60 and above. The equations are in the form of

$$\ln(\text{count}) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \ln(\text{midyear population})$$

where

count is the number of morbidity or mortality,

$\alpha$ is a constant,

$\beta$ is a coefficient,

$x$ is an independent variable,

midyear population is the number of population at midyear of a concerned province.

The steps are as follows:

1. Find a new series of each type of meteorological variables at lags from 0 to 7 days.
2. Find the relationship between the dependent variable (mortality and morbidity) and each meteorological variable as a single variable (univariate analysis) at lags 0 to 7 days, and record its *p*-value.
3. Consider the results in step 2 and choose the best lag using the criteria that it gives the least *p*-value.

The results from step 3 were then used to analyze the relationship with mortality and morbidity using either generalized estimation equation or generalized linear model (GLM) where appropriate. The predictive variables in the models are relative humidity, rainfall, wind speed, and temperature (separating into three models by maximum temperature, minimum temperature, and the average temperature).

## 3.3 Determination of Threshold Temperatures and Pre-alert Temperatures

Determination of threshold temperatures and pre-alert temperatures was conducted using total mortality data and temperatures so-called statistical-meteorological criterion proposed by Pascal et al., 2013. The results by region (using criteria of the Department of Meteorology) were followed the steps as:

1. Determine the meteorological indicator (MI) by averaging daily minimum and maximum temperatures of the current day, and the previous two days (totally three days), according to the formula:

$$MImin_d = (Tmin_d + Tmin_{d\_1} + Tmin_{d\_2})/3$$
$$MImax_d = (Tmax_d + Tmax_{d\_1} + Tmax_{d\_2})/3$$

where $Tmin_d$ is the minimum temperature of day *d*
$Tmax_d$ is the maximum temperature of day *d*.

2. Find the relationship between total mortality and $MImin_d$ and $MImax_d$ using GLM statistics categorized by region, including the Central, Northeast, North, South and East. The division of the Department of applied meteorology, as following.

| Regions | Provinces |
|---|---|
| Central | Nakhonsawan, Uthaithani, Ang Thong, Chai Nat, Lop buri, Phra Nakhon Si Ayutthaya, Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, Samut Sakhon, Saraburi, Samut Songkhram, Sing Buri, Suphan Buri , Kanchanaburi, Ratchaburi |
| Northeastern | Amnat Charoen, Bueng Kan, Buri Ram, Chaiyaphum, Kalasin, Khon Kaen,Loei, Maha Sarakham, Mukdahan, Nakhon Phanom, Nakhon Ratchasima, Nong Bua Lam Phu, Nong Khai,Roi Et,Sakon Nakhon, Si Sa Ket, Surin, Ubon Ratchathani, Udon Thani, Ubon Ratchathani |
| Northern | Chiang Mai, Chiang Rai, Lampang, Lamphun, Mae Hong Son, Nan, Phayao, Phrae, Uttaradit, Tak, Sukhothai, Phitsanulok, Phichit, Kamphaeng Phet, Phetchabun |
| Southern | Phetchaburi, Prachuap Khiri Khan, Chumphon, Nakhon Si Thammarat, Narathiwat, Pattani, Phatthalung, Songkhla, Surat Thani, Yala, Krabi, Phangnga, Phuket, Ranong, Satun, Trang |
| Eastern | Nakhon Nayok, Chachoengsao, Chanthaburi, Chon Buri, Prachin Buri, Rayong, Sa Kaeo, Trat |

3. Find the percentiles of the $MImin_d$ and $MImax_d$ from 1 to 99.
4. Predict the number of deaths in each percentile of $MImin_d$ and $MImax_d$ with models from the step 2 (expected mortality).
5. Find the average of the $MImin_d$ and $MImax_d$ over the duration of data (Mean MImin and MImax).

6. Predict the number of deaths at the average $MImin_d$ and $MImax_d$.
7. Calculate the percent excess mortality rate by finding the difference between the number of deaths in step 4 and step 6 divided by the number of deaths in step 6 multiplied by 100.
8. Plot a line graph of percent excess mortality rates and the percentiles.
9. Determine the threshold temperature by looking the inflexion at percentile marking the clear increase of percent excess mortality rate. The temperature at that percentile will be the threshold temperature.
10. Determine the pre-alert temperatures both minimum and maximum by considering the percentile that marks the early increase of the slope.

The analytic results are shown in the tables below:

**Table 2:** Proposed Threshold Temperature

| **Region** | **Proposed Threshold Temperature (°C)** | |
|---|---|---|
| | **Minimum (percentile)** | **Maximum (percentile)** |
| Central | 17.97 (3) | 38.23 (97) |
| Northeastern | 14.57 (3) | 38.13 (97) |
| Northern | 13.60 (3) | 38.97 (97) |
| Southern | 22.30 (36) | none* |
| Eastern | 23.30 (27) | none** |

* due to negative coefficent

** due to negative coefficent and not statistical significance

**Table 3 : Pre-alert Temperature**

| **Region** | **Pre-alert Temperature (°C)** | |
|---|---|---|
| | **Minimum (percentile)** | **Maximum (percentile)** |
| Central | 19.53 (6) | 37.40 (94) |
| Northeastern | 15.93 (6) | 37.30 (94) |
| Northern | 14.93 (6) | 37.47 (92) |
| Southern | 22.70 (39) | none* |
| Eastern | 23.83 (33) | none** |

*due to negative coefficent

** due to negative coefficent and not statistical significance

## Summary

According to the threshold and pre-alert therehold temperature analysis , **the national heat-health warning criteria for Thailand** is set up 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 in general.

**Table 4**: The national heat-health warning criteria for Thailand

| Level | Warning level | Trigger point (C) (Tmax) |
|---|---|---|
| **1** | **Surveillance** | **Less than 38** |
| **2** | **Alert** | **38.1 – 40.0** |
| **3** | **Warning** | **40.1 – 43.0** |
| **4** | **Danger** | **Above 43 Degree cencius** |

# Chapter 4

# Suggestions on the Heat Health Warning System and Mechanism for Thailand

## 4.1 Heat health warning mechanism in Thailand

**The heat health warning mechanism in Thailand** has adopted the guidelines proposed by WHO which are weather forecasting, risk assessment using the determined temperature threshold or other criteria, and warning messages to related parties, which include identifying vulnerable groups, and designing and preparing strategies in case of emergency. The emphasis is on the implementation during the summer, from March to May every year. The details are as follows.

### 4.1.1 Weather forecasting

On the heat health warning, the Meteorological Department makes forecast on the maximum, minimum and average temperature of each province and region for at least three and seven days in advance. The information for risk assessment can be accessed at https://www.tmd.go.th/climate/climate.php?FileID=1 .

### 4.1.2 Health risk data monitoring and analysis

Based on the weather forecast by the Meteorological Department, the Department of Health, Ministry of Public Health, monitors the situation daily, every three days and one week in advance, and makes health risk assessment according to Thailand's heat health warning criteria, as in Table 3-6. Healthcare measures for each level are then determined.

### 4.1.3 Warning messages

There should be four levels of warning according to the health warning criteria. That is to say, when the average maximum temperature from three days in advance is at the surveillance level (less than 38 degree Celsius), related parties must be prompted to communicate healthcare information to the public. If the average temperature exceeds the surveillance level, warning messages must be issued to general public and risk groups, and appropriate measures must be prepared should critical situation occurs. The frequency of communication depends on the situation's degree of hazard. (Exemplary measures in preventing health hazard from heat of each level of working parties are shown in Appendix A.

The warning communication mechanism is summarized in Figure 6

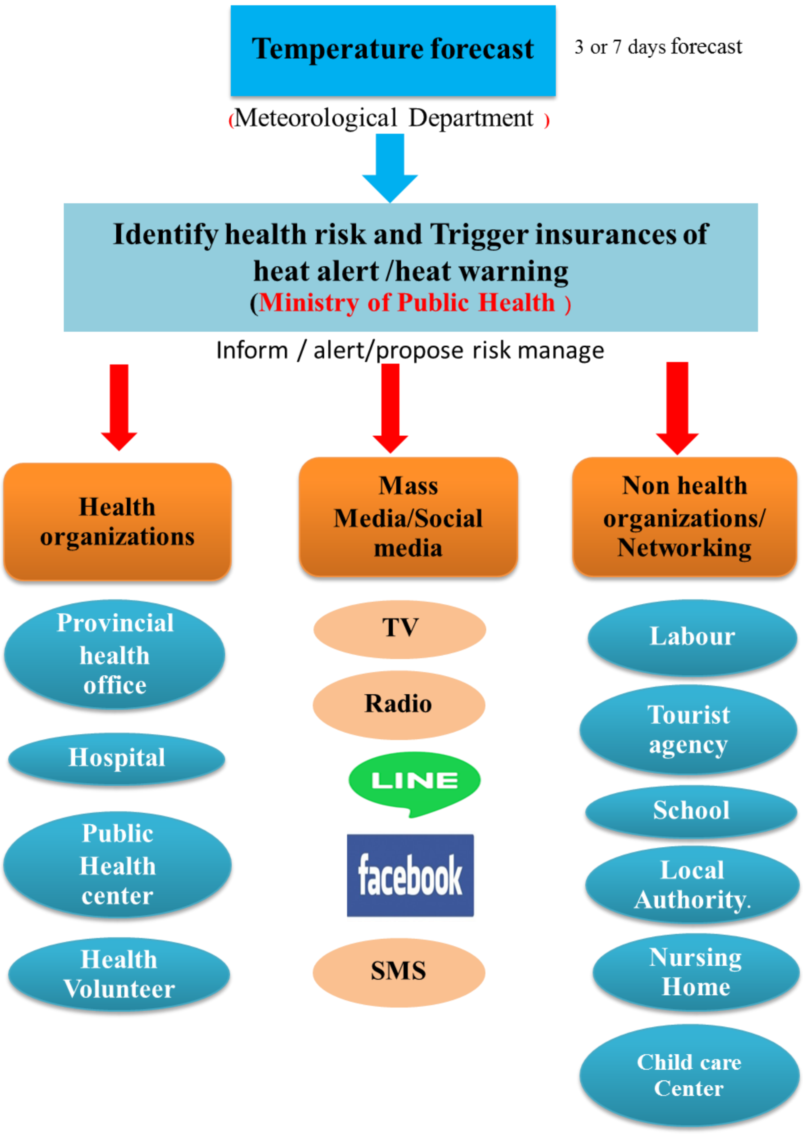



**Figure 6 -** The proposed mechanism for heat health warning system in Thailand

## 4.2 Message and media in warning communication

The content of the warning consists of the information on the situation, health impacts and behavior suggestions for each risk group. Examples include suggestions in preventing heat-related health risks and healthcare in extreme heat.

- **Suggestions for risk prevention and personal healthcare from heat hazard**

When the body is exposed to environmental heat, the body temperature rises above normal (37 degree Celsius). The systems would regulate the temperature back to normal. Inability to acclimatize to heat causes signs or heat-related illnesses so the knowledge and ability in prevention and first-aid management are crucial for the public to care for themselves and the people surrounding. The details are as

| No. | Risk Group | Suggestions |
|---|---|---|
| **1.** | Infants and children up to 5 years old | • Do not leave children or infants unaccompanied in the car parked under the sun. (Cars that are parked under the sun without the air-conditioner turned on can reach 50 degree Celsius in 20 minutes.)<br>• Wear clothes that are light-coloured, loose, lightweight and breathable to prevent heat rash.<br>• In extreme heat, avoid taking them outdoor. If necessary, wear hats, long-sleeved shirts, trousers and bring an umbrella for sun protection.<br>• Take good care of them because they are more susceptible to illnesses. If heat-related symptoms occur, consult a doctor as soon as possible. |
| **2.** | Elderly people of over 65 years old | • Drink clean water regularly throughout the day.<br>• Stay inside the residence, building or air-condition area.<br>• Do not use electric fan when the heat exceed 37 degree Celsius because it will draw in the heat. The fans should be put on oscillating mode and the window opened to transfer heat.<br>• Wear clothes that are light-coloured, loose and lightweight.<br>• Shower regularly to reduce body temperature.<br>• Have the phone number of the nearest healthcare institutions ready or dial 1669.<br>• Inform the nearest person if heat-related symptoms occur. |
| **3.** | Patients or people with pre-existing conditions | • Drink clean water regularly throughout the day.<br>• Stay inside the residence, building or air-condition area.<br>• Wear clothes that are light-coloured, loose and lightweight.<br>• Shower regularly to reduce body temperature.<br>• Have the phone number of the nearest healthcare institutions ready or dial 1669.<br>• Inform the nearest person if heat-related symptoms occur. |

| No. | Risk Group | Suggestions |
|---|---|---|
| **4.** | People working outdoor for a prolonged period of time | • Drink clean water regularly while working even without thirst.<br>• Avoid drinking high sugar-content beverages, which cause dehydration.<br>• Change outdoor work schedule by starting in the early or late morning to avoid working at noon, which is the hottest time of the day.<br>• Stay in shady areas with airflow, or inside the building or air-condition area during breaks.<br>• Wear breathable, light-coloured clothes and wear hats for sun protection.<br>• Work in group and if heat-related symptoms occur, inform the nearest person immediately. |
| **5.** | People who exercise outdoor | • Reduce the duration of outdoor activities, especially at noon, which is the hottest time of the day.<br>• Wear breathable sport clothes.<br>• Avoid continuous, intensive exercise sessions in extremely hot weather. If necessary, prepare the body for extreme heat exposure.<br>• Drink more clean water even without thirst to avoid cramps.<br>• Avoid drinking high sugar-content beverages, which cause dehydration.<br>• Exercise in group and if heat-related symptoms occur, inform the nearest person immediately. |
| **6.** | Pregnant women | • Drink 2 – 4 glasses of clean water every hour.<br>• Wipe the head, neck and body with a piece of cloth soaked in cool water to reduce the body temperature.<br>• Avoid leaving the residence during extremely hot period (12.00 to 16.00) and stay in breathable or air-conditioned area.<br>• Do not sue electric fans in extreme heat (more than 37 degree Celsius) because it will draw in the heat.<br>• Travel with companies for close care.<br>• In case of high body heat, fainting or fatigue, stay in shady areas to cool down the temperature. If there is no improvement within 30 minutes, consult a doctor as soon as possible. |

Heat health warning communication should be diverse in form, such as leaflets, infographics, animations, community radio program and public address system, in order to reach all target groups. Examples of communicative media created by the Department are as follows. (Further detail can be found at http://hia.anamai.moph.go.th/main.php?filename=hia_heat)


Leaflet on the prevention of heat-related health impact for public


Motion infographic providing guidelines on the prevention of heat-related health impact prevention


Motion infographic providing guidelines on the prevention of heat-related health impact prevention


Poster on health hazard from heat: how to deal with extremely hot weather



Infographics for issuing warnings and guidelines for self-care


Infographics providing self-care guidelines for each risk group

**Thailand's heat health warning programme**

Thailand's heat health warning computer programme is developed as a part of the heat health warning system that allows related public and private sectors, such as Department of Health, Health care centres, the Provincial Public Health Offices, health promoting hospitals and general public, to have quick access to the information and use it for communication, warning and preventive self-care. It is a web-based software that is used to collect data on heat events and it health impacts in Thailand, showing the maximum temperature, weather forecasts, areas at risk from heat in both the national and provincial scale. Results/data reports are shown in the form of a risk map. There are also PR media that provide information for related parties and the public, namely the manuals/guidelines for implementation, preventive self-care leaflets, self-care manuals, multimedia, infographics and etc. It is of great benefits for the preparation of heat-related health impact management.

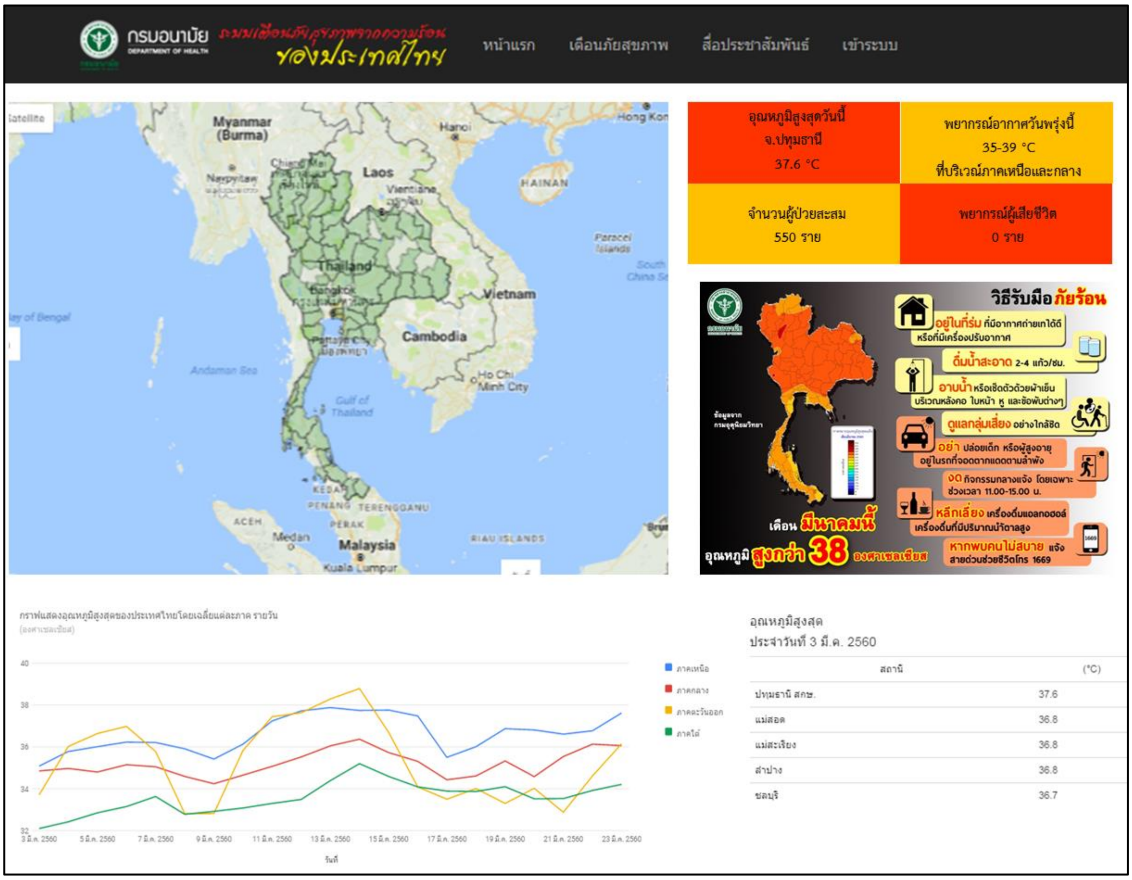



**Figure 7 - Thailand's heat health warning programme**

### 4.3 Suggestions on the roles and approaches of public health in heat events

| Level | Heat Level | The Province's Management |
|---|---|---|
| 1 | **Max Temp 38.0 C* – 40.0 C** | • Monitor the situation and communicate with the public.<br>• Create/update a list of risk groups and prepare healthcare plans for the patients and risk groups<br>• Prepare the cool rooms in the healthcare centres and the EMS system/necessary medical equipment. |
| 2 | **Max Temp 40.1 C – 43.0 C (Advisory)** | • Monitor the situation and issue warning once a day (at 09.00).<br>• SRRT และ VHV make home visit at risk groups' residence (every week).<br>• Prepare the EMS system/necessary medical equipment. |

| Level | Heat Level | The Province's Management |
|---|---|---|
| | | • Open the cool room in the health centres.<br>• Provide and monitor quality drinking water in the health centres. |
| **3** | **Max Temp 43.1 C- 45.0 C**(Alert)** | • Monitor the situation and issue warning twice a day (at 09.00/12.00).<br>• SRRT/ VHV/ family care team make home visit at risk groups' residence (every day).<br>• Open the cool room in the health centres.<br>• Provide and monitor quality drinking water in the health centres.<br>• Monitor the quality of drinking water in public places/governmental offices. |
| **4** | • **Max Temp 43.1 - 45.0°C for 3 consecutive days with suspected deaths and other complciations such as electricity and waterwork malfunction , or**<br>• **Max Temp 45.1°C ** onward (Extreme Heat alert)** | • Monitor the situation every 3 hours and issue warning three times a day (at 09.00/12.00/15.00).<br>• Open the cool room in the health centres.<br>• Adjust the follow-up period for risk group patientsas appropriate to avoid exposure to extreme heat.<br>• Cooperate with related parties to refrain from hosting outdoor activities and activities requiring extensive labour.<br>• Cooperate with related organizations such as local authorities and waterwork authorities in providing drinking water.<br>• The Provincial Public Health Offices open the provincial EOCs. |

## 4.4 Recommendation for further development

4.1.1 The criteria and suggestions of the heat health warning system should be tested for application suitability in the regional and national scale.

4.1.2 Related parties which are the Ministry of Digital Economy and Society (the Meteorological Department), the Ministry of Interior (Department of Disaster Prevention and Mitigation) and the Ministry of Public Health (the Department of Health and the Department of Disease Control) organize meeting to prepare a management plans combatting heat health risks together. Plans should be created integratively from the national, regional, provincial to communal scale. Participation from the public and private sector, the local administrative organizations and the public may reinforce the potentials, roles, equipment and budget of the existing organizations such as the Surveillance and Rapid Response Team (SRRT) in both the sub-district and district level. Also, participation from local organizations such as the District Public Health Offices, community hospitals, health promoting hospitals, local administrative organizations, Village health volunteers and other private organizations is of great importance.

4.1.3 Risk communication, preventive knowledge and skills education, detection of early signs of heatstroke, first-aid healthcare and others are essential. Risk groups such as elderly people, children, pregnant women, people with pre-existing conditions and outdoor workers, and their healthcare plan should receive great attention.

4.1.4 Long-term temperature reduction measures should be prepared in the long term, as follows.

1) Long-term temperature reduction measures by related parties should include a long-term strategy plan, consisting of searches for areas at risk of extreme temperature using previous meteorological data, analysis or research on the causes or factors affecting extreme temperature, prevention and solution, urban planning, green space establishment and public education.
2) The development of heat health impact surveillance system could adopt the proposed model by the Centers for Disease Control and Prevention (CDC), which consists of 1) data compilation, 2) data analysis, processing and interpretation 3) summary and report of the surveillance to related parties, and 4) implementation of the preventive methods or solutions.

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