A Review: The Relationship between Daily Temperature with Non-Accidental Mortality and its Spatial Pattern in Peninsular Malaysia

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Abstract-

Climate change is not only a future problem and an urgent identification of the population, assessing the health risk, and planning appropriate adaptation and mitigation policies is a must to protect human health. Malaysia experienced extreme hot temperatures with 40.1°C in Chuping Perlis in 1998, while the lowest temperature was 15.7°C in 2014. The Ministry of Health reported about 200 cases of heat-related illness with two cases of mortality in Johor and Kedah as a result of El-Nino in 2016. Furthermore, due to the high heat, the government temporarily closed more than 250 schools during that period. Besides that, the year 2019 also saw a lot of heat waves because of the El-Nino phenomenon. On March 5^{th} to 8^{th}, 2019, Chuping, Perlis had a heatwave with a high temperature of between 37.1°C and 37.7°C. The spatial pattern of temperature-related mortality is explored using Time Series of mortality analysis concerning the exposure over a period of time. It describes the variable that is subjected to a recurring periodic observation which can be at the individual (such as blood pressure monitoring) or aggregate levels (such as hospital admission rates) Additionally, it can be used to discover a pattern of behaviour that occurs in the natural environment, evaluate the variable's changes across the continuous spectrum, and forecast the future direction of the time series due to the variable's autocorrelation characteristic. Determining the relationship between daily temperature with non-accidental mortality provides an evidence-based medicine (EBM) on the temperature-mortality relationship. In the clinical and public health practice, this would guide the top management in the public health setting for the improvement of healthcare system preparedness and action plan, especially among vulnerable groups population. In the relation to Sustainable Development Goal (SDG) 2030 and the 12^{th} Malaysian Plan, will focus on increasing energy efficiency and urban resilience and the government can plans toward a low carbon state as one of the mitigation strategies and to improve endurance against climate change and disaster.

Index Terms - Daily Temperature, Non-Accidental Mortality, Spatial Pattern, Peninsular Malaysia

I. INTRODUCTION

Climate change is not only a future problem but also a current problem. Urgent identification of the population, assessing the health risk, and planning appropriate adaptation and mitigation policies are a must to protect human health. Climate change, especially heat waves, has recently become a significant concern among scientists, researchers, and politicians. It has been recognized as one of the most significant challenges of the 21^{st} century and has been recognized as a diver for climate-sensitive health hazards Further researchers found that at the beginning of the second half of the 20^{th} century, human activities such as the burning of fossil fuels, deforestation, and vehicle emissions were identified as contributing factors to an increase in a worldwide average temperature between 0.8°C and 1.2°C [1]. Four types of hazards related to climate-sensitive which are hydrological (e.g., flood, rainfall-induced landslide, ice caps melting, increasing sea level), climatological (e.g., drought and wildfire), biological (e.g., vector-borne diseases; and food and water-borne diseases) as well as meteorological hazards (e.g., temperature extremes, severe storms) [2].

According to a special report by the IPCC [1], the global mean surface temperature (GMST) increased by 0.87°C (0.20°C) between 2006 and 2015 compared to the pre-industrial levels (1850-1900), with recent warming averaging 0.2°C (0.10°C) per decade [1]. Another projection of GMST by IPCC showed that the global warming of 1.5°C could be reached in the 2030s, 2.0°C in 2050s, and even 4.0°C at the end of this century [3]. As a result, the Paris Agreement was signed in December 2015 to limit global average temperature increases to less than 2°C, preferably to less than 1.5°C above pre-industrial levels [4].

Previous studies demonstrated a significant association between temperature, particularly extreme heat conditions with health impacts [5]. Even a 1°C increase in temperature above a city-specific threshold would increase mortality and hospital admission [6, 7]. Nevertheless, the actual figure for heat-related mortality might be underestimated as the extreme temperature is rarely identified as purely the cause of death [8]. Therefore, the world must limit the increment of temperature beyond 1.5°C to avoid catastrophic health effects including mortality [1]. Examining the effects of temperature on mortality in Malaysia setting could help and strengthen the current public health actions to prevent the negative impacts of extreme temperature on health among Malaysian populations.

II. SITUATIONAL ANALYSIS OF THE TEMPERATURE IN MALAYSIA

Malaysia is one of the Southeast Asian Countries with an estimated population size of 32.6 million with a total land area of 30,803 sq km [9]. The country is characterized by high temperatures, high humidity, and plentiful rainfall throughout the year, with two climate variations, the Southwest Monsoons and the Northeast Monsoons, which occur in April-September and October-March, respectively. Malaysia is experiencing an equatorial climate with temperatures ranging from 26°C to 28°C and sometimes can reach up to 31°C in significant cities [10, 11].

Previous research has highlighted the relationship between extreme heatwaves events with human activities, especially in the case of unabated greenhouse emissions [12]. Besides the effect of global warming, Malaysia also experiences phenomena like EL-Nino- Southern Oscillation [13], Indian Ocean Dipole (IOD), and Madden-Julian Oscillation (MJO) [14]. Extreme heatwaves in Malaysia occurred in 1997,1998, and 2016, characterized by extremely long dry spells that affected the quality of life and as well as crop production in Malaysia [15]. Not only that, the atmospheric blocking could lead to a rise in temperature with a dry and hot spell, which was reported in Malaysia in 2014 in the absence of El Nino [11].

In 2016, Southeast Asia including Malaysia, Northern Eurasia, and Southern India was affected by extreme heatwaves event due to the El-Nino phenomena [16]. In fact, the Ministry of Health reported about 200 cases of heat-related illness with two cases of mortality in Johor and Kedah as a result of El-Nino in 2016 [11]. Furthermore, due to the high heat, the government temporarily closed more than 250 schools during that period. It was reported that the temperature soared by 5°C over usual [17]. Throughout history, Malaysia experienced extreme hot temperatures with 40.1°C in Chuping Perlis in 1998, while the lowest temperature was 15.7°C in 2014 [18]. Besides that, the year 2019 also saw a lot of heat waves because of the El-Nino phenomenon. On March 5th to 8th, 2019, Chuping, Perlis had a heatwave with a high temperature of between 37.1°C and 37.7°C. Subsequently, in the same month; from 18th to 22nd March 2019, Chuping, Perlis had another episode of a high temperature of between 37.2°C and 38°C [19].

Even though Malaysia is not among the top ten Asian countries plagued by extreme heat events, the risk exists. The average temperature in Malaysia has risen significantly over the past decade. More than a decade ago, Wai, Camerlengo [20] already highlighted that Malaysia has significant warming, evidenced by increased mean annual temperature ranging from 0.99°C to 3.44°C per 100 years. Tangang et al. (2007) supported this study, which examined the surface air temperature from 1961 to 2002 and found an increment in temperatures between 2.7°C to 4.0°C/100 years. A more recent study done by Jamaludin and Yusop [17] using meteorological data from 1980 to 2011 demonstrated an increase in temperature between 2.0°C to 5.0°C/100 years.

III. THE RELATIONSHIP BETWEEN TEMPERATURE AND MORTALITY

Minimum mortality temperature (MMT) is the value of temperature in which the mortality risk is the lowest. However, the mortality will gradually increase once the temperature is below or above the MMT value[21]. The significance of determining the MMT value is it allows to estimate of access mortality [22]. MMT varies according to population, region, and climate condition [23]. For example, MMT was observed at 34.7°C (66th percentile) in Kuwait, 28.2°C (68th percentile) in Klang Malaysia and 21°C in seven cities in China [24].

This variation will ultimately produce different types of mortality-temperature relationships, such as V-shaped, U-shaped or J-shaped. J-pattern indicates the risk of mortality is higher during high temperatures, U-shaped described the risk of mortality is higher during low and high temperatures [25]. Recently, the L-shaped pattern was identified in tropical and subtropical cities, which indicates the risk of mortality is higher during low temperatures, as compared to higher temperatures [26]. For instance, Kuwait signifies a V-shaped curve, and Hanoi and Vietnam had an L-shaped curve [25]. Governments need to understand the pattern of temperature-related mortality in their respective countries so that policies can be tailored to both low and high temperatures [25]

The impact of environmental stressors including the effect of temperature on health is not restricted to the period during which they are observed but rather is often delayed [27]. Furthermore, the duration of temperature effects appears to vary throughout the specific causes of mortality, age and sex. Exposure to high temperature is usually associated with acute effects (immediate and could last for 7 days); meanwhile, exposure to low temperature is usually associated with more delay effect (range from 9 days to 14 days) [28]. A systematic review and meta-analysis of studies conducted in South Asia found that the temperature thresholds above which mortality began to increase ranged from 19 to 30° C with lags 0–13 and 0–14 (cold effects), and that the temperature thresholds above which mortality began to increase ranged from 20 to 31°C with lags 0 –1 day (heat effects) [29].

IV. IMPACT OF TEMPERATURE ON MORTALITY

Climate change and global warming resulted in more frequent and intense extreme weather events such as heatwaves, cold spells and droughts. Besides being an environmental concern, climate change has also become a major public health concern [1]. Previous research has shown that exposure to ambient high and low temperatures is connected with increased morbidity and mortality [26]. Additionally, Anenberg, Haines [30] stated that even a slight increase in the daily mean or maximum temperature increases the risk of premature mortality. This number of mortality would further increase from 4.0% to 5.0% at the end of the century in the Representative Concentration Pathway (RCP) scenario of 8.5 [31]

Temperatures can impact human health, either directly or indirectly [32]. It is illustrated in Figure 1. Among the direct impacts of exposure to heatwaves include heat cramps, heat stress, heatstroke, exacerbation of other chronic diseases such as asthma, chronic obstructive pulmonary disease (COPD), mental health and increased rate of emergency visits and hospitalization, and accelerated and premature mortality from cardiovascular, respiratory disease [33, 34]. Moreover, extreme heat events also have been reported to be significantly associated with acute mortality from exacerbation of chronic kidney disease due to dehydration and volume loss [35]. As for the indirect effect, heatwaves cause crop yield changes which increase the risk of vector-borne and water-borne disease, population displacement, food insecurity, disruption of the infrastructure, conflict as well as economic and nutritional impacts following crop failure [34].

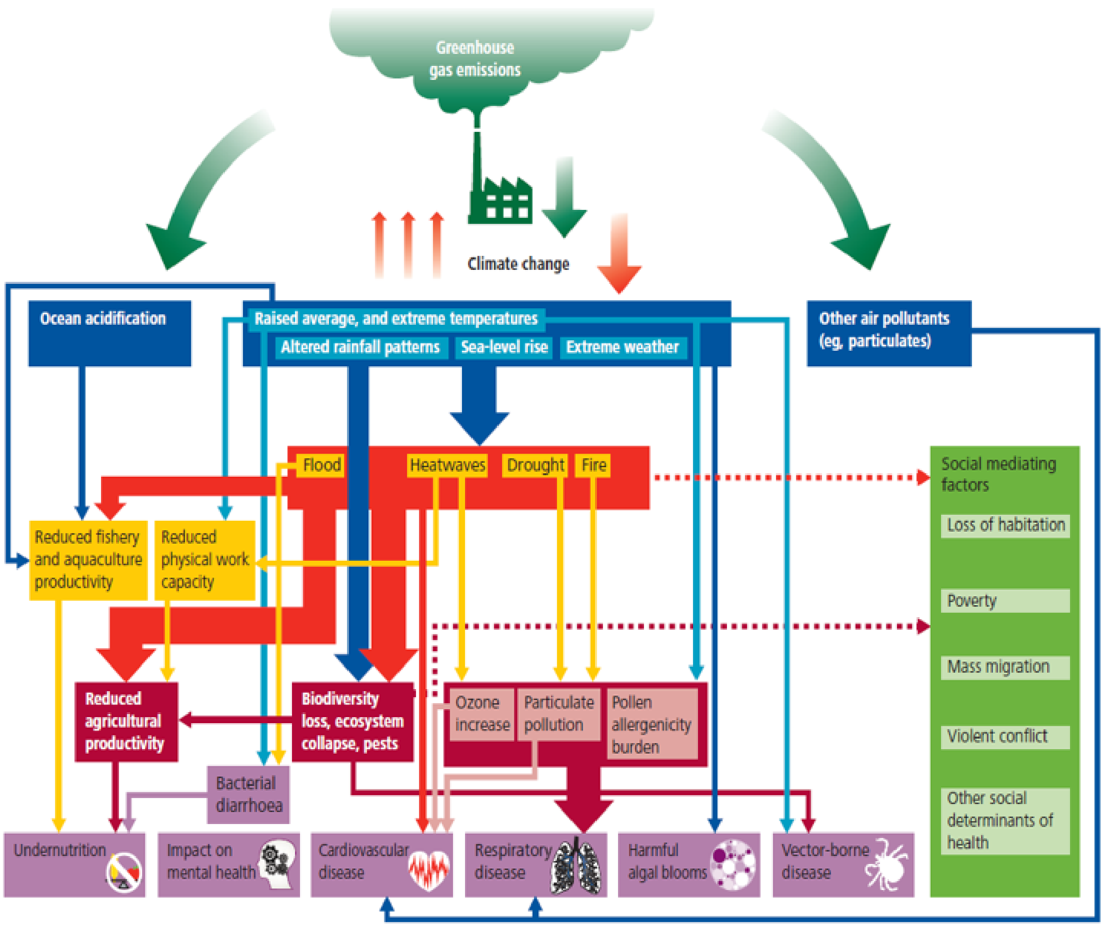

Figure 2: Health risk of climate change. Adopted from Watts et al., (2018). The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health. *The Lancet, 391*(10120), 581-630.

Nevertheless, due to the wide physiological impacts of extreme temperature on humans, exploring the relationship between mortality and ambient temperature can be challenging due to the possibility of incorrect classification of the causes of mortality [36]. Other challenges include lack of official surveillance, misreporting, and not capturing the impact of moderate non-extreme temperature, which occurs more frequently [26, 29]. Because of the tendency of underestimated mortalities related to temperature, many previous epidemiological studies use non-accidental causes to overcome the problem [28].

V. MORTALITY, METEOROLIGCAL AND AIR POLLUTANT DATA IN MALAYSIA

The non-accidental mortality data is obtained from the Department of Statistics Malaysia (DOSM). The information gathered includes cause of mortality, identification number, date of death, district and postcode, age, gender, race, nationality, and the status of location, either rural or urban. In addition, the longitude and latitude of each deceased are captured using Google Map for the mapping process.

Meteorological data is obtained from the Malaysian Meteorological Department (MetMalaysia) [18]. MetMalaysia is an agency under the Ministry of Environment and Water (KASA) and provides meteorological, climate and geophysical services. It collects and stores yearly, monthly, and hourly meteorological data such as temperature, humidity, rainfall, wind speed, and other meteorological data from all Malaysian stations [37].

Air pollutant data is obtained from the Department of Environment, Malaysia (DOE). In Malaysia, air quality monitoring is under the supervision and control of a private company since 1995 Alam Sekitar Malaysia Sdn.Bhd (ASMA) on behalf of the Department of Environment Malaysia. ASMA will be responsible for collecting, processing, analysing, and distributing air pollutants measurements [38]. Eight types of air pollutants are monitored which are Sulphur Dioxide, Nitrogen Oxide, Carbon Monoxide, ozone, hydrocarbon, PM_{10} and $PM_{2.5}$, and UV. All these values (excluding UV and hydrocarbon) will be collected hourly and sent to the Department of Environment to calculate the Air Pollution Index [39]. The data will subsequently be reported on the Department of Environment (DOE) website in its Air Pollutant Index Management System [40]. Each continuous air monitoring station is capable to read the air pollutants value within a 15km radius [41].

V. SPATIAL PATTERN OF TEMPURATURE-RELATED MORTALITY DETERMINATION IN PENINSULAR MALAYSIA

The spatial pattern of temperature-related mortality is explored using Time Series of mortality analysis (outcome) in relation to the exposure (air pollutants, relative humidity and temperature) over a period of time. Time series analysis describes the variable that is subjected to a recurring periodic observation (range from days to a century) or measurement, which can be at the individual (such as blood pressure monitoring) or aggregate levels (such as hospital admission rates) [42]. Additionally, it can be used to discover a pattern of behaviour that occurs in the natural environment, evaluate the variable's changes across the continuous spectrum, and forecast the future direction of the time series due to the variable's autocorrelation characteristic [43].

Time series quasi-poison regression in Generalized Linear Model (GLM) is used and coupled with the Distributed Lag-Non-Linear model (DLNM) to examine the relationship between daily temperature and mortality [26, 44]. Then, the Quasi-poison regression analysis is used to adjust the overdispersion of daily death count (Yt) due to its character that fits better to the overall variance-mean relationship as compared to negative binomial regression [27, 45, 46]. The general regression model used as below:

$$LogE(Y_t) = \alpha + \beta T_{t,1} + DOW_t + ns\,(time,\, df = i/year) + ns\,(RH_t,\, df = 3) + ns\,(PM_{10t},\, df = 3) + ns\,(O_{3t},\, df = 3)$$

(Equation (1))

Where:

t	:	the day of observation.
Yt	:	the number of daily deaths on day t.
α	:	the intercept.
β	:	the vector of regression coefficients for Tt,l.
$T_{t,l}$	:	the matrix is obtained by applying the 'cross-basis' DLNM functions to temperatures l refers to the lag days.
DOWt	:	is a day of the week on day t that is used to control the effect of day of the week on daily mortality (eg. the number of mortalities tend to be higher on weekend compared to weekdays)
ns	:	It indicates the smoothing parameter set to the natural cubic spline. - Based on previous research, natural cubic spline act as a smoothing parameter in DLNM functions to control long-term trend and seasonality as well as the confounders such as air pollutants; which also affect mortality [24, 25, 47].
time	:	is a continuous variable starting from the initial day of observation in this study until the last day of observations.
RH_t	:	Is relative humidity.

df : is a degree of freedom.
PM_{10} : is a particulate matter 10.
O_{3t} : is ozone.

Several covariates are incorporated in this model:

i. a natural cubic spline smooth function for *time* variable with *I* degree of freedom (df) per year was used to control long-term trend and seasonality,
ii. a natural cubic spline smooth function for air pollutants (Ozone (0_3) and PM_{10}) and relative humidity,
iii. indicator variables for 'day of the week (DOW_t)'.

The Akaike Information Criterion (AIC) is used to measure the goodness of fit [24, 25, 46, 48]. It is extensively used in environmental epidemiology time series regression analysis.

The following three steps are used to derive the ultimate model. The smallest value of AIC is selected for the df for temperature and lag [27]

Step 1: Goodness of fit for seasonal and long-term control for temperature-mortality model

A simpler model from Equation (1) that only consists of weekday and time variables:

$$Log\ (Yt) = \alpha + DOWt + ns\ (time,\ df = i/year) \qquad \text{(Equation (2))}$$

In which, the df per year (i.e I value) from 1 to 14 is tested and the smallest AIC value is chosen for the model. This value is selected based on a previous study by Yatim, Latif [24]

Step 2: Determine the best combination of df between temperature-mortality and lag-mortality dimensions via a cross-basis function in the DLNM

The maximum lag values at 7, 14, 21 and 28 are chosen based on previous studies [24, 25]. Then, cross-basis functions to the temperature variable ($T_{t,l}$) and varied the df from natural cubic spline from 3 to 10 in both temperature and lag dimensions are performed. Spline knots of temperature and lags are placed at equal spaces and intervals in the log scale. It is to ensure the flexibility of the temperature distribution and lag effects at shorter delays is allowed [27].

Subsequently, the Equation 2 is updated with the temperature variable and the df per year controlling for seasonality and long-term trend to produce Equation 3, as below

$$Log\ (Yt) = \alpha + \beta T_{t,l} + DOWt + ns\ (time,\ df = i/year) \qquad \text{(Equation (3))}$$

Step 3: Determine the relationship between temperature indicator and mortality categories

Then the mean, maximum and minimum temperature are compared for all categories of mortality. The temperature with the smallest value of AIC is chosen as the best predictor for mortality. In many studies, the daily mean temperature is the best indicator to investigate the relationship between temperature and mortality [49, 50]

Subsequently, the overall cumulative effect of daily mean temperature on all categories of mortalities over lag days will be plotted in the DLMN package to determine the Minimum Mortality Temperature (MMT). Later, the relative risk of mortality in all categories over the lags period is calculated by comparing it with the MMT value. The relative risk and confidence interval (CI) is calculated for both extremely low and extremely high temperatures. P-value < 0.05 is considered as statistically significant. Extremely hot temperature and extremely low temperature are determined from previous literature, which is set at the 99^{th} percentile and 1^{st} percentile of temperature respectively [24]. Spearman's correlation coefficients are used to summarize the correlation between daily temperature and air pollutants in each state of Peninsular Malaysia.

Finally, the sensitivity analysis is performed to determine the robustness of the result. The model is examined with the inclusion of air pollutants (PM_{10} and 0_3) and relative humidity at different lags period (0-3, 0-7 and 0-14 days). Besides that, residuals are examined to determine the adequacy of the model developed.

VI. CONCLUSION

There are many contributions to determining the relationship between daily temperature with non-accidental mortality. It provides an evidence-based medicine (EBM) on a temperature-mortality relationship. To the clinical and public health practice, this would guide the top management in the public health setting for the improvement of healthcare system preparedness and action plan, especially among vulnerable groups population. Besides that, the top management could also use this finding to improve monitoring and surveillance of temperature-related mortality. This is because the surveillance data related to temperature-related illness is usually lacking and under-reported.

In the relation to Sustainable Development Goal (SDG) 2030 and the 12th Malaysian Plan, it prioritises as part of Chapter 6's plan B6, which focuses on increasing energy efficiency and urban resilience. In Chapter 8, strategy A1, the government plans toward a low carbon state as one of the mitigation strategies. In strategy A4, the government plan to improve its endurance against climate change and disaster. Strategy A4 also highlighted the use of an integrated approach to climate change adaptation and disaster risk reduction; as well as improving the early warning system and active response to a disaster. Lastly, referring to SDG 13.1 and 13.3, the finding from this study also could assist the Ministry of Health and public health division in developing a guideline to increase the resilience and adaptive capacity toward the climate-related hazard (i.e. heatwaves).

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