

METHODOLOGY TO ASSESS THERMAL EXTREMES MORTALITY RISK IN URBAN AREAS

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Abstract – The impact of heat waves on mortality has been the subject of numerous studies and the focus of attention of various national and international governmental bodies. In the summer of 2003 alone, which was exceptionally hot, the number of deaths in 12 European countries increased by 70,000. The overall trend of warming will lead to an increase in frequency, duration and intensity of heat waves and to an increase in heat related mortality. The need to assess the risk of death due to extreme heat, at a detailed spatial scale, has determined the implementation of a research project based on a general model of risk for potentially destructive natural phenomena; the model uses the relationship between hazard and vulnerability and was designed primarily for urban areas. The major hazardous meteorological variables are those that determine the thermal complex (air temperature, radiative temperature, wind and humidity) and the variables related to air quality (mainly ozone and Particulate matter). Vulnerability takes into account the population sensitivity (at various spatial scales) and their exposure to thermal extremes.

Key words: Heat wave, mortality, risk, vulnerability, sensitivity.

Resumo – METODOLOGIA PARA A AVALIAÇÃO DE RISCO DE MORTALIDADE POR EXTREMOS TÉRMICOS EM ÁREAS URBANAS. O impacto das ondas de calor na mortalidade tem sido objecto de numerosos estudos e tem sido alvo da atenção de vários organismos governamentais nacionais e internacionais. Só no Verão de 2003, excepcionalmente quente, terá havido uma sobremortalidade de 70 000 pessoas em 12 países europeus. A tendência global de aquecimento levará a um aumento na frequência, duração e intensidade das ondas de calor e a um aumento na mortalidade atribuível ao calor. A necessidade de avaliar o risco de morte atribuível a extremos térmicos a uma escala espacial detalhada determinou o desenvolvimento de uma investigação alicerçada num modelo geral de risco para fenómenos naturais potencialmente destruidores assente na relação entre perigosidade e vulnerabilidade para ser aplicado essencialmente em áreas urbanas. Consideram-se como principais elementos constituintes da perigosidade as variáveis meteorológicas que determinam o complexo térmico (temperatura do ar, temperatura radiativa, vento e humidade)

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bem como variáveis relacionadas com a qualidade do ar (principalmente o ozono e as partículas). A vulnerabilidade é considerada tendo em conta a sensibilidade das populações (a várias escalas espaciais) e a sua exposição aos extremos térmicos.

Palavras-chave: Onda de calor, mortalidade, risco, vulnerabilidade, sensibilidade.

Résumé – MÉTHODOLOGIE POUR L’ÉVALUATION DU RISQUE DE MORTALITÉ DÛ AUX TEMPÉRATURES EXTRÊMES EN ZONES URBAINES. De nombreuses études ont été consacrées à l’impact des ondes de chaleur sur la mortalité, de la part d’organismes gouvernementaux ou internationaux. Pendant l’été 2003, exceptionnellement chaud, la surmortalité aurait atteint 70 000 individus, dans 12 pays européens. La tendance mondiale au réchauffement va augmenter la fréquence, la durée et l’intensité des ondes de chaleur et donc la mortalité résultante. Pour mieux connaître, à une échelle spatiale détaillée, le risque de mort attribuable aux extrêmes thermiques, on a développé une recherche basée sur un modèle général du risque applicable aux phénomènes naturels potentiellement destructifs en zones urbaines et reposant sur le rapport existant entre la périgosité et la vulnérabilité. Les principaux éléments constituant la périgosité seraient les variables météorologiques déterminant le complexe thermique (température de l’air, température radiative, vent et humidité) et les variables relatives à la qualité de l’air (surtout l’ozone et les particules). La vulnérabilité prend en compte la sensibilité des populations, aux diverses échelles spatiales, et leur degré d’exposition aux extrêmes thermiques.

Mots-clés: Ondes de chaleur, mortalité, risque, vulnérabilité, sensibilité.

I. INTRODUCTION

Impacts of heat waves on morbidity and mortality are largely known. Climate change is expected to increase climate health impacts during the summer months and probably decrease the impacts during the winter. Health impacts of extreme thermal events have mainly been studied at a national or regional level considering macro or mesoscale thermal features. But there are certainly local variations in mortality that depend on local climate spatial differences (due to features such as topography, land use and urbanization) and on the vulnerability factors (related to demographic and socioeconomic population characteristics).

The World Health Organization has stated that: “more research has to be done on how climate and global change will affect the thermal environment of cities: – more detailed regional and local climate models – downscaling to the urban level” and emphasized the need to develop detailed climate simulations in integrated assessment models (WHO, 2004: 96).

Given the scarcity of research into the spatial variations of mortality in urban environments, at a detailed scale, we have developed a conceptual geospatial analysis method of death risk during extreme thermal events².

² This conceptual framework analysis is part of Paulo Canário ongoing PhD thesis entitled “Spatial Modeling of Mortality Associated with Thermal Extremes in the Lisbon Metropolitan Area. Present Situation and Future Prospects”.

II. MODEL

A model of hazard – vulnerability – risk was developed in order to analyze the spatial variations of mortality in extreme thermal events, at city district level in Lisbon Metropolitan Area (Portugal). The model fits into the global risk assessment framework for natural disasters (Zêzere, 2001) and is intended to be used primarily in urban areas. Risk is considered as the product of hazard, vulnerability and value (fig. 1)

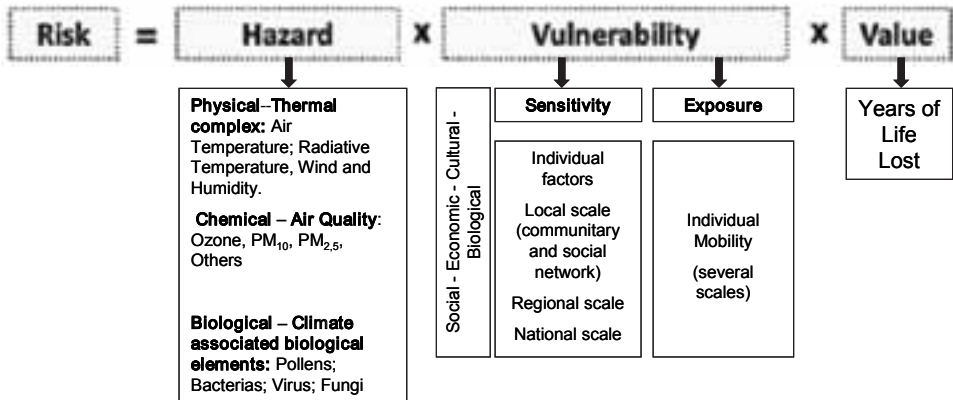


Fig. 1 – Thermal extremes risk conceptual model.
 Fig. 1 – Modelo conceptual de risco a extremos térmicos.

III. HAZARD ASSESSMENT

Hazard is defined as the probability of occurrence of an extreme climatic phenomenon that, directly or indirectly, induces illness and/or death, for a period of time and in a certain area (adapted from Zêzere, 2001). Hence hazard will assume values between zero and one.

Several dimensions can be found in the climatic hazardous phenomenon: physical, chemical and biological. The physical dimension includes the thermal complex variables: air temperature, radiative temperature, wind speed and humidity (Matzarakis, 1998). The chemical dimension includes elements associated with air quality (mainly ozone, PM₁₀ and PM_{2.5}). The biological dimension refers to the elements whose influence in mortality is enhanced by physical and/or chemical elements of hazard: pollens, bacteria, virus and fungi.

Hazard assessment will require spatial modeling of the meteorological elements in the study area. Several conditioning factors at different scales and contexts will determine the spatial variability of these elements and must be taken into account. In a macro scale context, synoptic conditions should be considered as the main determinant factor to influence hazard. The sea and estuarine breezes, as well as the topographic barriers to wind and air masses circulation are the main issues that should be considered at the mesoscale hazard influencing factors. At the local scale, land cover/land use should be

considered together with the topography (presence of hills and valleys, etc). Building characteristics and the urban design are the micro scale factors that should be taken into account.

Small scale variations of meteorological features during extreme thermal events were simulated with a Regional Atmospheric Model (Brazilian Regional Atmospheric Modeling System) taking into account the above multi-scale conditioning factors. The results were validated and calibrated using observation data from the CEG-UL urban network of termo-higrometers placed in sites with different urban characteristics.

IV. VULNERABILITY ASSESSMENT

The Intergovernmental Panel on Climate Change (IPCC, 2007) defines vulnerability as “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes”. In the present work we have used the definition of vulnerability as the degree of loss of the population at risk in a given area (death rate) resulting from the occurrence of a dangerous climate framework (extreme temperatures), for a certain period of time, Sánchez and Bertolozzi (2007) and Confalonieri *et al.*, (2007). Vulnerability is a function of population sensitivity and exposure that can be quantified from zero to one: zero being the absence of deaths attributable to climate extremes and one the complete loss of human lives due to a particular hazard.

Sensitivity is defined, according to Ebi (2006), as the degree to which, before a given exposure, a population is affected by a given climate framework – it represents the dose-response relationship; it depends on several population characteristics such as individual and demographic factors, as well as social, cultural and economic variables at different scales (fig. 2).

The sensitivity assessment at the individual level will focus on age, gender, ethnicity, underlying diseases, presence or absence of health risk factors associated with personal behavior and individual income. At the local level scale the community and social network should be taken into account. It is essential to analyse the importance of family structure and presence of homecare, especially for the elderly. The regional scale sensitivity assessment level will pay special attention to the education, health services and employment issues. The national scale is suitable to assess the specific weight of several indicators such as those related with economic development, social support, technological development and territory politics in sensitivity assessment.

Daily mobility of individuals determines the population exposure to heat. Mobility should be examined at several spatial scales. The frequent and prolonged use of green spaces, coastal and riverine areas could decrease the exposure to high temperatures during heat waves and eventually contribute to diminished heat related mortality.

Likewise, permanence in hot environments due to work reasons will contribute to a high exposure and consequently to raise the vulnerability of the individuals exposed.

Exposure (as the sensitivity) will be determined by social, economic, cultural and biological issues.

Exposure, together with the climate framework, defines the thermal load populations experience through a thermal extreme event.

Since many of these variables, either to assess sensitivity or exposure (mobility), can be redundant a set of indicators was used, including a multiple deprivation index.

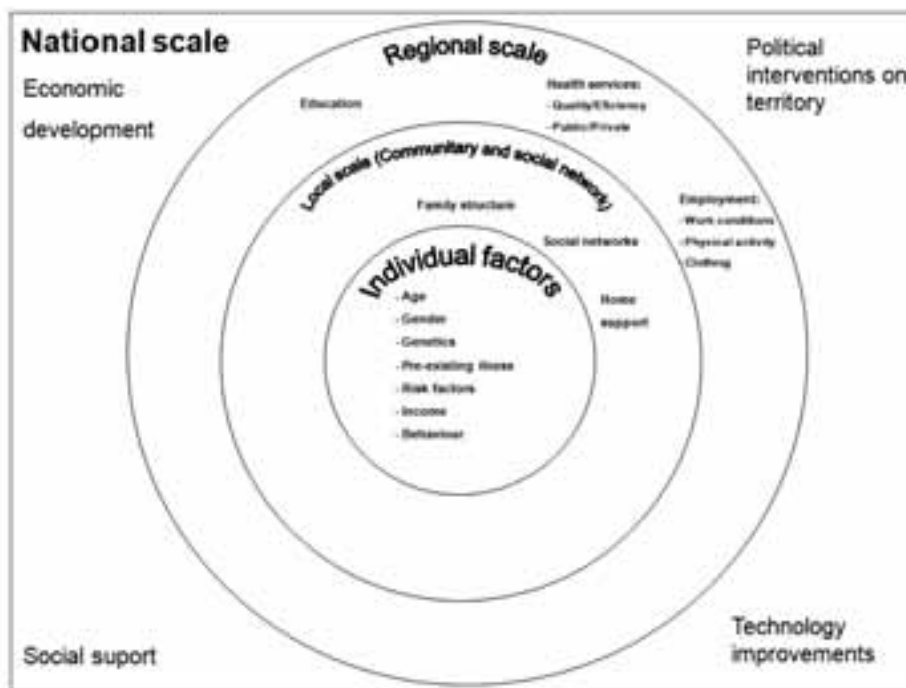


Fig. 2 – Sensitivity assessment framework.

Fig. 2 – Enquadramento da avaliação de sensibilidade.

V. RISK ASSESSMENT

The first step of this assessment involves modeling the current relationship between hazard factors and vulnerability with the aim to explain the spatial variations in mortality at the city-district scale. At each city-district the product of vulnerability and hazard will result in the specific risk. Whereas specific risk expresses the probability of deaths associated with certain extreme weather frameworks, total risk refers to the product of specific risk and value. “Value” is defined as the values of human losses measurable as “years of life lost” – YLL (Campbell-Lendrum and Woodruff, 2007; WHO 2008; Ezzati *et al.*, 2002) (fig. 1). The ability to determine total risk (Zêzere, 2001) depends on the possibility of assigning a “value” to the loss associated with the hazardous phenomenon. We will follow the World Health Organization methodology that has established some measures of the relative importance of disease and death in society. The concept of YLL (calculated from the average life expectancy) seems adjusted to the developed risk model. The mathematical concept of total risk may also include an economic value per death registered.

The second step involves the modeling of variations in risk related to climate and environmental changes. The adaptive capabilities of the population and its resilience must be taken into account at the IPCC scenarios under consideration. They are essential for predicting the consequences of dangerous climate frameworks because they can

amend the components of exposure and sensitivity (Ebi *et al.*, 2006; McMichael *et al.*, 2006) as well as the hazard component.

The changes in meteorological conditions in LMA will be considered according to IPCC (IPCC, 2007) and SIAM II scenarios (Miranda *et al.*, 2006) as will the prediction of urban development and land use changes in the area. Changes in sensitivity and exposure determinants will also be simulated. The result achieved with this risk assessment methodology is a prediction of future impacts (intensity and patterns) of the heat waves on mortality.

The model description is not intended to be exhaustive in every detail that must be considered either in the selection of variables and/or indicators and indexes of the various aspects of vulnerability, or in the conceptualization of statistical and mathematical methods to establish the relationships between several variables.

As a theoretical model it should be modified and adjusted according to the study area, data availability, analytical techniques chosen and other constraints resulting from the application of the model.

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