Social Science & Medicine 83 (2013) 110–118

Contents lists available at SciVerse ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Exploration of health risks related to air pollution and temperature in three Latin American cities

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ARTICLE INFO

Article history:
Available online 20 January 2013

Keywords:
Risk society
Environmental justice
Urban vulnerability
Health impacts
Air quality and climate
Bogota
Mexico City
Santiago

ABSTRACT

This paper explores whether the health risks related to air pollution and temperature extremes are spatially and socioeconomically differentiated within three Latin American cities: Bogota, Colombia, Mexico City, Mexico, and Santiago, Chile. Based on a theoretical review of three relevant approaches to risk analysis (risk society, environmental justice, and urban vulnerability as impact), we hypothesize that health risks from exposure to air pollution and temperature in these cities do not necessarily depend on socio-economic inequalities. To test this hypothesis, we gathered, validated, and analyzed temperature, air pollution, mortality and socioeconomic vulnerability data from the three study cities. Our results show the association between air pollution levels and socioeconomic vulnerabilities did not always correlate within the study cities. Furthermore, the spatial differences in socioeconomic vulnerabilities within cities do not necessarily correspond with the spatial distribution of health impacts. The present study improves our understanding of the multifaceted nature of health risks and vulnerabilities associated with global environmental change. The findings suggest that health risks from atmospheric conditions and pollutants exist without boundaries or social distinctions, even exhibiting characteristics of a boomerang effect (i.e., affecting rich and poor alike) on a smaller scale such as areas within urban regions. We used human mortality, a severe impact, to measure health risks from air pollution and extreme temperatures. Public health data of better quality (e.g., morbidity, hospital visits) are needed for future research to advance our understanding of the nature of health risks related to climate hazards.

Introduction

Urban populations and activities play a crucial role in the arena of environmental change, not only as sources of atmospheric emissions, but also as epicenters of risks from exposure to such hazards as air pollution and climate variability, which are expected to be further intensified with global climate change. As a result of their concentrations of energy use (Grübler, 2004), urban centers are faced with high levels of air pollutants which, when combined with adverse weather conditions, negatively affect the health of their populations. Severe local weather conditions, such as heat waves caused by climate change, can exacerbate the impact on public health in urban areas. The aggregate of health impacts from air quality and temperature changes becomes especially critical in middle-income countries of Latin America due to such processes as urbanization, urban and territorial governance, and industrial and transportation growth. In fact, Latin America is one of the most urbanized regions in the world, with urbanization levels of 77.8 percent in 2005 (Winchester, 2007), a high level of urban primacy (i.e., a large percentage of a nation's urban population living in a single city), and high levels of socio-spatial segregation and inequality.

Latin American urban areas with their high levels of urbanization and uneven distributions of wealth and resources are, in short, faced with hazards and inequalities that naturally lead to the question of whether the health-risks related to air pollution and temperature are spatially and socio-economically differentiated within and across cities. This question reflects the famous remark by Ulrich Beck that while poverty is hierarchic, risks are ubiquitous, affecting everybody equally, and are, presumably, a matter of concern to everyone (Beck, 1986, 2002). However, other schools of thought call Beck's sweeping statement into question. For example, environmental justice and political ecology scholars have noted that different capacities to cope exist within and across urban

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http://dx.doi.org/10.1016/j.socscimed.2013.01.009

centers, and that some groups and municipalities within cities are more vulnerable than others because they have higher exposure to environmental hazards and lack the assets and options for risk reduction (Morello-Frosch, Pastor, Porras, & Sadd, 2002; Morello-Frosch, Pastor, & Sadd, 2001; Moser & Satterthwaite, 2010; Mythen, 2005).

This paper explores whether the health risks associated with temperature and air pollution are ubiquitous or spatially and socio-economically differentiated within three Latin American cities: Bogota, Colombia, Mexico City, Mexico, and Santiago, Chile. To achieve this purpose, the paper first discusses three major approaches to risks. It then characterizes the methods and data applied to explore health risks in an integrated way, and describes the climatic, atmospheric and socioeconomic conditions that make these three cities sources of high emissions and hotspots of vulnerability. The findings on the nature and linkages between main dimensions of health risks are presented, and finally the paper closes with remarks and reflections on the implications of the study.

Theoretical foundations

Risk refers to the possibility of loss, injury and other impacts (Thywissen, 2006). However, risk can also be defined as the probability of the occurrence of an adverse event and the probable magnitude of its consequences (Shrader-Frechette, 1982). Although a risk-analysis framework has been widely used by scholars exploring the existing and potential health effects of air pollution and temperature (Makri & Stilianakis, 2008; Peng & Dominici, 2008), risk research is still characterized by inter-disciplinary differences in definition and scope as exemplified by the 25 definitions of risk (Thywissen, 2006). In this paper, we refer to three relevant risk approaches: risk society, environmental justice, and urban vulnerability as impact (see also Romero-Lankao & Qin, 2011) as they relate to the question of whether the health risks associated with temperature and air pollution are ubiquitous or spatially and socio-economically differentiated.

The first approach to risk is given by the *risk society theory* (Beck, 1986). Ulrich Beck, its founder, identifies three periods of modernity. In the first stage, simple industrial societies of scarcity were created, where the central issue and key political challenge revolved around the distribution of (scarce) goods (equity). The second is a transitional stage between the first (simple) and the third (reflexive) era. In the reflexive stage, progress in science and technology becomes the central mechanism to increase the production of goods, and thus to reduce material needs. The same scientific and technological developments, however, are the source of "bads", such as climate change and air pollution, which are the negative byproducts of industrialization, creating risks and dangers of uncertain proportions. Although Beck acknowledges a relationship between the distribution of wealth and the allocation of risk, he also states that with the globalization and intensification of risks in the current – reflexive – era of modernity, the possibilities for wealthy sectors to escape from and compensate for risks diminish or even disappear, and a "boomerang effect" takes place. In other words, the rich cannot escape from the risks of being negatively affected by hazards. Because risks resulting from modernization processes cut through existing class or status boundaries, Beck concludes that while "hunger is hierarchical, smog is democratic" (Beck, 1986, p. 48).

Although compelling, the *risk society theory* has been criticized for having many theoretical and empirical inconsistencies in its interpretation of risk (Atkinson, 2007; Bovenkerk, 2003; Mythen, 2005). Rather than engaging in this debate, however, we will focus here on Beck's concept of a "boomerang effect," whereby air pollution, climate change and other "*bads*" that cannot be circumscribed by human boundaries will have an equalizing effect, because they have not been met with coherent policies that could effectively limit their pervasiveness and mobility. Left unchecked, these itinerant threats will inevitably affect previously protected affluent countries and populations, the same populations that have been the primary beneficiaries of the industries and activities that have produced the "bads" and their widespread environmental damage. Beck's "boomerang" therefore, is this return of the "bads" to affect those who produced them.

In contrast to Beck, the risk paradigm put forward by many *environmental justice*, *political ecology, and livelihoods* scholars underscores the influence of class and social differentiation not only on people's income, access to goods and services, health and quality of life, but also on their hazard exposure, sensitivity and capacity for managing risks and health outcomes (Atkinson, 2007; Morello-Frosch & Lopez, 2006; Morello-Frosch et al., 2002; Moser & Satterthwaite, 2010). Economic elites of urban areas are able to monopolize the best land, and reap the rewards of local environmental amenities such as clean air, safe fresh water, open space, and tree shade (Bovenkerk, 2003; Morello-Frosch & Lopez, 2006). For instance, intra-urban differences in temperature relate to affluence, and as poorer areas are more densely settled and have a smaller proportion of green spaces, they have higher mean temperatures, and thus, higher temperature risks (Harlan, Brazel, Prashad, Stefanov, & Larsen, 2006; Ruddell, Harlan, Grossman-Clarke, & Buyantuyev, 2010). Furthermore, studies have found that poorer neighborhoods are exposed to higher levels of air pollution (Morello-Frosch et al., 2002) and that the less financial, human, natural or social resources or assets people have, the more vulnerable they generally are to the multiple hazards they face (Moser & Satterthwaite, 2010).

However, as suggested by previous environmental inequality research, at times the relationships between socioeconomic differentiation and risk from exposure to air pollution can be quite unexpected, even when looking at intra-urban differences in exposure and access to assets. A study undertaken in Chicago for instance, has found that "all the rich, most of the poor…almost all of the black…population resides in areas violating primary long-term particulate standards" (Szasz & Meuser, 1997, p. 101). In a more recent study exploring differentiated air pollution exposures in California's South Coast Air Basin, Marshall (2008) found that for benzene, butadiene, chromium particles, and diesel particles, mean exposures are higher than average for nonwhite, lower-income households inhabiting areas with high population density. Yet, for ozone (a secondary pollutant whose dynamics depend on sunlight), the reverse holds.

From an *urban vulnerability as impact* perspective, risks can be understood as the degree to which exposed populations are susceptible to and unable to cope with adverse effects of global climate and environmental change (Romero-Lankao & Qin, 2011). Risk analysis in vulnerability as impact research relates to a series of analytical concepts and tools used to assess a given or possible health outcome associated with *exposure* to such environmental *hazards* as air pollutants and temperature extremes, particularly in urban areas of North America and Western Europe, and to a much lesser extent in Latin America and other developing regions (Romero-Lankao, Qin, & Dickinson, 2012).

Urban vulnerability as impact studies have found that the risks of adverse health impacts depend on two series of factors. The first relates to the nature of the hazards to which urban populations are exposed, while the second relates to socioeconomic conditions influencing exposure, sensitivity and capacity for responding to risk and health outcomes, which may reflect inequalities in environmental conditions or access to services and welfare systems