Sustainable Cities and Society 21 (2016) 35–50

Contents lists available at ScienceDirect

Sustainable Cities and Society

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

Environmental-conscious factors affecting street microclimate and individuals' respiratory health in tropical coastal cities

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A R T I C L E   I N F O

Article history:
Received 5 January 2015
Received in revised form
18 September 2015
Accepted 10 November 2015
Available online 2 December 2015

Keywords:
Urban microclimate
Urban heat island
Street geometry
Public health
Coastal cities
Environmental assessment

A B S T R A C T

The research aimed to identify environmentally-conscious factors affecting urban street microclimate compromising individuals' respiratory health. Thirty two environmentally-conscious factors have been investigated clustered into three clusters; Geometry, Meteorological, and Streetscape. Among thirty two factors, street orientation, material of ground and facades, distance to the sea, dust and atmospheric particles, air pollution, vegetation, and traffic load factors significantly compromise respiratory health. Wind speed received the highest risk severity value (0.44) among other factors; in contrast, Dust and atmospheric particles absorbed the lowest value (0.07). Risk severity matrix shows wind speed is located in high-risk zone and other factors in moderate-risk zone.

Contents

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http://dx.doi.org/10.1016/j.scs.2015.11.001

1. Introduction

Urban climatology is a science shared between urban designers and climatologists (Mills, 1997). The climatologists initially focused on macro-scale UHI (Urban Heat Island) issue and moved smoothly towards meso-scale urban geometry issues (Oke, 2004; Ali-Toudert & Mayer, 2005; Ali-Toudert & Mayer, 2006). The urban designers were more attracted to the impacts of the environmental forces on buildings, indoor climate of buildings, design strategies, energy requirements of supporting indoor comfort, and passive solar gains, since 1973s oil crisis (Givoni & La Roche, 2000; Markus, Morris, & Reed, 1980; Givoni et al., 2003; Ali-Toudert, 2005). The urban designers have also gradually switched to urban geometry issues associated with rapid urban development, especially, in coastal cities.

Urbanization can affect negatively to the environment; such as, urban heat island (UHI) effect, high level air pollution (Son, Kim, & Bell, 2015), and traffic burden (Maoh & Kanaroglou, 2007). For instance, the UHI effect can increase energy resource consumption, change humidity levels, and worsen air pollution (Saitoh, Shimada, & Hoshi, 1996; Tran, Uchihama, Ochi, & Yasuoka, 2006). In this reasons, the microclimate environmental issue of urban street has become to the major issue for both urban designers and climatologists (Asimakopoulos, 2001; Steemers, 2003; Takebayashi, Kimura, & Kyogoku, 2014). Previous studies indicate that several factors affect the microclimate of the urban streets, such as urban geometry, properties of surfaces (i.e. Surface Albedo—SA), surface and forms characteristics, and the vegetation (Andreou, 2013; Yahia and Johansson, 2013; Shashua-Bar, Tsiros, & Hoffman, 2012; Ali-Toudert & Mayer, 2006). The improper functions of these factors have increased the environment's harshness and global warming (Oke, 2004). Prior researchers express that street geometry is the most effective factor impacts on street microclimate changes (Yoshida, Tominaga, & Watatani, 1991; Nunez & Oke, 1977; Santamouris, Papanikolaou, Koronakis, Livada, & Asimakopoulos, 1999; Bourbia & Awbi, 2004; Ali-Toudert & Mayer, 2006), and residents' health (Ali-Toudert & Mayer, 2005).

Due to climate changes, global air temperatures are expected to rise with 0.2 °C per decade over the next century (Intergovernmental Panel on Climate Change—IPCC, 2007). Moreover, extreme weather events will be more common in the future. For example, heat waves will be stronger and they will last longer, especially in regions with tropical climate. Indeed, ever-increasing air temperature may increase occurrence of heat stress and heat-related diseases (D'amato, Liccardi, D'amato, & Cazzola, 2001). Furthermore, human performance of mental and physical tasks may diminish at uncomfortably high temperatures (WHO, 2013). Deaths and illness caused by air pollution tend to increase during extremely warm weather (Harlan, Brazel, Prashad, Stefanov, & Larsen, 2006; Reid et al., 2009; Tomlinson, 2012). Besides, climate change affects air quality by increasing carbon dioxide and ground level ozone and fine particle concentrations which amplify the allergenicity, lungs inflammation, and droughts (WHO, 2013). Hence, urbanization and climate changes can cause the public health problems, such as, respiratory and cardiovascular disease, severe heat stress, infectious diseases, injuries and premature deaths, as well as, mental health (Delfino et al., 2003; D'amato et al., 2001). Respiratory diseases are ranked third after cardiovascular diseases and cancers (World Health Organization, 2010). The World Health Organization (WHO) has managed for an urgent action to decrease the respiratory diseases globally, called the Global Alliance Against Chronic Respiratory Diseases (WHO, 2008). According to the World Health Organization (WHO, 2008), water-borne diseases account for about 1.8 million human deaths annually. The WHO estimates 88% of water-borne diseases attributable to unsafe water supply, sanitation and hygiene (WHO, 2008). "Using solid fuels such as wood, charcoal and crops is associated with increased mortality from pneumonia and other acute lower respiratory diseases among children, as well as increased mortality from chronic obstructive pulmonary disease, lung cancer and other diseases among adults" (WHO, 2013). Previous studies have found "a higher risk of asthma and lower lung function associated with traffic-related air pollution" (Shankardass et al., 2009). "The global burden of asthma is rising with 4.2 million adults and 1.1 million children" (Asthma UK, 2011). Therefore, the respiratory diseases have become more controversial issue because of increased extreme weather events, climate changes, low air quality (due to coastal runoff), and heat waves (D'amato et al., 2001). The researchers have attempted to mitigate the climate change's hazardous health impacts by reducing air pollution through greening the urban surface and rooftops, reducing travel demands, decreasing travel distances, providing non-motorized transportation models (i.e. walking or biking), and many other mitigation actions. However, these actions were not sufficiently successful in mitigating all urban microclimate related respiratory diseases. This problem is much more harmful in urban streets at coastal areas, where are also facing sea-related respiratory diseases.Since early 1990, the urban design and planning guidelines, as well as, some of the environmental modeling and simulation software tools (such as, Wave, Envi-Net, CFD, Watch III, WRF/MM5, PRECIS, and RegCM) have been developed for environmental impact assessment (de Schiller & Evans, 1998; Aynsley & Gulson, 1999; Golany, 1996; Emmanuel, 2005). A wide range of environmental factors have been covered in these guidelines and models, such as shade, urban form, and street orientation, building orientation, surface material properties, surface tempreture, etc. Aynsley and Gulson (1999) state rapid urbanization often implies the uncontrolled growth of cities through the formation of substantial informal settlement, within which the climate-conscious issues are often disregarded. Hence, the increased respiratory diseases in coastal cities persuade the urban climatologist and designers to investigate street micro-scale environmental-conscious factors that need to be significantly considered in both urban design and planning guidelines and environmental simulation software tools as well. The term environmental-conscious is defined as the strategies for more global green, environment-friendly and environment-adaptive design and development taken by urban design and planning authorities (Nichol, 1994). The environmental-conscious strategies have been applied in different approaches. For example, Weng and Yang (2004) have investigated the environmental-conscious of UHI in relationship with urban growth and urban forest/vegetation. Pearlmutter, Bitan, and Berliner (1999) has expressed environmental-conscious factors have to be considered in new cities localization. Oke (2004) has stated street design, the canyon geometry are the environmental-conscious factors influence urban climate. Sharmin, Kabir, and Rahaman (2012) have proposed urban environmental-conscious design solutions for thermal comfort. And recently, Yuminoa, Uchidaa, Sasaki, Kobayashi, and Mochidaa (2015) have published a research entailed "Total assessment for various environmentally-conscious techniques from three perspectives: Mitigation of global warming, mitigation of UHIs, and adaptation to urban warming" which identifies various environmental-conscious techniques for mitigation of global warming and UHI, and also, proposes several techniques to adapt with urban warming.

In fact, urban climatology has been studied broadly in moderate regions, primarily in cities with mid-latitude; however, in low latitude tropical climates fewer studies have been conducted (Ali-Toudert & Mayer, 2005). On the other hand, the urban population is believed to larger than the rural population worldwide by the year of 2020 (World Bank, 2010). This dramatic trend of population