Habitat International 71 (2018) 156–168

Contents lists available at ScienceDirect

Habitat International

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

Investigating the association of healthcare-seeking behavior with the freshness of indoor spaces in low-income tenement housing in Mumbai

Ronita Bardhan[a,*], Ramit Debnath[a,b], Arnab Jana[a], Leslie K. Norford[c]

[a] Centre for Urban Science and Engineering, Indian Institute of Technology Bombay, Mumbai 400076, India
[b] Department of Engineering, University of Cambridge, Cambridge CB21PZ, United Kingdom
[c] School of Architecture + Planning, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

ARTICLE INFO

Keywords:
Low-income housing
Built-environment
Indoor air quality
Healthcare-seeking behavior
Building simulation
Habitat policy

ABSTRACT

In this study, the strength of association of the subjective measure of the freshness of the indoor spaces and the health care-seeking behavior of the occupants was evaluated in low-income tenement houses of Mumbai. Mixed-mode research methods were employed, where the household survey data and feedback from local authorities regarding the health status of the occupants in the tenement housing were used to formulate the qualitative policy variable for assessing the built environment-health nexus. Multi-zone airflow modeling and simulations were performed to estimate the local mean age (LMA) of air, which subjectively indicated the 'freshness' of the space. The results show LMA was within the range of 5 min and 48 min, with the majority of units having an LMA range of 5 and 15 min. A parametric analysis of the site-based wind-flow characteristics stressed the need of early design interventions based on its orientation and obstructions, such that the natural wind flow characteristics of the site are optimally utilized for effective cross-ventilation in the living spaces. The health care-seeking behavior of the occupants for respiratory diseases was found to be infrequent in the units that had relatively higher fresh air exchanges. This study has larger implications in terms of creating a way-forward for the local authorities in sustainable renewal and rejuvenation of the low-income tenement housing in Mumbai.

1. Introduction

It is well acknowledged in the literature that the built environment (BE) has a significant relation to public health. These health-space interactions evolve over a life course that intrinsically links human-space interactions at the micro-, meso- and macro-level of the urbanization process (Sarkar & Webster, 2017). According to The World Bank, the BRICS countries will witness the next phase of world urbanization growth, to the extent that future urbanization will largely be a BRICS phenomenon (World Bank, 2016). Hence, any decision taken by these countries will largely impact global sustainability, livability, and public health. Additionally, given the socio-economic conditions of these nations, the future urbanites will face challenges of inequality, ecological damage, reduced green spaces, the housing crisis and resource depletion, ultimately leading to diminishing quality of life (QoL) (Bardhan, Kurisu, & Hanaki, 2015).

This study investigates the human-space interaction of the occupants of the low-income tenement housing in Mumbai, India. These houses, commonly known as 'chawls,' were constructed during the 19th Century as single-dwelling units for housing the industrial workers. They are one/two-room tenement apartments of approximately 18.58 m^2 in area, attached to a common corridor with shared toilets. Currently, pressures from urbanization have deteriorated these houses to 'slum'-like living conditions, affecting adversely the health and well-being of the occupants. The poor QoL of these dwellings is indicated by high levels of indoor air pollution, use of relatively dirty fuels for cooking, sick building syndromes and, lack of proper sanitation (Bardhan, Sarkar, Jana, & Velaga, 2015; Chafe et al., 2014; Goyal & Khare, 2011; Jackson, 2003; Jana, Bardhan, Sarkar, & Kumar, 2016; Kulshreshtha & Khare, 2010; MCGM., 2010; Yuan, Ng, & Norford, 2014).

The political, socio-cultural and technical needs of the local authorities and the occupants. Motivates the evaluation of BE-health in the chawls. Cross-sectional household surveys were conducted to investigate the health status of the occupants using the frequency of the visits to the health facilities as a surrogate for ill-health. The primary intention of the survey was to understand the health condition of the occupants from the perspective of BE and their space usage. The local authority enabled this assessment of the 'policy variable' of the study. The aim of this study is to highlight a latent problem in the low-income

* Corresponding author.
E-mail address: ronita.bardhan@iitb.ac.in (R. Bardhan).

https://doi.org/10.1016/j.habitatint.2017.12.007
Received 11 September 2017; Received in revised form 4 November 2017; Accepted 9 December 2017

tenement housing, where a large population is exposed to high pollution that can have potentially adverse effects on health. Objectively, this study intends to assess the strength of association of health-seeking behavior with a qualitative measure of air change effectiveness within the living spaces of these chawls. This will aid the authorities to undertake low-income BE sustainability measures while planning for urban renewal and rejuvenation. Because there is a lack of representation of this population and housing type in the existing literature, this study is potentially the first account of the BE-health nexus of such low-income communities of Mumbai.

2. Background

The lack of etiological evidence of the slum BE and health interactions acts as a bottleneck for sustainable low-income urban planning measures in Mumbai, leading to a higher occurrence of diseases pertaining to environmental pollution, sick building syndrome, and poor QoL (Bardhan, Kurisu, et al., 2015; Marten et al., 2014; MCGM., 2010; Rishud, 2003; Srivastava, Pandit, Sharma, Rao, & a, 2000). Additionally, the linkages between health determinants of the slum and chawl occupants and environmental factors are also not well represented in the existing literature. Thus, this study attempts to initiate a point of investigation for such type of habitats, who comprise more than 50% of Mumbai's population.

However, studies from other parts of the world provide evidence of strong linkages between BE and health, especially in those cities where industrialization demanded the need for tenement housing to accommodate the migrant worker population. In the U.S., Krieger and Higgins (2002) found that around 2 million people, mostly from city downtowns, make frequent emergency room visit for asthma and other BE-induced respiratory diseases. Similarly, in the tenement houses of Edinburgh, U.K., constructed in the 19th century, Stein (1950) found a strong association (R^2 = 0.678: C.I. 99.9%) between the occurrence of tuberculosis (TB) and sub-standard housing conditions. A strong correlation of mortality rate due to TB in the high-density tenement houses was also observed. Fonseca et al. (1996) found that in Fortaleza, Brazil, there exists a strong association (odds ratio = 1.05, 95% C.I.) between childhood pneumonia and poor living conditions.

Overcrowding and inadequate ventilation increase interior moisture and dampness, leading to the growth of molds, mites, roaches and respiratory viruses, which play a significant role in respiratory disease pathogenesis (Billings & Howard, 1998; Krieger & Higgins, 2002; Markus, 1993). Additionally, the deviation of indoor temperature from the recommended comfort ranges[1] has been found to cause cardiovascular diseases, frequent headache, body ache, and fatigue (Collins, 1986; Moonen, Defraeye, Dorer, Blocken, & Carmeliet, 2012; Salata et al., 2017). Poor ventilation of such low-income and high-density housing increases the probability of exposure to indoor smoke from cooking, burning of incense sticks, and mosquito repellents, which is manifested in headache, asthma, sick building syndromes, hypertension and neurodevelopmental abnormalities (Krieger & Higgins, 2002; Liu et al., 2003; Rosen, 1995). At neighborhood-level, the health effects include elevated rates of cardiovascular diseases (Diez Roux et al., 2001), tuberculosis (Graham Barr, Diez-Roux, Knirsch, & Pablos-Méndez, 2001), and depression (Schulz et al., 2000). The proximity of the dwellings to vehicular roads, bus depots, airports and trucking routes, was also found to contribute significantly to the deteriorated IAQ (Perlin, Wong, & Sexton, 2001; Sánchez-Soberón et al., 2015).

[1] ASHRAE recommends operative temperature range from 21 °C to 24 °C in the winter, and from 24 °C to 27 °C in the summer, with an indoor relative humidity to be kept under 65% (NIOSH, 2017).

3. Data and methodology

The negative health outcomes of a poor BE were evident from the reconnaissance survey of the chawls. These houses had spatial proximity to the arterial road with a high volume of vehicular traffic. Internally, the spaces within the houses were extremely cramped, with the kitchen accommodated within the living space and each floor having a block of shared toilets. Currently, the local authorities are attempting to upgrade the living conditions within this low-income tenement housing, as they observed an increased rate of health-facility visits by the occupants and suspected poor indoor air quality as a trigger for such behavior. However, they were unable to quantify the problem for prescribing possible solutions. Conventional survey methods ceased to be effective in such specific cases, as the occupants were extremely guarded in revealing information. They didn't approve of installation of any sort of sensors in their living quarters and were reluctant to provide detailed information about their health bills and energy usage. However, they agreed to provide information about the frequency of their healthcare visits in the locality, irrespective of the disease type, and this formed the basis of this study's investigation of the BE-health nexus. The variable of 'the frequency of the health visit of the occupants' was considered as a semi-quantitative indicator of 'health care-seeking behavior.' It was found that every surveyed household had at least one instance where the occupants sought health care in the past three months. an indication of the critical BE-health vulnerability of this chawl community.

The local authorities wanted a simple and binary indicator of this problem, which could be used as a possible policy variable for future urban renewal missions. They required a common BE air quality indicator that was easily perceivable by the occupants. Thus, the indicator of 'freshness of the space' was adopted in this study. The local authorities were keen on using this indicator as it was easily interpretable and explainable in the local language (Marathi). The freshness of the living space is represented by the local mean age of air (LMA), where higher values of LMA were undesirable (Etheridge & Sandberg, 1996; A K; Persily et al., 1994). The current literature identifies LMA as a subjective measure that can qualitatively represent the state of the IAQ (Bartak et al., 2001; Etheridge & Sandberg, 1996; Persily, 1996; Roulet, 2008; Sundell et al., 2011). This study intends to investigate the qualitative state of IAQ and its impact on the occupant's health, such that the local municipal authorities can successfully sensitize the chawl occupants to the importance of a continuous supply of fresh air in the living spaces.

LMA was calculated using steady-state Reynolds Average Navier Stroke (RANS) airflow modeling equations, which was solved using a standard k-ε turbulence model. The site airflow characteristics were simulated using EnergyPlus v8.3, which was coupled with the computational fluid dynamic (CFD) solver in DesignBuilder v4.7 to solve the three-dimensional continuity and mass equations. This method is widely verified and validated in the literature (Debnath, Bardhan, & Banerjee, 2017, 2016; Baharvand et al., 2013; Sánchez-Soberón et al., 2015). Debnath et al., (2016) have subjectively represented the effectiveness of rural kitchens in India in removing stale air using LMA. The authors found that the LMA profiles in the rural kitchen designs varied drastically, indicating the lack of standard design guidelines. However, they showed that the policy implications of such analysis in designing effective rural kitchens could reduce the pollution accumulation during cooking period by 60% through natural ventilation only. This case suggests that LMA can qualitatively represent the state of IAQ in the chawls.

Comprehensively, this study was carried out in three steps, where the first step involved understanding the problem intrinsically through field surveys of human-space interactions. This enabled the determination of 'freshness of space' as a critical policy variable (based on interaction with local authorities and occupants). The second step involved multi-zonal airflow modeling to determine LMA profiles. The