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The ecological city: considering outdoor thermal environment

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Abstract

The construction of eco-city is a hot spot nowadays, aiming to build harmony between human and nature. Ecological city is able to deal with the relationship between human and the environment, whose key point is to establish a comfortable outdoor thermal environment. To evaluate the built microclimate environment, a campus area located in Northwest China was selected. Different scenarios with extra greening, high albedo pavement materials, water body and their combinations were numerically analyzed through Universal Thermal Climate Index (UTCI) incorporated in the software ENVI-met V4.0. Results demonstrated that the scenarios with water body or high albedo materials was found to have little contribution to reduce UTCI, while the green scenario significantly reduced the UTCI peak (6.9℃) and also the duration (4.5 hours) of heat stress. The present study may be used as a guide for urban planning and construction for ecological city.

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Keywords: ecological city; universal thermal climate index (UTCI); ENVI-met simulation; outdoor thermal comfort

1. Introduction

With the improvement of the economic level, people's demand for outdoor thermal comfort is increasing. Global warming has a variety of effects throughout the world [1]. The environmental

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deterioration concentrates on urban heat island (UHI) effect; furthermore, the urban heat intensity influences remarkably the energy consumption of buildings [2]. Urban environmental quality has been influenced by complex and spatial dynamic factors, such as UHI, the distribution of greenery, building density, and air quality. The local microclimatic conditions can vary along with the site features, for example, urban density and morphology, surface properties, extent of vegetation, and sources of anthropogenic heat emissions [3]. Amongst the above-mentioned factors, greening, surface materials and water body are the three key factors for the outdoor thermal comfort, due to their strong effects on adjusting air temperature and remitting UHI effect [4].

Vegetation has been shown to play an essential role in ameliorating urban microclimates and it should be given fully consideration on urban planning and designing outdoor spaces [5, 6]. To explore the influence of green cover during summer on microclimate, Hamida bencheikh carried out field measurements in both green and built-up areas [5]. The investigation demonstrated that the oasis microclimate was able to improve thermal comfort and reduce cooling energy consumption and densely vegetated areas displayed higher cooling effect. For a better comfort of urban outdoor space, to explore bioclimatic strategies served to mitigate the atmosphere [6]. Based on the numerical simulation on the thermal environment of a densely populated neighborhood in Rome, Carnielo and Zinzi [7] found that thermal comfort was significantly influenced by the air temperature caused by different surface materials. Through utilizing Cool Asphalts (a kind of pavement material), they suggested, solar reflectance was dramatically increased, leading to reducing surface and air temperatures and mitigating the UHI [8, 9]. Recently, Taleghani at al. [10] explored the effects of courtyard vegetation, high albedo surfaces and courtyard ponds upon the outdoor thermal comfort by field measurements and simulations in a university campus environment (Portland, Oregon, USA) during a summer period. A difference of maximum temperature (16℃) was found for the courtyard with and without water pool.

To both qualitatively and quantitatively evaluate the outdoor thermal comfort, many indexes have been developed. Amongst them, Physiological Equivalent Temperature (PET) [11], Predicted Mean Vote (PMV) and Universal Thermal Climate Index (UTCI) are the three popular indexes. Compared with other indexes, UTCI was developed mainly for outdoor thermal comfort and it has shown better feasibility [12]. UTCI is very sensitive to changes in ambient stimuli and it describes temporal variability of thermal conditions better than other indices [13]. UTCI incorporated with ENVI-met (a commercial software) has been extensively exploited to evaluate urban microclimate.

The present study focuses on investigating the influence of the above-mentioned three key factors (greening, surface materials, water body) upon the microclimate in a built environment. Numerical simulations for five different cases were carried out in the selected university campus through a commercially-available numerical software ENVI-met. The outdoor thermal environment for these five cases was evaluated by UTCI and Mean radiant temperature.

2. Methods

2.1 Study area

This study was carried out in the context of the summer season in the city of Xi'an (a typical district in Northwest China), whose outdoor thermal environment has not been studied by UTCI. The study area is located at the Qujiang campus of Xi'an Jiaotong University (34.23 °N, 109.01 °E), as shown in Fig 1. The campus has a beautiful environment, and trees are planted on both sides of the road. The northern part of campus has a square for people to relax and entertain, and there is a pool on both sides of the square; there are parking lots in the south of the campus. The square, parking lots and a garden were separately selected for investigation.