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Editorial

Urban Heat Island and Mitigation Technologies in Asian and Australian Cities—Impact and Mitigation

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1. Introduction

Heat island is one of the more documented phenomena of climate change. It deals with increased urban temperatures compared to those of the surrounding rural or suburban areas [1]. Heat islands in low and mid-latitude areas increase the cooling load of buildings, thermal discomfort, pollution levels and heat-related illness. Studies have shown that urban heat islands (UHI) have an effect on pollution [2] and on human health [3,4] from. The World Health Organisation estimates that over 150,000 lives annually are affected by the trends towards temperature and precipitation increase [5]. The impact on the energy consumption of buildings and cooling energy consumption has also be documented [6,7], especially the peak electricity demand [8]. High temperatures have been shown to intensify urban pollution problems, especially the increase in ozone concentrations [2]. With the deteriorating outdoor thermal comfort conditions, the urban ecological footprint was affected [9].

Asian countries, according to the Population Division of the United Nations Department of Economic and Social Affairs, account for almost 60% of the world's population. Hence, with a much larger number of dense cities and a huge population in these Asian and Australian cities, the urban heat island phenomenon is attracting great attention in these cities and we must develop mitigation technologies accordingly.

A study by Santamouris [10] has analysed the heat island magnitude and characteristics in 100 Asian and Australian cities and regions. It was found that the magnitude of the UHI in Asian and Australian cities is significant, with the value varying between 0.4 K and 11.0 K. If the value is reported using mobile traverses and non-standard stations, it goes up to 4.1 K and 5.0 K, respectively; compared with the standard measuring stations method, the average annual intensity is 1.0 K, and the average maximum is 3.1 K. A study on the UHI in Southeast Asian cities was conducted by Kotharkar [11]. It was found that the cities of Delhi, Mumbai and Chennai in India, Dhaka in Bangladesh and Colombo in Sri Lanka were the focus of over 50% of the published papers in the representative sample. More studies on urban planning and the assessment of UHI impacts are crucial for mitigating UHI in South Asia.

Although UHI is a global phenomenon, studies have reported that the urbanization in Asian cities is responsible for the UHI, especially in tropical and subtropical cities, where UHI is superimposed on a generally hot or warm climate, leading to more serious implications for comfort, health, energy consumption, and greenhouse gas emissions [12,13], while studies show that the magnitude of UHI in tropical areas is usually smaller than that in temperate cities [14].

The maximum intensity time is also found to be a bit different in Asian cities. In most cities the maximum UHI intensity is observed during the late afternoon, night or early morning [15,16]. However, the maximum intensity is observed in many Asian cities during the daytime, with the increased release of anthropogenic heat as one of the main contributors. Studies from Japan shows the

Tokyo urban area's anthropogenic heat flux exceeding 400 W/m^2 in the daytime, and the value goes up close to 1590 W/m^2 in winter [17]. A study [18] on anthropogenic heat distribution in central Beijing found that the heat flux was between 40 and 220 W/m^2 in summer, and between 60 and 300 W/m^2 in winter [18]. A model by Narumi et al. [19] and Kondo and Kikegawa [20] simulated the addition of anthropogenic heat in Osaka and Tokyo and showed that the increase in urban temperature is about 1 °C for the two cities. A similar study by Ohashi et al. [21] and Kikegawa et al. [22] estimated a value of 1–2 °C from the impact of anthropogenic heat in Tokyo. Different studies have collected data on the relationship between the urban heat island, its associated thermal conditions, and mortality in Asian and Australian cities. The conclusion is that the mortality rate could be exacerbated by the UHI phenomenon [23,24]. An almost linear relationship between UHI intensity and excess mortality rate was demonstrated through a study of 30 years of data in Shanghai [3].

Looking to the intensity of UHI across Asian and Australian cities and its impact on the health, pollution, energy consumption, ecological footprint, etc., there is an urgent need to find mitigation strategies to help urban development follow a more sustainable route. Extensive mitigation techniques, including shading, highly reflective materials, ventilation, a decrease in anthropogenic heat, green infrastructure, solar control of open spaces, the use of environmental heat sinks and increase of wind flow, etc., are needed to counterbalance the heat island phenomenon [25–28]. Mitigation solutions look at different parameters affecting the UHI. The study by Deilami [29] reviewed the factors affecting the UHI intensity, identifying 37 different factors and ranking them in the reviewed literature. Two categories of solutions are widely developed: indoor solutions and outdoor solutions. The indoor solutions are investigated using technologies to reduce the anthropogenic heat from buildings or to reduce the building energy demand, which contributes to the anthropogenic heat emissions [30]. The waste heat from buildings due to electricity consumption to maintain acceptable indoor conditions can be estimated as the waste heat being rejected from buildings, with a lag between consumption and heat rejection [31]. Advanced technologies and strategies to improve the building energy efficiency and reduce building energy demand are widely applied to mitigate anthropogenic heat, hence mitigating the UHI effect [32]. Many studies have adopted retrofitting solutions to improve the energy efficiency of buildings [33–35], covering passive design solutions, active design solutions, and combined approaches. The outdoor strategies consist of four main approaches: (1) albedo modification to have better thermal properties of building and construction materials in urban areas; (2) application of greenery; (3) better urban ventilation; and (4) environmental management [36]. The first involves the use of more high-albedo materials in urban areas, so that more solar heat can be reflected rather than absorbed. This has been applied to building roofs, urban pavements, and road surfaces to mitigate the UHI in many studies [37–39]. Greenery was used to mitigate the UHI intensity with the rationale that green areas can moderate the number of impervious surfaces, which is positively associated with the UHI effect in urban areas. Studies have shown the application of greenery as urban parks [40], green roofs [41], street trees [42], or green facades [43]. The air flow in the urban area and between the rural and urban areas is also one of the parameters governing the urban heat island and has been studied [44,45].

2. The Special Issue

We are all aware that the UHI in cities affects human health and sustainability. Despite a lot of research progress in Asian and Australian cities, the situation in these areas is still complicated and worthy of investigation so we can develop mitigation technologies. The objective of this Special Issue is to look at the urban heat island phenomenon and mitigation solutions in cities. We collected and published scientific research in the areas of (1) urban heat island studies in Asian and Australian cities; (2) microclimate at the urban scale due to the urban heat island; (3) mitigation technologies; (4) performance evaluation demonstration and active intervention at an urban level; (5) big data solutions for remote monitoring, data analysis, and control/optimization for urban heat island study; and (6) case studies in Asian and Australian cities and best practice on mitigation solutions.

Following this guest editorial commentary, the Special Issue includes the following case study, review, and research papers:

Österreicher and Sattler look at how to maintain comfortable summertime indoor temperatures by means of passive design measures to mitigate the urban heat island effect. They conducted a sensitivity analysis of residential buildings in the city of Vienna. The key message delivered is to look into the waste heat generated because of the use of air conditioning systems, as it significantly contributes to the urban heat island effect (UHI) during the summer period. Hence, a series of passive design measures have to be adopted to mitigate this. The study examined different design scenarios to see how residential buildings in Vienna can limit the use of air conditioning systems under both the current and future climate conditions. The results of a case study also highlighted the potential passive design measures, with a comparison between the different variants. The results of the study show the possibility of using passive design measures without large additional costs so as to achieve adequate thermal comfort during the summer in residential buildings, even for future climate scenarios.

The study by Falasca and Curci on the impact of highly reflective materials on meteorology, PM10 and ozone in urban areas focuses on the use of highly reflective materials for urban surfaces. Numerical experiments by forecasting the weather, together with the CHIMERE model are applied to investigate the effects of these materials on the meteorology and air quality in the urban area of Milan, Italy. Results show that up to 2–3 °C of UHI intensity could be decreased by increasing the albedo of urban areas from 0.2 to 0.7.

The study also found that a decrease of the planetary boundary layer height, together with the effect from wind speed and the increased reflected solar radiation, may have a positive correlation with photochemical production during the daytime. An increase by a factor of about 2 is observed for PM10 and ozone concentration between urban and surrounding areas due to the reduction of planetary boundary layer height.

Polydoros, Mavrakou and Cartalis tried to quantify the trends in land surface temperature and surface urban heat island intensity in Mediterranean cities in view of smart urbanization. Eighteen-year time series data of the land surface temperature with respect to the spatial and temporal distribution in five cities were analysed to show the trend in this study. The land surface temperature values and trends were also examined for each city by taking into consideration the land cover characteristics and patterns. A positive land surface temperature was observed in urban areas, especially during the night-time, ranging from +0.412 K in Marseille to +0.92 K in Cairo. This also revealed that the surface urban heat island has intensified during the last 18 years; a magnitude of +0.332 K and +0.307 K was observed for Rome and Barcelona, respectively.

The study on urbanisation-induced land cover temperature dynamics for sustainable future urban heat island mitigation disentangles the spatial heterogeneous variations, considering the changes in land cover and land surface temperature to understand urban heat island effect dynamics. Urban land cover is among the fastest growing land cover types globally, which has a direct impact on the urban heat island. The complexities have not been investigated in detail, especially through temperature analysis studies of the urban heat island effect. Previous methods adopted oversimplification and did not consider the heterogeneity of urban surfaces as well as the land surface temperature dynamics. This study tries to use accurate spatial information pertaining to these land cover change—temperature relationships across space. The results show an annual daytime and night-time temperature change of 0.40 °C and 0.88 °C, respectively, when the land cover change from forest to urban is the greatest. Conversely, a change from grassland to urban area minimises the temperature change to 0.16 °C and 0.77 °C for annual daytime and night-time temperatures, respectively.

Jusuf et al. presented a study on a path to integrated modelling between IFC and CityGML for neighbourhood-scale modelling. A mapping framework with details and use cases has also been considered. Model visualization for web application is achieved through this study, together with the energy consumption application. In addition, a Sketchup file was used for the urban microclimate model, making the framework more robust.

3. Concluding Remarks and Research Directions

This Special Issue generates new insights by investigating the UHI effect and mitigation solutions from various disciplinary angles (i.e., urban simulation, urban planning, architecture, mechanical engineering, environmental science, etc.) and country contexts (i.e., Australia, the UK, Singapore, Greece, India, and Austria) as well as some comparisons.

In the light of the UHI-related matters discussed by the authors of the Special Issue, we compile the research questions from these studies, focusing on future research directions as follows:

(1) Automate the entire urban modelling process. Different kinds of special or external urban features should be considered.
(2) A more holistic study of the relationship between the reduction of temperature in the urban environment and its consequences for the reduction of emissions should be considered.
(3) A more accurate depiction of homogeneous urban areas is needed in order to decrease the variability of the land surface temperature trends.

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