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Experimental Study on the Influence of Urban Water Body on Thermal Environment at Outdoor Scale Model

Nedyomukti Imam Syafii[a]*, Masayuki Ichinose[a], Nyuk Hien Wong[b], Eiko Kumakura[a], Steve Kardinal Jusuf[c] and Kohei Chigusa[a]

[a] *Department of Architecture and Building Engineering, Tokyo Metropolitan University, Japan*
[b]*Department of Building, National Univeresity of Singapore, Singapore*
[c]*Sustainable Infrastructure Engineering (Building Service), Singapore Institute of Technology, Singapore*

Abstract

Urban Heat Island (UHI) has become a common urban problem that may lead to human health issues and increase in air-conditioning energy demand due to increase of air temperature. In order to reduce the UHI effect and improve the outdoor thermal environment is necessary to assess the effect of various measures. Water bodies' ability to regulate the microclimate arguably has the potential to mitigate the effect. Water bodies commonly found in urban area are usually described as a permanent or temporary collection of water in form of small stationary water or pond. These water bodies contribute to altering the surrounding thermal environment due to its cooling effect, either by evaporation or transfer of heat between air and the water. In real urban condition, however, the heterogeneity makes it difficult to assess the cooling benefits and to isolate the effects of individual parameter (such as shape, surface area, wind condition or solar radiation) under the complex physic process involved in the urban meteorology. As an alternative method, an outdoor measurement on a physically reduced scale model was conducted in summer. The outdoor-scaled model consists of an array of 1.5 m concrete cubes and able to recreate thermal pattern similar to the actual urban condition. A typical of commonly found water bodies in urban areas, pond, was installed in the scale model to have a better understanding on potential benefits of water bodies in urban area. In this paper, the author present initial findings on the characteristic of surrounding microclimate and its influential factors, particularly ambient air temperature near urban water body derived from the proposed approach. The experiment result shows interesting patterns, which generally shows cooling effect during the day and even though is limited it also happen during the night. Moreover, the present of more solar radiation and low wind conditions are found further enhance the cooling effect.

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* Corresponding author. Tel.: +818095370681.
E-mail address: nedyomukti@ugm.ac.id

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1. Introduction

Water bodies have the ability to adjust the surrounding microclimate. The temperature mitigating capacity of water bodies in urban environment can potentially reduce energy consumption, increase outdoor thermal comfort and mitigate the Urban Heat Island (UHI) effect. Air temperature near bodies of water is found different from that over land owe to differences in the way water heat and cool. Water bodies are known as the best absorbers of radiation, nevertheless show very little thermal response [1]. Owe to its transparency, large thermal capacity and volume, the incident solar radiation is able to transmitted to considerable depths and be spread throughout large volume. Together with unlimited water for evaporation, bodies of water create an efficient heat sink and further cool the surface layer. Furthermore, based on the energy budget point of view, more evaporation increases latent heat (Qh) and affects the energy partitioning of sensible heat (Qe) and the stored energy (Qs), in which reduction of Qe and decrease magnitude of Qs, make its immediate surrounding air temperature lower.

Study on the temperature reduction due to water bodies have been conducted by many researchers utilizing various methods. By remote sensing, researchers estimate the cooling effect by analyzing the surface temperature of different land use in urban area [2,3,4] and shows cooling effect of up to 5.63°C if urban wetlands are compared to urban area [3]. By collecting data from on-site measurement, Katayama found that the air temperature above the river was found lower than the nearby street when the sea breeze was blowing [5]. Yet, similar study shows a difference about 3-5°C in air temperature between the river and the city area on fine days in warmer seasons [6]. In the United Kingdom, England, another on site measurement study [7] on the microclimate around a small urban river show significant cooling over the river, with an average cooling of nearly 1°C during ambient conditions greater than 20°C which most likely happen during the hottest time of the day. Above a water pond, furthermore, the air temperature is found 1°C to 2°C lower than the average air temperature of the surrounding park during daytime and much lower with the introduction of water spray [8]. Likewise, field measurement study in Singapore found that water features, such as pond and water wall are able to reduce the air temperature up to 1.8°C during sunny clear day [9]. Using WRF (Weather Research and Forecasting) meso-scale model, Theeuwes found that bigger lake tends to have a higher influence within the city with the respect to wind direction, while smaller lake equally distributed, although have a smaller cooling effect, may influence a much higher percentage of the city [10]. A recent studies utilizing numerical simulation study shows that beside the ability to reduce the air temperature the presence of water bodies able reduce the energy consumption [11] and with additional vegetation, it will also provide better outdoor thermal comfort [12]. All of these researches show a clear evidence of water bodies modify the thermal environment by cooling down the surrounding air temperature through evaporation cooling and convection. However, most of these studies provided less information on the factors influencing the effects. Other than that, the effects of these factors are not fully understood yet in actual condition. Further research is needed to evaluate the effect of water bodies to its immediate surrounding within urban setting while finding the distinguish factors which may influence the effect. In the real case, finding an ideal condition for comparison purposes is difficult. Thus, this paper looks at the issues in more detail from studying the effect of water bodies on its surrounding thermal environment by utilizing a scale model, namely Comprehensive Outdoor Scale Model (COSMO).

The scale model was built with an objective to simulate an idealized urban thermal environment [13]. As it is located outdoor and it is simpler than the real urban condition, such a scale model has the advantages of observing various physical phenomena under real climate conditions and arranging comprehensive measurement on a relatively uniform area, thus, the result is easier to interpret. Yet, the scale model ability to recreate thermal pattern similar to the actual urban condition, shows the benefits of finding the impact of urban modification, especially water bodies, on street level thermal environment [14,15,16,17]. To clarify an evaluate the effects of water bodies on the thermal environment and the influence factor affecting the cooling effect of an urban canyon in typical summer days, an experimental study with a simple pond design, were installed inside the COSMO.