A New Method to Alleviate the Heat Island Effect by Reversibly Used Cooling Tower

Haifeng Guo, Junyu Deng, Yanli Song, Xin Chen, Cen Feng and Tianshu Zhang

ABSTRACT

With the accelerating process of urbanization, the heat island effect has become a hot spot of concern. The heat island effect seriously affects the city's thermal environment, energy consumption, and the health of the citizens. Therefore, how to alleviate the urban heat island effect has become the main direction of current scholars. This paper mainly introduces the causes and harms of the heat island effect. Reviews the strategies and research progress of mitigating the heat island effect in recent years, a new idea of reversibly used cooling tower to solve the heat island effect is proposed.¹

KEYWORDS

Heat island effect; Reversibly used cooling tower.

INTRODUCTION

The urban heat island is a phenomenon in which the urban temperature caused by the urbanization process is higher than the surrounding non-urban environment. The effect caused by the urban heat island (UHI) is called the urban heat island effect and is expressed by the heat island intensity, that is, the difference between the

¹ Haifeng Guo, Junyu Deng, Xin Chen, Cen Feng, Tianshu Zhang, Shenyang Jianzhu University, Shenyang, China, 110168
Yanli Song, Northeastern University, Shenyang, China, 110819
highest temperature in the central area of the city and the temperature in the suburb [1]. Wanphen & Nagano [2] found that the temperature difference between the city and the surrounding environment (rural) may be as high as 5-15 °C. Such temperature differences have been observed by experts, and they have proposed measures to alleviate the urban heat island effect. Figure 1 shows the distribution of daytime temperature in different regions of the city, indirectly explaining the existence of the heat island effect.

![Bar chart showing daytime temperature in various land use areas.](image)

**CAUSES AND HAZARDS OF HEAT ISLAND EFFECT**

(1) Human activities and emissions of exhaust gases (2) Low albedo of materials (3) Unreasonable urban layout (4) Reduction of urban vegetation coverage [4]. The harm caused by the heat island effect is divided into three aspects: human, microclimate, and energy consumption. From the perspective of humans, Wong [5] studied the relationship between heat island effect and mortality, found that high temperature weather is easy to breathe and cardiovascular disease, and mortality and temperature become a J-shaped function. From the perspective of microclimate, the increase of temperature in local areas seriously affects the local ecosystem, and the greenhouse effect is obvious [6]. In terms of energy consumption, with the heat island effect, in summer, in order to meet indoor comfort, air-conditioning energy consumption increases, resulting in more economic losses [7].

**HEAT ISLAND EFFECT MITIGATION STRATEGIES**

In recent years, with the major breakthroughs in related fields, there are many methods to alleviate the heat island effect. Many of them have been applied to
practical projects and have a positive effect on the heat island effect. The following are the most common. Mitigation strategies are summarized:

In his paper, Al Kaabi [8] studied the interaction between urban canopies and buildings with double façades (DSF) and found that DSF can reduce the heat gain of the building envelope. Susorova, I [9] studied the enveloping of plant layers on the outer layers of buildings, assessing the thermal performance and energy consumption of the opposite sides, and reviewing the different types of green exterior walls and living wall cooling processes. Barthel [10] developed a self-cooling concrete paver to replace traditional concrete with low thermal conductivity. Andrew A [11] investigated the potential of urban vegetation to alleviate urban microclimate warming and obtain vegetation sheltered buildings. The surface can effectively alleviate the heat island phenomenon. Matteos [12] found that the heat island effect in Sydney is related to urbanization. The heat island intensity is up to 6 °C. Increasing the city's albedo is the most effective method to achieve 3 °C reduction in environment. Konasova, S [13] assessed the efficiency of the green roof mitigating the heat island effect by monitoring the temperature in Rio de Janeiro and found that the temperature difference between the green roof and the reinforced concrete roof was 1.82 °C, which could reduce the city temperature.

Despite of the great reduction of ambient air temperature resulted by those mitigation strategies. They have few disadvantages. Although the double-walled exterior wall has good cooling performance, the construction cost is high, and there is also a phenomenon of overheating inside the wall [14]. For trees to be used to cover buildings, it is necessary to wait for the trees to form a certain size to function. Vertical greening can affect the aesthetics of the building and may attract biological groups that destroy the building [15].

**REVERSIBLY USED COOLING TOWER**

Due to these unstable factors, this paper proposes a new idea for everyone to study and think about. The reversibly used cooling tower is used to alleviate the heat island effect. The cooling tower uses water as a circulating refrigerant to absorb heat from a system to the atmosphere. Medium to reduce the temperature of the water. The reversibly used cooling tower is to exchange heat from the low-temperature water and the high-temperature outdoor air taken from the underground in the summer to obtain the air with reduced temperature, so as to alleviate the heat island phenomenon in the local area. The advantage is that it does not need to consider the limitations of external conditions, the cost is low, it does not affect the design of the building and aesthetics of the building. The groundwater with elevated temperature after exchange can release the heat into ground or used in other aspects. Principle of operation : when saturated humid air is in contact with cold water (Ta>Tw Pa>Pw). The humid air is cooled and some of the water vapor condenses. The water is pumped into the pipeline through the water pump, and the water droplets are evenly dropped into the packing through the spraying device. The high-temperature and
high-humidity air enters the tower from the bottom of the tower, exchanges heat and moisture with the water droplets in the packing, and the cooled air passes through the power of the fan. When it is discharged outdoors, the outdoor air is lowered. As shown in Figure 2. Combined with the experimental data of Zhang [16] on calculating the performance parameters of the counter-flow reversibly used cooling tower, it is found that the water flow rate $L_a$ and the air flow rate $G_a$ are equal to 1.48 kg/s and 9.2 kg/s, respectively, and the air temperature is 11.8 °C reduced to 9.8 °C, the water temperature increased from 7.3 °C to 8.7 °C, the characteristics of cooling effect is illustrated.

Figure 2. The schematic diagram of reversibly used cooling tower.

CONCLUSIONS

(1) Certainly understanding of the causes and hazards of the heat island effect, summarizing the methods of environmental heat island effect in recent years.

(2) The newly proposed method of reversibly used cooling tower to mitigate the heat island effect is validated.

REFERENCES

1. Oke T R. (1987). Boundary layer climate [M]. Cambridge: Great Britain at the University Press, 1-3.
2. Wanphen, S., & Nagano, K.. (2009). Experimental study of the performance of porous materials to moderate the roof surface temperature by its evaporative cooling effect. Building & Environment, 44(2), 338-351.
3. Jusuf, S. K., Wong, N. H., Hagen, E., Anggoro, R., & Hong, Y.. (2007). The influence of land use on the urban heat island in singapore. Habitat International, 31(2), 0-242.
4. M.E. Hulley. 2012. The urban heat island effect: causes and potential solutions[J]. Metropolitan Sustainability. 79-98.
5. Wong, Kaufui V.; Paddon, Andrew; Jimenez, Alfredo. (2012). Heat Island Effect Aggravates Mortality[J]. Proceedings Of The ASME International Mechanical Engineering Congress And Exposition, 2011, Vol 4, PTS A and B, 271-285.
6. Ningrum, W. (2018). Urban Heat Island towards Urban Climate. IOP Conference Series: Earth & Environmental Science. IOP Conference Series: Earth and Environmental Science.
7. Priyadarsini, & Rajagopalan. (2009). Urban heat island and its impact on building energy consumption. Advances in Building Energy Research, 3(1), 261-270.
8. Al Kaabi M (2016) Double skin façade as an Urban Heat Island mitigation strategy - case study of a health care facility in Abu Dhabi Thesis : Masdar Institute of Science and Technology
9. Susorova, I.. (2015). Green facades and living walls: vertical vegetation as a construction material to reduce building cooling loads. Eco-Efficient Materials for Mitigating Building Cooling Needs, 127-153.
10. Barthel, M., Vogler, N., Schmidt, W., & Hans-Carsten Kühne. (2017). Outdoor performance tests of self-cooling concrete paving stones for the mitigation of urban heat island effect. Road Materials and Pavement Design, 18(2), 11.
11. Millward, A. A., Torchia, M., Laursen, A. E., & Rothman, L. D., (2014). Vegetation placement for summer built surface temperature moderation in an urban microclimate. Environmental Management, 53(6), 1043-1057.
12. Santamouris, M., Haddad, S., Saliari, M., Vasilakopoulou, K., Synnefa, A., & Paolini, R., et al. (2018). On the energy impact of urban heat island in sydney: climate and energy potential of mitigation technologies. Energy & Buildings, 166.
13. Konasova, S. (2017). The efficiency of green roofs to mitigate urban heat island effect in Rio de Janeiro[J]. Advances and Trends In Engineering Sciences and Technologies II. 465-470.
14. Poirazis H . (2006). Double Skin Facade a Literature Review. Lund University, Lund Institute of Technology Department of Architecture and Built Environment.
15. Sharp R et al. (2008). Introduction to Green Walls: technology, benefits & design Toronto: Green Roofs for Healthy Cities.
16. Zhang, Q., Wu, J., Zhang, G., Zhou, J., Guo, Y., & Shen, W.. (2012). Calculations on performance characteristics of counter flow reversibly used cooling towers. International Journal of Refrigeration, 35(2), 424-433.