Healthy city versus the urban heat island effect in the context of global warming. Passive and active methods reduction of UHI

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The paper explores on the global and local factors that affect the thermal conditions in a city and consequently threaten the health and life of its inhabitants. The aim of the research is to identify factors contributing to the formation of an urban heat island. The results of studies were used to identify methods of risk mitigation and to evaluate their efficacy. The author divides the methods of preventing and limiting the urban heat island effect into passive and active solutions.

On a global scale, climate change is mainly characterized by an increase in temperature and intensification of atmospheric phenomena. In Poland, recent changes mainly concern the increase in temperature (by 0.60°C on average) and the increase in precipitation (up to 16%) [1]. The negative effects of climate change decrease the living comfort of the inhabitants and may even pose a threat to health and life. An alarming symptom of the deteriorating living conditions in the city is the increase in the number of alerts telling residents to stay at home due to heat, smog, storms, winds or floods.

Urban heat island (UHI)

The urban heat island problem has been studied by many authors [2]. The article presents UHI in the context of climate change. The worldwide increase in temperature and the number of hot days caused by global warming is further exacerbated by unfavorable processes that take place in urban areas, such as:

- the urban heat island effect characterized by a rise in temperature;
- a decrease in wind speed due to a dense blocks of buildings, which limits ventilation and cooling;
- an increase in exposure to solar radiation caused by sunlight reflected from glass facades;
- the generation of heat as a result of human activity.

The unnatural increase in temperature is a consequence of continuing urbanization. The urban heat island (UHI) effect occurs in urban areas in which temperatures are higher than the surrounding suburban areas. In large Polish cities, the highest recorded diurnal temperature range variations were 70°C, 90°C in Cracow, 90°C in Wrocław, 110°C in Warsaw and 120°C in Łódź [3].

There is a correlation between the general increase in temperature and the number of hot days caused by global warming and the local urban heat island effects and smog. This synergy has resulted in the deterioration of living conditions in the city thus increasing the direct threat to the health and life of its inhabitants (cardiovascular and respiratory diseases, cancer, allergies).

During the heatwaves of 2003 and 2010, tens of thousands of additional deaths were recorded in Europe [4]. Given a global temperature increase of 1.50°C, in a scenario of no improvement in adaptability, the projected heatwave-related mortality may increase by 162% for the working age population and by 87% for the non-working age population (the difference is due to the projected changes in the demographic structure) [5].

Passive reduction methods

Passive methods consist in modifications regarding the usage, the parameters and the layouts of buildings and spaces. The first step is to identify the possibilities of eliminating or reducing the causes of urban heat island formation. Adaptation actions should include modifications to those elements of the urban environment which may contribute to the problem. There are four main factors influencing UHI formation:

- surfaces and fabric – a large proportion of reduced-albedo, heat-absorbing fabrics that cover the area and the buildings and a small percentage of green areas that reduce thermal balance stability;
- urban geometry – multiplication and channelization of solar reflections in urban canyons and limited ventilation due to reduced wind speed and air stagnation [6, 7];
- anthropogenic factor – production of heat as a result of human activities, including industry, transport, heating and air conditioning [8].
- climate – urban greenhouse effect which increases the absorption, emission and re-emission of radiation while reducing long-term radiation [3] and global warming characterized by a general increase in temperature;

In this scenario, passive solutions consist in reducing the risk of UHI through the use of surfaces and fabrics that have higher albedo (reflectivity) and lower thermal conductivity (to reduce energy absorption), are porous and permeable (to increase water evaporation), or biologically active (greenery protects against heating and increases the cooling effect).

Passive methods also include such shaping of the environment which ensures, on the city scale, the protection and development of air regeneration areas and ventilation corridors, on the local scale, the optimization of street geometry and orientation, and on the micro scale, universal design (the facilitation of human activities), partial shading of

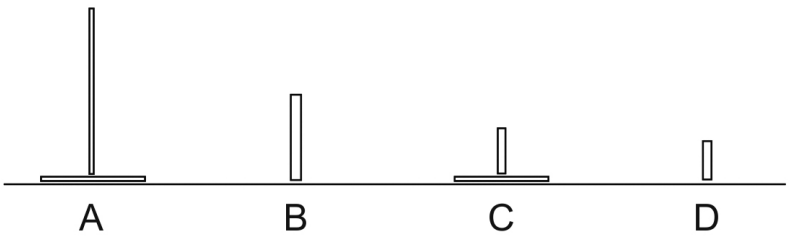

Fig. 1. Selected examples of wind towers. A) Manzanares solar updraft tower; height (m) 194,6; radius (m) 5,08 9,25; Collector radius (m) 122,0. B) Xi'an air purifier, height (m) 100,0. C) Wuhai solar updraft tower, height (m) 53,0; radius (m) 9,25; collector area (m^2) 6170,0. D) Masdar wind tower, height (m) 45,0

public spaces and reduction of energy and water consumption (thermo-modernization of buildings, retention).

Active reduction methods

Active methods of reducing the urban heat island effect can also be classified according to scale but large projects which cover an entire city are still being developed as theoretical models because they are unprofitable. Nevertheless, on the city scale, it is possible to identify actions that protect against heat stress through a monitoring and alerting system, combined with the promotion of safe behaviors and organization of crisis management.

Local-scale solutions include the use of new technologies that reduce anthropogenic emissions of heat (produced by manufacturing, transport, services, and air conditioners), as well as the design of complexes in which buildings and adjacent spaces function as partially or fully insulated habits with controlled temperature, humidity and air quality. On the micro scale there are many more forms of protection against heat but their scope is unavoidably limited. These actions include the use of sun-tracking shading systems, the development of blue infrastructure (fountains, water curtains, graduation towers, barrages, foggers, drink tap water and birdbaths), and the Venturi effect used when planning buildings.

Dense blocks of buildings are particularly susceptible to the urban heat island effect and a possible solution to this problem could be forced air circulation to exchange warm air with cooler air. The use of convection currents in construction dates back to Persia. The so-called wind towers caught wind through air intakes and were cooled by water evaporating from damp wall surfaces. The cooling effect can be increased by adding an underground canal (ground air collector) that connected the wind tower with a water reservoir located even several dozen meters away (Fig. 1.).

This principle has many applications not only in modern buildings, such as the Manitoba Hydro Place in Winnipeg, Canada, but also as a method of cooling public spaces to create thermal comfort zones.

Projects that deserve mention are those implemented in cities struggling with the problem of urban heat islands. What stands out are the interesting forms of three Climatic Trees built in 2004 in Vallecas Ecoboulevard in Madrid. The cold water sprayed from the top of the tower evaporates and absorbs energy from the incoming air, which then flows downwards and cools the area under the tower. This lowers the air temperature by up to 90°C.

Another example of a wind tower is the Foster & Partners project built at the Masdar Institute in Abu Dhabi (United Arab Emirates) [9]. The 45m tall tower forces the wind down producing the effect of ventilation. Circulation is enhanced by computer-controlled blinds that react to the wind blowing from the desert. The air intake surface is covered in teflon to reduce air friction and prevent moisture condensation. The spraying of water is also controlled by a computer.

Summary

On a large scale, in the urban environment, it is possible to direct the flow of energy and matter by means of layout, size, height, alignment and form of buildings as well as fabric [10]. The understanding of factors that are responsible for an increase in temperature can be useful in developing solutions that are designed to mitigate and counteract the effects of negative climatic phenomena typical for cities, such as the urban heat island effect. By appropriately utilizing natural convection on the urban scale (wind corridors) it is possible to produce the required air exchange, remove pollutants and cool the ventilated spaces. (Fig. 2.).

On the architectural scale, aerodynamic phenomena can be utilized to lower the temperature in thermal comfort zones (wind towers), create natural ventilation in buildings (atriums, double facades, air distribution boxes in ceilings, convection chimneys), heat up air drawn from outside (energy recovery using solar gains from glazing and pressure differences resulting from orientation or height) or produce a cooling effect (air and water curtains and ground heat exchanger).

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Abstract: As people become more environmentally aware they tend to pay greater attention to the quality of the environment when choosing a place to live. Given the ongoing and projected depopulation, in order to retain current residents and attract new ones, many Polish cities are taking actions aimed at shaping a healthy urban environment.

Regardless of the causes of global warming, the effects of climate change are indisputable and we need to adapt to them. This impact is particularly high in the urban environment due to population density and land use. The worldwide increase in temperature and the number of hot days caused by global warming is further exacerbated by unfavorable processes that take place in urban areas, such as the urban heat island effect (UHI). In combination with global warming an urban heat island poses a direct threat to people by putting them at risk of heat stress. Children and the elderly are particularly vulnerable to heatstroke.

The paper explores on the global and local factors that affect the thermal conditions in a city and consequently threaten the health and life of its inhabitants. The aim of the research is to identify factors contributing to the formation of an urban heat island. The results of studies were used to identify methods of risk mitigation and to eval-

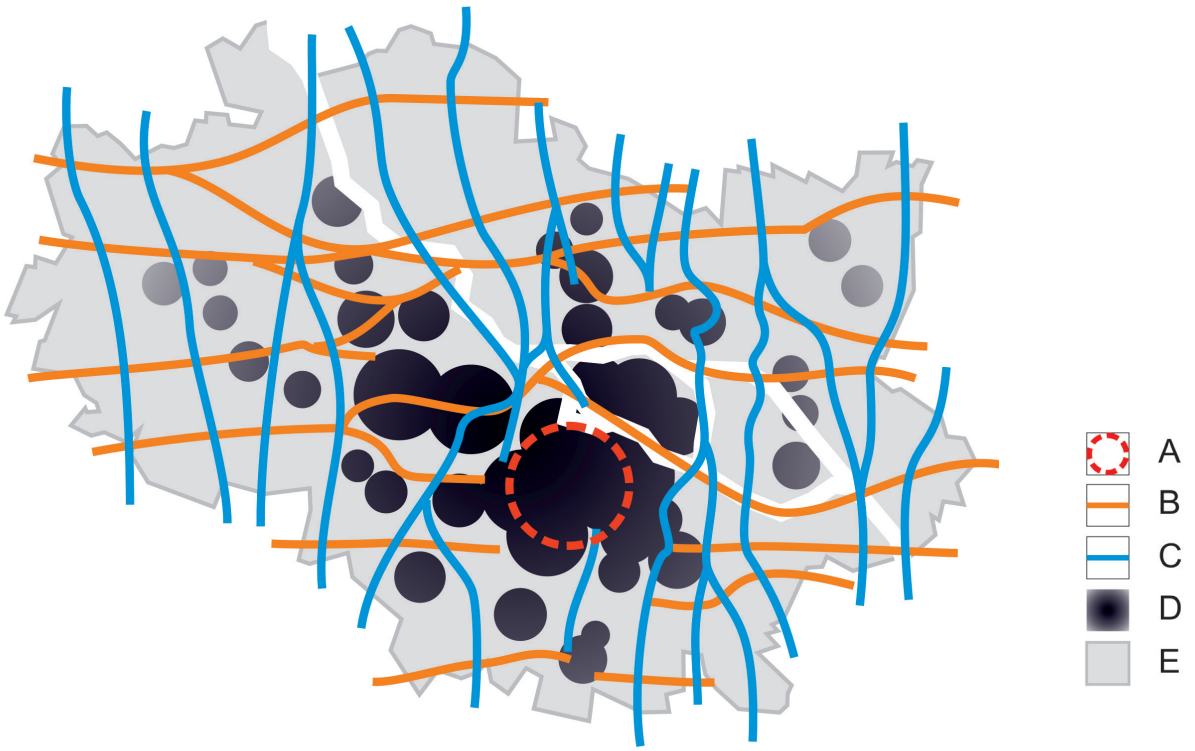

Fig. 2. Areas of occurrence of the UHI effect and ventilation corridors, based on the example of Wrocław. A) Unventilated urban heat island zone, B) Ventilation corridors from the west, C) Ventilation corridors from the north, D) Areas of occurrence of the UHI effect, E) City area

uate their efficacy. The author divides the methods of preventing and limiting the urban heat island effect into passive and active solutions.
Keywords: healthy urban environment, climate change, urban heat island

Streszczenie: ZDROWE MIASTO A PROBLEM MIEJSKIEJ WYSPY CIEPŁA W ASPEKCIE GLOBALNEGO OCIEPLENIA. PASYWNE I AKTYWNE METODY REDUKCJI MWC. Wraz ze wzrostem świadomości ekologicznej coraz częściej przy wyborze miejsca zamieszkania wpływ na decyzje ma jakość środowiska. Ze względu na obecną i prognozowaną depopulację w wielu miastach polskich, aby zatrzymać obecnych oraz przyciągać nowych mieszkańców, podejmowane są działania zorientowane na kształtowanie zdrowego środowiska miejskiego.

Niezależnie od przyczyn globalnego ocieplenia bezspornie skutki zmian klimatu występują i należy się do nich adaptować. Wpływ ten nasila się szczególnie w środowisku miejskim ze względu na gęstość zaludnienia oraz sposób zagospodarowania i użytkowania terenów. Negatywne zjawisko ogólnego wzrostu temperatury oraz zwiększenia liczby upalnych dni spowodowane globalnym ociepleniem jest intensyfikowane przez niekorzystne procesy występujące na obszarach zurbanizowanych, takie jak m.in. miejska wyspa ciepła. Stres cieplny jest bezpośrednim zagrożeniem dla ludzi, jakie stwarza miejska wyspa ciepła w połączeniu z globalnym ociepleniem. Na udary cieplne szczególnie narażone są dzieci i osoby starsze.

W pracy podjęto problematykę czynników globalnych oraz lokalnych wpływających na warunki termiczne miasta, a w konsekwencji zagrażających zdrowiu i życiu mieszkańców. Celem badań jest rozpoznanie czynników mających wpływ na powstawanie miejskiej wyspy ciepła. Wnioski z analiz wykorzystano do określenia metod redukcji zagrożenia oraz oceny ich efektywności. W pracy zastosowano proponowany przez autora podział na pasywne i aktywne sposoby ograniczania zjawiska miejskiej wyspy ciepła oraz zapobiegania mu.
Słowa kluczowe: zdrowe środowisko miejskie, zmiany klimatyczne, miejska wyspa ciepła