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The Urban Heat Island Effect: Causes, Health Impacts and Mitigation Strategies

What is an Urban Heat Island (UHI)?

The term "heat island" describes built-up areas that are hotter than nearby rural areas. The average air temperature of a city with 1 million people or more can be 1 to 3°C warmer than its surroundings. In the evening, the air temperature difference can be as high as 12°C (Oke, 1987).

About 80% of Canadians live in cities where the urban atmosphere is strongly affected by the design and density of buildings and by man-made changes to the urban environment. Urbanization negatively impacts the environment by the covering of the soil surface, the modification of the physical and chemical properties of the atmosphere (smog), and by the production of pollution being emitted from high road traffic.

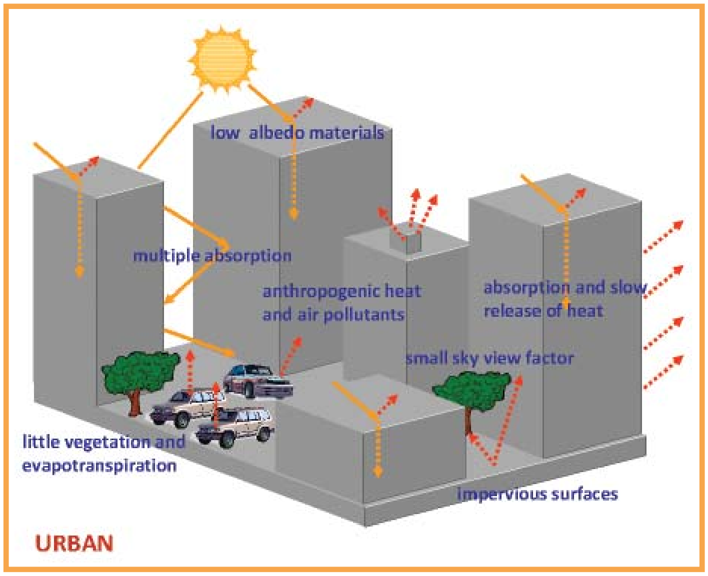
Heat islands can form over any built-up area, but especially occur over large cities where surfaces have a tendency to absorb large quantities of solar radiation during the day for later release at night.

What are UHI causes?

Natural surfaces, like vegetation, absorb a relatively large proportion of solar energy and use it through an evaporation process (release of water vapour) that helps to cool the air in the neighbourhood. By contrast, built surfaces are largely made up of non-reflective and waterproof construction materials. Consequently, they tend to absorb a significant proportion of the solar radiation, which is then released as heat.

When natural land cover, such as parks, is decreased and replaced by buildings, the cooling process through evaporation is reduced. As well, when rural areas that surround cities are urbanized, the atmospheric circulation systems that carry cooler air to city centres are restricted. These atmospheric cooling systems are normally generated by the temperature differences which exist between cool rural and warm urban environments.

Furthermore, the arrangement and size of buildings along narrow streets forms a so-called urban canyon that inhibits the release of the reflected radiation from urban surfaces back to space. This radiation becomes absorbed by the building walls. Paved roads, concrete sidewalks and parking lots also have a high tendency to absorb solar radiation and release it as heat.



Courtesy of J. Forkes, 2009

> ***Albedo*** (or solar reflectance) is the measure of a material's ability to reflect sunlight on a scale of 0 to 1. For example, a low albedo material indicates that its surface absorbs most of the solar radiation.

Additional factors have been recognized as potential causes of the UHI effect, such as atmospheric pollutants that intercept, absorb and re-radiate the solar radiation in the lower atmosphere, and the production of waste heat from air conditioning, industrial processes and vehicles.

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UHI health impacts

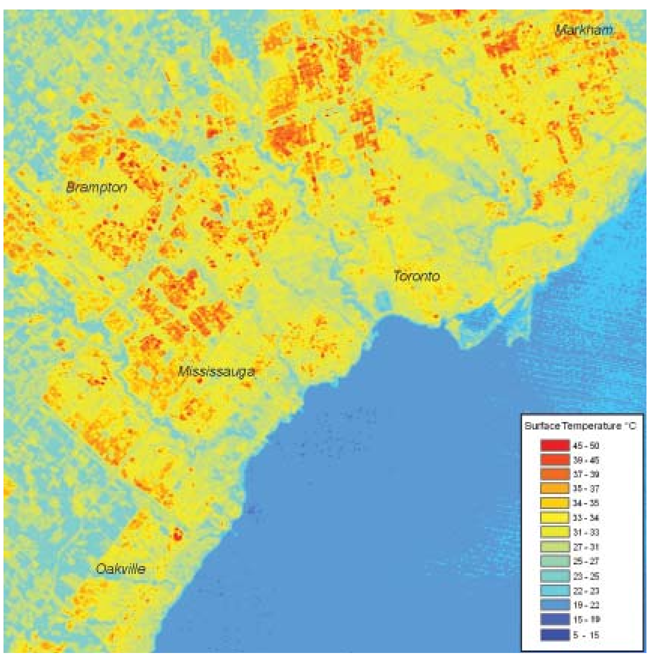
Extreme heat events (EHE), which can be defined as periods of abnormally hot and often humid weather, are dangerous to some and can result in increased rates of heat-related mortality and morbidity. The Centers for Disease Control and Prevention estimates that in the United States from 1979 to 2003, excessive heat exposure contributed to more than 8,000 premature deaths. This figure exceeds the number of mortalities resulting from hurricanes, lightning, tornadoes, floods, and earthquakes combined (Luber, et al., 2006).

By increasing day-time temperatures and reducing night-time cooling, heat islands can exacerbate the impact of EHEs. Populations who are vulnerable to heat, such as children, seniors, and people with chronic illness, are at particular risk of general discomfort, respiratory difficulties, heat cramps, exhaustion, heat stroke, and heat-related mortality. UHI also affects indoor thermal characteristics (such as air temperature, humidity and air movement), especially in buildings where air conditioners and mechanical ventilation systems are not available.

Measuring and localizing UHIs

UHI effects can be measured by two methods: (1) direct measurement of surface and/or air temperatures using sensors at fixed or mobile observation sites; and (2) indirect remote measurement using satellite and aerial sensors that detect radiation emitted by surfaces.

Greater Toronto Area—
Surface temperature map (2008-09-03)



Source: Natural Resources Canada, Earth Sciences Sector

Contact: Matthew Maloley, Natural Resources Canada

The surface urban heat island effect is observed as a temperature difference between surfaces such as roofs and tree canopies or open fields and parking lots. Satellite thermal images can be used to determine the location of "hot spots" in the urban environment (as illustrated in the map above). This information could be used as a basis for strategic implementation of UHI mitigation measures. However, the localization of these "hot spots" should be combined with information related to building characteristics and socio-economic factors to better protect at-risk populations by increasing their resiliency to heat.

UHI mitigation strategies

There are two main UHI reduction strategies: first, to increase surface reflectivity, in order to reduce radiation absorption of urban surfaces (i.e., achieve high albedo); and second, to increase vegetation cover, mainly in the form of urban forests and parks, in order to maximize the various vegetation benefits in controlling temperature rises.

Increasing the reflectivity of surfaces can be accomplished either by using lightly coloured construction materials or by covering the construction material surface with a white membrane. Both techniques have been applied mainly on roofs and paved surfaces. Currently, few Canadian communities have implemented policies or programs that will increase the use of high albedo materials in order to mitigate the UHI (Forkes et al., 2009).

Increasing vegetation cover is mainly focused on planting trees around residential and commercial buildings. Strategically placing trees in front of windows and on the sunniest sides of houses can maximize energy savings. Trees placed on the east and west sides of buildings are most effective because they block the sun both in the morning and the afternoon. Several Canadian communities have established Tree Planting Programs, for example, in Hamilton, Ontario, 2,100 trees have been planted on city streets since 2006; in Kelowna, British Columbia, from 600 to 1,400 trees are planted annually; and London, Ontario plans to have a tree in front of every home (Forkes et al., 2009).

Also, emphasis is being placed on roof top gardens (i.e., green roofs), in order to achieve the same result as lighter-coloured roofs. Recently, the City of Toronto, Ontario adopted a bylaw to require and govern the construction of green roofs on all new developments above 2,000 m^2 of Gross Floor Area.

The success and the efficiency of these mitigation measures depend strongly on the engagement and collaboration of a variety of partnerships such as municipal governments, public health authorities and provincial and federal governments. Awareness and outreach to a wide range of stakeholders, including the public, is a key element in the reduction of UHI effects.

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Urban Heat Islands, www.urbanheatislands.com

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