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MITIGATION PLANNING FOR URBAN HEAT ISLAND

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***Abstract*—The cumulative effect of all negative externalities, such as pollution, waste heat output from human activity, water stress, and so on, is exacerbated by increasing urbanisation. Significant vegetation is lost as cities and towns develop or expand, and urban surfaces are paved or covered with structures, resulting in less shade and moisture to keep urban regions cool. Cities with more built-up areas evaporate less water, resulting in higher surface and air temperatures. The degree of urban heat island effect is determined by the qualities of urban materials, which include solar reflectance, thermal emissivity, and heat capacity, as well as the ability to reflect, emit, and absorb solar energy, all of which contribute to urban warming also known as the Urban Heat Island effect. Mitigation of Urban heat requires control of urban geometry, generation of heat from sources like vehicles and industries, and green planning.**

***Keywords*—Urban Heat Island; Sustainability; Urban Planning; Mitigation.**

I. INTRODUCTION

Urbanization has gained more traction and more urban areas are being developed resulting in changes to the existing environment, building, roads and other supporting infrastructure due to rapid growth of the population. Open ground and vegetation in the form of permeable surfaces are replaces with concrete surfaces that are impermeable and dry by nature.

As a result of this development, urban heat islands occur in which metropolitan areas have warmer temperatures than their rural surrounds.

The purpose of this study is to provide an overview on urban heat islands, as well as the mechanisms that cause them, and to establish a broad conceptual component for reducing the effect of heat islands.

II. THE URBAN HEAT ISLAND EFFECT

Increased urbanisation exacerbates the cumulative effect of all negative externalities, such as pollution, waste heat output from human activity, water stress, and so on. As cities and towns grow and expand, significant vegetation is destroyed, and urban surfaces are paved or covered with structures, resulting in less shade and moisture to keep urban areas cool. Cities have more densely packed populations evaporate less water, resulting in higher surface and air temperatures. The properties of urban mate-rials, such as solar reflectance, thermal emissivity, and heat capacity, as well as the ability to reflect, emit, and absorb solar energy, all contribute to urban warming.

The factors related to urban design and buildings which are responsible for the higher temperatures present in urban areas.

A. Change in Land use

The removal of trees and green space for the purpose of Land development, as well as the addition of heat-absorbing materials, is a major cause of urban temperature change.

B. Green cover

Depending on the vegetation coverage, the evaporation energy de-creases from urban to rural area. This tends to increase heat stored and form UHI

C. Waste heat emission

Temperature is also raised by waste heat, mostly from energy use in buildings and vehicles. Waste heat emissions are significant to change the temperature in city cores on a weekly basis, however during weekends especially in the mornings, can have lower temperatures because fewer people are driving into and out of the city core.

D. Material used

Materials with high thermal conductivity tend to conduct heat to depths and materials with high heat capacity are able to store more heat in their volume. Large numbers of buildings and streets mean that a large proportion of the ground surface in cities is covered by impermeable materials such as concrete and asphalt. The original natural land cover may be preserved in lawns or parks, but usually occupies only a small part of the city area. The albedo of a city adds to increase in surface temperature, i.e., orientation, materials for roofs, pavements, etc.

E. Air pollution

UHI is amplified due to the effects of air pollution and vice versa. Warmer air (which contains more particulate matter) and reduced wind (which helps heat dissipate) are two factors that contribute to smog formation. This smog entraps heat causing higher temperatures.

F. Urban geometry

Urban geometry also has an effect on a community's net radiation levels. It includes: i) Average building height, ii) Site coverage ratio, iii) Façade to site ratio and iv) Spacing between buildings (density of built).

Temperature and heat distribution are influenced by the characteristics of a city and its buildings. The size and form of a city, as well as its texture—the pattern in which its streets and buildings are arranged—are important factors of UHI intensity. The urban heat island effect can be exacerbated or mitigated by a variety of building styles. Tall buildings, for example, provide shade (cooling effect), but they also trap heat between them, slowing or blocking wind speeds (heating effect).

III. IMPACTS OF EXTREME HEAT

Extremely high temperatures have immediate and long-term effects on individuals, the economy, and infrastructure. Higher temperatures caused by urban heat islands can have an impact on the environment and quality of life, especially during the summer as:

G. Health impact

Heat cramps, non-fatal heat stroke, and heat-related mortality are all effects of increased air temperature and pollution on human health. According to the Centers for Disease Control and Prevention, excessive heat exposure caused more than 800 early deaths in the United States between 1979 and 1999.

H. Economy

Owing to a variety of reasons such as changes in worker productivity, increases in health care expenditures, effects on agricultural production, and changes in consumption patterns can impact the economy of a city such as online shopping etc. Further, UHI can increase the consumption of energy for cooling needs, which require significant resources.

I. Infrastructure

During extreme heat events, high energy demand impairs power plant operations and transmission capability, potentially resulting in power outages. Heat may also cause deterioration of infrastructure such as buckling of roads or rail track and increase safety concerns.

J. Environment

Extreme heat makes other weather-related catastrophes like wildfire and drought more likely. Because of high temperatures, many plant and animal species have been impacted. Rising temperatures degrade storm water quality, harming aquatic species and making storm water and landscape management more challenging.

IV. MEASURES OF MITIGATION

K. Vegetation

An important UHI mitigation measure is to increase the amount of greenery in urban areas. Through the process of transpiration and shade, vegetation helps to cool the air. Green roofs and walls, as well as urban greenspaces, have been identified as two types of urban greening measures. Vegetation has an average cooling effect of 1–4.7 ◦C that spreads 100–1000 m into an urban area, but is highly dependent on the amount of water the plant or tree has available. An urban forest or a park is a green area within an urbanized environment. These areas have a lower air and surface temperature and thus form a PCI (Park Cool Island). By producing oxygen, capturing carbon, and reducing smog, which accumulates more as the temperature rises, trees improve the quality of the air. Plantation of trees also reduce CO_2 indirectly from the atmosphere since they help in reducing the demand for cooling, thereby minimising the pressure on power plants for electricity production. Indirectly, trees limit the emission of these precursors from power plants by reducing the combustion of fossil fuels, which in turn reduces NO_x emissions from power plants. Trees directly trap ozone precursors through dry deposition, a process in which ozone is directly absorbed by tree leaves.

L. Open water

Through evaporation and sensible heat transfer between the air and water, the presence of water bodies has the ability to mitigate the UHI impact. During the summer, aquatic bodies are thought to have the most effective UHI lowering impact. A study in Japan shows air temperature measurements on the leeward side of a fountain with a reduction of approximately 3 ◦C. The effect of the water system can be felt (from 14.00 to 15.00 h) up to 35 m distance.

M. Built form

The density and form of the structures are factors influencing UHI. The site shading factor has a strong influence on daytime UHI, low density urban form has higher daytime UHI. Wide streets and other open spaces enhance air flow, improving the ability to ventilate a city's interior and lowering temperatures. The orientation of streets in relation to the main wind directions is also of interest, as opening up streets to a river provides for a greater cooling impact than streets that are not connected to the river.

N. Material

The usage of cool materials has gained popularity as a way to reduce UHI. High solar reflectance (albedo), infrared emissivity, and porosity are all characteristics of cool materials. Materials with a low albedo absorb more solar radiation than those with a higher albedo (high albedo). This warms the surface, which warms the atmosphere eventually. In most of the urban areas, roofs and pavements constitute almost 60% of the land surface area. These surfaces especially the dark-coloured roofs, streets and pavements absorb the solar energy and transmit them inside the buildings and contribute to urban heat island effect. Albedo of the pavement and roofs should be increased in order to minimize the buildup of heat and keep the surfaces at low temperature. High-performance roof coating products, such as elastomeric and polyurea membranes, light-coloured tiles and gravel have higher albedos than conventional materials and more suitable for flat roofs. The albedo of pavement can be increased by adding reflective pigments to asphalt and concrete

O. Anthropogenic sources

Buildings and motorised vehicles consume energy, resulting in anthropogenic heat and water vapour emissions into the urban environment. Improvements in building thermal insulation and usage of passive cooling techniques can reduce the amount of energy required for air conditioning during the summer, resulting in a reduction in anthropogenic heat emissions from buildings.

V. CONCLUSIONS

With the increasing rise of urbanisation, the urban heat island and its effects are becoming more of a worry. It has a variety of effects, including increased energy consumption, negative health effects, air and water pollution, and so on. It must be adequately addressed by urban planners, and all mitigating measures, some of which are discussed in this paper, must be used to effectively minimise the urban heat island effect.

Planting specialised flora provides trees with shade and cooling capabilities, im-proving the thermal comfort of the outdoor space. Certain cool surface treatment processes aid in the reduction of ambient temperature. Despite all of the proposed solutions to minimise the Urban Heat Island, their effects are mostly localised. Mitigation planning requires both micro and macro level interventions to control the heat stress experienced by urban areas.

The SVF and Albedo characteristics of the place have a significant impact on the amount of radiation retained in the area. The amount of radiation trapped in the area causes the air and surface temperature to rise. The following measures, which alter the air temperature by 2-4 degrees Celsius and the soil temperature by 4-8 degrees Celsius, can reduce UHI. These solutions can effectively reduce the ambient temperature by counteracting the area's UHI effect. Initiatives such as high F.A.R with reduced MOS, the expansion of Urban Forestry, the use of high reflecting materials for horizontal and vertical surfaces, and cool roofing techniques should be encouraged and implemented to lower the possibility of UHI in the city.

Heat islands have a range of impacts which highlight the relevance of urban climates not just for local habitats but also for the planet's overall environment. Urban heat islands are small-scale phenomenon that encompass a small percentage of the Earth's surface. However, there are linkages between the urban and global scales that should be considered as well. An urban heat island mitigation strategy must be based on an integrated and multidisciplinary approach to urban development and re-quires the participation of various actors, particularly from the community concerned, as well as various sectors, for example public health, urban planning, municipal statutes, architecture, transportation and natural resources. Creating awareness, sharing information and knowledge among cities across the globe, concerning their achievements and the evaluation of their experiences is essential for optimal mitigation of urban heat island effect.

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