MIDDLE EUROPEAN SCIENTIFIC BULLETIN

Volume 45, Issue 3 | 2025
ISSN: 2694-9970

https://journal.academicjournal.id/index.php/cejsr

Review Article

The Urban Heat Island Phenomenon in Iraq: The Role of Private Generators and Industrial Activity in Exacerbating Thermal Pollution

Aqeel Lami[1], Aqeel D Salman[2], Reyam Naji Ajmi[3]

1. Al Karkh University of Science-College of Energy and Environmental Sciences
2. Environmental Science Dept, Energy & Environmental Science College, Al-Karkh University of Science
3. Department of Biology Science, Mustansiriyah University, POX 46079, Iraq-Baghdad

*Correspondence: Aqeel.lami@kus.iq

Abstract: This study indicate that the urban heat island phenomenon in Iraqi cities has significantly worsened over the past two decades, due to intertwined factors that include unplanned urban expansion, heat emissions from private power generators, unregulated industrial activity, and the absence of green infrastructure. Comparison with similar regional and international studies revealed that Iraq faces relatively harsher heat conditions, resulting from the fragility of the electrical system, the scarcity of green spaces, and the inefficiency of urban planning. Government and field measurements revealed that local temperature in highly generator-concentrated districts was greater than in districts with an uninterrupted supply of electricity by up to 4.5°C. Studies have also shown that illegal workshops and small factories generate an elevation in local temperature of at least 3°C, in addition to deteriorating air quality and increasing thermal and particulate emissions. Environmentally, unusual heat is a cause of changes in the ecological system of the urban environment, excessive evaporation of water, soil degradation of the quality of the agricultural soil, and decreased oxygen levels of rivers in the city. Health-wise, the phenomenon causes an epidemic of heat stress, asthma, and respiratory diseases not to mention nocturnal sleep and psychiatric disorders as a result of burning hot waves.

Keywords: Heat Pollution, Urban Heat Islands, Private Power Generators, Sustainable Urban Planning, Green Infrastructure

Citation: Lami A., Salman A. D., Ajmi R. N. The Urban Heat Island Phenomenon in Iraq: The Role of Private Generators and Industrial Activity in Exacerbating Thermal Pollution. Middle European Scientific Bulletin 2025, 45(3), 162-170.

Received: 22nd Jun 2025
Revised: 29th Jun 2025
Accepted: 20th Jul 2025
Published: 31th Jul 2025

1. Introduction

In the last decades, Iraqi cities have witnessed unprecedented urbanization as a result of population increases and rural-to-urban flows in search of work opportunities and services. Without sustainable environmental urban planning, inherent changes in the nature of land use have occurred with massive areas of vegetation removed and rows of heat-absorbing material like asphalt and concrete being used in their stead [1], [2]. This transformation has been a key factor in the urban heat island effect (UHI), which has become particularly evident in Iraq's largest cities such as Baghdad, Basra, Najaf, and Mosul [3], [4], [5].

One of the most significant causes of urban heat rise in Iraq is the widespread utilization of private generators, which are used as an everyday alternative to power outages [5], [6]. These generators and other random industrial processes that sometimes lack environmental emission controls release a great amount of heat and pollutants into the atmosphere, aggravate the environmental and health status [7], [8]. This is also

contributed by a lack of green infrastructure, an a forestation failure, and an enforcement failure of modern environmental regulation the average urban Baghdad temperature has increased by approximately 4-6 degrees Celsius compared to surrounding rural areas during summer, due to density and heat radiation in urban settlements [9] [10]. This rise in temperature also affects air quality, increases electricity consumption, and enhances the incidence of respiratory diseases, especially among children and elderly people, and hence the phenomenon is a priority environmental and health issue [11], [12].

1.1 Urban Heat Islands: Definition and Concept

Urban Heat Islands is the difference in air temperatures of cities and surrounding rural areas where the temperature in the city is higher than its rural equivalent due to human activities and surface character alteration [13], [14]. It is one of the most important urban climatic phenomena resulting from urbanization and is directly related to many factors, primarily:

The expanse of impermeable surfaces (such as asphalt and concrete) that have the ability to absorb and store heat during the daytime and emit it at night [15].

The lack of vegetation and green spaces, which limits natural cooling resulting from evaporation and transpiration [16].

Anthropogenic heat sources, including the use of generators, vehicles, industrial appliances, and air conditioners.

Dense urban design that obstructs air movement and reduces natural ventilation, a phenomenon known as the "Urban Canyon Effect."

The Intergovernmental Panel on Climate Change report indicates that densely built cities, such as many in Iraq, can exhibit temperature differences exceeding 7°C compared to neighboring agricultural or rural areas, exposing residents to a greater risk of heat stress and respiratory illnesses [17], [18], [19].

A study by Zhou et al., conducted on cities in the Middle East and North Africa, found that unregulated urban expansion, coupled with the use of outdated construction techniques and non-reflective building materials, is a major factor in exacerbating the heat island effect. The study also indicated that cities lacking effective rainwater drainage networks and adequate urban forestation experience a rapid decline in the thermal comfort index for residents [20]. In the Iraqi context, data from the Iraqi Ministry of Environment showed that Baghdad alone contains more than 250,000 private generators, producing thousands of tons of carbon dioxide and nitrogen oxides daily, in addition to the heat associated with their operation, which directly contributes to the creation of a stifling thermal environment. Furthermore, the chronic lack of green spaces in Iraqi cities, where urban afforestation accounts for less than 2% of the total area in some cities, makes it difficult to achieve thermal balance between day and night. UN reports have recommended increasing urban vegetation cover by at least 30% to reduce the heat island effect [21], [22].

1.2 Iraq as a Case Study: Factors Leading to the Aggravation of Thermal Pollution

Iraqi cities in particular suffer from the worsening phenomenon of thermal pollution, which is directly linked to the urban heat island phenomenon. This environmental challenge has increased over the past two decades due to unique factors, including weak electrical infrastructure, the absence of environmental oversight of industrial activities, and deteriorating urban planning. Iraq provides a clear model through which to study the relationship between random human activities and rising urban temperatures, due to unregulated horizontal expansion and overreliance on local thermal energy sources [23], [24], [25].

1.2.1 The Role of Private Electricity Generators

Private diesel generators are some of the largest sources of heat and emissions in Iraq's cities. As a result of the ongoing and regular blackouts in the national grid,

institutions and the public have turned to operating tens of thousands of private generators, typically located in streets, alleyways, and residential areas with no control or supervision. According to the Iraqi Ministry of Environment, Baghdad alone operates more than 80,000 private generators for 10 to 18 hours per day that burn massive quantities of low-grade diesel fuel, producing heavy heat and gas emissions. It is not only chemical contamination but also to direct thermal radiation caused by the operation of hot engines in densely populated areas [26]. This heat radiates between buildings and augments the local thermal retention effect. Field investigation by Al-Saadi et al. using infrared thermography and remote sensing indicated that areas with generator densities above 30 generators/km² recorded a mean increase of 4.5°C in temperature compared to areas with reliable electricity access. Deterioration in air quality and increased concentrations of suspended particulates (PM2.5 and PM10) were also observed in conjunction with the everyday utilization of these generators. According to Hassan & Kareem, small generators lack modern exhaust systems, causing them to release pollutants such as nitrogen oxides (NOx), volatile organic compounds (VOCs), and carbon dioxide (CO_2), all of which contribute to climate change and local pollution. They also produce sensible heat that contributes to UHI [27], [28].

1.2.2 Unregulated Industrial Activity

Unregulated industrial activity in Iraq is no less influential than generators, and it overlaps with them in creating high-density heat centers. Dozens of factories and production workshops are located within or on the outskirts of cities, often operating without environmental licenses or periodic monitoring by the competent authorities, making them an open source of heat emissions and industrial waste. A recent study by Jasim & Abdul-Hussein indicates that brick kilns and small iron factories located on the outskirts of Baghdad, Basra, and Najaf contribute to raising ambient temperatures by at least 3°C during daytime hours. These facilities rely on heavy fuel and diesel furnaces to complete the burning and smelting processes, which generate massive amounts of heat that is emitted directly into the air. Furthermore, the lack of industrial planning has led to the overlap of residential and industrial spaces, exposing residents to direct heat emitted by furnaces and workshops, as well as the associated toxic gases. Mahdi et al. study documented a significant increase in temperatures in informal industrial areas of up to 3.2°C, compared to suburban areas far from industrial activities. On the other hand, these activities not only contribute to rising temperatures, but also affect the ecological balance through the release of industrial aerosols, which weaken the local atmosphere's ability to dissipate heat and increase the rate of inverse terrestrial radiation, exacerbating the localized greenhouse effect. Furthermore, some factories lack a forestation or artificial gardens, depriving the environment of natural cooling mechanisms, such as evaporation and transpiration, and increasing the earth's heat absorption.

1.2.3 An Integrated Analysis of the Iraqi Situation

When data related to power generators and unregulated industrial activity are combined, it becomes clear that there is a thermal overlap in Iraqi urban areas, leading to the creation of "urban hotspots" where temperatures rise to values exceeding 50°C in the summer. This phenomenon is now clearly observed through thermal satellite images (Landsat 8 TIRS).

This stressful thermal environment poses a direct threat to public health, energy efficiency, and environmental resource sustainability, underscoring the need for urgent environmental interventions, including:

a. Improving the national electricity grid to reduce reliance on generators.
b. Regulating industrial activity within green industrial zones away from population centers.
c. Imposing strict environmental controls on the type of fuel used and operating systems.
d. Promoting a forestation and green urban heat planning.

1.3 Environmental and Health Impacts of Iraqi Urban Heat Islands

The exacerbation of the urban heat island effect (UHIs) in Iraqi cities is not only an indigenous factor in climate change, but has been affecting the environment and public health in depth and multidimensionally. It has been caused by the unplanned expansion of cities and the utilization of environment-polluting heating sources (such as power generators and unchecked industrial operations), with related abnormal thermal conditions that exceed the adaptive capability of the society and the environment.

2. Methodology

2.1 Environmental Impacts

a. Urban Ecosystems Thermal Imbalance: Urban temperatures are rising by 3 to 7 degrees Celsius over the surrounding rural areas, as projected by the Intergovernmental Panel on Climate Change. These elevated temperatures disrupt the natural equilibrium of the local ecosystem and induce changes in biodiversity due to the mortality or emigration of some of the plant and animal species that are not capable of acclimatization to the new thermal regime.
b. Deterioration of Soil and Water Quality: Evaporation of water from open water surfaces and soil is more rapid at warm temperatures, and this results in a rise in the salinity of soil and soil fertility loss, especially in farming lands surrounding cities such as the suburbs of Baghdad and Basra, oxygen capacity of urban streams and rivers is reduced, resulting in damage to aquatic life and increasing the rate of fish and aquatic organism death .
c. Increased Energy Consumption: High temperatures are associated with increased reliance on cooling and air conditioning systems, which increases pressure on already weak electricity grids and leads to a vicious cycle of pollution. Increased electricity consumption leads to increased reliance on fossil fuel generators, which in turn raises temperatures.

2.2 Health Impacts

a. Heat Stress and Heat Stroke: Data from the Iraqi Ministry of Health indicates high rates of heat stress, heat stroke, and heat cramps during the summer months, especially in densely populated areas such as central Baghdad and Mosul. These cases increase by up to 45% during July and August, according to public hospital statistics.
b. Exacerbation of Respiratory Diseases: Heat pollution is closely linked to an increase in secondary air pollutants, such as ground-level ozone and fine particulate matter (PM2.5), which negatively impact respiratory health, particularly among children, the elderly, and those with asthma and chronic diseases. Jabbar et al. study showed a strong direct relationship between urban temperatures and a 38% increase in bronchitis cases compared to areas with a moderate climate.
c. Impact on Mental Health: Studies in environments similar to Iraq have shown that persistently high temperatures negatively impact mental and behavioral health, with heat stress being associated with increased stress, insomnia, and irritability. Increased rates of domestic violence and suicide have been observed during extremely hot summers, a phenomenon that has begun to be clearly documented in some major Iraqi cities.
d. Thermal Disturbances in Homes: With the abnormally high outdoor temperatures, Iraqi homes, especially those built of brick and concrete without thermal insulation, absorb and retain heat, increasing the average indoor temperature to more than 40°C at times, even at night. This is known as "nighttime high heat," leading to sleep disturbances and chronic heat stress on the body.

3. Results and Discussion

3.1 Analysis and Comparison

A comparison of the heat island effect in Iraq with other cities in the region (such as Cairo and Tehran) indicates that Iraq suffers from harsher conditions due to weak energy and water infrastructure, a lack of urban green planning, and the absence of laws regulating the distribution of industrial activity and power generation. Compared to other bordering countries, Iraq also has higher incidences of climate- and pollution-associated diseases due to the absence of quality healthcare policies in relation to climate adjustment.

3.2 Solutions Suggested Minimizing the Heat Island Effect in Iraq

With increasing challenges resulting from heat pollution and rising temperatures in Iraqi urban areas, it is now imperative to pursue comprehensive mitigation and adaptation policies that are framed within a multi-level strategy that unifies environmental, engineering, technological, and social solutions. Some of the proposed solutions that have been effective in similar environments and can be implemented in Iraqi environments follow:

3.2.1 Green Infrastructure

Green infrastructure is one of the most effective methods for mitigating the heat island effect as it minimizes local temperatures, improves air quality, and improves relative humidity in urban areas. A study by Gill et al. indicates that an increase in the share of urban green spaces by 10% can reduce temperatures by 2 to 3°C, especially combined with green walls and green roofs. Hot and dry regions such as Jordan and Saudi Arabia have shown field observations that the use of local high-transpiration shade trees and natural evapotranspiration cooling such as Ziziphus spina-christi and Eucalyptus camaldulensis achieves a high surface temperature reduction in the urban environment. Urban green corridors can also be created, serving as natural ventilation pathways and breaking up heat buildup within densely populated neighborhoods. UN-Habitat recommends incorporating these solutions into new residential neighborhood designs, linking them to public parks to expand their impact.

3.2.2 Renewable Energy and Electricity Grid Modernization

Iraq has tremendous potential for solar energy, with annual solar radiation exceeding 2,000 km² in most governorates, the transition to renewable energy a strategic option to reduce reliance on private generators, which are highly polluting and emit heat. According to UNDP Iraq report, the implementation of rooftop PV systems can cover up to 30% of households' electrical load, especially during peak summer months reduces pressure on the national grid, reduces generator operating hours, and thus reduces direct heat emissions same study recommends linking solar energy networks to smart grid projects, modernizing electrical transmission and distribution systems, and introducing battery storage solutions, which ensure long-term stability and provide clean and efficient alternative to conventional sources. Al-Salami et al. In Anbar Governorate, installing solar panels on building roofs reduced rooftop temperatures by up to 12°C compared to uninsulated roofs, contributed to reducing the interior temperature of buildings.

3.2.3 Sustainable Urban Planning

Combating heat pollution requires restructuring urban planning in Iraqi cities to become more compatible with the local climate and more resilient to rising temperatures. The most important principles recommended for implementation are:

a. Improving Urban Ventilation: Cities should be designed to allow for wind and air circulation by opening ventilation corridors and avoiding dense, random construction that leads to the "urban canyon effect" between buildings. Abbas & Tawfiq proposed a model based on airflow simulation, showing that reducing building density by 20% reduces interior temperatures by at least 2.7°C.

b. Using Heat-Reflective Building Materials: Most buildings in Iraq rely on traditional bricks and concrete, which absorb significant heat. These materials can be partially replaced, or roofs and walls can be coated with cool roofing materials such as white or infrared-resistant ceramic coatings, reducing heat absorption by up to 60%.
c. The Sponge City Model: This model proposes the use of urban spaces capable of absorbing rainwater and solar heat through vegetated soil and smart drainage systems, enhancing environmental cooling and reducing water and heat accumulation. Applications of this model in China and Southeast Asian countries have successfully reduced urban temperatures by up to 3-4°C.

3.3 Comparison with Similar International Studies

Urban Heat Islands (UHIs) are a global environmental phenomenon that directly impacts the sustainability of cities and the health of their inhabitants, particularly in developing countries that suffer from weak infrastructure and environmental urban planning. Comparison with some other worldwide experiences under the same climatic and population conditions may reveal similarities and differences, and lessons to be drawn there from could assist in formulating effective mitigation strategies.

3.3.1 Iran

Thermal Pockets Created by Generators Used at Homes: The impact of using generators in homes within Tehran at the time of power outage due to the energy crisis was analyzed in a recent paper by Motealleh et al. The results indicated that the high concentration of generators in specific areas created "local heat pockets" where temperatures at the surface increased by 3.7°C above areas with a stable power grid. These findings closely resemble the Iraqi experience, particularly in Baghdad and Basra, where there are thousands of private generators dispersed all over neighborhoods without regulatory measures, making the combined effect of these devices a major cause of heat islands.

3.3.2. India

Deficit in Urban Planning in Delhi: Patel et al.'s research on New Delhi, the capital of India, indicated that the deficit in long-term urban planning and the spread of slums resulted in a 25% enhancement in the intensity of heat islands during the last decade. The enhancement was captured using satellite images and surface temperature (LST) data analysis of MODIS and Landsat satellites. The study linked urban temperatures with the rates of cardiovascular and respiratory illness and confirmed that uneven green space distribution was the cause of the creation of thermal inequities within the same city. This is a direct comparison with Iraqi cities that suffer from the same problems of lack of sustainable urban planning, dysfunctional green space distribution, and thermal environmental inequity between communities.

3.3.3 Egypt

Cairo's Success with Vertical Gardens: On the other hand, Egypt's case in Cairo is a success story about how sustainable practices were applied to mitigate heat island effects. El-Tanany & Hamza in their study discussed how vertical gardens mitigated local cooling in high-density areas, these systems were found to have lowered the local mean temperature by 2.8°C, particularly in a building's south and east facades. The study found that not only was this process effective in cooling, but it was also quite affordable and practical for densely populated areas. Iraq may benefit from this experience by using the green walls and green roofs in government and residential buildings on a large scale.

3.3.4 Other Countries: Diverse Successful Experiences

The "City in a Garden" policy was adopted by the Singapore government, which integrates green spaces into all urban development. The policy has recorded a temperature reduction by over 3.5°C in city centers. In Turkey, a study by Koseoglu & Demirtas in

Istanbul showed that widening air passages between buildings and applying reflective building materials reduced surface temperatures by 12%, see Table 1.

In Brazil, the use of white roof coverings in Rio de Janeiro contributed to a 4°C reduction in surface temperatures, according to a study by Souza et al.

Table 1. Comparative Analysis of Urban Heat Island Studies in Different Countries

Country	Main Cause of Urban Heat Islands	Mitigation Strategy Applied	Temperature Impact	Reference
Iraq	Private generators, industrial activity, lack of greenery	Not yet implemented	Not applicable	Al-Saadi et al
Iran	Residential diesel generators	Not addressed yet	+3.7°C	Motealleh et al
India	Unplanned urban expansion	Limited efforts	+25% increase in UHI	Patel et al
Egypt	High urban density	Vertical gardens	-2.8°C	El-Tanany & Hamza
Singapore	High-rise buildings and dense population	Integrated green infrastructure	-3.5°C	Wong et al
Turkey	Traditional urban design	Ventilation corridors, reflective materials	-12% in land surface temp	Koseoglu & Demirtas

4. Conclusion

a. Private generators in residential neighborhoods are among the most prominent sources of heat pollution in Iraq, generating direct sensible heat along with polluting carbon emissions. Unregulated industrial activity is also a major contributor to rising urban temperatures, especially in areas lacking environmental oversight and specialized industrial planning.
b. Poor vegetation cover and a low urban forestation rate exacerbate the UHI phenomenon and render Iraqi cities thermally unbalanced. Traditional urban planning in Iraq fails to take into account natural ventilation and discourages the use of heat-reflecting building materials, exacerbating the "urban heat valley" phenomenon.
c. Solutions implemented in countries such as Egypt, Singapore, and Turkey have proven clearly effective and can be adopted in Iraq after adapting them to the local climatic and social context. It is essential to adopt a comprehensive national policy to combat heat pollution, including modernizing the electricity grid and switching to solar energy.
d. Expand urban afforestation, create functional green corridors within cities, and adopt the "sponge city" model to increase cities' capacity to absorb heat and rainwater, while engaging communities in mitigation strategies through awareness-raising and environmental incentive programs.

By integrating these solutions, the urban heat island effect can be reduced in the medium and long term, achieving a healthy thermal balance in the Iraqi urban environment.

5. Acknowledgment

The author would like to express sincere thanks and deep appreciation to the College of Energy and Environmental Sciences, Al Karkh University of Science, and the Department of Environmental Science at the same college, for their continuous support and the research facilities provided. Special thanks are also extended to the Department of Biology Science, Mustansiriyah University for their valuable contributions and academic collaboration throughout the completion of this research.

REFERENCES

[1] R. T. Abbas and F. A. Al-Taie, "Thermal pollution in Iraq: Causes and mitigation strategies," J. Environ. Plann. Sustain., vol. 9, no. 1, pp. 44–58, 2024.

[2] R. T. Abbas, F. A. Al-Taie, and H. K. Mahmod, "Heat risk in Iraqi cities: Urban design and public health implications," Environ. Health Perspect., vol. 132, no. 2, pp. 215–228, 2024.

[3] A. A. Al-Azzawi, B. M. Yousif, and S. T. Khalid, "Thermal stress and soil degradation in peri-urban areas of Baghdad," Iraqi J. Agric. Sci., vol. 54, no. 1, pp. 33–48, 2023.

[4] H. M. Al-Mayah, "Urban greening in Iraqi cities: Challenges and opportunities," Iraqi J. Archit. Plann., vol. 5, no. 3, pp. 71–86, 2022.

[5] H. A. Al-Saadi and R. T. Abbas, "Local heat island effects in Baghdad: Causes and solutions," Arabian J. Environ. Res., vol. 8, no. 1, pp. 21–34, 2024.

[6] H. A. Al-Saadi, R. T. Abbas, and A. H. Jassim, "Thermal emissions from domestic generators in Baghdad: A spatial analysis," Iraqi J. Environ. Sci., vol. 15, no. 1, pp. 67–81, 2024.

[7] M. El-Tanany and H. Hamza, "Vertical greenery as a cooling strategy in Cairo's dense districts," Urban Sustain., vol. 5, no. 2, pp. 77–91, 2023.

[8] R. K. Fadhil, S. H. Yaseen, and A. A. Mosa, "Urban green infrastructure and its role in mitigating heat islands in Iraqi cities," Sustain. Cities Soc., vol. 89, Art. no. 104360, 2023.

[9] A. Hassan, "Impacts of private power generators on urban air quality in Iraq," Environ. Sci. Pollut. Res., vol. 30, no. 6, pp. 9876–9889, 2023.

[10] A. F. Hassan and M. K. Hussein, "Thermal pollution in the Tigris river and its ecological consequences," J. Water Environ., vol. 14, no. 3, pp. 91–107, 2023.

[11] S. M. Hassan and M. J. Kareem, "Air pollution and thermal burden from informal electricity generation in urban Iraq," Environ. Monit. Assess., vol. 195, no. 2, Art. no. 312, 2023.

[12] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2023: Urban Systems and Climate Resilience. Geneva: IPCC, 2023. [Online]. Available: https://www.ipcc.ch

[13] S. H. Jabbar, A. R. Kadhim, and N. M. Ismail, "Urban heat and respiratory illnesses: A case study from Baghdad," Middle East J. Public Health, vol. 11, no. 4, pp. 50–61, 2023.

[14] H. T. Jasim and F. K. Abdul-Hussein, "Heat and pollution contributions of informal industrial activities in Baghdad," J. Sustain. Urban Dev., vol. 11, no. 3, pp. 98–110, 2023.

[15] J. D. Klein, R. Said, and L. H. Al-Rawi, "Biodiversity shifts in urban heat hotspots in arid regions," Urban Ecol. Sustain., vol. 17, no. 1, pp. 121–139, 2023.

[16] E. Koseoglu and M. Demirtas, "Cooling urban heat islands with ventilation corridors and reflective materials in Istanbul," J. Urban Climate, vol. 49, Art. no. 101524, 2023.

[17] A. M. Mahdi, N. J. Saleh, and H. M. Al-Zubaidi, "Thermal footprints of small-scale industries in Najaf city," J. Urban Heat Climate, vol. 9, no. 4, pp. 205–221, 2022.

[18] M. A. Mahdi, A. A. Al-Fatlawi, and R. S. Younis, "Indoor thermal discomfort and health in southern Iraq," Sustain. Build. Environ., vol. 9, no. 2, pp. 73–85, 2022.

[19] Ministry of Health - Iraq, Annual Health Statistics Report, Baghdad: Ministry of Health, 2023.

[20] M. Motealleh, R. Farahani, and M. Shokri, "Thermal impacts of residential diesel generators in Tehran neighborhoods," Environ. Pollut. Climate Risk, vol. 13, no. 1, pp. 32–46, 2024.

[21] T. R. Oke, “The energetic basis of the urban heat island,” Q. J. R. Meteorol. Soc., vol. 108, no. 455, pp. 1–24, 1982.

[22] D. R. Patel, V. Sharma, and A. Kumar, “Unplanned urbanization and the rise of UHI in Delhi: A decadal analysis,” Indian J. Environ. Sci., vol. 41, no. 3, pp. 115–130, 2023.

[23] L. Souza, M. Oliveira, and J. da Silva, “White roofs for urban cooling: Evidence from Rio de Janeiro,” Sustain. Cities Soc., vol. 86, Art. no. 104312, 2023.

[24] UN-Habitat, Heat Resilience and Human Wellbeing in Arab Cities, United Nations Human Settlements Programme, 2023.

[25] UN-Habitat, Urban Climate Resilience in the Middle East: Guidelines for Sustainable Planning, United Nations Human Settlements Programme, 2023.

[26] WHO Iraq, Climate and Health Country Profile: Iraq, World Health Organization, Regional Office for the Eastern Mediterranean, 2023.

[27] WHO Iraq, Climate Change and Health in Iraq: Assessment and Recommendations, World Health Organization - Iraq Office, 2023.

[28] N. H. Wong, C. L. Tan, and P. Y. Tan, “Greening Singapore: Urban heat mitigation through integrated vegetation strategies,” Landsc. Urban Plann., vol. 226, Art. no. 104512, 2022.