E ISSN : 3024 - 9961
JOURNAL OF CLIMATE CHANGE SOCIETY
JCCS
https://jccs.ppj.unp.ac.id rccc.lp2m.unp.ac.id

SYSTEMATIC LITERATUR REVIEW: THE IMPACT OF URBAN HEAT ISLAND (UHI) ON AIR QUALITY

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ARTICLE INFORMATION

DOI : 10.24036/jccs/Vol2-iss2/38
Page : 75 - 84

Received : Nov 20, 2024
Revised : Nov 29, 2024
Accepted : Nov 30, 2024

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ABSTRACT

The Urban Heat Island (UHI) phenomenon causes an increase in temperature in urban areas, significantly impacting air quality and public health. This study aims to identify the causes of UHI, its effects on air quality, and to assess vegetation-based solutions for its mitigation. The method used includes a systematic literature review of 30 relevant articles on the impact of UHI on air quality, particularly its effects on human health. Data sources include articles published between 2019-2024 that are relevant to the study and have been cited more than 100 times. The results show that UHI can increase temperatures in urban areas by 5-10°C, worsen air quality by raising ozone concentrations, and affect public health, particularly among vulnerable groups. Tree planting and expanding green areas have been shown to effectively reduce temperatures by up to 3°C. The conclusion highlights that UHI mitigation through greening is an essential step to improve air quality and public health in urban environments. Policies supporting tree planting and the development of green open spaces are crucial for creating healthier and more sustainable cities.

KEYWORDS : Urban Heat Island, Air Quality, Public Health

INTRODUCTION

Air is one of the essential components for life on Earth, alongside soil and water. Every living organism requires air, making it crucial to monitor and maintain its quality. Air quality is an important indicator that reflects environmental health and its impact on human well-being. Worldwide, air pollution has become one of the most pressing environmental issues, with harmful effects on public health, ecosystems, and economies. According to the World Health Organization (WHO), poor air quality contributes to around 7 million premature deaths annually, particularly in countries with rapid urbanization[1]. In many large cities, air pollution levels often exceed set limits, potentially causing respiratory disorders, heart disease, and other long-term health issues[2].

One factor that has received increasing attention in the context of air quality is the Urban Heat Island (UHI) phenomenon. UHI is a natural phenomenon occurring in urban areas, where temperatures are higher compared to surrounding rural areas[3]. This topic has become a significant area of study

among climate researchers worldwide. The temperature difference between urban and rural areas can reach 3-10°C, and this phenomenon leads to an increase in urban temperatures, which in turn affects the timing and intensity of local rainfall[4]. UHI is usually caused by human activities, such as building densification, reduced vegetation, the greenhouse effect, population growth, increased construction using concrete infrastructure, excessive energy use[5], complex urban geometries, and the high thermal capacity of building materials[6]. These contributing factors interact over time, eventually causing urban areas to experience higher temperatures compared to surrounding open areas and those covered by natural vegetation.

Higher temperatures resulting from UHI can affect atmospheric dynamics and air quality. Studies have shown that increased temperatures from UHI can raise pollutant concentrations, such as ozone, which forms from chemical reactions between other pollutants under sunlight[7]. Additionally, higher temperatures can worsen the presence of fine particulate matter (PM2.5)[7] and volatile organic compounds (VOCs)[1], all of which contribute to deteriorating air quality. Moreover, UHI also leads to greater atmospheric stability, reducing air mixing, which traps pollutants close to the surface, further worsening air quality. If not addressed, the UHI trend is likely to worsen over time. UHI directly negatively impacts public health[5]. People living in areas with severe UHI are at higher risk of respiratory and cardiovascular diseases. This is due to increased concentrations of pollutants in the air, which raise the risk of respiratory problems, heart disease, and other chronic conditions. Additionally, poor air quality can affect work productivity, increase healthcare costs, and reduce the attractiveness of cities for investors and tourists. Therefore, a deep understanding of the relationship between UHI and air quality is crucial for formulating effective and sustainable policies.

Understanding UHI is vital for the public, and it is essential to conduct in-depth research that explicitly and comprehensively examines the impact of UHI on air quality. This systematic literature review aims to identify, analyze, and synthesize recent studies on the impact of Urban Heat Island (UHI) on air quality and public health. The study also aims to evaluate mitigation strategies proposed in the literature. A thorough review of previous studies is expected to provide deeper insights into the relationship between UHI, air pollution, and health, as well as recommend effective measures to reduce these negative impacts.

METHODS

This study uses a systematic literature review method aimed at identifying, evaluating, and synthesizing all relevant evidence from previous and current research related to the impact of UHI, particularly on air quality. The study utilizes findings from previous studies as primary data sources (Praveen & Sharma, 2019). The articles reviewed were obtained through a search on Google Scholar using keywords such as UHI, air quality, and air pollution. From this search, 17,800 relevant articles were identified, which were then filtered based on publication year (2019-2024), relevance to the topic, and citations (with more than 100 citations). Ultimately, 30 articles were selected as the primary data sources for this research. This approach was taken to ensure the relevance and quality of the studies included in the review. By prioritizing articles with over 100 citations, this study aims to ensure that only well-recognized research with significant contributions is included in the analysis.

The data collection process was carried out in three stages. First, a literature search was conducted using the defined keywords. Second, selection was based on the relevance of the articles to the

abstract and keywords. Third, articles that passed the initial selection were further analyzed to ensure they met the inclusion criteria[8]. The data obtained were analyzed by comparing the results and conclusions from each article to identify common patterns, differences, and research gaps. Validation was performed by comparing findings from various studies and evaluating the methodological quality of each study reviewed[9]. The key findings of this review are then reported under several themes, namely: the impact of UHI trends on air quality with a focus on public health.

RESULTS AND DISCUSSION

Results

1. *Search and Quality Assessment Results*

At this stage, article sources were searched using Google Scholar with the keywords: Urban Heat Island (UHI), air quality, and public health, applying a filter for articles that are relevant to the research and have been cited more than 100 times. The results of the search process can be seen in Table 1.

Tabel 1. Search Results and Quality Assessment

No.	Years	Referred to	Research Region	Indexed by Scopus	Titles
1	2023	145 times	US: New York and New Jersey	Q1	Urban heat islands and their effects on thermal comfort in the US: New York and New Jersey
2	2019	225 times	Rome, Italy	Q1	Regulating Ecosystem Services and Green Infrastructure: assessment of Urban Heat Island effect mitigation in the municipality of Rome, Italy
3	2019	109 times	Sivas City, Turki	Q2	The Impact of Land Use/Land Cover (LULC) Changes on Land Surface Temperature in Sivas City Center and Its Surroundings and Assessment of Urban Heat Island
4	2020	143 times	India	(Book)	Urban ecology and human health: implications of urban heat island, air pollution and climate change nexus
5	2019	145 times	Bucharest, Romania	Q1	Land Use/Land Cover changes dynamics and their effects on Surface Urban Heat Island in Bucharest, Romania
6	2021	158 times	Italy	Q1	Surface urban heat islands in Italian metropolitan cities: Tree cover and impervious surface influences
7	2022	130 times	Beijing, China	Q1	Urban Heat Island Studies with emphasis on urban pavements: A review

8	2020	643 times	Australia	Q1	Recent progress on urban overheating and heat island research. integrated assessment of the energy, environmental, vulnerability and health impact synergies with the global climate change
9	2020	178 times	Korea	Q1	Recent development and research priorities on cool and super cool materials to mitigate urban heat island
10	2019	304 times	North America	Q1	Urban heat island: Aerodynamics or imperviousness?
11	2021	186 times	Europe	Q1	Crowdsourced air temperatures contrast satellite measures of the urban heat island and its mechanisms
12	2022	145 times	Global	Q2	Urban Air Pollution, Urban Heat Island and Human Health: A Review of the Literature
13	2021	378 times	Global	Q1	On the linkage between urban heat island and urban pollution island: Three-decade literature review towards a conceptual framework
14	2021	127 times	US	Q1	Cool pavements for urban heat island mitigation: A synthetic review
15	2020	149 times	Global	Q1	Green Infrastructure as an Urban Heat Island Mitigation Strategy—A Review
16	2020	191 times	Nanjing, China	Q1	Impact of urban heat island on energy demand in buildings: Local climate zones in Nanjing
17	2020	139 times	Singapore	Q1	Mitigating intensity of urban heat island by better understanding on urban morphology and anthropogenic heat dispersion
18	2021	170 times	Asia	Q1	Study of the Urban Heat Island (UHI) Using Remote Sensing Data/Techniques: A Systematic Review
19	2019	272 times	China	Q1	Influences of urban spatial form on urban heat island effects at the community level in China
20	2020	195 times	North of Beijing, China	Q1	Modeling the impact of 2D/3D urban indicators on the urban heat island over different seasons: A boosted regression tree approach
21	2021	115 times	Seoul, Korea	Q1	Exploring the relationship between particulate matter, CO, SO2, NO2, O3 and urban heat island in Seoul, Korea

22	2019	200 times	China	Q1	Impacts of urban configuration on urban heat island: An empirical study in China mega-cities
23	2019	260 times	Global	Q1	Towards the next generation of green building for urban heat island mitigation: Zero UHI impact building
24	2019	136 times	Lebanon	Q1	Impact of urban heat island mitigation measures on microclimate and pedestrian comfort in a dense urban district of Lebanon
25	2019	219 times	China	Q1	The footprint of urban heat island effect in 302 Chinese cities: Temporal trends and associated factors
26	2021	103 times	Pakistan	Q1	Environmental impacts of shifts in energy, emissions, and urban heat island during the COVID-19 lockdown across Pakistan
27	2020	106 times	Tehran, Iran	Q1	Numerical assessment of the urban green space scenarios on urban heat island and thermal comfort level in Tehran Metropolis
28	2020	150 times	United States	Q1	A spatially explicit surface urban heat island database for the United States: Characterization, uncertainties, and possible applications
29	2021	114 times	Singapore	Q1	Interaction between heat wave and urban heat island: A case study in a tropical coastal city, Singapore
30	2021	108 times	Global	Q2	Urban Heat Island: Causes, Consequences, and Mitigation Measures with Emphasis on Reflective and Permeable Pavements

2. Results of Selection Based on Inclusion and Exclusion Criteria

A comprehensive literature search was conducted using the keywords "Urban Heat Island (UHI), Air Quality", and "Public Health". The initial search with the keyword "UHI" resulted in approximately 1,650,000 related articles. To narrow down the results, the search was limited to articles published between 2019 and 2024, yielding 16,100 articles. Further refinement was done by adding related keywords to better focus on the impact of UHI on air quality and public health. This resulted in around 14,000 articles more directly related to the topic. These articles were then sorted based on relevance to ensure that the most pertinent studies were selected. The final filter applied was based on citation count, selecting articles that had been cited more than 100 times. This process resulted in a selection of 30 articles with the highest rankings. The search was conducted using Google Scholar, with priority given to articles indexed in Scopus, MDPI, Elsevier, or Springer, which are recognized as reputable

publishers and journals in the field of scientific research. This approach ensured the quality and credibility of the articles included in the review, providing a comprehensive overview of the impact of Urban Heat Island on air quality and public health.

Discussion

The Urban Heat Island (UHI) phenomenon has gained global attention due to its significant impact on the quality of life in cities. This study reviews 30 articles related to UHI, exploring its definition, causes, effects on air quality and public health, as well as vegetation-based solutions in urban areas.

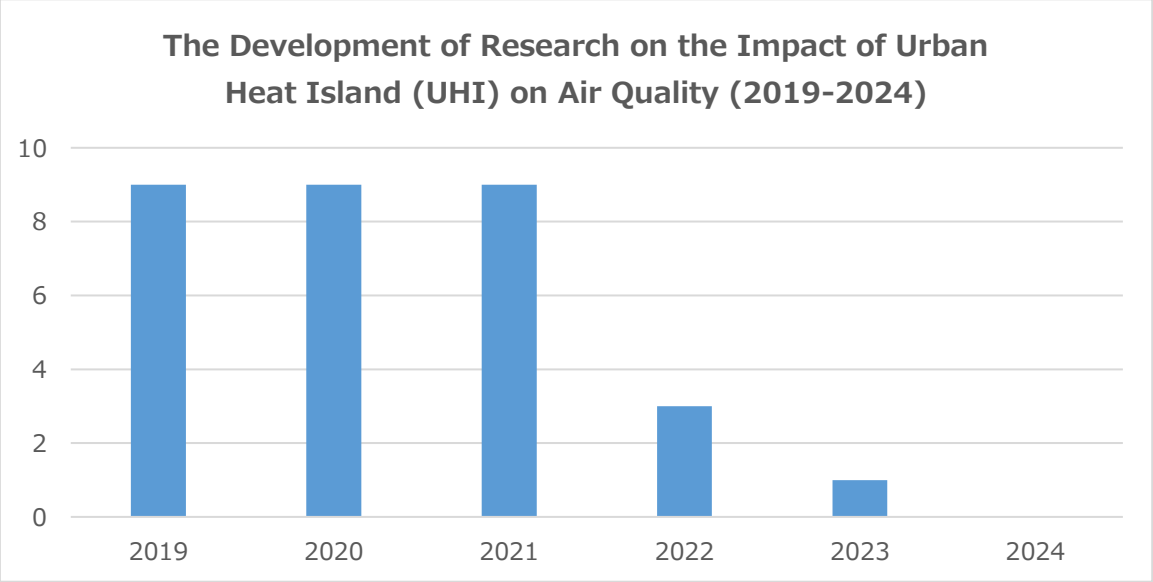

Figure 1. Graph of The Development of Research on the Impact od UHI on Air Quality form 2019-2024

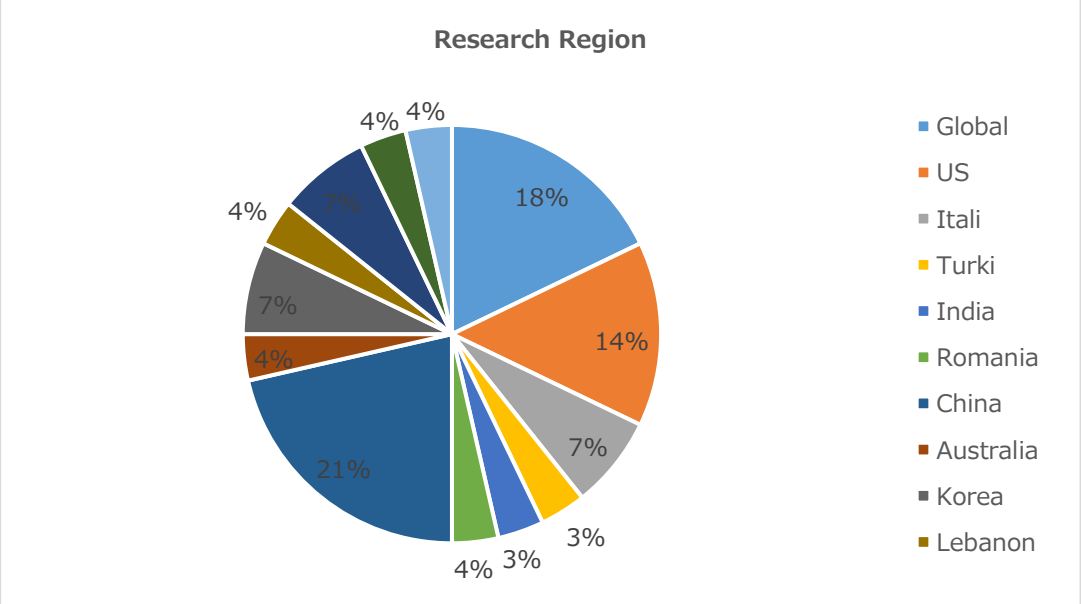

Figure 2. Distribution of Research Areas

Based on Figures 1 and 2, it is evident that in the past five years, the number of studies on the impact of Urban Heat Island (UHI) on air quality and public health has increased significantly. This reflects growing attention to the complex environmental issues caused by rapid urbanization and climate change. Various studies have explored the relationship between rising temperatures in urban areas, declining air quality, and health risks such as respiratory diseases, cardiovascular issues, and heat-related health problems. A significant concentration of research has been conducted in China, which is experiencing major impacts due to massive urbanization and industrialization. This increase in research is driven by the urgent need to find effective solutions, including the development of green infrastructure, sustainability policies, and adaptive urban planning. This trend shows that the topic has become a significant concern in both academic and global policy fields.

Urban Heat Island (UHI) is the phenomenon where temperatures in urban areas are higher compared to surrounding areas[10]. The primary causes of UHI include building density, the use of heat-absorbing materials[11], and the reduction of vegetation[12]. UHI results in significant temperature differences, often reaching 5°C to 10°C, particularly during the night in major cities like Los Angeles and New York[13]. UHI can alter local climate patterns and affect energy consumption in cities. During hot months, the increased demand for cooling energy can rise by 20-50%, contributing to higher energy costs and greenhouse gas emissions[14]. As temperatures rise, energy demand for cooling also increases, which impacts greenhouse gas emissions and air pollution[15].

UHI is directly related to increased ozone (O3) concentrations, with each 1°C increase in temperature raising O3 levels by 5-10%[13]. This means that the higher the temperature, the more chemical reactions occur, producing more ozone. Ground-level ozone (tropospheric ozone) forms through chemical reactions between pollutants such as nitrogen oxides and volatile organic compounds under sunlight[16]. The increase in ozone concentration can negatively affect human health, causing respiratory issues, eye irritation, and other health conditions, especially in vulnerable individuals such as children, the elderly, and those with respiratory diseases[7].

Several factors contributing to UHI have been identified in this study, including:

1. Construction materials

   Concrete, asphalt, and other building materials absorb heat and re-radiate it into the environment. Urban building materials tend to have low albedo values, resulting in more heat being trapped[17].

2. Population density and human activities

   The increase in vehicle numbers, use of electronic devices, and industrial activities generate heat emissions. Areas with high population density have higher temperatures, particularly during the day[3]. Areas with many buildings, roads, and infrastructure absorb and store more heat compared to areas with open vegetation. In densely populated areas, human activities such as vehicle use, air conditioning, and industrial processes also generate additional heat.

3. Reduction of vegetation

   Deforestation and the removal of green spaces eliminate the natural cooling functions provided by vegetation. In fact, tree planting can lower the surrounding temperature by up to 3°C, highlighting the importance of vegetation in mitigating UHI[18]. Plants undergo evapotranspiration, where water from the soil and leaves evaporates into the atmosphere, reducing

air temperature and increasing humidity, creating a cooler environment. Additionally, tree canopies absorb sunlight and provide shade, reducing the amount of solar radiation reaching the ground and buildings. Vegetation also enhances air circulation.

The impact of UHI on air quality is significant. Higher temperatures can increase the concentration of air pollutants such as PM2.5, NO2, and O3[7]. Chemical processes in the atmosphere, including photochemical reactions that produce ozone, are triggered by high temperatures. Poor air quality contributes to various health problems, including respiratory and cardiovascular diseases, and even premature death. According to a WHO report, air pollution causes approximately 7 million deaths each year, many of which are linked to rising temperatures and poor air quality[1].

The relationship between UHI and public health is a key focus of this study. UHI contributes to extreme heat, which can cause heat stress, dehydration, and even death. The rise in temperatures due to UHI is linked to an increase in mortality rates from heart attacks and strokes. Heat stress can exacerbate pre-existing health conditions and increase the risk of respiratory and cardiovascular diseases. In urban areas, increased temperatures can raise temperature-related deaths by up to 20%[19]. This highlights the urgency of addressing UHI and protecting public health, especially in large, densely populated cities.

The importance of green space-based solutions in mitigating UHI cannot be overstated. The analysis shows that adding green areas can significantly contribute to temperature reduction and improved air quality[20]. Proposed approaches include tree planting in urban areas, which has proven effective in lowering temperatures and improving air quality, as well as rooftop gardens, which not only serve as insulation for buildings but also reduce building surface temperatures and decrease the need for cooling energy. Additionally, green spaces provide areas for physical activity, which positively impacts mental health. Increasing urban green areas can reduce air pollution by up to 40% and enhance the quality of life for residents[21]. Parks, gardens, and other green spaces serve as important areas for recreation and social interaction.

CONCLUSION

This study reveals that Urban Heat Island (UHI) causes an increase in temperature in urban areas compared to surrounding regions, primarily due to building density, the use of heat-absorbing materials, and the reduction of vegetation. The impact of UHI affects not only comfort but also air quality, with an increase in the concentration of harmful pollutants such as ozone, which can potentially worsen public health. The rise in temperature associated with UHI has been shown to increase the risk of respiratory and cardiovascular diseases, especially for vulnerable populations such as children and the elderly. As a solution, tree planting and the enhancement of green spaces in urban areas have proven to be effective in mitigating the impact of UHI. The processes of evapotranspiration, heat absorption, and improved air circulation produced by vegetation can lower the surrounding temperature by up to 3°C. Therefore, policies that support greening, such as tree planting and the development of green open spaces, are essential. Collaborative efforts between the government, communities, and stakeholders are needed to create a healthier, more sustainable, and comfortable urban environment for all.

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