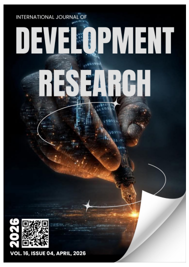
Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 16 Issue, 04, pp. 70408-70411, April, 2026
https://doi.org/10.37118/ijdr.30875.04.2026



RESEARCH ARTICLE **OPEN ACCESS**

POPULATION DENSITY, INEQUALITY, AND EXPOSURE: THE SPATIAL AND CULTURAL RECONFIGURATION OF ENVIRONMENTAL HEALTH IN LARGE CITIES

***Buket Şahin**

Instructor of French at the School of Foreign Languages, Adnan Menderes University

ARTICLE INFO

Article History:
Received 11th January, 2026
Received in revised form
19th February, 2026
Accepted 08th March, 2026
Published online 30th April, 2026

Key Words:

Population Density, Urban Health, Environment, Exposure, Inequality.

Corresponding author: Buket Şahin

ABSTRACT

This study aims to analyze the impact of population density on urban health within the framework of environmental exposure and spatial inequalities. The research integrates population density data with air quality indicators—particularly PM2.5 and PM10 measurements—per capita green space availability, waste generation statistics, and tap water quality reports. The findings indicate that dense urban development reduces access to green spaces, while increased traffic, heating, and energy consumption exacerbate air pollution. Infrastructure pressure generates additional risks in waste management and water quality. PM2.5 levels are strongly associated with cardiovascular and respiratory diseases, and neighborhood-level disparities in waste accumulation and water quality are more pronounced in low-income areas. These results highlight that urban health cannot be reduced solely to service delivery; instead, it requires data-driven, risk-based, and equity-focused environmental health planning grounded in population density and socio-economic vulnerability. Cities in the 21st century, with rising population densities, are at the intersection of demographic, environmental, and health-related transformations. Population density directly affects the spatial distribution of environmental risks, including air quality, water security, waste management, and urban heat island effects. As density increases, infrastructure capacity is strained, environmental exposures become spatially concentrated, and vulnerable populations face elevated risks. In Turkey, highly populated cities such as Istanbul, Ankara, and Izmir demonstrate that standard, uniform environmental health services are insufficient. This study discusses how environmental health services in high-density cities should be tailored, considering spatial risk patterns and policy tools.

Citation: Buket Şahin, 2026. *"*Population Density, Inequality, and exposure: The Spatial and Cultural Reconfiguration of Environmental Health in Large Cities". *International Journal of Development Research*, 16, (05), 70408-70411.

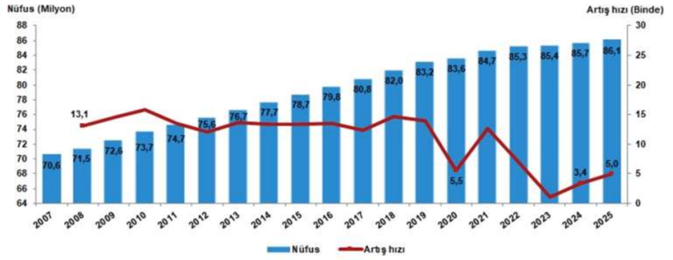
INTRODUCTION

The increase in population density brings about not only a demographic transformation in urban space but also a restructuring of environmental, spatial, and social relations. The intensification of settlement patterns reduces the amount of green space per capita; the expansion of impermeable surfaces and increasing building density strengthen the urban heat island effect and may disrupt microclimatic balance. In parallel, rising traffic volumes, energy consumption, and industrial activities increase air and noise pollution, while elevated levels of particulate matter (PM2.5 and PM10) particularly heighten the risk of respiratory and cardiovascular diseases (WHO, 2021). At the same time, population density places significant pressure on essential urban infrastructure systems such as water supply, sewage, transportation, and solid waste management. As these systems approach or exceed their capacity limits, technical failures are accompanied by the spread of environmental risks that directly affect public health.

In areas where unplanned urbanization processes prevail, infrastructural deficiencies lead to a spatially unequal distribution of environmental exposure (WHO, 2026). In this context, the distribution of environmental risks is not independent of social inequalities. Low-income or disadvantaged neighborhoods are often exposed to higher levels of air pollution, insufficient green spaces, poor water quality, and limited access to public services. As emphasized in the environmental justice literature, this leads to the concentration of environmental burdens on specific social groups and deepens health inequalities (WHO, 2016). Therefore, urban health can be regarded as a multidimensional field that cannot be reduced solely to the provision of healthcare services. It constitutes a multi-layered governance domain that requires the anticipation of risks, the consideration of spatial justice, and the integration of planning processes with a public health perspective. In this framework, urban health can be understood both as a "service delivery" domain and as an integrated outcome of risk management, environmental monitoring, and spatial planning processes. Rather than treating urban health merely as the organization of healthcare services, it is necessary to approach it as a result of spatial production processes.

The concentration of population in specific areas increases environmental exposures such as air pollution, noise, insufficient green space, waste accumulation, and infrastructural pressure, while the distribution of these risks often overlaps with socio-economic inequalities (Martinez et al., 2026:25). Thus, population density becomes not only a demographic indicator but also a determinant in which inequality and vulnerability are spatially manifested. For this reason, urban health is not merely a field that intervenes after disease has emerged; it should instead be understood as a multi-layered governance structure that necessitates early risk detection, neighborhood-level data-driven analyses, the principle of spatial justice, and the integration of planning decisions with a public health perspective. In other words, rethinking environmental health in large cities goes beyond service provision; it requires re-evaluating risk management, resource allocation, and urban design in ways that reduce inequalities (Corburn, 2009:1).

Population (million) Growth rate (per thousand)



Population Growth rate

Figure 1. Population and annual population growth rate, 2007–2025: https://veriportali.tuik.gov.tr/tr/press/53899

When considered in the context of Turkey, the annual population growth rate was 3.4 per thousand in 2024 and rose to 5 per thousand in 2025. Turkey's population stood at 86,092,168.

Percentage of the total population (%)						
Counties	Total	Men	Women	total	men	women
İstanbul	15 754 053	7 851 344	7 902 709	18,30	18,23	18,36
Ankara	5 910 320	2 911 853	2 998 467	6,87	6,76	6,97
İzmir	4 504 185	2 227 738	2 276 447	5,23	5,17	5,29
Bursa	3 263 011	1 628 212	1 634 799	3,79	3,78	3,80
Antalya	2 777 677	1 397 014	1 380 663	3,23	3,24	3,21

Figure 2: The 5 provinces with the largest populations, 2025: https://veriportali.tuik.gov.tr/tr/press/53899

The concentration of a large share of the population in urban areas places significant pressure on infrastructure systems and can also make it more difficult to ensure the sustainability of environmental services (TÜİK, 2025). In particular, when water, waste, and transportation infrastructures approach their capacity limits, environmental exposure tends to increase, and this exposure may become unevenly distributed across different neighborhoods. When this differentiation is considered from an environmental justice perspective, it indicates that low-income and disadvantaged groups are more likely to be exposed to higher environmental risks. Accordingly, the environmental justice literature demonstrates that environmental burdens are distributed unequally across society and that this contributes to the deepening of health inequalities (United States Environmental Protection Agency, EPA, 2023).This study is designed as descriptive research aiming to examine the relationship between population density and environmental risks from a spatial perspective. In the study, thematic maps showing population density at both the national level in Turkey and across major metropolitan areas were used to visualize density distribution, and this distribution was linked to environmental exposure zones. The dataset was constructed within the framework of population density data obtained from official statistical sources and environmental health indicators found in the literature, including air pollution, waste generation, water quality, and the presence of green spaces. The spatial interpretation based on these maps aims to reveal how differences in population density are reflected in the distribution of environmental risks. In addition, the study adopts a descriptive approach based on the visual analysis of quantitative data, and the findings are interpreted from the perspectives of environmental justice and urban health.This study is designed asdescriptive and comparative research aiming to identify how environmental health services should be tailored in cities with high population density. In the study, quantitative data and the theoretical framework were evaluated together, enabling the relationships between environmental risks and spatial and social variables to be addressed through a holistic approach. The sample of the study consists of three major metropolitan cities in Turkey with high population density: Istanbul, Ankara, and Izmir. These cities provide an appropriate basis for comparative analysis due to both their demographic size and their differing spatial structural characteristics. The data used in the study include key environmental indicators such as population density, per capita green space, air pollution indicators (PM2.5 and PM10), daily waste generation, and municipal water quality reports. These data were obtained from open data sources of public institutions, primarily the Turkish Statistical Institute, as well as relevant academic studies. In the analysis process, environmental indicators in the selected cities were associated with population density, and the findings were interpreted within the frameworks of environmental justice and urban health approaches. In this context, particular attention was given to differences at the neighborhood scale, and the spatial distribution of environmental exposure as well as its impacts on public health were evaluated. Accordingly, the study is not limited to describing the current situation; it also aims to emphasize the need to develop recommendations for restructuring environmental health services in high-density cities through a risk-based, spatially targeted, and vulnerable-group-sensitive approach.

Environmental Risk Areas Produced by High Population Density: Population density is considered one of the key structural factors shaping the relationship between environmental exposures and health outcomes. In areas where urbanization is intensified, increasing population pressure deepens environmental risks through processes such as rising transportation demand, higher energy consumption, and the concentration of industrial and traffic-related emissions. In this context, particularly when examining the relationship between air pollution and traffic congestion, numerous studies have shown that levels of fine particulate matter (PM2.5) and coarse particulate matter (PM10) increase in relation to the rise in motor vehicle numbers and the use of fossil fuels (European Environment Agency (EEA), 2026). This situation indicates that air quality in urban areas is not only an environmental issue but also a direct public health concern (Balcılar, 2024:1115–1126). On the other hand, noise pollution is not only an environmental nuisance but is also regarded as a multidimensional public health problem associated with psychophysiological effects such as increased chronic stress levels, impaired sleep quality, and, in the long term, a higher risk of cardiovascular diseases. Therefore, in the assessment of environmental risks, it is emphasized that both the levels of physical exposure and the socio-biological effects of these exposures must be taken into account (Özden et al., 2024:1807–1824). The increase in waste generation volume and the strain on infrastructure capacity make it essential to evaluate environmental health in terms of water quality, vector proliferation, and environmental hygiene. The pressure on municipal water networks and the resulting disparities in water quality between neighborhoods also make visible the relationship between infrastructural strain and public health. In addition, the urban heat island effect and insufficient green spaces may play a determining role in both physical and mental health outcomes. When these dimensions are conceptualized within a "density → exposure → health outcome" chain, the causal structure of urban health becomes more clearly articulated (Kök, 2018:145–157).

Even if the overall city average appears sufficient, the distribution at the neighborhood level may be highly unequal. Therefore, it is necessary to plan environmental health services by taking spatial inequalities into account. Green space per capita is a key protective health indicator for reducing environmental exposure in densely populated cities and can be considered a strategic parameter in the planning of environmental health services. Findings on the health impacts of green spaces in highly populated urban areas indicate that environmental health services cannot be implemented through a standardized or uniform model (Rigolon et al., 2021:2563). Dense built environments, limited open spaces, increasing traffic, and the urban heat island effect can generate a chain of risks ranging from mental health problems to cardiovascular diseases. Urban air pollution, in particular, can trigger serious health conditions such as heart attacks, strokes, cancer, and chronic obstructive pulmonary disease (Mears et al., 2020:11). Evidence of negative impacts on children's neurological development is also steadily increasing, and according to WHO data, acute lower respiratory infections linked to air pollution caused the deaths of approximately 600,000 children in 2016. In addition, factors such as heavy traffic congestion, exposure to excessive noise, high ambient temperatures, and reduced physical activity generate additional risks that threaten public health in urban settings. This situation demonstrates that air pollution is not limited to respiratory diseases but has wide-ranging effects on both physical and psychosocial health (UN-Habitat, 2022:150).

For this reason, it is emphasized that environmental health services should be designed not only as inspection- and intervention-oriented systems but also as preventive and spatially targeted mechanisms. Customized environmental health services are expected to include planning decisions aimed at increasing access to green spaces in disadvantaged neighborhoods, air quality and noise monitoring systems, and heat-sensitive early warning mechanisms. In densely populated areas where per capita green space is limited, micro-scale interventions such as pocket parks, vertical gardens, and the public use of schoolyards are increasingly considered as legitimate public health measures. In this way, green space can be conceptualized not only as an aesthetic element but also as a protective health infrastructure that reduces cardiovascular risks, promotes physical activity, and lowers stress levels. Within this framework, it becomes meaningful to tailor environmental health services at the levels of spatial targeting, focus on vulnerable groups, and integrated planning (Barton & Rogerson, 2017:79–81).Daily waste generation is a key indicator representing the total volume of household and municipal solid waste produced in a city, and it is generally expressed in tons per day or kilograms per capita per day. When population density increases, the total waste volume rises rapidly even if per capita generation remains constant; this places significant pressure on collection, sorting, and disposal systems. Dense residential patterns, high consumption rates, increasing use of packaging and plastics, and growing volumes of organic waste can trigger a range of environmental health problems—especially in cities where infrastructure capacity is insufficient—such as waste accumulation, pest proliferation, odor, groundwater contamination, methane emissions, and fire risks. For this reason, waste management is not only a sanitation service but also a public health policy instrument in terms of preventing vector-borne diseases, reducing respiratory risks, and addressing environmental inequalities. In highly populated cities, dynamic planning tools are required, such as creating neighborhood-level waste generation maps, enforcing source separation, establishing local composting systems for organic waste, and adjusting collection frequency according to population density (Kaza et al., 2018:1–2).

Similarly, municipal water quality reports are among the critical indicators of environmental health. These reports assess the safety of drinking water through parameters such as pH, nitrate and heavy metal levels, microbiological analyses (e.g., E. coli), turbidity, and chlorine concentration. However, as population density increases, infrastructure systems are subjected to greater strain; aging pipelines, pressure fluctuations, and treatment facilities operating near capacity generate indirect risks. Even if the overall city average appears safe, quality disparities may emerge between neighborhoods. In particular, in low-income areas, older infrastructure, insufficient maintenance, and limited access to individual water treatment solutions can transform water quality risks into a more intensely experienced reality. This situation brings the environmental justice perspective into focus: environmental risks often overlap with socio-economic vulnerabilities. Therefore, neighborhood-level monitoring, transparent sharing of risk maps, prioritization in infrastructure renewal, and support programs targeting vulnerable groups should be considered integral components of environmental health services (Taş, 2025:59–71).

Density, Inequality, and Risk Communication: The Spatial and Cultural Restructuring of Environmental Health Services

The relationship between population density, inequality, and environmental exposure is shaped not only through physical infrastructure and spatial distribution, but also through communication processes and cultural practices. In large cities, individuals' access to information about environmental risks, the ways in which they interpret this information, and their everyday practices can directly influence levels of exposure (Koç, 2023:421–433). In particular, environmental awareness, risk perception, and the development of protective behaviors are not evenly distributed across different socio-economic and cultural groups. This situation demonstrates that environmental health services should not be limited to technical interventions alone; rather, they require an approach that also takes into account the cultural characteristics of target groups, communication channels, and modes of access to information. In this context, the spatial reconfiguration of environmental health in densely populated cities appears possible through both the regulation of the physical environment and the strengthening of risk communication, the enhancement of public awareness, and the development of culturally adapted intervention strategies. Thus, it is suggested that the reduction of environmental risks can become sustainable not only through infrastructure investments but also by strengthening the capacity of individuals and communities to perceive and manage these risks (Mavi, 2025:295–313). In the context of densely populated cities, it is considered more appropriate to adopt a micro-planning model based on density and risk at the neighborhood scale rather than a general and uniform service approach. While this approach aims to differentiate services by taking into account the spatial distribution of environmental exposures and health risks, within the proposed solution framework it is suggested that neighborhood-based air quality monitoring systems could be established. In addition, acoustic planning can be conducted using noise maps, and organic waste management can be optimized through waste separation and local composting programs (Kılıç et al., 2021:792–804). Transparent water quality reports, when disseminated at the neighborhood level, enable prioritization in line with both infrastructural pressure and socio-economic vulnerabilities. Similarly, green space interventions based on heat maps may reduce the urban heat island effect while supporting both physical and mental health in vulnerable areas. In this way, density-based micro-planning moves beyond conventional environmental health services and offers a public health strategy that is both preventive and justice-oriented.Population density is not merely a demographic variable; it is a fundamental structural determinant shaping the spatial distribution of environmental exposure. For this reason, it is emphasized that in high-density cities, environmental health services should be redesigned not as standardized systems but as risk-based approaches that take spatial inequalities into account.

CONCLUSION

Cities with high population density are spaces where demographic growth is accompanied by the intensification of environmental risks and the increasing visibility of spatial inequalities. The factors addressed in this study—such as air pollution, waste management, water quality, and insufficient green space—demonstrate that urban health is shaped not only by individual health behaviors but also by environmental conditions and urban infrastructure. The findings indicate that environmental exposure is not distributed homogeneously within cities; instead, it is experienced more intensely in socio-economically disadvantaged areas and neighborhoods with weaker infrastructure. This situation places the concept of environmental justice at the center of urban health discussions and makes it necessary to consider environmental health services both as a technical instrument and as a tool of social policy. Within this framework, it is argued that in high-density cities, environmental health services should be restructured through a data-driven and holistic approach that takes into account differentiated neighborhood-level risks, rather than relying on standardized and uniform practices. It is emphasized that services ranging from air quality monitoring systems to waste management strategies, from water quality inspections to green space planning, should be designed with an approach aimed at reducing spatial inequalities, which is of critical importance for the sustainability of urban health. In conclusion, urban health should be regarded not merely as a service field that responds to existing problems, but as a governance practice that anticipates risks, aims to reduce inequalities, and seeks to improve the overall quality of urban life in a holistic manner. Furthermore, both waste management and municipal water quality are key indicators that reveal the delicate balance between infrastructure capacity and public health in densely populated cities. Instead of standardized and average-based municipal services, a data-driven, risk-oriented, and justice-focused environmental health model that takes density and spatial inequalities into account is deemed necessary.

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