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# AIR QUALITY IN YEREVAN IN THE CONTEXT OF CLIMATE CHANGE

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**Abstract**

Over the past five years, the atmospheric air quality in Yerevan has continued to deteriorate, primarily attributed to a significant increase in airborne dust, particularly during the hot summer months that coincide with the peak tourist season. This phenomenon reflects a complex interplay among atmospheric emissions, air quality, emission source altitudes, changes in chemical composition, solar radiation, weather patterns, and topographic conditions. Sources of dust pollution in Yerevan include industrial activities, vehicular emissions, road dust, and construction activities. Data from various administrative districts indicate that, over the past five years, concentrations of dust, nitrogen dioxide, and sulfur dioxide frequently exceed established standards. Additionally, there are unregulated static sources of dust pollution within the city. This study conducts a comparative analysis of the primary pollutants in the context of climate change and urbanization in Yerevan over the last five years. It also assesses green areas and evaluates the effectiveness of greening initiatives, while considering compliance with national legislation in the Republic of Armenia.

***Keywords:*** monitoring stations, dust, nitrogen dioxide, construction, transportation, green space, climate change

## Introduction

As of 2023, global data indicates that the Republic of Armenia ranks 31st out of 134 countries for the concentration of harmful airborne substances, surpassing the indices of neighboring Georgia (62nd) and Azerbaijan (52nd) [1]. Within the region, Yerevan, the capital, is recognized as having the driest climate and the most polluted air among the capitals of the South Caucasus. Historically, Yerevan experienced high levels of air pollution due to its geographical location and industrial activities, particularly during the Soviet era. However, in the years following Armenia's independence, urban planning initiatives emphasized the importance of public green spaces and forested areas, such as the Nork forests, Dalma Gardens, and Haghtanak Park. Unfortunately, many of these areas have since been repurposed for urban development.

The significance of green spaces for urban ecosystems is well-documented [1]. Studies have shown that the dust concentration in green areas is 42% lower during the spring and summer months and 37% lower in winter compared to non-vegetated areas[2]. Additionally, approximately 0.405 hectares of tree cover can sequester more than 40 tons of carbon dioxide[2], highlighting the crucial role that vegetation plays in mitigating air pollution and enhancing urban life

Green areas play a crucial role in mitigating air pollution by absorbing fine particulate matter (PM10), which poses significant health risks, as well as filtering harmful pollutants such as sulfur dioxide, nitrogen oxides, and ethylbenzene (a component of petroleum products)[3]. However, various studies indicate that the pollution abatement capacity of urban green spaces is limited. As emissions sharply increase, the efficiency of these areas in filtering pollutants tends to decline over time.

While similar studies have not yet been conducted in Armenia, international research has demonstrated a clear correlation between tree-covered urban areas and the reduction of ozone (O3), PM10, and PM2.5 levels in the air[4]. Although the improvement in air quality may occur slowly, often over decades, it is a consistent trend.

It is essential to consider multiple factors when assessing the impact of urban tree cover on air quality. These factors include precipitation levels, humidity, the presence of water bodies, and the strength and direction of prevailing winds. Unfortunately, such comprehensive evaluations have not yet been performed in Yerevan, limiting our understanding of the full impact of green spaces on atmospheric air quality in the city.

Numerous studies confirm that green areas in urban environments play a significant role in mitigating urban heat and enhancing the microclimate. These spaces positively impact both mental and physical health, which is increasingly critical in the context of climate change. By providing shade, reducing heat absorption, and improving air quality, urban greenery contributes to overall well-being and resilience against climate-related stressors. As cities face rising temperatures and environmental challenges, the preservation and development of green spaces become essential components of sustainable urban planning[5].

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[1] https://www.iqair.com/us/world-air-quality-report-press-kit

[2] Nowak et all

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**Conflict Setting**

The authors emphasize that emissions from anthropogenic sources significantly impact the air quality of Yerevan (Fig. 1) and must be strictly controlled. It is crucial not to subordinate the management of these emissions to the sole objective of increasing green areas, as the positive effects of greenery on air quality tend to manifest over a longer time frame. Immediate and effective measures to reduce emissions are essential for achieving timely improvements in urban air quality, while also recognizing the long-term benefits that green spaces provide. The article also examines the legal mechanisms in force in the Republic of Armenia concerning atmospheric air quality and urban microclimate. The review reveals that existing regulations regarding both greening and air quality improvement, as outlined in the local self-government laws and decisions by the Council of Elders of Yerevan, are often incomplete, absent, or inadequately enforced. For instance, the «Technical Regulation of Requirements for the Size and Composition of Residential Green Zones», issued by the Government of Armenia on October 30, 2008, is not effectively implemented. Although Decree No. 1318 specifies the types of plants suitable for various regions, including Yerevan, this information is not reflected in the action plan of the «Landscape Gardening and Environmental Protection» Community Non-Profit Organization under the Yerevan Municipality. Instead, the CNPO presents tree species for urban gardening not mentioned in the aforementioned regulation for urban greening initiatives. Furthermore, the selection of tree species by the relevant agency is not informed by local or international scientific studies, and the goals of these greening actions are not aligned with the provisions of any ratified conventions or agreements, such as the Paris Agreement or the UN Sustainable Development Goals. This lack of coherence raises concerns about the effectiveness of current policies in addressing air quality and enhancing urban green spaces. Fig. 1 illustrates the primary sources contributing to air pollution in Yerevan, based on data from 2023.

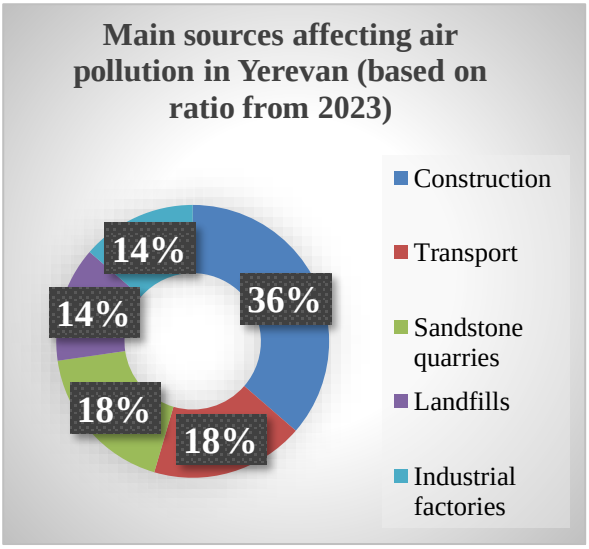


**Fig. 1 The primary factors affecting air quality in the city of Yerevan, based on 2023**

Approximately 21 metals have been identified in the dust of cities across the RA, as reported by the «Hydrometeorology and Monitoring Center» (SNCO). Among these metals, Standard Threshold Concentrations (STCs) have been established for nickel, molybdenum, and cobalt, however, STCs for the remaining metals are absent. The purpose of this article is to underscore the significance of evidence based decision making in developing policies for the capital, as well as contribute insights to the existing situation with air pollution in Yerevan.

By emphasizing the importance of data-driven decision-making, the article seeks to highlight the potential for leveraging data analytics and evidence-based approaches to enhance the sustainable policy development in the city of Yerevan.

**Materials and Methods:**

This study utilizes atmospheric air monitoring data from 2020 to 2023, specifically focusing on dust concentrations in Yerevan [8]. Data were sourced from the Yerevan Municipality regarding the city's green areas, as well as from the official legal databases available on the website of the Hydrometeorology and Monitoring Center and RA Ministry of Environment. In Yerevan, monitoring of dust, sulfur dioxide, nitrogen dioxide, and ground-level ozone is conducted at 45 observation points and 5 monitoring stations (Fig. 1).

The research method involves a multi-faceted approach, incorporating data analyzing methods such as quantitative & comparable analysis. Relevant data has been collected from state reports & official publications. Quantitative analysis techniques were then applied to assess the current state of green spaces per capita, airborne dust & other pollution levels.

Dust sampling is being conducted actively using filter paper, with calculations performed through simple weighing. The annual average concentrations of selected metals in dust are reported on the website; however, organic components were not included in the analysis. Additionally, the ability to differentiate dust fractions, such as PM10, PM5.0, and PM2.5, is not available. Notably, organic matter in dust has not been included in these assessments, and research in this area is currently lacking.

The observation period for this study was chosen randomly, with the SNCO website providing daily data on dust, nitrogen dioxide, and sulfur dioxide levels for each month [8].

It is important to note that the state website does not include information on precipitation days, significant drops in air temperature, or instances of strong winds in Yerevan. Such meteorological data are crucial for understanding the influence of weather conditions on dust concentrations and for conducting a comprehensive assessment of air quality.

**Research Results:**

According to data from the Hydrometeorology and Monitoring Center of the Republic of Armenia, in 2023, daily concentrations of dust and nitrogen dioxide in Yerevan's atmosphere exceeded established limit values on 129 days and 43 days, respectively. Specifically, dust concentrations ranged from 1.1 to 4.8 times the limit, while nitrogen dioxide levels ranged from 1.1 to 2.7 times the limit. The highest recorded dust concentration (0.988 mg/m$^3$) occurred on March 7 in the Nor Nork district, while the peak nitrogen dioxide concentration (0.110 mg/m$^3$) was measured on October 15 in the Shengavit district.

Data from the «Hydrometeorology and Monitoring Center» State Non-Commercial Organization (SNCO) indicate an increasing trend in dust and nitrogen dioxide concentrations over the past five years, contrasting with a decrease in sulfur dioxide and ground-level ozone levels. The primary source of nitrogen dioxide in the urban atmosphere is motor vehicle emissions, whereas dust pollution arises from multiple sources, including construction activities, industrial processes, vehicular traffic, road dust, and insufficient green spaces. Importantly, the study of the geochemical and organic composition of dust has not been

conducted. Elements such as sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), potassium (K), calcium (Ca), and others are not currently quantified in dust samples, nor do standard threshold concentrations (STCs) exist for these elements in Armenia. These elements are commonly found in construction materials, and their analysis could provide valuable insights into the sources of dust pollution. Presently, the identification of dust sources relies on indirect inference, which underscores the need for more comprehensive research in this area.

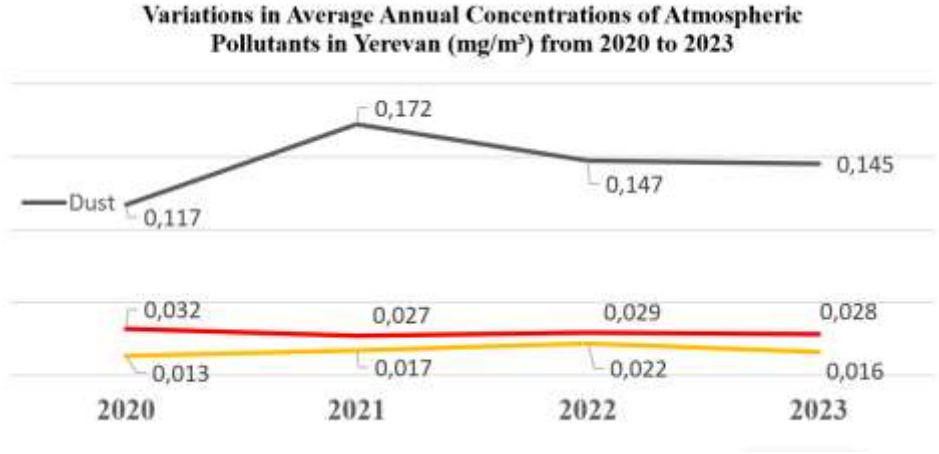


**Fig. 2 Average Annual Concentrations of Harmful Substances in the Atmospheric Air of Yerevan City (2020-2023)**

Analysis of the observations conducted over the past three years reveals that exceedances of standard threshold concentrations (STCs) occurred in 35% of the measurements for dust, 29% for nitrogen dioxide, and 18% for sulfur dioxide. This data clearly indicates that dust is the primary contributor to air pollution in Yerevan, followed by nitrogen dioxide (Tab. 1).

Furthermore, the analysis shows an increasing trend in the concentrations of dust, ground-level ozone, sulfur dioxide, and nitrogen dioxide over the past five years. This upward trajectory raises concerns about the deteriorating air quality in the city and underscores the need for effective regulatory measures to address these pollutants.

**Table 1. Changes in the Average Annual Concentrations of Substances (mg/m³) in the Atmospheric Air of Yerevan City (2020-2023) [8]**

| Substance | Characteristic | 2020 | 2021 | 2022 | 2023 | Tendency |
|---|---|---|---|---|---|---|
| Dust | Average annual concentration | 0.117 | 0.172 | 0.147 | 0.145 | 0.0064 |
| Sulfur dioxide | Average annual concentration | 0.013 | 0.017 | 0.022 | 0.016 | 0.0006 |
| Nitrogen dioxide | Average annual concentration | 0.032 | 0.027 | 0.029 | 0.028 | 0.0023 |
| Ground-level ozone | Average annual concentration | 0.004 | 0.005 | 0.006 | 0.007 | 0.0005 |

Despite ongoing greening initiatives in Yerevan since the 1990s, approximately 1,023 hectares of green space have been lost and remain unreplenished. Although regular budget

allocations are made for greening operations, progress has been slower than anticipated, failing to keep pace with rapid urbanization and climate change.


**Fig. 3 Stationary (large black dots) & Mobile (small black dots)**
**Observation Stations for Atmospheric Air Quality Monitoring in Yerevan[8]**

For instance, between 2020 and 2023, the green area of Yerevan expanded by only 37.8 hectares, while the population during the same period increased by approximately 14,900 residents reducing green space per capita from 8.5 m² to 8.2 m².[7]. This disparity underscores the need for more effective and accelerated greening strategies to adequately meet the demands of a growing population and mitigate the impacts of urbanization and climate change on air quality and public health

The dynamics of changes in green areas during 1990-2023 is presented in Fig. 3.

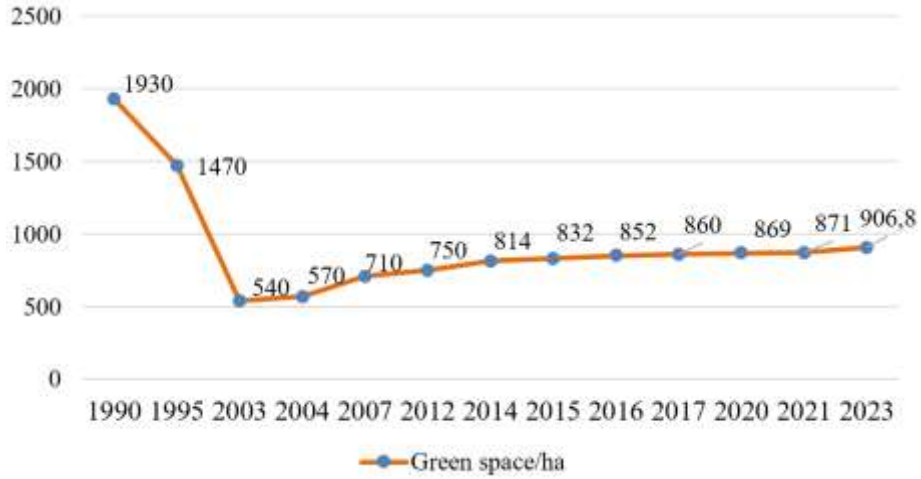


**Fig. 2. Dynamics of Green Space Reduction in Yerevan (1990-2023)**

The total area of Yerevan is 22,328 hectares[3], of which only 906.8 hectares—approximately 4%—is designated as green space. It is important to note that the concept of green spaces includes also privately owned green areas, which are not accessible to the public, as well as flowerbeds and lawns.

According to the Green City Action Plan, supported by a grant from the European Bank for Reconstruction and Development (EBRD), the aim is to increase this figure to 10 square meters per capita by 2030. However, as of 2022, the target was only 8.5 square meters per capita, indicating that this goal has yet to be met.

Approximately 36.9% of the Republic of Armenia's population resides in Yerevan, and population growth trends in the capital over the last four years are illustrated in Figure 3. The World Health Organization recommends a minimum of 9 square meters of green space per inhabitant, while the Yerevan city master plan stipulates a target of 17 square meters per person—twice the current average. This gap highlights the urgent need for enhanced greening strategies to improve urban living conditions and environmental health.

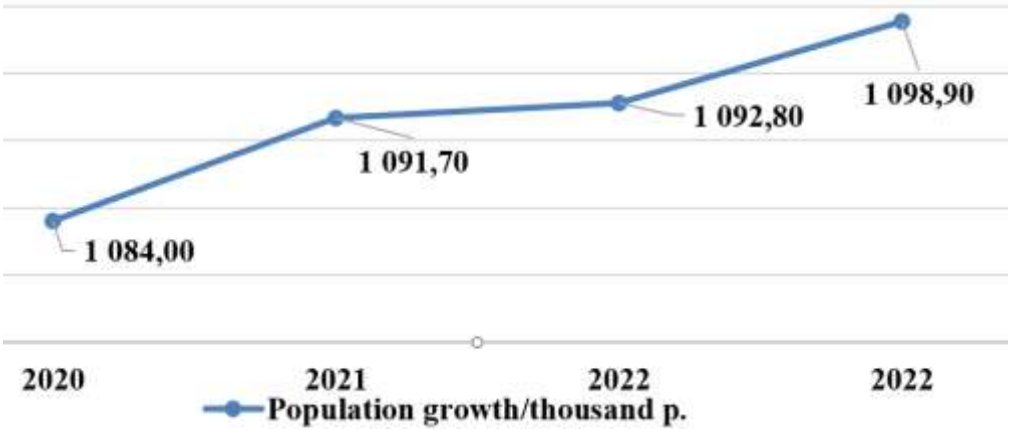


**Fig. 3 The population growth of Yerevan in 2020-2023**

The elemental layout of buildings in Yerevan adversely affects air quality by disrupting the natural flow of mountain-valley winds and the city's natural ventilation system. This disruption also interferes with the airflow from Lake Sevan through the Hrazdan Gorge to Yerevan. As a result, these changes can exacerbate pollution levels, hinder the dispersal of airborne contaminants, and contribute to the overall deterioration of urban air quality. Effective urban planning and architectural considerations are essential to restore and enhance the city's natural ventilation dynamics [8].

The absence of an effective rainwater drainage system in Yerevan exacerbates dust accumulation in the air, leading to persistent dust levels in the city. Additionally, the limited presence of water bodies further compounds this issue; currently, there are only three artificial lakes with significant surface areas: Yerevanyan Lake, Vardavar Lake, and Kanaker HPP Lake. The lack of sufficient water areas reduces the city's ability to mitigate dust and improve local humidity levels, highlighting the need for integrated urban planning that incorporates water management strategies to enhance air quality[6:]

During periods of intensive construction in Yerevan, there is a significant violation of essential ecological and safety requirements. These infringements can lead to increased air pollution, disruption of local ecosystems, and heightened health risks for residents. It is crucial to implement stricter regulations and oversight during construction activities to ensure compliance with environmental standards and to safeguard public health. Enhanced monitoring and enforcement measures are necessary to mitigate the adverse effects of urban development on air quality and overall environmental integrity.

[6] small artificial lakes built in some city park areas were not taken into account

**Fig. 4 The process of dismantling the building in Yerevan, 2024.**

For comparison, the per capita green space in three major cities of the Republic of Armenia is illustrated in Fig. 5, while Fig. 6 displays the total area of greenery in these cities. These visual representations highlight disparities in green space availability and underscore the importance of enhancing urban green areas to improve quality of life and environmental health across the region.

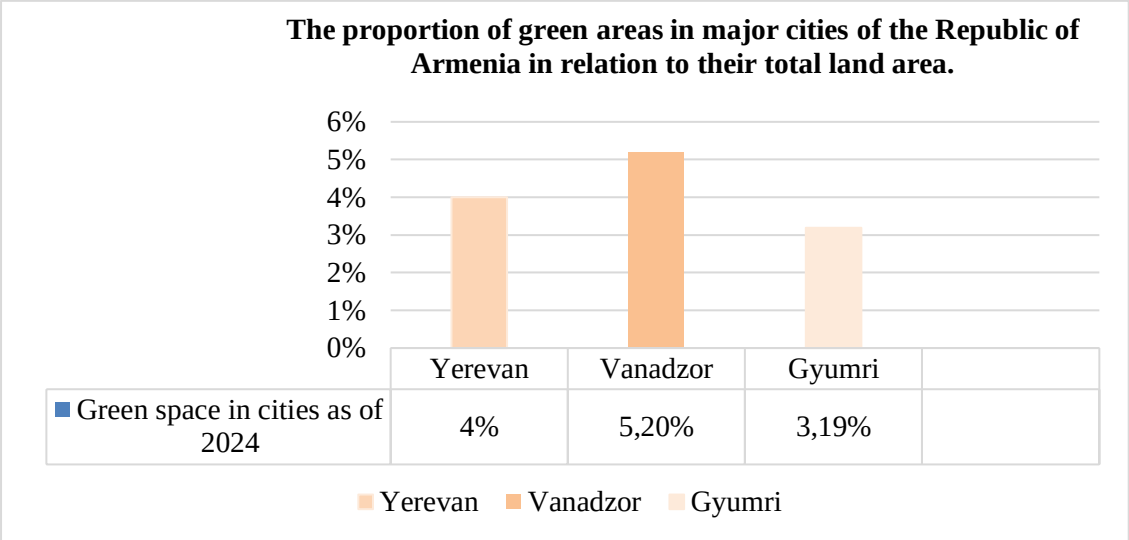


**Fig. 5 Green areas of major cities of RA in relation to the total area**

It is evident that, relative to its population, Yerevan has fewer green spaces compared to Vanadzor, and its green area per capita is also lower than that of Gyumri when considering population density.

Legal regulations governing greening efforts in Yerevan are established by several Armenian laws and resolutions, including:

1. RA Law on Flora.
2. Technical Regulation of Requirements for the Size and Composition of Residential Green Zones (Government Resolution No. 1318-N, dated October 30, 2008).
3. Rules for the Preservation and Use of Green Spaces of General Use in the City of Yerevan (Council of Elders Decision No. 36-N, dated November 18, 2009)

4. Procedure for the Mandatory Improvement of Real Estate within the Administrative Boundaries of Yerevan (Council of Elders Decision No. 48-N, dated February 2, 2009)

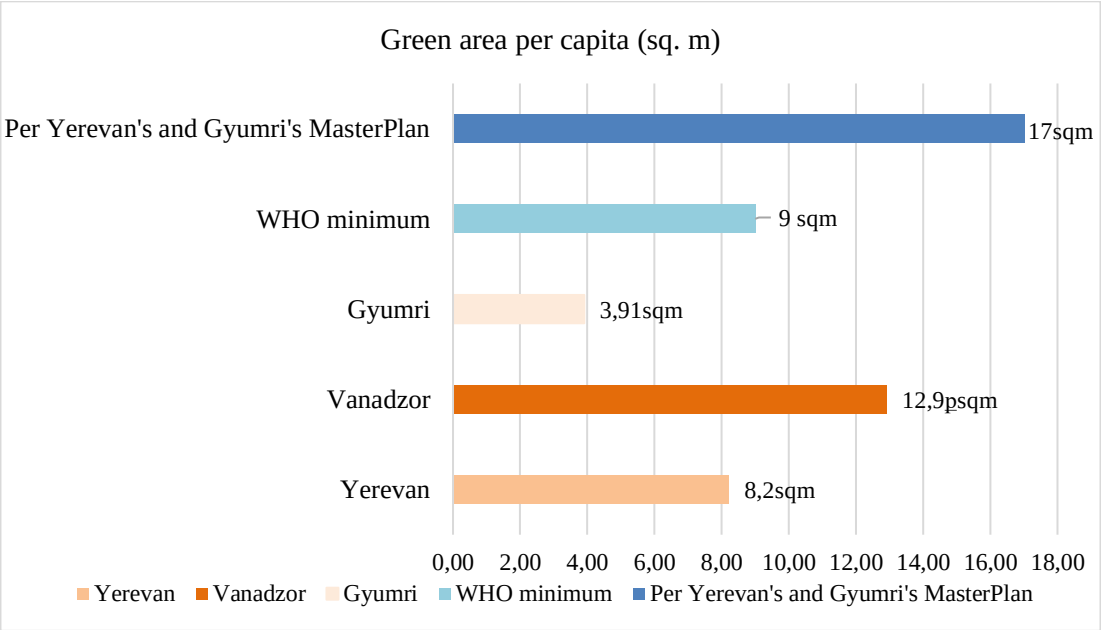


**Fig. 6 Per capita green spaces in RA major cities: Yerevan, Gyumri, Vanadzor.**

These regulations are intended to ensure the effective management and preservation of green areas, yet the implementation and enforcement of these laws need to be strengthened to adequately address the current shortfall in green spaces in the city

The Nubarashen landfill significantly adversely affects air quality in Yerevan, primarily due to its reliance on only two waste disposal methods: burning and landfilling. The burning of waste can release harmful pollutants into the atmosphere, while landfilling can contribute to the generation of methane and other noxious gases [5].

Additionally, urban transport is a significant contributor to ecological stress in Yerevan, with pollution levels from this sector increasing by 35-40% compared to 2017 [5].

Industrial factories, along with 39 stone and sand processing mines located within the administrative boundaries of Yerevan, significantly contribute to dust pollution in the city. The operations of these facilities generate substantial amounts of particulate matter, exacerbating air quality issues and posing health risks to the local population [8].

An essential international standard for air quality assessment mandates the monitoring of primary atmospheric pollutants, including sulfur dioxide, nitrogen oxides, carbon monoxide, dust, and ground-level ozone, which is classified as a secondary pollutant. In compliance with these requirements, the concentrations of these primary pollutants are routinely measured in Yerevan's atmosphere. This systematic monitoring is critical for evaluating air quality, informing public health policies, and implementing effective pollution control measures [8].

The primary source of nitrogen dioxide in Yerevan is transportation, while sulfur dioxide predominantly arises from industrial emissions. Concurrently, there is a notable increase in both dust levels and nitrogen dioxide concentrations in the city, alongside a rise in average temperatures, which have increased by 1.23 °C to date. Forecasts predict that average

temperatures in Yerevan could rise by an additional 1.6 °C by 2040 and by 3.3 °C to 9 °C by 2070. This projected warming, combined with increasing pollution levels, poses significant challenges for public health and environmental sustainability in the region[7].

In October 2023, the average temperature in Yerevan reached 15.1 °C, marking a deviation of 1.4 °C above the historical norm. Notably, on October 29, the daily maximum temperature soared to 25.3 °C, surpassing all previous records for that date. November 2023 continued this trend, becoming the warmest November recorded since observations began.

During that month, total precipitation was only 13.5 mm, which constituted just 56% of the typical November average. Significant temperature anomalies were observed on November 7, 10, 12, 13, and 27, with daily maximum temperatures reaching unprecedented levels of 19-22 °C.

Furthermore, from 1935 to 2023, the average summer temperature in Yerevan increased by 2.1 °C, while precipitation decreased by 31%[8]. Table 2 and Fig. 6 below illustrate the average temperatures of 2023 observed monthly in Yerevan.

**Table 2.**

**The deviation of monthly temperatures in 2023**

| ***Month*** | ***Recorded temperature*** | ***Deviation from norm*** |
|---|---|---|
| January | -1.4°C | +2.2°C |
| February | 1.3°C | +1,8°C |
| March | 11,7 °C | +5,4 °C |
| April | 13,8 °C | +0,8 °C |
| May | 18,4 °C | +0,7°C |
| June | 23.5°C | +0.7°C |
| July | 26.8°C | +0.2°C |
| August | 29.2°C | +2.9°C |
| September | 22.3 °C | +1.1 °C |
| October | 15.1 °C | + 1.4°C |
| November | 9.8 °C | + 3.9 °C |
| December | 2.6°C | +3°C |
| | | |

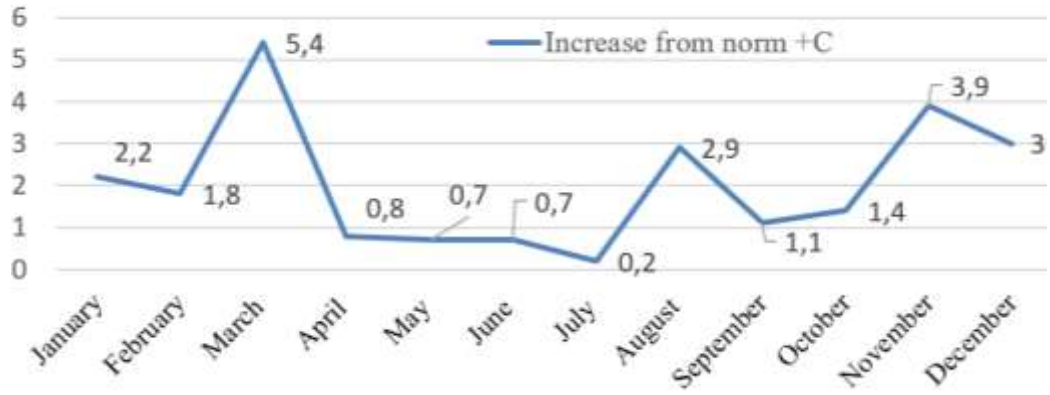


**Fig. 6 Temperature increase from normal in 2023.**

[7] Data of RA Ministry of Environment

[8] https://meteomonitoring.am/public/admin/ckfinder/userfiles/files/texekanq/eramsjak/III%20Eramsyak%202023.pdf

**Conclusion**

The comparative analysis of atmospheric pollutant data from the "Hydrometeorology and Monitoring Center" of the Republic of Armenia indicates that dust concentrations in Yerevan have consistently exceeded permissible limits over the past five years. The primary sources of dust generation include construction activities that violate ecological standards, vehicular emissions, road dust, and 39 stone and sand processing mines located within the city's administrative boundaries, as well as various industrial processes.

Current legal frameworks are inadequately enforced by businesses, and Yerevan lacks a comprehensive environmental policy. The objectives for greening initiatives are not aligned with the goals outlined in the Paris Agreement or the United Nations Sustainable Development Goals. As a result, emissions from anthropogenic sources remain unregulated, and the negative impacts of rapid urbanization are not being effectively addressed.

Violations of the RA Law «On Atmospheric Air Protection» in stone and sand processing mines and industrial facilities, coupled with insufficient state oversight, have led to a significant increase in dust levels in Yerevan, frequently surpassing permissible concentrations. This trend has serious health and economic implications for the city's residents.

While the existing green spaces in Yerevan cannot sufficiently filter the high levels of emissions from these sources, they do contribute positively to mitigating the rising temperatures associated with climate change and enhancing the well-being of the urban population. The increasing frequency of record-high temperatures highlights the critical role of green infrastructure, especially given the limited availability of water bodies in the city.

Therefore, effective management of urban green infrastructure and strategic urban planning are essential. This should encompass the selection of appropriate plant species, as well as the development of care and irrigation schedules, all tailored to address the current and anticipated challenges posed by climate change and included in respective sustainability development policies of Yerevan Municipality.

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# ԵՐԵՎԱՆ ՔԱՂԱՔԻ ՄԹՆՈԼՈՐՏԱՅԻՆ ՕԴԻ ՈՐԱԿԸ ԿԼԻՄԱՅԻ ՓՈՓՈԽՈՒԹՅԱՆ ՀԱՄԱՏԵՔՍՏՈՒՄ

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[2]*Հայաստանի ազգային պոլիտեխնիկական համալսարան*

Վերջին հինգ տարիների ընթացքում Երևան քաղաքի մթնոլորտային օդի որակը շարունակում է վատթարանալ, որը պայմանավորված է օդում փոշու քանակի շեշտակի աճով հատկապես ամառվա շոգ ամիսներին՝ համընկնելով զբոսաշրջային ակտիվ սեզոնի հետ: Մթնոլորտային օդի արտանետումների և օդի որակի միջև գոյություն ունի բարդ փոխկապակցվածություն, որը ներառում է արտանետման աղբյուրների բարձրությունները, քիմիական կազմի վերափոխումները, արևի ճառագայթների, եղանակային և տոպոգրաֆիկ պայմանները: Փոշով աղտոտվածությունը գալիս է տարբեր աղբյուրներից՝ արդյունաբերական գործընթացներ, տրանսպորտային միջոցներ, ճանապարհային փոշի, շինարարություն: Երևանի մի շարք վարչական շրջաններում վերջին 5 տարիների ընթացքում փոշու, ազոտի և ծծմբի երկօքսիդի քանակները գերազանցում են ՍԹԿ-ները, քաղաքում առկա են փոշով աղտոտվածության չկարգավորվող ստատիկ աղբյուրներ: Աշխատանքում իրականացվել է Երևան քաղաքում վերջին 5 տարիներին հիմնական աղտոտիչների համեմատական վերլուծություն կլիմայի փոփոխության և ուրբանիզացման համատեքստում, ինչպես նաև կանաչապատ տարածքների ուսումնասիրություն, կանաչապատման գործողությունների արդյունավետության գնահատում և համադրություն ՀՀ ներպետական օրենսդրության նորմերի հետ:

***Բանալի բառեր***. մոնիթորինգային դիտակայաններ, փոշի, ազոտի երկօքսիդ, շինարարություն, տրանսպորտ, կանաչապատ տարածք, կլիմայի փոփոխություն:

# КАЧЕСТВО АТМОСФЕРНОГО ВОЗДУХА ГОРОДА ЕРЕВАНА В КОНТЕКСТЕ ИЗМЕНЕНИЯ КЛИМАТА

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В течение последних пяти лет наблюдается ухудшение качества атмосферного воздуха в Ереване, что обусловлено резким увеличением концентрации пыли, особенно в жаркие летние месяцы, совпадающие с активным туристическим сезоном. Существует сложная взаимосвязь между выбросами в атмосферу и качеством воздуха, которая включает такие факторы, как высота источников выбросов, изменения химического состава, солнечная радиация, а также погодные и топографические условия. Пылевое загрязнение возникает из множества источников, включая

промышленные процессы, транспорт, дорожную пыль и строительство. В ряде административных районов Еревана за последние пять лет уровень пыли, а также концентрация оксидов азота и диоксида серы превышают нормативные значения, установленные стандартами качества окружающей среды. Кроме того, в городе существуют нерегулируемые стационарные источники пылевого загрязнения.

В данной работе проведен сравнительный анализ основных загрязнителей в условиях изменения климата и урбанизации в Ереване за последние пять лет. Также было исследовано состояние зеленых зон и оценена эффективность мероприятий по озеленению в соответствии с нормами национального законодательства Республики Армения

***Ключевые слова:*** станции мониторинга, пыль, диоксид азота, строительство, транспорт, зеленые насаждения, изменение климата**.**

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Այս հրապարակումը պատրաստվել է Եվրոպական միության ֆինանսական աջակցությամբ: Բովանդակության համար պատասխանատվություն են կրում նյութի հեղինակները, եւ պարտադիր չէ, որ այն արտահայտի Եվրոպական միության տեսակետները:

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