

Atmospheric Particulate Matter Pollution in Batumi and Its Surroundings: Evidence from Operational Monitoring and Field Measurements

Liana N. Intskirveli^{1*}, Aleksandre A. Surmava², Vepkhia G. Kukhalashvili², and Natia G. Gigaauri¹

¹ Institute of Hydrometeorology, Georgian Technical University, Tbilisi, Georgia

² Mikheil Nodia Institute of Geophysics, Ivane Javakhishvili Tbilisi State University, Tbilisi, Georgia

*Corresponding author: Liana N. Intskirveli

Email address: intskirvebi2@yahoo.com ; ORCID: <https://orcid.org/0009-0006-3052-5440>

Abstract

Atmospheric particulate matter poses a significant environmental and public-health challenge in rapidly developing urban areas. This study assesses the temporal variability of fine and coarse particulate matter (PM_{2.5} and PM₁₀) in Batumi, Georgia, and its surrounding area using operational air-quality observations and experimental measurements. Batumi is Georgia's second-largest city, the capital of the Autonomous Republic of Adjara, and an important transport and tourism centre connecting regional routes across the South Caucasus. Its coastal location, complex terrain, climatic conditions, transport infrastructure, and continuing urbanisation make systematic air-quality assessment particularly important. The analysis uses observations collected at two urban air-quality monitoring locations during 2025. Temporal variations in PM_{2.5} and PM₁₀ concentrations were evaluated by determining their ranges, mean values, minima, maxima, and the frequency of exceedances of applicable daily concentration limits. Linear correlation coefficients were calculated to examine the relationship between the two particulate-matter fractions. The findings reveal a strong positive association between PM_{2.5} and PM₁₀ concentrations, suggesting that their temporal behaviour may be influenced by shared or interacting emission sources and meteorological processes. Recorded concentrations generally remained within permissible limits, while exceedances occurred only on a limited number of observation days. On the basis of the observed concentration ranges and the low frequency of daily-limit exceedances, Batumi may be characterised as a slightly polluted urban area during the study period. Nevertheless, conclusions regarding the city's overall air quality remain constrained by the limited spatial coverage of the existing monitoring network. Considering Batumi's complex topography and heterogeneous urban development, expanding observations through a dense network of calibrated, low-cost sensors is recommended to improve pollution mapping, source identification, exposure assessment, and evidence-based environmental management.

¹ Received: 2 January 2026; Accepted: 13 March 2026; Published: 8 August 2026

© 2026 The Author. Published by IMCRA. This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits unrestricted use, distribution, adaptation, and reproduction in any medium, provided that the original author and source are properly credited.

<https://creativecommons.org/licenses/by/4.0/>

Keywords: air-quality monitoring; Batumi; field measurements; particulate matter; PM_{2.5}; PM₁₀

Introduction. Microparticles present in the atmosphere of urban territories, which sizes don't exceed 2.5 μm and 10 μm – PM 2.5 and PM10, are extremely hazardous for human and animal health. Due to small sizes, they easily penetrate human body, cause many types of diseases and even result in death [1-10]. That is why, protection of urban areas from micro aerosol pollution is a critically important environmental problem. This problem is especially noteworthy for large cities – administrative and industrial centers [11-14], as well as for small towns [15-16] – touristic and medical and health-promoting resorts, with gathering of large crowds for recreation and health-improving and curative measures takes place.

Over the last 5-8 years, important practical air-protecting measures have been carried out in the cities of Georgia, aimed to monitoring of PM2.5 and PM10 pollution of atmospheric air of Georgian cities both through field observation and mathematical modeling [17-22].

Batumi, the second largest administrative and transport city of Georgia is a hub center connecting east and west, north and south. It links the Eastern Europe and Russia with countries of the lesser Asia. At the same time, it is a very important cultural and resort city, with millions of humans, coming here every year from different regions of the world and taking a rest here. That is why, preservation of clean air and ecologically safe environment of Batumi is an urgent problem.

Routine operating supervision of PM2.5 and PM10 concentrations in the city of Batumi has been made since 2018 in two observation points located on T. Abuseridze Street and in the Central city park. Both stations are situated at the heavily urbanized territory of the city and located at 1.8 km distance from each other. Monitoring has been conducted by the Batumi branch of the National Environmental Agency of Georgia according to internationally recognized standard program [23].

Research results and discussion.

Analysis of operational observation data. The pattern of Batumi atmospheric air pollution with PM2.5 and PM10 particles has been analyzed in the presented article based on 2025 operating supervision data and using statistical techniques. Fig. 1-fig.4 presents the average daily trend of PM2.5 and PM10 concentrations for the 4 seasons of 2025 (winter, spring, summer, autumn) based on data from operational observation points located in T. Abuseridze and Central Park.

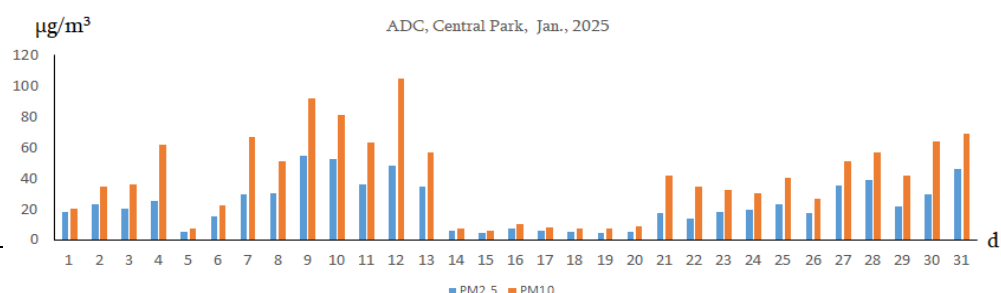
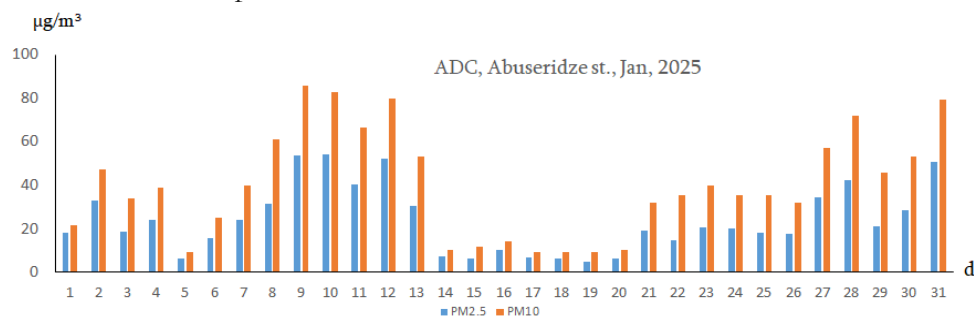


Fig. 1. Average daily concentrations of PM_{2.5} and PM₁₀ particles in January, at stations, located on T. Abuseridze Street and in the Central city park

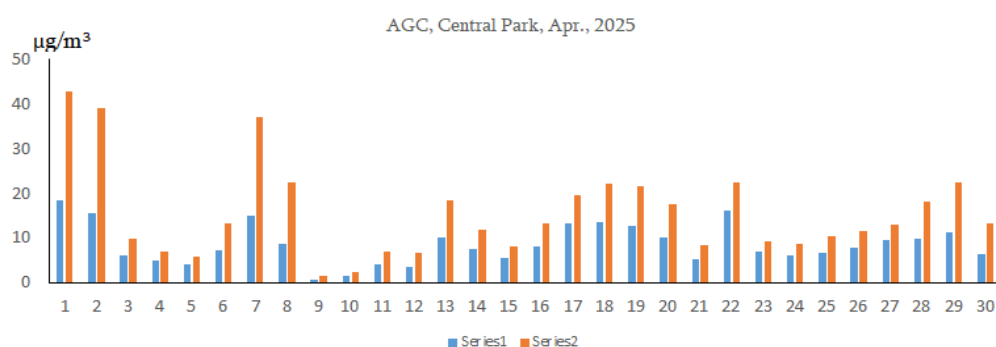
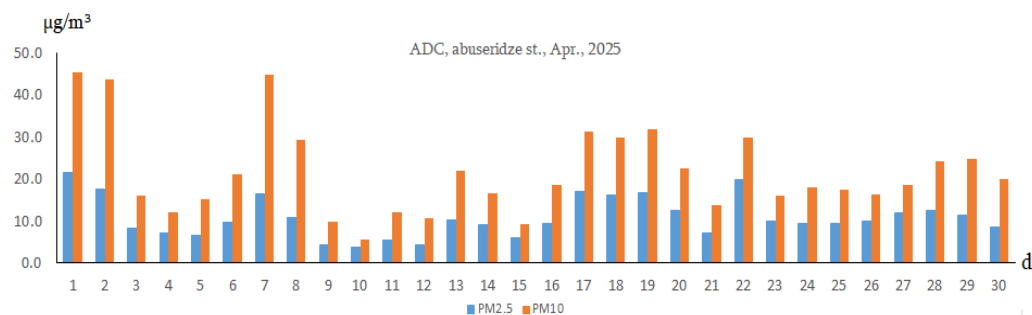
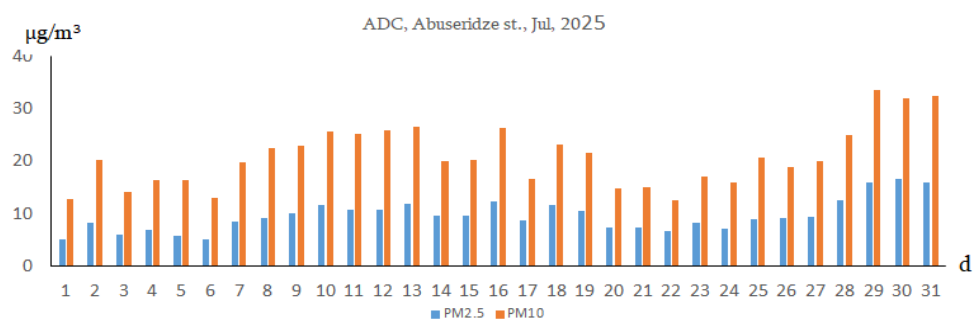


Fig. 2. Average daily concentrations of PM_{2.5} and PM₁₀ particles in April, at stations, located on T. Abuseridze Street and in the Central city park



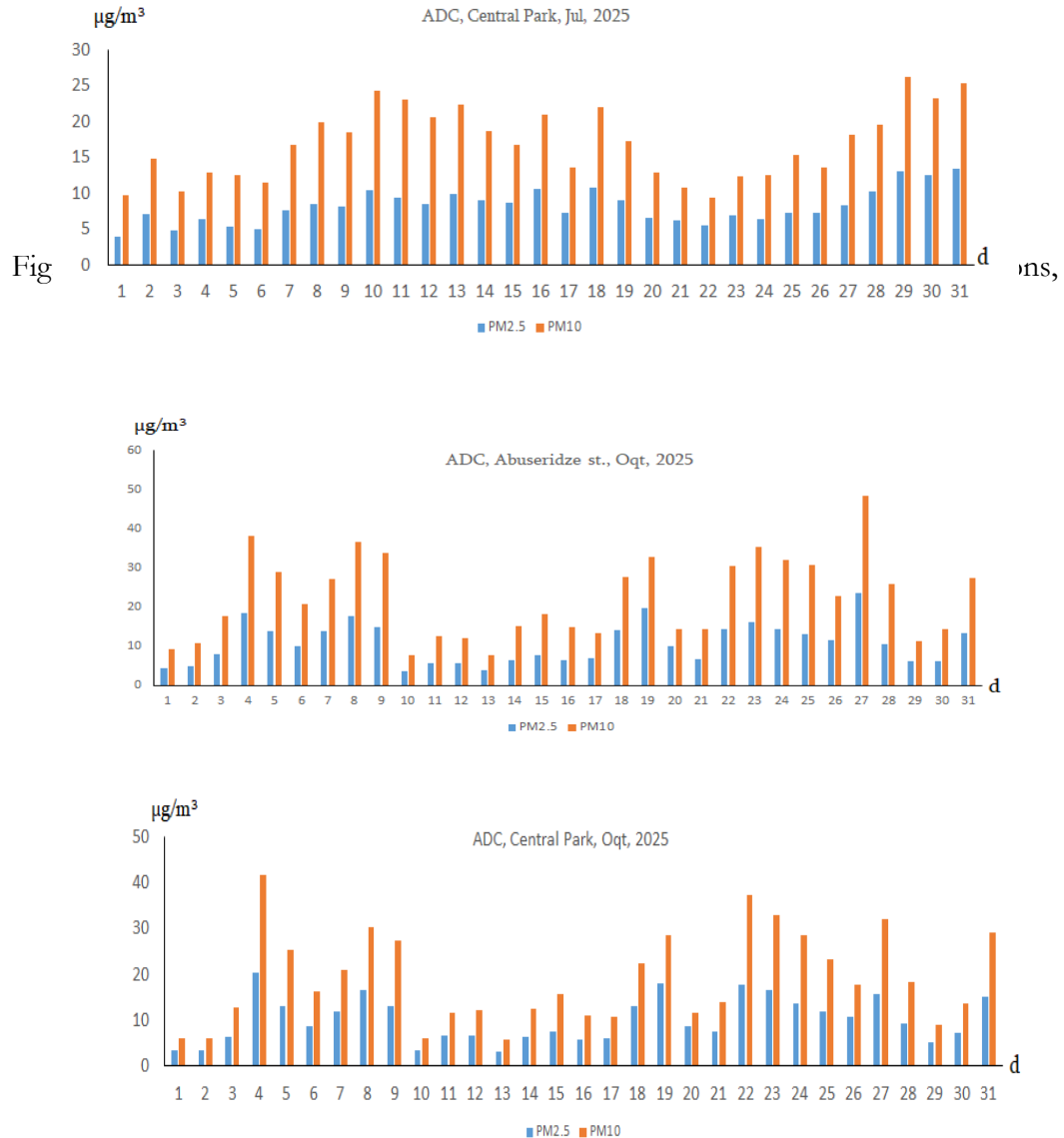


Fig. 4. Average daily concentrations of PM2.5 and PM10 particles in October, at stations, located on T. Abuseridze Street and in the Central city park

Fig. 1–fig.4 and the data from other months of 2025 show that microaerosol concentrations generally change synchronously: the concentration of PM2.5 is always lower than the concentration of PM10, and their increase/decrease interval in time coincides with the increase/decrease interval of PM10. The number of concentration increase/decrease intervals is within 2-4 per month, and the duration of each time interval varies from 3 to 8 days. Mentioned effect is probably related to changes in local meteorological conditions. At the same time, there are individual exceptions to the general pattern - short-term (one-day) sharp changes in concentration. For example, on January 12, 31, February 14, etc., a sharp increase in concentration for 1 day is observed. In some days, the exceedance of average daily concentrations over maximum permissible average hourly concentrations is obtained. In case of PM2.5 particles, the mentioned exceedance took place 44-times throughout 2025, while for PM10 – in 46 times.

The correlation analysis of ADC had shown that correlation between PM2.5 and PM10 concentrations is quite high. Linear correlation values mainly exceed 0.90. Only in two cases, in March and August,

linear correlation coefficients are less than 0.9 and equal to 0.80 and 0.76 in observation points located on T. Abuseridze Street and in the Central park. In terms of quantity, the data observed in the air quality observation station located at the territory of the Central park are similar to concentrations values obtained on T. Abuseridze Street. In particular, minimal value of PM_{2.5} average daily concentration varies within a range of 0.13-6.9 $\mu\text{g}/\text{m}^3$, average one – 7.3-25.6 $\mu\text{g}/\text{m}^3$, and maximal – 11.8 – 54.6 $\mu\text{g}/\text{m}^3$. For PM₁₀ particles, these data are as follows: 0.5-10.9 $\mu\text{g}/\text{m}^3$, 13.9-43.9 $\mu\text{g}/\text{m}^3$, 20.4-129.8 $\mu\text{g}/\text{m}^3$, respectively. As for the PM₁₀/PM_{2.5} ratio, its values vary within following ranges: minimal – 1.1-1.7, average – 1.7-2.4, and maximal – 2.1-4.5.

Proceeding from complex terrain of the city, its infrastructure, social, medical, health-promoting importance, it becomes evident that it is insufficient to monitor microaerol pollution of atmospheric air in two observation points only to provide a complete picture. In this regard, it is worth noticing the Italian experience, which lies in creation of network of multiple observation points using cheap sensors [25,26]. Therefore, at the first stage it is reasonable to carry out determination of PM_{2.5} and PM₁₀ concentrations in the atmosphere through field measurements made in Batumi and its adjacent territory on a frequent enough fine grid. For this purpose, in 2025 field observations on PM_{2.5} and PM₁₀ concentrations have been made during spring, summer and autumn seasons in up to 40 points located in Batumi and its surrounding. Measurements have been made using the mobile portable measuring device Aeroqual Series 500.

Field measurement results. Field measurement results. On the Batumi physical map (Fig. 5), by means of column diagrams, there are given values of PM₁₀ and PM_{2.5} concentrations on the field measurement stations at the territory of the city on 4-7 of May within a time interval of 10AM - 8PM. Fig. 6 shows the concentration values during the same time interval both for the city and its surroundings. It is seen from Fig. 5 and Fig. 6 that average daily concentration of PM₁₀ in the city area air is mainly within 10-20 $\mu\text{g}/\text{m}^3$, while PM_{2.5} concentration – within 5-15 $\mu\text{g}/\text{m}^3$ range. PM₁₀ concentration exceeds MPC (maximum permissible concentration. MPC for PM₁₀=50 $\mu\text{g}/\text{m}^3$) in three observation points – F. Khalvashi Street (120 $\mu\text{g}/\text{m}^3$), Tamar Mepe Avenue (56 $\mu\text{g}/\text{m}^3$) and Airport Highway (82 $\mu\text{g}/\text{m}^3$). As for the mentioned observation points, PM_{2.5} concentration slightly prevails over MPC in one of them – on F. Khalvashi Street, while in other sites microaerosol concentrations are less than MPC. In the territories adjacent to Batumi, PM₁₀ and PM_{2.5} concentrations exceeds MPC only in one observation point (Gonio-Kvariati).



Fig.5. Column diagrams of PM₁₀ (blue) and PM_{2.5} (red) concentrations

on the physical map of Batumi (5-7 May, 2025)

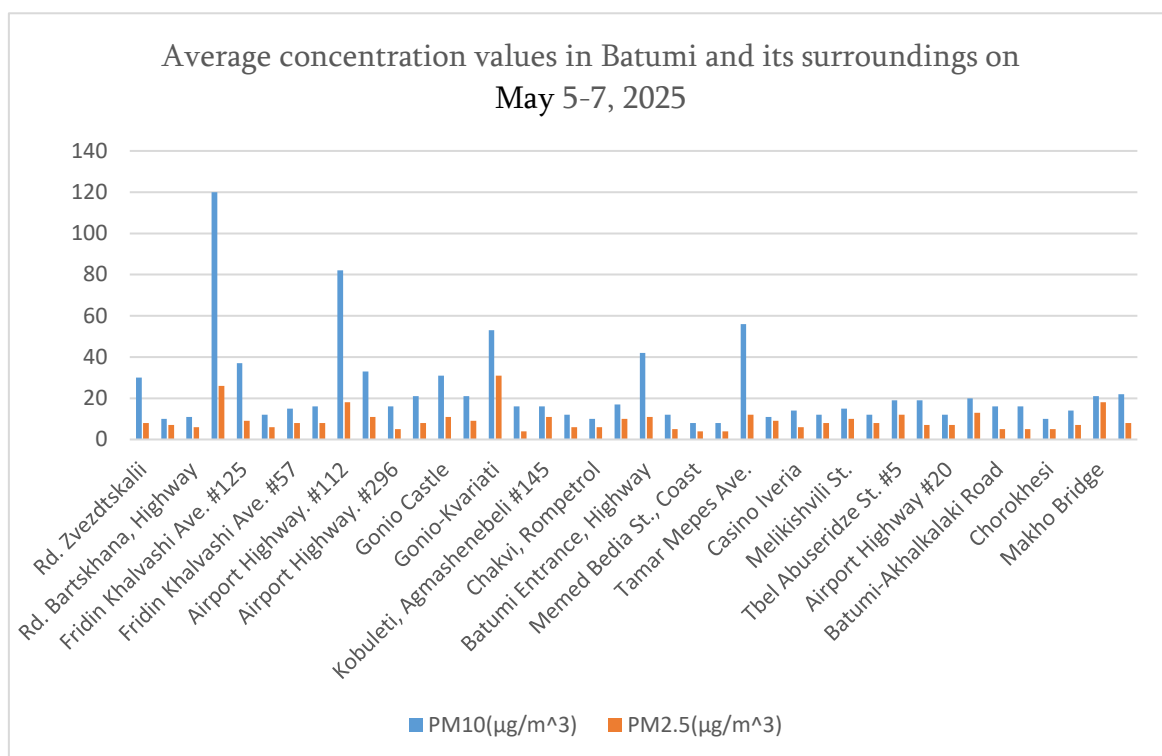


Fig. 6. Column diagrams of PM10 (blue) and PM2.5 (red) concentrations in the field observation points of Batumi and adjacent territories (5-7 May, 2025)

In Fig. 7, there is given the microparticle distribution in the maximally urbanized, central part of Batumi adjacent to the Black Sea. It is seen from Fig. 3 that average values of PM10 concentration are high in two observation points located on Z. Gorgiladze and I. Gogebashvili Streets. This concentration is especially high on Z. Gorgiladze Street ($82 \text{ mkg}/\text{m}^3$), while in the point situated on I. Gogebashvili Street it barely exceeds MPC ($54 \text{ }\mu\text{g}/\text{m}^3$). Relatively high concentrations have been established in the vicinity of the Orbi City Hotel ($44 \text{ }\mu\text{g}/\text{m}^3$), Rustaveli ($35 \text{ }\mu\text{g}/\text{m}^3$), Gogol ($33 \text{ }\mu\text{g}/\text{m}^3$) and I. Noneshvili Streets ($32 \text{ }\mu\text{g}/\text{m}^3$). In other measurement points PM10 concentrations mainly vary within a limit of $5\text{-}25 \text{ }\mu\text{g}/\text{m}^3$. As for PM2.5 concentrations, they don't exceed $20 \text{ }\mu\text{g}/\text{m}^3$, both in Batumi, and in the measurement points located at the territory of the cities nearby: Kobuleti, Lanchkhuti and Chakvi (Fig. 4)

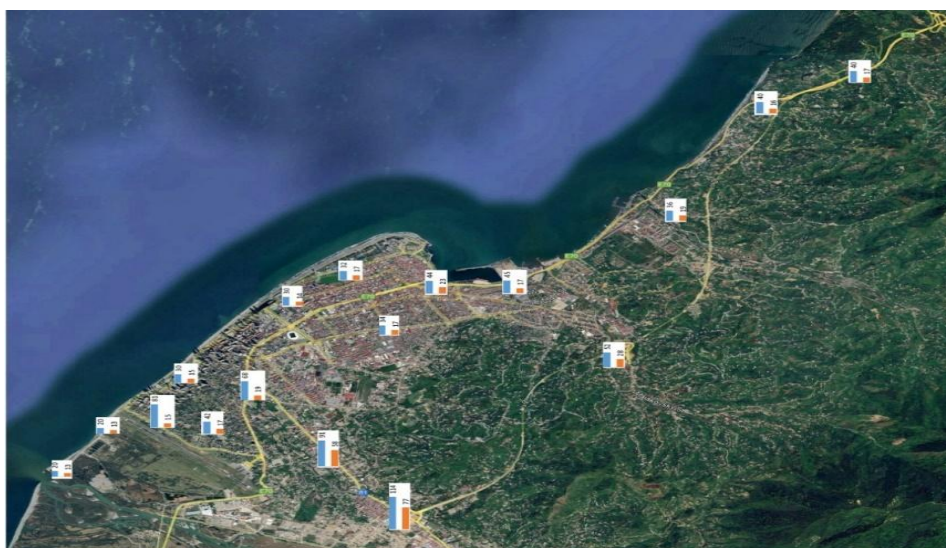


Fig. 7. Column diagrams of PM10 (blue) and PM2.5 (red) concentrations on the physical map of Batumi (November 26-28, 2025)

Field measurements made on 26-28 of November showed that PM10 concentrations exceed MPC in the south-west part of the city, in the vicinity of Airport, on G. Antsukhelidze Street, at the economic and industrial territory located on F. Khalvashi Street, and on Adlea Street (Fig. 5). In these locations, PM10 concentrations vary within the limits of 68-114 $\mu\text{g}/\text{m}^3$. PM10 values exceeding MPC are obtained in the settlements situated in the vicinity of Batumi, namely: Khajalia Village, Poti Port, Poti Central Square and Batumi by-pass crossroad.

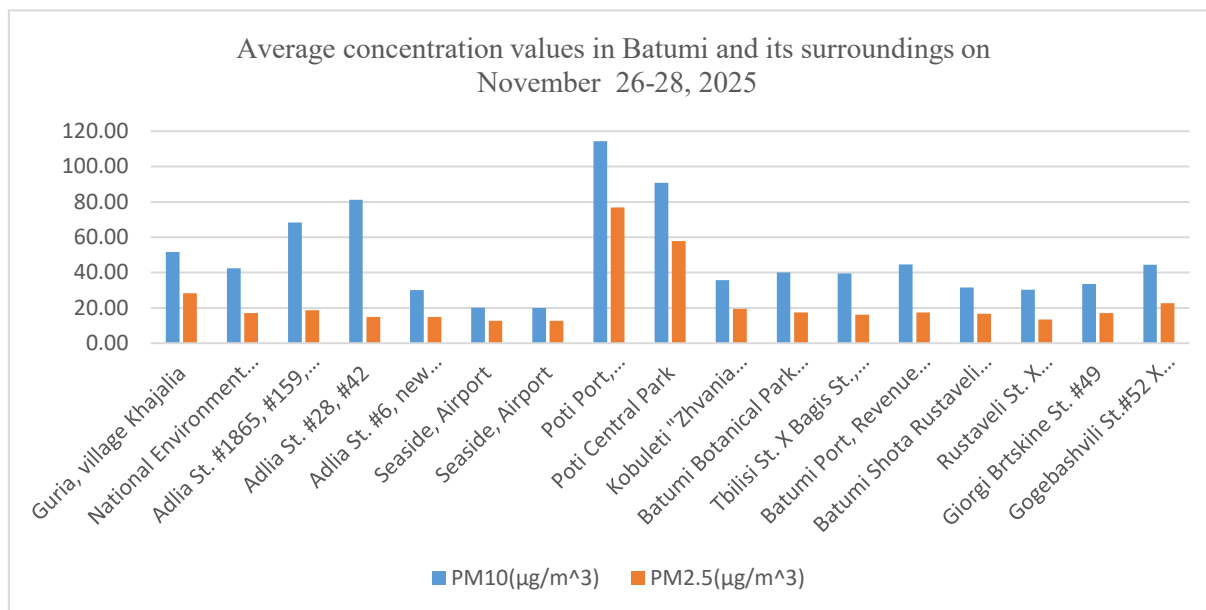


Fig. 8. Column diagrams of PM10 (blue) and PM2.5 (red) concentrations in the field observation points of Batumi and adjacent territories (November 26-28, 2025)

Visual inspection of territories surrounding the field measurement points showed that high PM10 concentrations are mainly associated with road maintenance and construction works. As for PM2.5 concentrations, they are especially high at the economic and industrial territory located on F. Khalvashi Street, where their values are higher than 2MPC (Fig. 5 and 6), while in the city center and heavily urbanized territories the values of microparticle concentrations are smaller than MPC.

Linear correlation between PM10 and PM2.5 concentrations has been assessed during all three field measurements. It has been obtained that the values of linear correlation coefficient in May and November are quite high and equal to 0.76 and 0.83, respectively. As for July, correlation coefficient between PM10 and PM2.5 concentrations equals to 0.58. At the same time, it is less than a correlation coefficient value between concentrations measured in operating observation points. The mentioned circumstance presumably points at the fact that while in the central part of the city PM10 and PM2.5 concentration field is formed by a single source (probably by motor transport), in the whole city and adjacent territories there are other significant pollution sources.

Concluzions: Based on operational observations and experimental measurements, the spatial distribution of PM2.5 and PM10 in the ambient air of Batumi and the surrounding area has been estimated for the year 2025. It is accepted that there is a high linear correlation between their concentrations, both between data from the same observation point and from different observation points. Analysis of the range of changes in PM2.5 and PM10 concentrations in the atmosphere, the

small number of days when the average daily concentration exceeds the MPC, allows us to conclude that Batumi can be classified as a slightly polluted city in terms of ambient air quality. At the same time, given the complex terrain of the city, the surrounding area and the nature of the city's urbanization, it is advisable to increase the number of observation points located in the city. For this purpose, frequent low-cost sensor networks of observations implemented in Europe can be used [24, 25].

Acknowledgment. The scientific research has been funded and performed within the frameworks of the Grant project FR-24-223 of the Shota Rustaveli National Scientific Foundation.

Declarations

Ethics Approval: Not applicable; the study involved no human participants or animals.

Consent to Participate: Not applicable.

Conflict of Interest: The authors declare no conflicts of interest.

Funding: The authors received no specific external funding for this study.

Author Contributions: All authors contributed to the study design, data analysis, interpretation of results, and preparation and revision of the manuscript.

Data Availability: The data supporting the findings are available from the corresponding author upon reasonable request.

References

1. Agrawal, G., Mohan, D., & Rahman, H. (2021). Ambient air pollution in selected small cities in India: Observed trends and future challenges. *LATSS Research*, 45(1), 19–30. <https://doi.org/10.1016/j.iatssr.2021.03.004>
2. Air Quality Portal of Georgia. (n.d.). *Air quality monitoring data*. Retrieved August 17, 2026, from <https://air.gov.ge/>
3. Anderson, J. O., Thundiyil, J. G., & Stolbach, A. (2012). Clearing the air: A review of the effects of particulate matter air pollution on human health. *Journal of Medical Toxicology*, 8(2), 166–175. <https://doi.org/10.1007/s13181-011-0203-1>
4. Bell, M. L., & Davis, D. L. (2001). Reassessment of the lethal London fog of 1952: Novel indicators of acute and chronic consequences of acute exposure to air pollution. *Environmental Health Perspectives*, 109(Suppl. 3), 389–394. <https://doi.org/10.1289/ehp.01109s3389>
5. Chiesa, S., Di Pietro, A., Pollino, M., & Taraglio, S. (2022). Urban air pollutant monitoring through a low-cost mobile device connected to a smart road. *ISPRS International Journal of Geo-Information*, 11(2), Article 132. <https://doi.org/10.3390/ijgi11020132>
6. Commersant.ge. (n.d.). *The five most polluted and cleanest countries in the world: Where does Georgia rank?* Retrieved August 17, 2026, from <https://commersant.ge/news/world/msoflioshi-5-yvelaze-dabindzurebulisufta-qveyana-romel-adgilzea-saqartvelo>
7. Earth.Org. (n.d.). *Most polluted cities in the world*. Retrieved August 17, 2026, from <https://earth.org/most-polluted-cities-in-the-world/>
8. Gigauri, N., Intskirveli, L., & Surmava, A. (2023). Study of Rustavi city atmospheric pollution with particulate matter—PM_{2.5} and PM₁₀. *Bulletin of the Georgian National Academy of Sciences*, 17(4), 74–80.
9. Gigauri, N., Intskirveli, L., Surmava, A., & Kukhalashvili, V. (2024). The results of Kutaisi city atmospheric air pollution with PM particles. *Bulletin of the Georgian National Academy of Sciences*, 18(3), 90–96.
10. Gigauri, N., Surmava, A., & Intskirveli, L. (2023). Numerical modelling of PM₁₀ distribution in the atmosphere of Rustavi City, Georgia, during background northerly winds [Conference presentation]. *Fifth Euro-Mediterranean Conference for Environmental Integration (EMCEI 2023)*.

11. IQAir. (n.d.-a). *World's most polluted cities: Historical data, 2017–2022*. Retrieved August 17, 2026, from <https://www.iqair.com/world-most-polluted-cities>
12. IQAir. (n.d.-b). *World's most polluted countries and regions*. Retrieved August 17, 2026, from <https://www.iqair.com/world-most-polluted-countries>
13. Kobza, J., Geremek, M., & Dul, L. (2018). Characteristics of air quality and sources affecting high levels of PM₁₀ and PM_{2.5} in Poland's Upper Silesia urban area. *Environmental Monitoring and Assessment*, 190, Article 515. <https://doi.org/10.1007/s10661-018-6797-x>
14. Lefler, J. S., Higbee, J. D., Burnett, R. T., Ezzati, M., Coleman, N. C., Mann, D. D., Marshall, J. D., Bechle, M., Wang, Y., Robinson, A. L., & Pope, C. A., III. (2019). Air pollution and mortality in a large, representative U.S. cohort: Multiple-pollutant analyses and spatial and temporal decompositions. *Environmental Health*, 18, Article 101. <https://doi.org/10.1186/s12940-019-0544-9>
15. LIFE Prepair. (2023, June 22). *The 2022 air quality assessment report for the Po Valley Basin and Slovenia is online*. <https://www.lifeprepare.eu/index.php/2023/06/22/online-the-2022-air-quality-assessment-report-for-the-po-valley-basin-and-slovenia/?lang=en>
16. Nemery, B., Hoet, P. H. M., & Nemmar, A. (2001). The Meuse Valley fog of 1930: An air pollution disaster. *The Lancet*, 357(9257), 704–708. [https://doi.org/10.1016/S0140-6736\(00\)04135-0](https://doi.org/10.1016/S0140-6736(00)04135-0)
17. Pope, C. A., III, Burnett, R. T., Thun, M. J., Calle, E. E., Krewski, D., & Ito, K. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA*, 287(9), 1132–1141. <https://doi.org/10.1001/jama.287.9.1132>
18. Surmava, A., Gigauri, N., Intskirveli, L., & Dumbadze, G. (2025). PM₁₀ concentration distribution in the surface layer of the atmosphere of Kutaisi City, Georgia, during calm weather. In *Proceedings of the Twelfth International Conference on Environmental Management, Engineering, Planning and Economics* (pp. 67–75). ISBN 978-618-5710-90-3.
19. Surmava, A., Gigauri, N., Kukhalashvili, V., & Intskirveli, L. (2025). Assessment of Kutaisi city atmospheric air pollution with high-risk PM_{2.5} particles by means of numerical modeling. *Reliability: Theory & Applications*, 20, Special Issue 9(87), 137–1267.
20. Surmava, A. A., Kukhalashvili, V. G., Gigauri, N. G., & Intskirveli, L. N. (2024). Study of Kutaisi city atmospheric air pollution with PM₁₀ particles using numerical modeling: A case of a fresh western background breeze. *Journal of the Georgian Geophysical Society: Physics of Solid Earth, Atmosphere, Ocean and Space Plasma*, 27(1), 19–24.
21. Surmava, A. A., Kukhalashvili, V. G., Gigauri, N. G., Intskirveli, L. N., & Gverdtseteli, L. V. (2025). Numerical modeling of Kutaisi city atmospheric air pollution with PM_{2.5} particles in winter during ground-level calm and background eastern wind in the free atmosphere. *Journal of the Georgian Geophysical Society: Physics of Solid Earth, Atmosphere, Ocean and Space Plasma*, 28(1), 40–49.
22. U.S. Environmental Protection Agency. (2010, November 16). *History of the Clean Air Act*. <https://www.epa.gov/clean-air-act-overview/evolution-clean-air-act>
23. U.S. Environmental Protection Agency. (2019). *Integrated science assessment for particulate matter* (EPA/600/R-19/188). <https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter>
24. Wikipedia contributors. (n.d.). *List of countries by air pollution*. In *Wikipedia*. Retrieved August 17, 2026, from https://en.wikipedia.org/wiki/List_of_countries_by_air_pollution
25. World Health Organization. (2020). *Mortality and burden of disease from ambient air pollution*. <https://www.who.int/data/gho/data/themes/air-pollution/ambient-air-pollution>
26. World Health Organization Regional Office for Europe. (2013). *Review of evidence on health aspects of air pollution: REVIHAAP project—Technical report*. <https://iris.who.int/handle/10665/341712>

