**712.25:504.61(477.51)** **DOI: 10.58407/bht.3.24.8**



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# ASSESSING THE LEVEL OF ANTHROPOGENIC PRESSURE ON PARK ECOSYSTEMS IN CHERNIHIV

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# ОЦІНКА РІВНЯ АНТРОПОГЕННОГО НАВАНТАЖЕННЯ НА ПАРКОВІ ЕКОСИСТЕМИ ЧЕРНІГОВА

**ABSTRACT**

**Objective**: To evaluate the condition of park ecosystems in Chernihiv in relation to urbanization levels and air pollution from vehicular emissions.

**Methodology**: The study assessed the state of park ecosystems (PE) in various districts of Chernihiv, following the methodological guidelines by Lavrov et al. (2021). Species composition, the health of vegetation by layers, and the impact of anthropogenic pollution were examined in temporary sample plots (0.2–0.6 ha) established in mature park areas in 2023. The urbanization index was calculated using the Urbanisation Score software, which analyzes land use—such as asphalt, buildings, and green space intensity—using Google Maps imagery. Road traffic load and phytotoxic emissions near the PEs were estimated based on the methodology of Miroshnyk et al. (2022). Maps were generated with the GIS tools Golden Software Surfer 19.2.213, using the kriging method, and QGIS 3.16.3.

**Scientific Novelty:** This study provides the first environmental assessment of Chernihiv's green infrastructure a year after the intense warfare of spring 2022. The findings reveal that urbanization index values in Chernihiv range from 2.5 to -5, decreasing as one approaches the Dnipro River valley.

**Conclusions**: The study found that the regional landscape park 'Yalivshchyna' and the remaining forest area in the Podusivka neighborhood are significantly impacted by vehicular aerotoxicants. The central park, 'City Garden', and the municipal forest park, 'Maryin Hai,' situated within the river valley, display better sanitary conditions than those in the city's central areas. Urbanization levels decrease closer to the river valley. Additionally, the Ski Base forest area suffered notable damage to its green infrastructure due to warfare during the city's siege in February-April 2022.

**Keywords**: green infrastructure, sustainable development, urbanisation index, warfare, biodiversity, air pollution

**АНОТАЦІЯ**

**Мета роботи**. Оцінювання стану паркових екосистем міста Чернігова залежно від рівня урбанізації та аерозабруднення від автошляхів.

**Методологія.** Стан паркових екосистем (ПЕ) м. Чернігова, розташованих в різних районах міста за методичними рекомендаціями (Lavrov et al., 2021). Видовий склад, санітарний стан насаджень за ярусами і вплив аеротехногенного забруднення вивчали на тимчасових пробних площах (площа 0.2-0.6 га) у середньовікових насадженнях у 2023. Індекс урбанізації, розрахований за допомогою програми Urbanization Score, яка аналізує поверхню землі за категоріями – асфальт, будівлі та інтенсивність зелених насаджень за знімками Google Maps. Навантаження автошляхів та кількість викинутих у повітря фітотоксикантів біля ПЕ обраховано за методикою (Miroshnyk et al., 2022. Для побудови карт використовували ГІС-пакет Golden Software Surfer 19.2.213 з методом кригінгу та QGIS 3.16.3.

**Наукова новизна.** Вперше, через рік після активних бойових дій, навесні 2022 року провели екологічну оцінку зеленої інфраструктури Чернігова. Результати дослідження показують, що значення індексів урбанізації в Чернігові коливаються від 2,5 до -5 і зменшуються з наближенням до долини р. Дніпро.

**Висновки.** Встановлено, що регіональний ландшафтний парк «Ялівщина» та залишки лісового масиву мікрорайону Подусівка зазнають значного впливу аеротоксикантів автомобільних викидів. Центральний парк культури і відпочинку «Міський сад» і міський лісопарк «Мар'їн Гай», розташовані в долині річки, мають кращий санітарний стан, ніж у центральній частині міста. З наближенням до долини річки ступінь урбанізації зменшується. Значні пошкодження зеленої інфраструктури в лісовій зоні Лижної бази зафіксовано внаслідок бойових дій під час облоги міста в лютому-квітні 2022 року.

**Ключові слова:** зелена інфраструктура, сталий розвиток, індекс урбанізації, військові дії, біорізноманіття, забруднення повітря

### Problem Statement

Urbanization, air pollution, and the condition of urban green infrastructure (GI) are interlinked factors that influence GI's capacity to provide essential ecosystem services. Sustainable forest management, preservation of natural habitats, biodiversity, and sustainable urban development are key global objectives within the Sustainable Development Goals (A/RES/70/1, Agenda for Sustainable Development). This strategic document highlights the need to improve air quality and conserve green spaces as integral to achieving sustainable urban development. Currently, Ukraine's policy on Sustainable Development Goal implementation, as outlined in a Presidential Decree (2019), emphasizes the «protection and restoration of terrestrial ecosystems, promotion of their sustainable use, sustainable forest management, combating desertification, reversing land degradation, and halting biodiversity loss.»

Policy recommendations for GI management and conservation in the context of rapid urbanization have been provided for Ukrainian cities (Lavrov et al., 2021; Miroshnyk et al., 2023). Interdisciplinary research supporting biodiversity conservation, policy development, and global sustainability is especially critical for Ukraine in the context of European integration and the current emergency of warfare on its territory (Blachowski & Hajnrych, 2021; Dubyna et al., 2023; Lukash et al., 2024). An analysis of prior research demonstrates that an interdisciplinary approach has been developed and recommended to assess ecosystem functionality effectively.

**The aim of the study** to assess the condition of park ecosystems in Chernihiv in relation to urbanization levels and air pollution from vehicles.

### Research methodology

The park ecosystems of Chernihiv were studied during the summer of 2023 (Table 1). Research methods for analyzing tree and grass layers were based on Lavrov et al. (2021). Species composition, sanitary condition of vegetation by canopy layers, and the impact of air pollution were assessed in temporary test plots (TP) with areas ranging from 0.2 to 0.6 ha in medieval plantations.

*Table 1*

**List of studied park ecosystems in Chernihiv city**

| № | Name of PE | GPS coordinates | |
|---|---|---|---|
| 1 | Forest area «Ski base» | 51.53088440631798 | 31.354794952338857 |
| 2 | Berezovyi Hai Forest Park | 51.52045510031688 | 31.333408574947587 |
| 3 | Yalivshchyna Regional Landscape Park with Yalivshchyna Forest Reserve | 51.52312061880307 | 31.297746013397923 |
| 4 | Central Park of Culture and Recreation – City Garden | 51.499204613766736 | 31.324535312073664 |
| 5 | Urban forest park «Maryin gai» | 51.49435137384146 | 31.31177328156124 |
| 6 | Park-monument of landscape art «Boldina Gora» | 51.478441697497544 | 31.284755172370115 |
| 7 | Remnants of the Podusivka neighbourhood forest | 51.489222660694054 | 31.238644469751556 |

Urbanisation Index (*UI*) calculated using the Urbanisation Score software (Seress et al., 2014), which analyses the land surface by categories such as asphalt, buildings and green space intensity using Google Maps images. The load of roads and the amount of phytotoxicants released into the air near the PEs were calculated using the methodology (Miroshnyk et al., 2022). The intensity of car traffic in Chernihiv was determined in the locations shown on the figure 1.


**Fig. 1. Locations of determining the intensity of traffic in the Chernihiv city**

## Results

Chernihiv is the administrative center of the Chernihiv region in Polesie, situated in the mid-reaches of the Desna River. The city had a population of approximately 300,000 people before the full-scale invasion in 2022. The average annual temperature is +7.6°C, and annual rainfall averages 613 mm. Chernihiv is home to the Desna and Stryzhen rivers, as well as several ponds and lakes. Green spaces include remnants of pine, oak-pine, and birch forests, along with cultivated plantings. In parts of the Desna River floodplain, alder and willow-poplar forests have also been preserved (Zavialova, 2011). According to Ukraine's floristic zonation, the study area belongs to the European region, the Eastern European province, Polesie sub-province, and the Left Bank Dnipro district (Geobotanical zoning …, 1977).

The primary stabilizing framework of Chernihiv's urban ecosystem consists of areas that have retained a near-natural character, including green spaces and riparian zones along natural water bodies such as the floodplain of the Desna River and the slopes of its high right bank. This framework encompasses the territories of the nature reserve fund, squares, parks, and forest parks. The total area of the city is 7,132 hectares, of which 3,100 hectares are covered by green spaces (Pototska, 2014). Researchers have conducted detailed studies on the city's woody vegetation and parks (Pototska, 2014; Lukash & Andrienko, 2011). In Chernihiv, there are 265 species and 75 cultivars of woody plants, belonging to 125 genera and 54 families. In terms of quantitative indicators, the *Magnoliophyta* division predominates, with 229 species. Among angiosperms, the most diverse families are *Rosaceae*, with 75 species, and *Salicaceae*, with 22 species. Among gymnosperms, the most numerous families are *Pinaceae*, with 17 species, and *Cupressaceae*, with 13 species (Pototska, 2014). The vegetation of specific green spaces in Chernihiv was studied in 2022 (Karpenko et al., 2022).

Between 24 February and 6 April 2022, intense warfare took place in Chernihiv and the region, and Chernihiv was besieged and heavily shelled by Russian troops, including aviation (War Crimes in Chernihiv Region).

We conducted field research in 7 PEs in Chernihiv (Fig. 2).

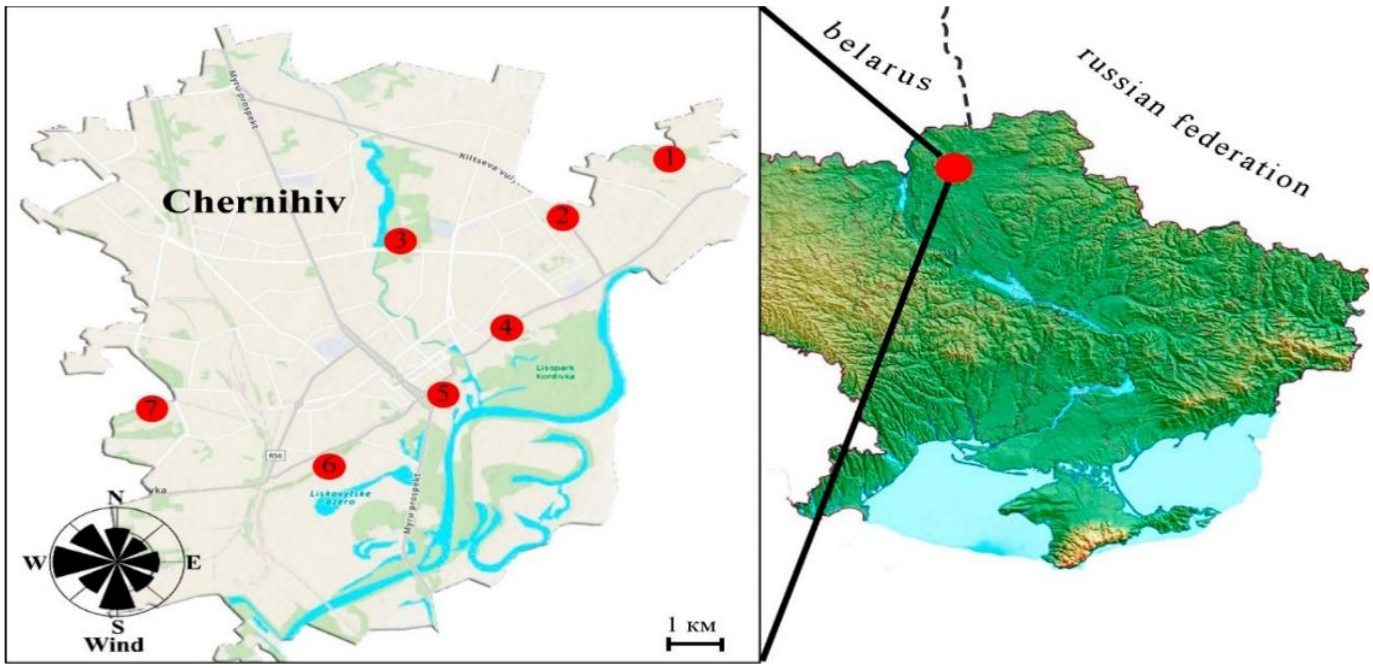


**Fig. 2. Investigated PEs in Chernihiv (2023):**
**1 – Forest area «Ski base»; 2 – Forest park «Berezovyi hai»;**
**3 – Regional landscape park «Yalivshchyna» with forest reserve «Yalivshchyna»;**
**4 – Central park of culture and recreation – «City garden»; 5 – City forest park «Maryin hai»;**
**6 – Park-monument of landscape art – «Boldyna Hora»;**
**7 – Remains of Podusivka neighbourhood forest area**

A relief map (Fig. 3) was created to assess the dynamics of the spread of air pollutants from vehicles, as the relief drops into the Desna River valley as it approaches the river. Consequently, air pollutants could migrate to the river valley to a greater extent due to the prevailing wind directions.

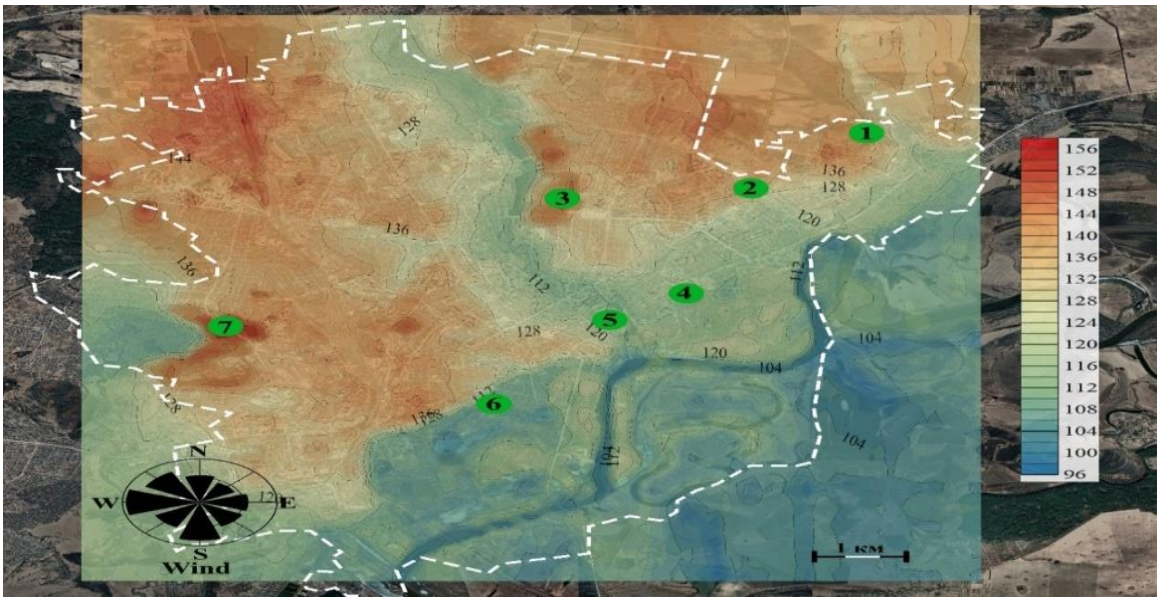


**Fig. 3. Relief of the Chernihiv city, where the numbers indicate the distance in m above sea level. PE numbers as in the Fig. 2**

The level of urbanization in the city was analyzed (Fig. 4). It was observed that the degree of urbanization decreases as one approaches the river valley. The research results indicate that urbanization index values in Chernihiv range from 2.5 to -5, which suggest a healthy condition for the studied landscapes. The lowest urbanization index value reflects the

least degree of urbanization and is characteristic of natural, undisturbed areas. Overall, the level of urbanization in Chernihiv is significantly lower than that of Kyiv. In Chernihiv, the maximum urbanization index is 2.5, while the minimum (indicating good landscape condition) is -5. In comparison, Kyiv has a maximum urbanization index of 3.5 and a minimum of 4 (Miroshnyk et al., 2022a).

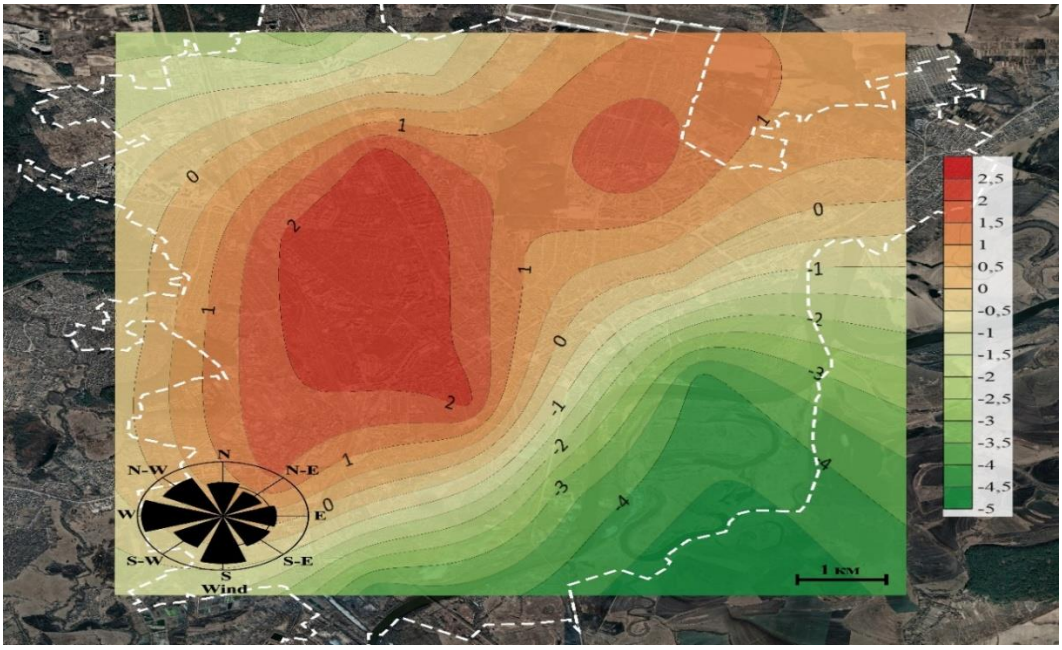


**Fig. 4. The value of the urbanization indice (*UI*) of the Chernihiv landscapes**

The intensity of traffic in the city was assessed using the number of cars per hour (Fig. 5). It was found that the highest volume of traffic occurs in the neighborhoods near the Yalivshchyna and Podusivka residential areas, which corresponds with a high level of urbanization in these regions (Fig. 5).

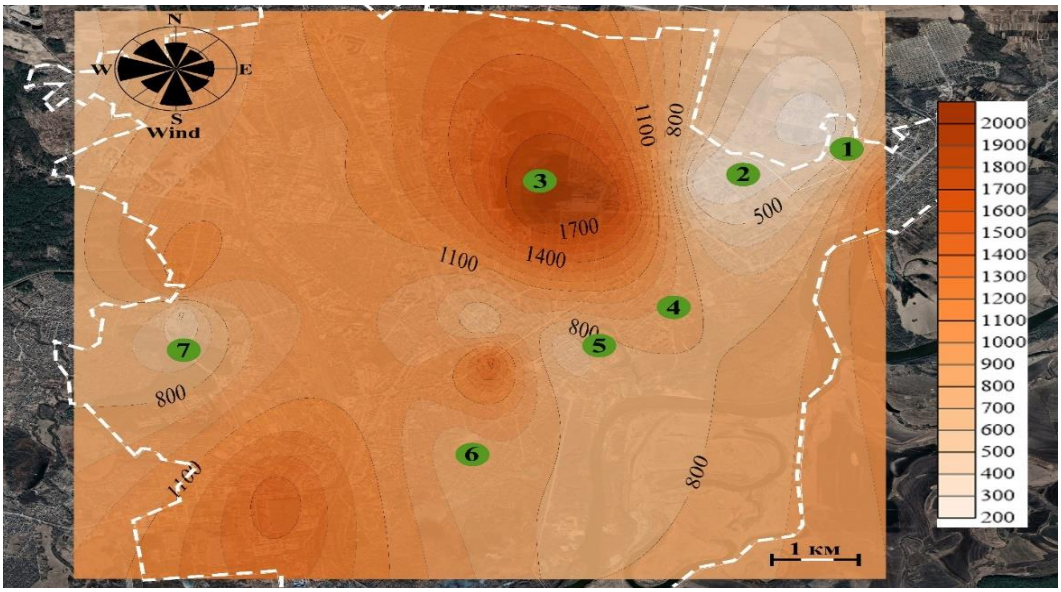


**Fig. 5. Number of cars per hour, Chernihiv, where the numbers on the green background indicate the studied Pes, 1 – Forest area «Ski base»; 2 – Forest park «Berezovyi hai»; 3 – Regional landscape park «Yalivshchyna» with forest reserve «Yalivshchyna»; 4 – Central park of culture and recreation – «City garden»; 5 – City forest park «Maryin hai»; 6 – Park-monument of landscape art – «Boldyna Hora»; 7 – Remains of Podusivka neighbourhood forest area**

In terms of vehicle emissions, the most severe pollution was found in the city center ($NO_x$, $SO_2$, soot, hydrocarbons, formaldehyde, Pb compounds), particularly along Myru Avenue and Pashina Street (Fig. 6). Myru Avenue serves as one of the city's main thoroughfares, and the presence of checkpoints at the entrances and exits of the border city further impacts traffic intensity and flow.

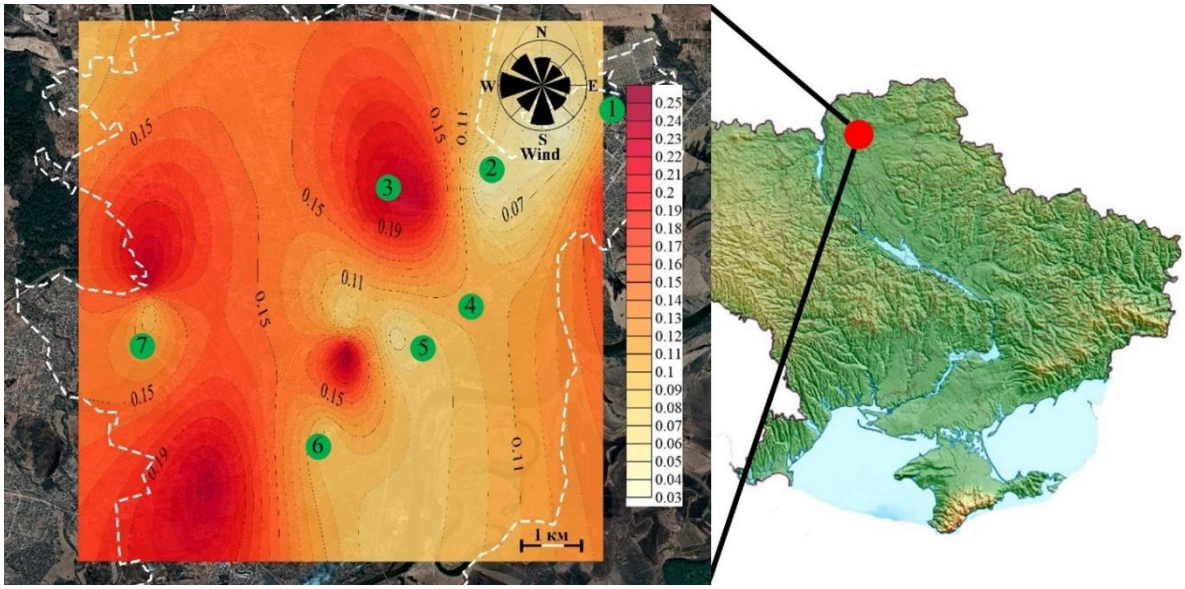


**Fig. 6. Total emissions from transport traffic, 1 – Forest area «Ski base»; 2 – Forest park «Berezovyi hai»; 3 – Regional landscape park «Yalivshchyna» with forest reserve «Yalivshchyna»; 4 – Central park of culture and recreation – «City garden»; 5 – City forest park «Maryin hai»; 6 – Park-monument of landscape art – «Boldyna Hora»; 7 – Remains of Podusivka neighbourhood forest area**

The highest number of cars and total emissions ($NO_x$, $SO_2$, soot, hydrocarbons, formaldehyde, Pb compounds) were on 77th Guards Division, Pashina Street, First of May, Peremohy Avenue (Fig. 7).

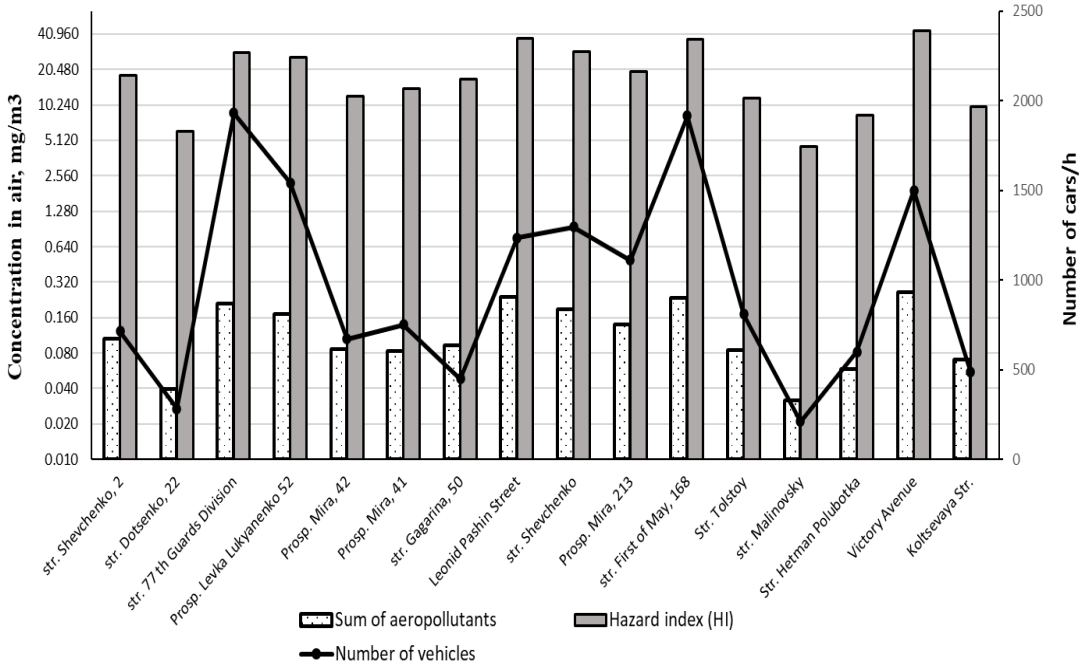


**Fig. 7. Traffic indicators and pollutant hazard index (*HI*), Chernihiv**

The highest levels of hydrocarbon (HC) and nitrogen oxide (NOx) emissions are particularly concentrated on the central streets, such as Peremohy Avenue, as well as on the outskirts where there is a high volume of truck traffic, including Pashina Street and Levka Lukyanenko Street (Fig. 8).

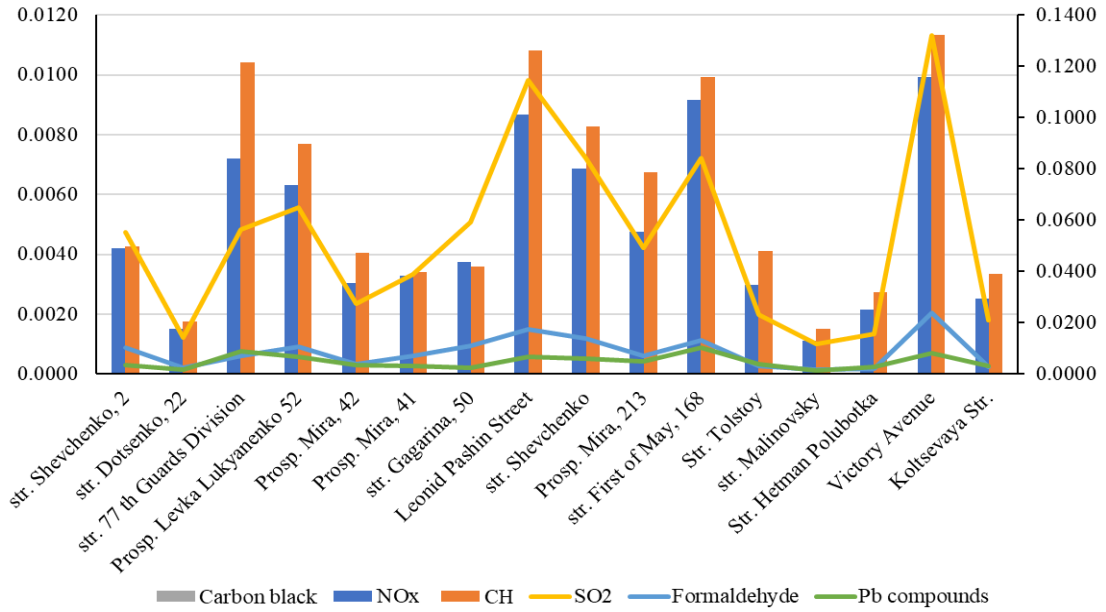


**Fig. 8. Pollutant emissions from motor vehicles**

A comparison of anthropogenic load and the geographical locations of the park ecosystems (PEs) reveals that PEs 3 and 7 are situated in a highly urbanized part of the city, with PE 3 located in the city center. Consequently, it is significantly affected by aerotoxicants from vehicle emissions. In contrast, PEs 1, 4, 5, and 6 are located on the outskirts of the city, in less urbanized areas, with PEs 5 and 6 also situated in the river valley. As a result, their sanitary conditions are better than those found in the central part of the city (see Fig. 9).

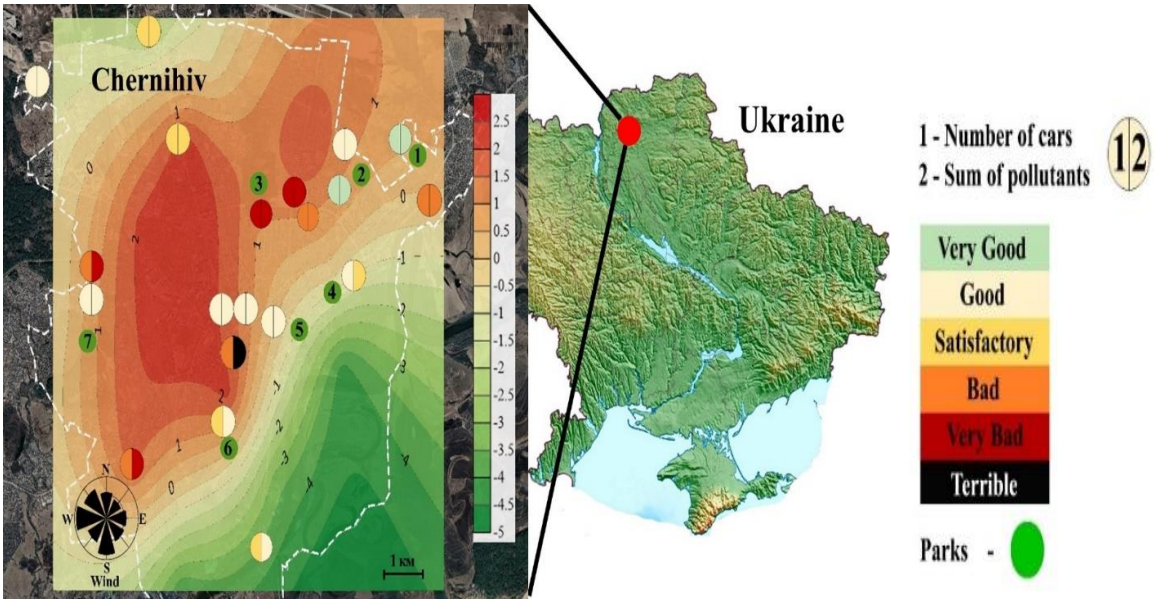


**Fig. 9. Map of the condition of PEs and the degree of urbanisation in Chernihiv, with the scale on the side showing the degree of urbanisation (*UI*), 1 – Forest area «Ski base»; 2 – Forest park «Berezovyi hai»; 3 – Regional landscape park «Yalivshchyna» with forest reserve «Yalivshchyna»; 4 – Central park of culture and recreation – «City garden»; 5 – City forest park «Maryin hai»; 6 – Park-monument of landscape art – «Boldyna Hora»; 7 – Remains of Podusivka neighbourhood forest area**

In August 2023, field research was conducted to assess the state of green infrastructure following the impact of warfare in 2022. The 'Ski Base' forest area was surveyed, which had been subjected to shelling and increased mine danger during the occupation in 2022 due to the proximity of enemy equipment (Fig. 10).We also documented damage to green spaces caused by shelling, fires, and shell fragments in various parts of the city. Notably, significant damage was observed along the city border and in Novoselivka village (located in the northern part of the city), which experienced heavy shelling.

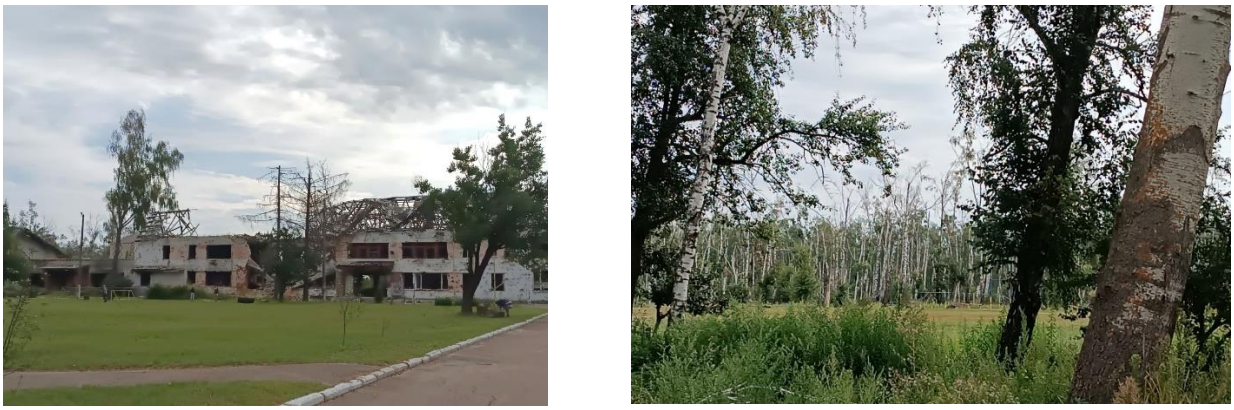

**Fig. 10. Park plantations near the Ski base for training athletes (Miroshnyk N., August 2023)**

Significant damage to trees and soil was observed, with nearly all of the upper portions – specifically the crowns – destroyed, and 80% of the tree trunks affected by shell fragments and fires. The condition of the stands is severely weakened, leading to drying and deterioration.

## Conclusion

An environmental assessment of Chernihiv's green infrastructure has been conducted. The results indicate that urbanization index values in Chernihiv range from 2.5 to -5. A comparison of anthropogenic load and the geographical locations of the park ecosystems reveals that the Yalivshchyna Regional Landscape Park and the remnants of the forest area in the Podusivka neighborhood are significantly affected by aerotoxicants from vehicle emissions. In contrast, the central cultural and recreational park, «City Garden», and the municipal forest park, «Maryin Hai», are situated in the river valley, resulting in better sanitary conditions than those found in the central part of the city. It was observed that the degree of urbanization decreases as one approaches the river valley. Additionally, significant damage to green infrastructure in the Ski Base forest area was recorded due to the warfare during the city's siege from February to April 2022.

To effectively study urban ecosystems, it is essential to implement sustainable development goals in the management of urban parks, while also considering social aspects and the impact of warfare and internal migration on the state of these parks. This approach will enable more effective mitigation of the effects of warfare on the urban green environment and biodiversity, ultimately improving the quality of life and health of city residents. Future research prospects include the development of recommendations for managing the condition of urban green spaces. This is crucial for establishing an optimal policy for managing urban green spaces in a sustainability and for predicting the state of urban ecosystems.

**Фінансування / Funding**

Це дослідження фінансується Національною академією наук України (№ SR 0122 U000570) та грантом на індивідуальне дослідження доктора Мірошник Н.В. з Дослідницького інституту сталого розвитку (RIFS), Потсдам, Німеччина https://www.rifs-potsdam .de/en. / This research was funded by the National Academy of Sciences of Ukraine (No. SR 0122U000570) and a grant for individual research of Dr. Miroshnik N.V. from The Research Institute for Sustainability (RIFS) Potsdam, Germany https://www.rifs-potsdam.de/en.

**Заява про доступність даних / Data Availability Statement**
Набір даних доступний за запитом до авторів / Dataset available on request from the authors.

**Заява інституційної ревізійної ради / Institutional Review Board Statement**
Не застосовується / Not applicable.

**Заява про інформовану згоду / Informed Consent Statement**
Не застосовується / Not applicable.

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**Received**: 06.11.2024. **Accepted**: 09.12.2024. **Published**: 30.12.2024.

**Ви можете цитувати цю статтю так:**

Miroshnyk N., Tertychna O. Assessing the level of anthropogenic pressure on park ecosystems in Chernihiv. *Biota. Human. Technology*. 2024. №3. P. 149-158.

**Cite this article in APA style as:**

Miroshnyk, N., & Tertychna, O. (2024). Assessing the level of anthropogenic pressure on park ecosystems in Chernihiv. *Biota. Human. Technology,* 3, 149-158.

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