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Determination of the ecological state of atmospheric air in the Ivano-Frankivsk territorial community

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Abstract. Anthropogenic activity affects the state of the environment and transforms it, disrupting the ecological balance. Its main unifying element is atmospheric air – monitoring its state serves as the basis for environmental assessment and forecasting future changes in the ecosystem. The aim of the work was to assess the state of atmospheric air in the Ivano-Frankivsk territorial community and its surroundings using geographic information systems in environmental monitoring. The study used: actual measurements on the ground with gas analysers CEM GD-3803 and CEM DT-9881M, a statistical method for collecting and analysing data on pollution of the components of the surface layer of air with solid particles of fine-grained dust PM2.5 and PM10, carbon monoxide CO, carbon dioxide CO2. Visualisations of the distribution of pollution components were created using mapping. For this, the collected field data were subjected to mathematical processing and interpolated using the Kriging method in the Surfer program, after which the results were transferred to MapInfo. As a result, maps of the distribution of chemical pollutants in the territory of the Ivano-Frankivsk territorial community were created, a variant of building an environmental monitoring system was proposed, and a project cartographic model was developed. This will allow for more effective environmental monitoring in the future and planning measures to improve the condition of the territory. Automation was used in the MapInfo software for detailed step-by-step analysis of the environment and environmental monitoring of the studied territory of the community. The results of the study have practical significance for environmental management and planning, for the sphere of state and local environmental management, public initiatives and educational programs

Keywords: mapping; PM2.5 and PM10 particulate matter; transport emissions; GIS technologies; automation

Introduction

The atmosphere can contain dust particles and aerosols from various natural processes as well as anthropogenic activities (Melnychenko *et al.*, 2024). Sometimes, changes in natural emission sources occur due to extreme weather events, such as forest fires and wind-borne dust storms (Adamenko *et al.*, 2024). The largest anthropogenic contribution to atmospheric emissions mainly comes from the energy sector and transport, two-thirds of which are mainly from fuel combustion. Intensive economic activity, in particular the development of transport infrastructure and industry, takes place in the territory of the Ivano-Frankivsk territorial community, which has led to an increase in emis-

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sions of pollutants into the atmospheric air. This causes the entry into the atmosphere of components that are not typical for natural conditions in their nature, concentration and volume. The criterion for the division of atmospheric air (as a natural object) and other air is the natural, inviolable connection of air with the environment.

Law of Ukraine No. 2707-XII (1992) does not regulate relations regarding the air of residential, industrial and other premises. PM2.5 and PM10 are dangerous for the human body due to their size and ability to absorb other harmful substances on their surface. Large particle sizes most often come from construction sites, motor vehicles, soil dust and industrial enterprises. Small particles are more often released into the air from combustion processes such as forest fires and the conversion of gaseous compounds (Bondar & Tsiupa, 2024). According to studies by R. Popek *et al.* (2024), the presence of plastic microparticles and harmful heavy metals was detected in solid particles of urban aerosols. In particular, the danger of urban dust pollution lies not only in the physical penetration of fine particles into the lung tissue, but also in their ability to accumulate ferromagnetic nanoparticles of magnetite, which, in combination with iron oxides and heavy metals, exhibit increased toxicity and pose a significant risk to human health, as noted by K.M. Bondar & I.V. Tsiupa (2024).

Atmospheric PM particles that are part of urban aerosols increase risks to human health. In 2013, they were classified as carcinogens by the International Agency for Research on Cancer (World Health Organization, 2013). PM is a global risk factor that contributes to and is associated with increased mortality from cardiovascular and respiratory diseases (Chen & Hoek, 2020). The chemical composition of PM is dominated by highly reactive organic compounds, toxic chemicals and metals, which lead to excessive formation of reactive oxygen species. PM solid particles have the ability to cause oxidative stress and inflammation. They provoke the development of respiratory, cardiovascular diseases and cancer. Particles smaller than 5 μm, which are able to penetrate the alveoli of the lungs and the systemic bloodstream, are of particular danger (Lim & Kim, 2024).

The presence of risks to public health due to atmospheric air pollution is confirmed by epidemiological studies I. Manisalidis *et al.* (2020). However, the quantitative effects of long-term exposure to pollutants still remain difficult to accurately assess, especially in conditions of chronic pollution, when the concentrations of impurities vary depending on weather conditions, topography, seasonality and the presence of emission sources. Air pollution with fine particles (PM10 and PM2.5) is a factor that causes or complicates the course of respiratory diseases, cardiovascular diseases, and may also be associated with the development of oncological pathologies, diabetes mellitus, and neurodegenerative conditions. Despite the introduction of state monitoring of atmospheric air quality since 2019, its implementation in many regions, including areas with high anthropogenic load, remains fragmented. As noted by C.A. Belis *et al.* (2025), a significant part of the requirements of this monitoring are not met due to a number of technical, regulatory, and organisational barriers. O. Rybalova *et al.* (2022) in their study assessed the risk to public health due to atmospheric air pollution in industrialised regions of Ukraine. The authors note the increase in the incidence of chronic respiratory and cardiovascular diseases, as well as a decrease in the birth rate and an increase in mortality as one of the manifestations of an unfavourable ecological situation.

Thus, the study of the state of atmospheric air and the impact of its pollution on demographic and medical and biological indicators of the population is one of the key tasks of modern environmental science, which requires consistent implementation of air basin protection policies. Ivano-Frankivsk territorial community as a territorial object of study is indicative from many points of view. On the one hand, it is not too small for studying the state of the atmosphere, as it contains rural and urban landscapes that are subject to anthropogenic influence. And from the point of view of physical geography, such objects as rivers, lakes, hills, plains, forests, roads, industrial areas of a technogenic nature and settlements of varying density are contained and interact here. All this in a complex of factors makes it possible to talk about the isolation and search for new factors of influence on the state of atmospheric air. Therefore, the purpose of this study was to assess the level of air pollution in Ivano-Frankivsk territorial community using GIS monitoring tools.

Materials and Methods

The study of the state of atmospheric air within the Ivano-Frankivsk territorial community was carried out using a comprehensive interdisciplinary approach in March 2025. It combined instrumental monitoring methods, statistical analysis and geoinformation technologies. The study area has an increased level of anthropogenic load, caused by intensive car traffic in the central part of the Ivano-Frankivsk, emissions from industrial enterprises located mainly on the periphery, among which enterprises of the processing industry, mechanical engineering and the energy sector dominate. Instrumental measurements were carried out using gas analysers of the CEM GD-3803 and CEM DT-9881M models (brand CEM Instruments, China), which provide a high level of accuracy in determining the concentrations of both gaseous and aerosol impurities in the air.

The selection of locations for forming the coverage grid (frequency of points on the map) was based on the criteria of traffic intensity in the road and transport network and dense development. This is due to the accumulation of the bulk of pollutants due to constant anthropogenic impact. A total of 142 representative points were measured (Fig. 1), where the content of the following air pollution indicators was recorded: carbon monoxide (CO), carbon dioxide (CO_2), as well as particulate matter of the PM10 and PM2.5 fractions. The determination of priority pollutants was carried out in accordance with Appendix 2 of the Resolution of the Cabinet of Ministers of Ukraine No. 827 (2019). This document defines a list of key chemical substances that are formed as a result of human production, transport and household activities. Particular attention was paid to identifying so-called "dynamic pipes" – areas where constant wind flows contribute to the active transfer of pollutants from emission sources to the boundaries of residential buildings (Hsu & Chang, 2024).

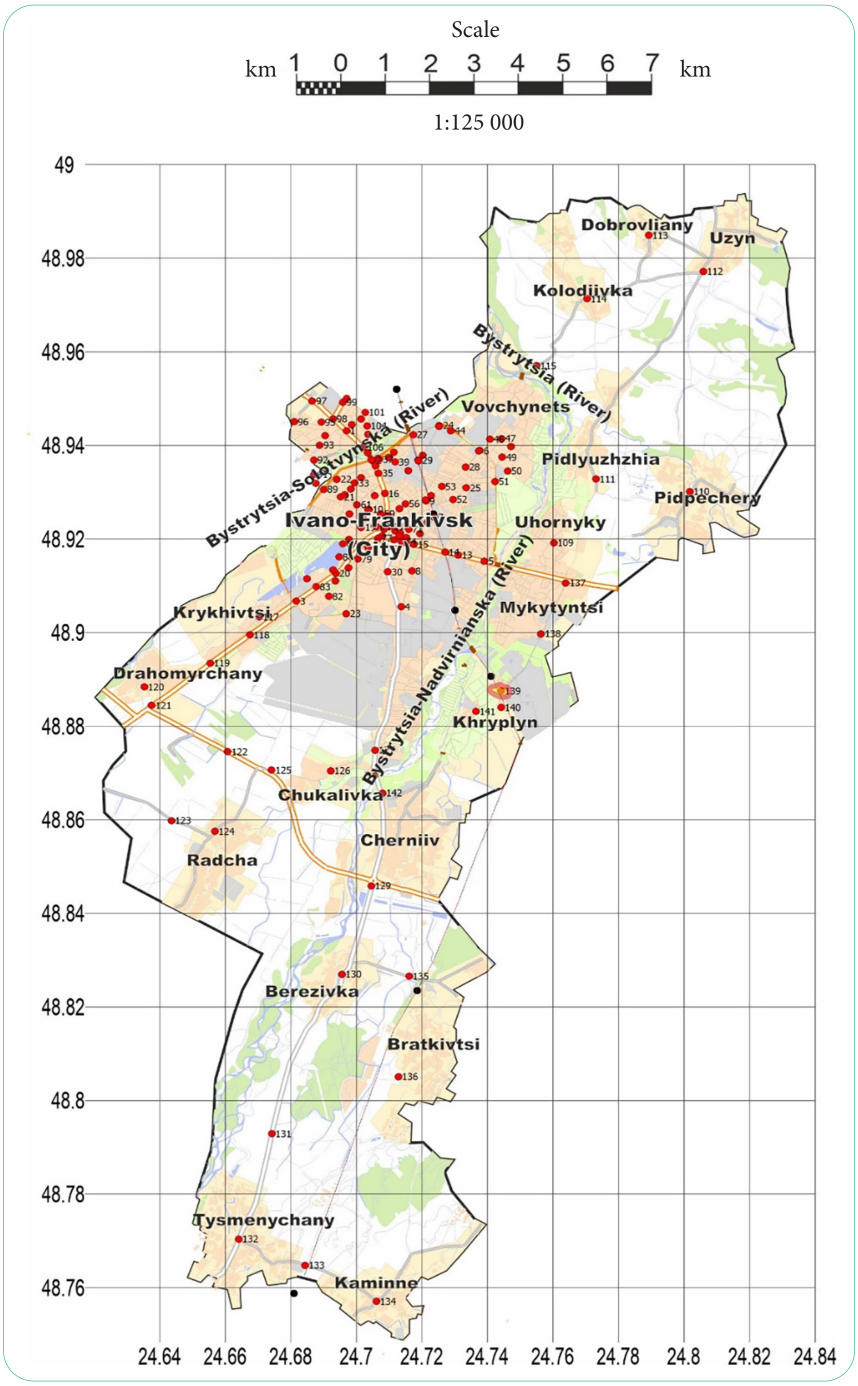

Figure 1. Map of factual material

Source: created by the authors

To process the obtained concentrations of pollutants, statistical methods were used, aimed at quantitatively assessing the spatial structure of the data and identifying deviations in concentration indicators. The value of the anomalous content was calculated by comparing the measured concentrations with the calculated background content indicator, i.e., selecting a group of indicators that is 2/3 and determining the average indicator for the group. The prepared data were used to construct a uniform grd-grid and perform interpolation using the Kriging method

(Salehi & Oral 2023) in the Surfer software environment, which ensured the formation of continuous concentrations within the polygons. To compare CO data, the maximum permissible concentrations (MPC) were taken as the average daily concentration of 3 mg/m^3, the maximum single MPC was 5 mg/m^3 (DSP-201-97, 1997) and the 8-hour MPC, the norm in accordance with the standards for monitoring atmospheric air in the EU, was 10 mg/m^3 (Directive of the European Parliament and of the Council No. 2024/2881, 2024).

To assess the spatial structure of pollution, GIS mapping was used in the MapInfo program. This made it possible to model concentration fields and determine the centres of formation of elevated pollution levels. To simplify and analyse routine monitoring and mapping processes, a functionality was created to display the environmental situation – this is a software module in MapInfo. The created function provided the opportunity to identify common pollution zones and divide them into categories for graphical display of the current state taking into account pollution data. This tool allowed to quickly and clearly depict the areas of overlap between two pollutants, while simultaneously identifying areas with anomalous pollution.

Results and Discussion

Based on the results of the study, a spatial-ecological database was created, which includes both numerical values of the content of chemical substances and geographical coordinates of each sampling point. The measured concentrations of carbon dioxide (CO_2) in the air were divided into intervals and calculations of the background and anomalous content of the substance in the air were performed (Table 1).

Table 1. Calculations of the background content (Cb) CO_2 (ppm)

Content intervals			
415	503	600	800
425	503	600	828
434	506	600	830
436	507	609	830
437	507	621	864
438	508	632	865
438	512	634	896
438	512	640	900
439	512	642	1,290
442	512	654	1,590
443	513	668	
444	514	685	
444	515	700	
444	521	700	
446	521	721	
448	521	731	
449	522	756	
451	522	762	
453	524	780	
455	528	794	
456	530		
457	532		
458	532		
458	532		
459	533		
460	533		
460	535		
460	535		
460	538		
462	540		
463	543		
465	547		
465	551		
466	557		
467	564		
468	566		
468	573		
469	580		
469	583		

Table 1. Continued

Content intervals			
470	585		
470	585		
470	590		
471			
471			
474			
475			
475			
475			
479			
479			
480			
480			
480			
482			
483			
484			
488			
488			
488			
488			
489			
489			
490			
491			
491			
496			
497			
498			
499			
499			
$\sum_{n=1}^{70} = 32{,}598$	$\sum_{n=1}^{42} = 22{,}447$	$\sum_{n=1}^{20} = 13{,}529$	$\sum_{n=1}^{10} = 9{,}693$
$\overline{x} = \frac{32{,}598}{70} = 465.6$	$\overline{x} = \frac{22{,}447}{42} = 534.4$	$\overline{x} = \frac{13{,}529}{20} = 676.4$	$\overline{x} = \frac{9{,}693}{10} = 969.3$
$I_c = 465.6$	$I_c = 534.4$	$I_c = 676.4$	$I_c = 969.3$

Backgrond (C_b) (96 samples from 142 samples (middle value) 2/3 або 66.6%) = 511.9896
Abnormal content (C_a) = 3 × C_b = 3 × 511.9896 = 1,535.969
Permissible concentrations CO_2 (ppm) = 600
Limited permissible concentrations CO_2 (ppm) = 1,000
Isoconcentrates (I_c) for the map

$$= \underset{Min}{415} - 465.6 - \underset{Background}{511.9} - 534.4 - \underset{Permissible}{600} - $$
$$- 676.4 - 969.3 - \underset{Limited}{1{,}000} - \underset{Abnormal}{1{,}535.9} - \underset{Max}{1{,}590}$$

Source: created by the authors

The carbon dioxide (CO_2) content was compared with the limited permissible and permissible values according to DBN V.2.5-67:2013 (2013) and rules were formed for constructing isoconcentrates for maps by interpolation method. According to Table 1, a visualisation map of the carbon dioxide content in the air of the Ivano-Frankivsk community was created (Fig. 2). The map shows that only two zones of overestimated CO_2 content were recorded at Nadrichna Street, 7, in the Ivano-Frankivsk, which is 1,590 ppm, and in the Khryplyn Village near the railway crossing, which is 1,290 ppm. Accordingly, the zones exceeding the limited permissible values of 600 ppm are located nearby and extend in space to the south of the community in the direction of the Kaminne Village. A separate zone has been allocated to the territory from the Bystrytsia River, the Kolodiivka Village in the direction of the Dobrovlyany Village, the concentration exceeds the permissible value and does not exceed the limited permissible value of 1,000 ppm. Considering the situation on the map, it can be concluded that the territory of the community in terms of CO_2 concentration is in a completely satisfactory state, but with local islands of abnormally high indicators.

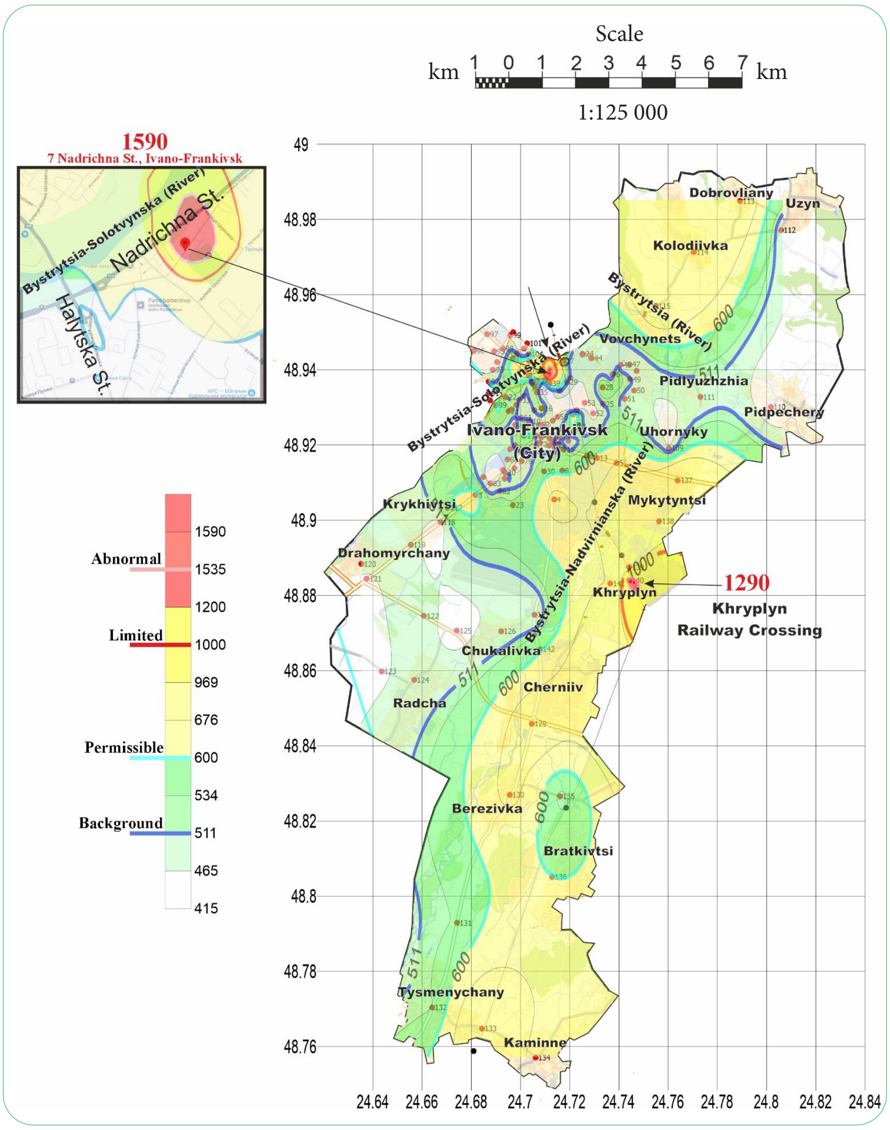

Figure 2. CO_2 concentration in the atmospheric air of Ivano-Frankivsk territorial community, 2025
Source: created by the authors

For carbon monoxide (CO), the obtained data were structured by dividing them into three analytical groups and calculations of the background and anomalous concentrations of the substance in the air were performed (Table 2).

Table 2. Calculations of the background content of CO (C_b)

Content intervals		
0	1	3
0	1	3
0	1	3
0	1	4
0	1	4
0	1	4
0	1	5
0	1	
0	1	
0	1	

Table 2. Continued

Content intervals		
0	2	
0	2	
0	2	
0	2	
0	2	
0	2	
0	2	
0	2	
0	2	
0	2	
0		
0		
0		
0		
0		
0		
0		
0		
0		
0		
0		
0		
0		
0		
0		
0		
$\sum_{n=1}^{36} = 0$	$\sum_{n=1}^{20} = 30$	$\sum_{n=1}^{7} = 26$
$\overline{x} = \frac{0}{36} = 0$	$\overline{x} = \frac{30}{20} = 1.5$	$\overline{x} = \frac{26}{7} = 3.7$
$I_c = 0$	$I_c = 1.5$	$I_c = 3.7$

Background (C_b) (43 samples from 63 samples 2/3 or 66.6%) = 0,55814
Abnormal content (C_a) = 3 × C_b = 3 × 35.7 = 1.674419
MPC (per day) – 3
MPC (one-time) – 5
MPC 8-hours, according to the atmosphere's monitoring norm, European Union Directions – 10
Isoconcentrates (I_c) for the map = $\underset{Min}{0} - \underset{Background}{0.55} - 1.5 - \underset{Abnormal}{1.6} - \underset{MPCper\text{-}day}{3} - 3.7 - \underset{MPCone\text{-}time}{5}$

Source: created by the authors

For carbon monoxide (CO), five zones exceeding the MPC of 3 mg/m^3 were recorded, namely an indicator of 5 mg/m^3 on the Vovchynetska-Zaliznychna ring road, and 4 mg/m^3 at the intersection of Tysmenytska-Mykytynetska streets, in the Khryplyn Village near the railway crossing, traffic rings on Konovaletsa Street, and on Nadrichna Street (Fig. 3). It is worth noting that the peak values of CO concentration (Fig. 3) coincide with the points of significant transport load, which directly indicates its dominant role in the formation of local pollution islands. The indicators of the content of fine-grained dust fraction PM2.5 are divided into three intervals (Table 3) and calculations of the background and anomalous content of PM2.5 concentration in the air environment are made.

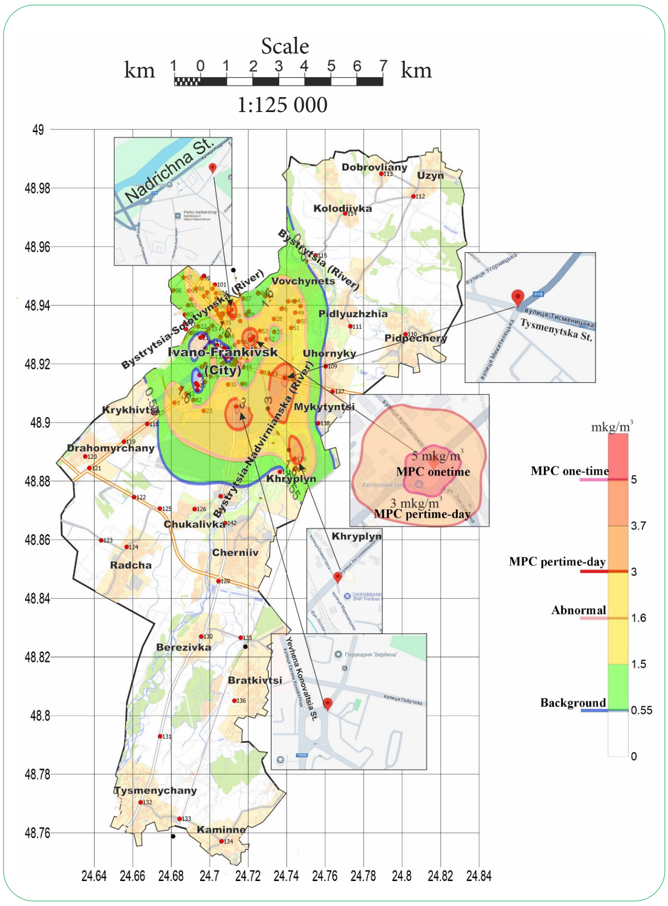

Figure 3. CO concentration in the atmospheric air of Ivano-Frankivsk territorial community, 2025

Source: created by the authors

Table 3. Calculations of the background content (C_b) PM2.5 ug/m

Content intervals		
2	11	21
2	11	21
2	11	21
2	11	22
3	12	26
3	12	27
3	12	31
4	13	37
5	13	38
5	14	42
6	14	61
6	15	209
6	15	
6	16	
7	17	
7	17	
7	18	
7	19	
7	19	
7	19	
7	19	
7		
7		
8		

Table 3. Continued

Content intervals		
9		
10		
10		
10		
10		
10		
10		
$\sum_{n=1}^{70} = 195$	$\sum_{n=1}^{70} = 308$	$\sum_{n=1}^{70} = 556$
$\overline{x} = \frac{195}{34} = 6.29$	$\overline{x} = \frac{308}{21} = 14.6$	$\overline{x} = \frac{556}{12} = 46.3$
$I_c = 6.29$	$I_c = 14.6$	$I_c = 46.3$
Background (C_b) (44 samples from 64, 2/3 or 66.6%) = 11.68182 Abnormal content (C_a) = 3 × C_b = 3 × 11.68182 = 35.04545 Safety levels (24 hours) 0-60mkg/m³ Isoconcentrates (I_c) for the map = $\underset{Min}{2} - 6.29 - \underset{Background}{11.68} - 14.6 - \underset{Abnormal}{35} - 46.3 - \underset{\text{Safety level}}{50} - \underset{Max}{290}$		

Source: created by the authors

According to the results presented in Figure 4, one area with an elevated level of PM2.5 dust particles was identified. The safe level is considered to be between 0 and 50 μg/m³ (US-EPA 2016 standard). The background dust content in the community is 11.68 μg/m³, which can be considered a good value. For comparison, according to the standards for monitoring atmospheric air in the EU (Directive of the European Parliament and of the Council No. 2024/2881, 2024) where the value of 25 μg/m³ is the limit for the protection of human health, and must be achieved by December 11, 2026.

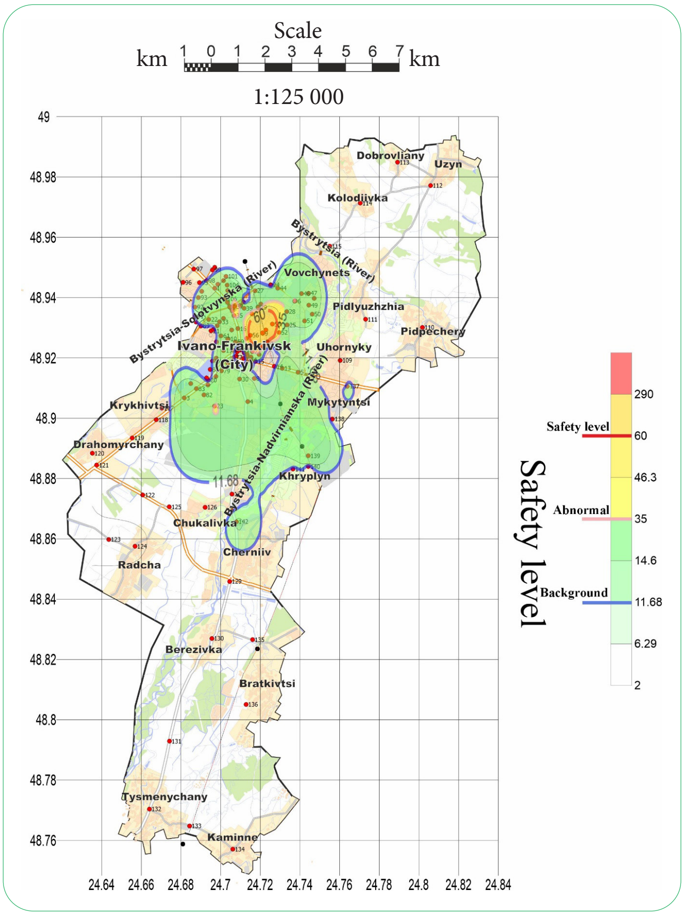

Figure 4. PM2.5 concentration in the atmospheric air of Ivano-Frankivsk territorial community, 2025
Source: created by the authors

Indicators of the content of fine-grained dust of the PM10 fraction were divided into three groups (Table 4) and calculations of the background and anomalous concentration content were carried out. For the PM10 fraction dust, one value exceeding the MPC was also recorded on Vovchynetska Street (Fig. 5)

Table 4. Calculations of the background content (C_b) PM10 ug/m

Content intervals		
3	22	76
5	23	76
6	23	79
10	23	79
11	24	84
11	26	88
12	26	91
12	28	94
14	28	97
15	29	98
15	29	100
15	29	111
15	31	151
15	31	775
17	32	
17	33	
18	33	
18	36	
18	38	
18	40	
18	43	
	43	
	45	
	54	
	55	
	56	
	64	
	66	
	67	
$\sum_{n=1}^{21} = 283$	$\sum_{n=1}^{29} = 1{,}077$	$\sum_{n=1}^{70} = 195$
$\bar{x} = \frac{283}{21} = 13.47$	$\bar{x} = \frac{1{,}077}{29} = 37.13$	$\bar{x} = \frac{1{,}999}{14} = 142.7$
$I_c = 13.47$	$I_c = 37.13$	$I_c = 142.7$

Background (C_b) (44 samples from 64, so 2/3 or 66.6%) = 35.7

Abnormal content (C_a) = 3 × C_b = 3 × 35.7 = 107.1

Safety levels (24 hours) 0-100 mkg/m³

Isoconcentrates (I_c) for the map = $\underset{Min}{3} - 13.47 - \underset{Background}{35.7} - 37.13 - \underset{\text{Safety levels}}{100} - \underset{Abnormal}{107.1} - 142.7 - \underset{Max}{775}$

Source: created by the authors

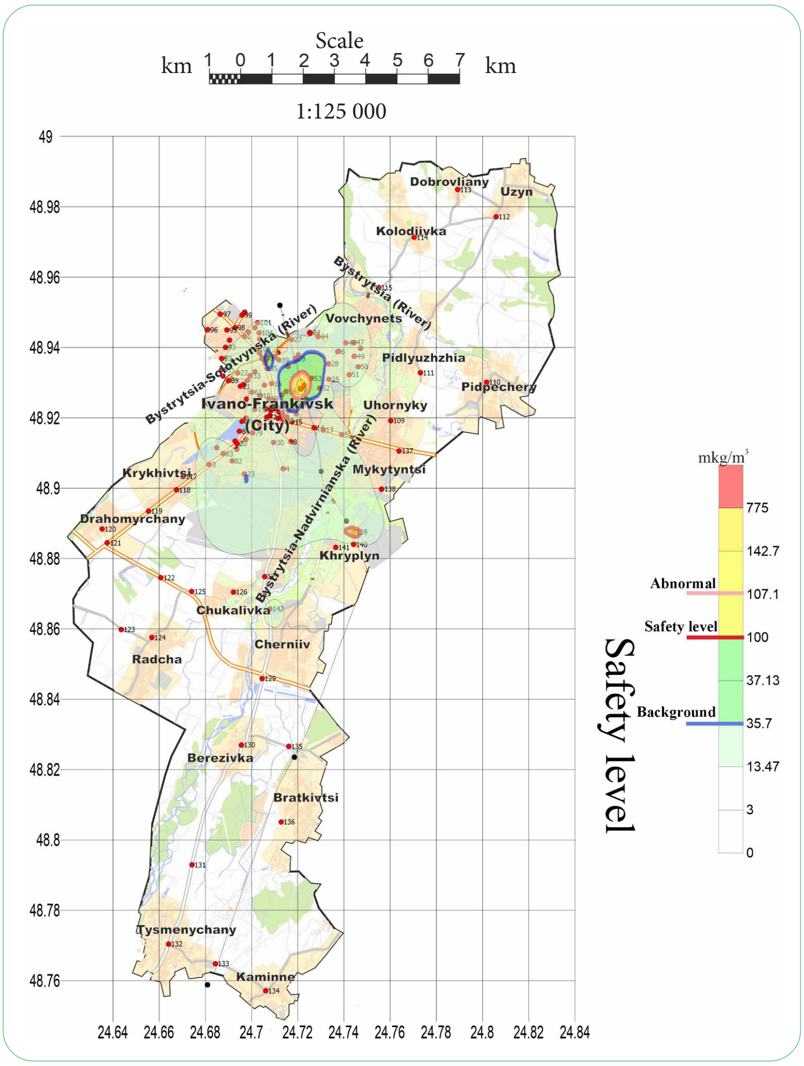

Figure 5. PM10 concentration in the air of Ivano-Frankivsk territorial community, 2025

Source: created by the authors

Using the MapInfo software module, a joint map of the overlap of the two pollutants CO and CO_2 was created (Fig. 6). The resulting map identifies four zones with an increased total level of pollution, which indicates the need for increased attention when planning environmental management measures.

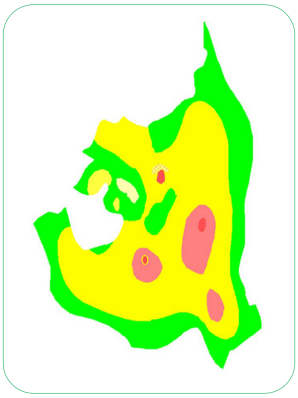

Figure 6. Map of CO and CO2 pollutants overlap

Source: created by the authors

According to the results of the study, several zones with exceeding the MPC for both small PM2.5 and large PM10 fractions were identified. These anomalous areas (central highways, railway crossings) are clearly visible on the maps, although there is a high but not 100% correspondence between the PM2.5 and PM10 maps. These facts suggest that there is a general pattern of dust distribution, while at the same time they indicate different mechanisms for retention and deposition of fractions in the air. Five zones of exceeding the single MPC of 3 mg/m^3 for carbon monoxide CO have been identified. Analysing the maps, it is worth noting that the peak values coincide with points of significant transport load, which directly indicates the dominant role in the formation of local islands of CO pollution. With carbon dioxide CO_2, the situation is similar, but it is worth noting that it is not identical, only two zones with increased anomalous air pollution were identified, this is in Khryplyna near the railway crossing and on Nadrichna Street 7 in the Ivano-Frankivsk. Despite the similar chemical composition, there are different factors for the accumulation of CO and CO_2 in the air.

The air of the Ivano-Frankivsk community is characterised by moderate pollution with a clear spatial connection to transport arteries and railway crossing points. This emphasises the need for environmental management, which consists in expanding green zones along the identified points near highways using plant species with a rough or hairy leaf surface (for example, maple, elm), which have the ability to accumulate solid particles well. It is also recommended to reduce the frequency of mowing grass along roads to increase the accumulation capacity of grassy barriers. Measures to limit peak hours by changing public transport routes in problem areas will also be effective. To control the situation, it is worth expanding the physical network of stationary monitoring to cover points with increased pollution levels.

A comparative analysis of the results of the study of atmospheric air within the Ivano-Frankivsk territorial community with similar works, in particular the study of Yamnytska UTC by scientists Y.O. Adamenko & T.B. Kachala (2022), dedicated to the analysis of the dispersion of PM10 and PM2.5 particles, allows to identify a number of common approaches and differences that have both scientific and practical significance for the development of an air pollution monitoring system in the region. Both studies use the CEM-DT-9881 device for field measurements of particulate matter (PM10 and PM2.5), which ensures methodological consistency and allows comparing the obtained data. In the work of Y.O. Adamenko & T.B. Kachala (2022) focused on modeling dust dispersion using EOL-PLUS software and further comparing theoretical calculations with actual measurement results. In the current study, the focus is shifted to real air quality indicators, geoinformation analysis of spatial pollution distribution, and calculation of total and anomalous pollution indices.

The advantage of the approach used in the study for Ivano-Frankivsk territorial community is the inclusion of a spectrum of impurities (CO, CO_2, PM10, PM2.5), which allows for a more comprehensive characterisation of the state of atmospheric air. While the study for Yamnytsia UTC focuses mainly on studying the dust load and spatial impact of a specific source (Private Joint-Stock Company "Ivano-Frankivsk Cement"), in the case of the current article, the general structure of pollution at the level of the urban community is studied – taking into account transport, residential development, industrial facilities and topographic features of the territory. It is worth noting that the study for Yamnytsia UTC pays special attention to comparing national and international legislation on permissible dust concentrations, which is an important contribution to the formation of the regulatory framework. The current work also mentions the action of Resolution of the Cabinet of Ministers of Ukraine No. 827 (2019).

Thus, the study of Yamnytsia territorial community is more highly specialised and technically oriented, while the study of Ivano-Frankivsk territorial community covers a wider range of environmental and socio-hygienic problems, demonstrating an integrated approach to assessing air quality and its impact on public health. Both approaches are complementary and can serve as the basis for creating a unified regional environmental monitoring system that will take into account both local emission sources and global atmospheric processes.

Compared to the study of N. Moskalchuk *et al.* (2022) of noise pollution in the suburban area of Ivano-Frankivsk, the author's study focuses on studying the chemical composition of atmospheric air within the Ivano-Frankivsk territorial community. Both works have common methodological approaches – a network of control points, experimental measurements, mapping of results. However, while the study of N. Moskalchuk *et al.* (2022) focuses on acoustic exposure, this work analyses the distribution of toxic substances that have a chronic impact on the health of the population. The key difference is the type of exposure assessed: noise – short-term and mainly localised, atmospheric – long-term, accumulative and more dangerous in terms of oncological and respiratory morbidity. Together, these studies complement each other, demonstrating the multifactorial nature of environmental risk for urban areas.

S.Y. Adamenko *et al.* (2024) analysed the temporal patterns of dust particle concentrations (PM2.5 and PM10) based on data from four stationary stations of the Ecocity system – in the centre of Ivano-Frankivsk, near the Burshtyn TPP, near the woodworking enterprise and in the recreational zone of the Mykulychyn Village. In the same case, mobile monitoring was used, which covers a slightly wider range of indicators (CO, CO_2, PM10, PM2.5) and provides high spatial resolution across the community. Common to both approaches is the use of local pollution measurements, which makes it possible to identify the impact of transport and industry on the urban area. In two works, data show an increase in pollution concentrations in areas of high anthropogenic load and may exceed permissible MPCs. Observational data confirm: near highways, emissions form local anomalous zones with elevated levels of PM and CO. In total, the combination of stationary and mobile observations creates a more complete picture of the situation: the former provide a reliable temporal context, the latter – high spatial detail. Such integrated information contributes to the justified placement of green infrastructure (Ferrini *et al*., 2020), the optimisation of transport flows and, in general, increasing the effectiveness of measures to improve air quality in the Ivano-Frankivsk community.

The study by K. Grygoriev (2023) used combined monitoring: data from the state system from 4 posts are supplemented with indicative measurements at compact public monitoring stations in the Mykolaiv. The current study was conducted using portable devices CEM-3803 and CEM-DT-9881, which provide high accuracy in determining pollutant concentrations, taking into account key areas of the Ivano-Frankivsk territorial community. The main differences are in the duration of observations: K. Grygoriev (2023) relied on multi-year state monitoring data (2016-2021) and selected indicative points (2021-2023), while the approach in the current work was based on specialised portable air quality gas analysers in short-term monitoring that can be used to supplement and verify the results of stationary stations. Both approaches assess pollutant concentrations relative to permissible pollution standards and calculate pollution indices. Both studies focus on the impact of transport emissions: due to intensive transit flows in the air, chronic excesses of pollutant concentrations are observed. Both analyses pay attention to particulate matter (PM2.5, PM10), noting their concentrations and excesses of the MPC. For example, in Mykolaiv, maximum PM10 concentrations reached 0.09 mg/m^3, which is consistent with monitoring observations in Ivano-Frankivsk, where elevated PM levels are recorded near highways.

Monitoring activities allow tracking changes over time, which may indicate both an improvement in the overall state of the environment and a deterioration in the state of things (Mora-Barrantes *et al*., 2021). Systematic monitoring of atmospheric air is a key element in assessing the level of pollution and developing scientifically sound environmental management measures. To increase the accuracy of such assessments, both remote sensing data, in particular satellite platforms (Badapalli *et al*., 2022), which provide large-scale spatial analysis of pollutants, as in the study by P. Gupta *et al*. (2020), and unmanned aerial systems capable of making local measurements with high resolution, as in T.F. Villa *et al*. (2016), are used. In addition, an important component is the results of ground-based measurements performed by certified instruments, which provide accurate reference concentrations of pollutants for calibration and validation of remote data.

Monitoring of the state of atmospheric air should be considered as the recording and analysis of current parameters of the atmospheric environment within a specified time interval. It provides the opportunity to objectively assess the effectiveness of measures aimed at preserving and improving air quality (Wang *et al*., 2021; Alolaiyan *et al*., 2024). The use of MapInfo and Surfer software is proposed for a detailed analysis of the environmental state, which will contribute to the adoption of effective management decisions to reduce pollution levels and improve the state of atmospheric air. In-depth analysis of pollutant concentrations in the urban atmosphere is key to making management decisions. Monitoring data allows you to identify locations with the highest levels of air pollution (in particular, near congested highways), which helps to optimise the placement of environmental posts and recreation areas.

Conclusions

Based on the results of the study, a comprehensive spatial and ecological database was formed, which combined the results of measurements of chemical concentrations with the geographical coordinates of sampling points. Analysis of the obtained data allowed to establish that the state of atmospheric air in the Ivano-Frankivsk territorial community is generally satisfactory, but is characterised by the presence of local zones of abnormally high pollution. In particular, two main zones of elevated CO_2 content (up to 1590 ppm) were identified in the area of Nadrichna Street and the Khryplyn Village, and the zones exceeding the limited permissible values extend to the south of the community. For carbon monoxide (CO), five zones of exceeding the MPC were recorded, the peak values of which (up to 5 mg/m^3) clearly coincide with key transport hubs and city rings. This directly indicates the dominant role of motor vehicles in the formation of local pollution centres.

The situation with the content of PM2.5 and PM10 fractions remains mostly within the normal range with a low background indicator of 11.68 $\mu g/m^3$, however, the detected point exceedances of the MPC on main streets confirm the common pattern of distribution of particulate matter along transport arteries. Summarising the results, it can be stated that the air environment of the community is moderately polluted with a pronounced spatial connection to the logistics infrastructure. The detected discrepancies in the localisation of peak values of various pollutants indicate different mechanisms of their accumulation and retention in the air. Taking into account the obtained maps of the superposition of indicators, the priority environmental management measures should be the expansion of the stationary monitoring network, optimisation of traffic during peak hours and the creation of protective green barriers using plants capable of intensive accumulation of particulate matter.

The results of the research emphasise the importance of monitoring of various types for the creation of regional plans for improving the quality of atmospheric air. The quality of monitoring data affects rational decision-making in environmental planning of the city and compliance with regulations. Further research involves expanding the functionality of the tool for calculating cartographic entropy, which will allow assessing the degree of separation of concentration zones from each other. This will provide the opportunity to identify common sources of pollution in different components of the environment, in particular in the atmosphere, soil and surface waters. In addition, it is planned to implement the function of automated calculation of background and anomalous levels of pollutants to improve environmental monitoring.

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Conflict of Interest

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Визначення екологічного стану атмосферного повітря Івано-Франківської міської громади

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Анотація. Антропогенна діяльність впливає на стан довкілля і трансформує його порушуючи екологічну рівновагу. Її основним об'єднуючим елементом є атмосферне повітря – проведення моніторингу його стану служить основою для екологічної оцінки і прогнозування майбутніх змін екосистеми. Метою роботи було оцінити стан атмосферного повітря Івано-Франківської міської громади та її околиць із використання геоінформаційних систем в екологічному моніторингу. У дослідженні використовувалися: фактичні виміри на місцевості газоаналізаторами CEM GD-3803 та CEM DT-9881M, статистичний метод для збору та аналізу даних забруднення компонентів приземного шару повітря твердими частками дрібнозернистого пилу PM2,5 та PM10, оксидом вуглецю CO, діоксиду вуглецю CO_2. Створено візуалізації поширення компонентів забруднення за допомогою картографування. Для цього зібрані польові дані було піддано математичній обробці та проінтерпольовано з використанням методу Kriging в програмі Surfer, після чого результати було перенесено в MapInfo. У результаті було створено карти розповсюдження хімічних забруднювачів території Івано-Франківської міської об'єднаної територіальної громади, запропоновано варіант побудови системи екологічного моніторингу та розроблено проектну картографічну модель. Це в майбутньому дозволить ефективніше здійснювати екологічний моніторинг та планувати заходи покращення стану території. У програмному забезпеченні MapInfo використано автоматизацію для детального покрокового аналізу середовища і екологічного моніторингу досліджуваної території громади. Результати дослідження мають практичне значення для екологічного менеджменту і планування, для сфери державного та місцевого екологічного управління, громадських ініціатив та освітніх програм

Ключові слова: картографування; тверді частинки PM2,5 та PM10; транспортні викиди; гіс-технології; автоматизація