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ASSESSMENT OF TECHNOGENIC LOAD ON THE AIR BASIN OF THE WESTERN UKRAINE REGIONS

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Abstract. The issue of assessing the technogenic load on the air basin in the regions of Ukraine, especially under martial law conditions, is highly relevant. The territory of Western Ukraine, in general, does not belong to regions with high load indicators compared to other regions. However, some scientific works are dedicated to assessing the state and specific types on the air basin load of the western regions of Ukraine. The aim of this study was to assess the state of the air basin in the regions of Western Ukraine under the influence of technogenic activity over the period 2005–2023. The module of technogenic load on the air basin (M_{AB}) and the integral indicator of atmospheric air condition (I_{atm}) were applied. The highest emission levels were recorded in Ivano-Frankivsk and Lviv regions, while the lowest were in Chernivtsi region. The application of two indicators for assessing technogenic load showed similar results. The substances most frequently associated with the likelihood of developing non-carcinogenic health effects included nitrogen dioxide, formaldehyde, and some specific pollutants. The highest indicators of the combined impact of pollutants on the potential development of non-carcinogenic effects were observed in cities such as Lutsk, Uzhhorod, Lviv, and Rivne. In recent years, there has been an almost noticeable trend of a slight decrease in technogenic impact indicators.

Keywords: technogenic load, air basin, module, integral indicator, risk of developing non-carcinogenic effects, hazard index.

1. Introduction

In terms of pollution levels and technogenic load, Western Ukraine, in general, does not belong to regions with high load indicators compared to other regions of Ukraine. However, according to official information from the B. Sresnevsky Central Geophysical Observatory, in 2022–2023, cities with high atmospheric pollution levels among the regions included Lutsk, Lviv, Rivne, and Uzhhorod (Tsentralna heofizychna observatoriia, 2023). It should be noted that this territory is also not among the regions where active hostilities have been taking place since the beginning of the full-scale war in Ukraine, which could lead to increased pollution levels and technogenic impact.

The issue of assessing the state and level of technogenic load on the air basin of the western regions of Ukraine has been the subject of investigation by separate authors. For instance, in study (Kuzyk et al., 2024) the impact of automobile transport on the formation of overall atmospheric air pollution levels in Lviv was examined. For Lviv, this type of pollution source is predominant, which justifies the relevance of the investigation. Additionally, the issue of transport load on the air basin of Ternopil oblast was considered in the investigation (Stetsko, 2019). The author analyzed the intensity of impact from various types of automobile transport and identified the predominant influence of motor vehicles on the formation of atmospheric pollution levels in the region.

Some publications on the assessment of the state and quality of the air basin in the regions of Western Ukraine belong to the authors of works (Chugai et al., 2023; Chugai et al., 2024).

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2. Materials and methods

The aim of the investigation was to assess the state of the air basin in the regions of Western Ukraine (Zakarpattia, Ivano-Frankivsk, Lviv, Chernivtsi, Volyn, Rivne, Ternopil, and Khmelnytskyi oblast) under the influence of technogenic activity over the period 2005–2023. As initial data, the work used official statistical information on air quality indicators and the volumes of pollutant emissions into the air basin.

The assessment of technogenic load on the air basin was carried out based on the calculation of two indicators: the module of technogenic load on the air basin (M_{AB}) and the integral indicator of atmospheric air condition (I_{atm}). M_{AB} is calculated as a total emissions of pollutants from all sources per year, relative to the area of the studied region. The methodology provides for separate assessments from stationary and mobile emission sources or an assessment based on total indicators (Chugai & Safranov, 2021).

The integral indicator of atmospheric air condition is calculated using the formula:

$$I_{atm} = 0{,}001 \times m \times I, \quad (1)$$

where I_{atm} is the determined in tons of conditional load (t. c l.); m is the actual mass of pollutant emissions per year from all sources in the studied region, thousands of tons; I is the regional coefficient that accounts for the level of impact of socio-economic and natural-climatic factors, as well as the ecological and economic consequences of technogenic load across the regions of Ukraine (Khlobystov et al., 2008; Telizhenko et al., 2008).

An assessment of the risk from atmospheric air pollution was also conducted. Air pollution is a direct factor affecting public health. Various approaches to such assessments exist, for example, the application of modeling methods (Fan et al., 2022; Ting et al., 2022).

It is known that the assessment of the risk of developing non-carcinogenic effects for specific substances is carried out based on the calculation of the hazard index:

$$HQ = LADI / Rf, \quad (2)$$

where HQ is the hazard index, a dimensionless value; Rf is the reference (safe) dose, mg/kg (Integrated Risk Information System, 2024).

The authors of the work (Movchan et al., 2013) suggested that in cases where information on the reference (safe) dose Rf is unavailable, the following formula should be used:

$$HQ = Ai / A_{MPC}, \quad (3)$$

where Ai is the average concentration of the i-th pollutant, mg/m³.

The characterization of the risk of developing non-carcinogenic effects for assessing the combined impact of chemical substances is carried out based on the calculation of the hazard index:

$$HI = \sum HQi, \quad (4)$$

where HQi is the hazard indices for individual pollutants (Poddashkin & Rybalova, 2007; Metodychni rekomendatsii, 2007).

According to the methodology, three gradations of risk characterization are distinguished based on the HQ value – from low ($HQ < 1$) to the possibility of an increased probability of adverse effects proportional to the increase in HQ ($HQ > 1$).

3. Results and discussion

The calculations were performed separately for all regions of Western Ukraine. It should be noted that for some regions (Volyn and Ternopil ones), data were missing for the certain years (2005–2009). Additionally, since 2016, official statistics have lacked data on pollutant emissions from mobile sources. Therefore, in some cases, these data were interpolated considering information on emissions from previous years.

The indicators of emissions from stationary and mobile sources were analyzed. Given the significant volume of initial data, average emission indicators for 2005–2023 were calculated (Fig. 1). The presented figure shows that the highest pollutant emission levels were recorded in two regions – Ivano-Frankivsk and Lviv, while the lowest were in Chernivtsi one. In most regions, mobile sources are the predominant contributors to emissions. Their income in the formation of overall pollution levels ranged on average from 53 % (Lviv region) to 90 % (Chernivtsi region). Only in Ivano-Frankivsk region the stationary sources have a significant impact on air pollution levels, contributing more than 80 %.

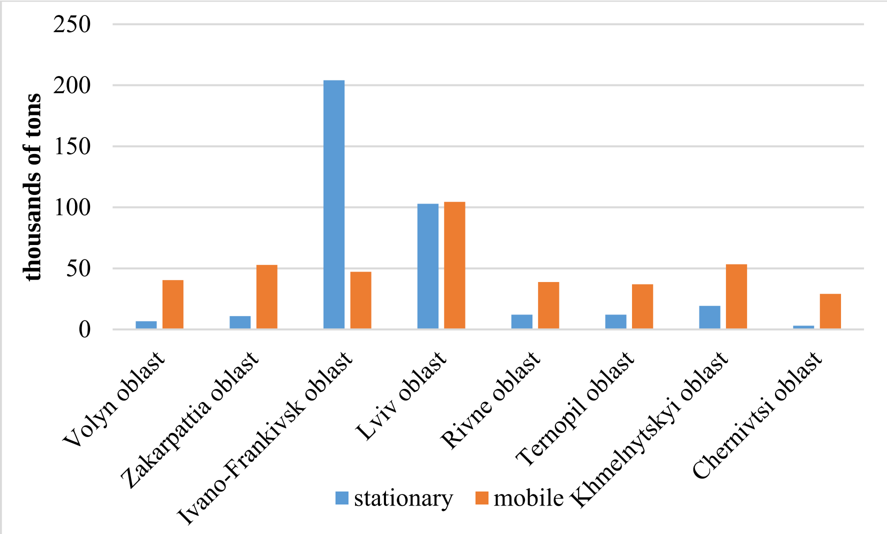

Fig. 1. Average indicators of pollutant emissions into the atmospheric air from stationary and mobile sources in the regions of Western Ukraine in 2005–2023

The analysis of the dynamics of emission changes (Fig. 2) showed that during the investigation period, there was a general trend of decreasing pollutant emissions. The peak was observed in 2007–2008. In subsequent years, the indicators gradually decreased, and as of 2023, their values amounted to 50 % of the 2007 levels. This trend is a result of the reduction in emissions from both stationary and mobile sources on the territory of Western Ukraine.

Based on the data on pollutant emission volumes, the module of technogenic load on the air basin (M_{AB}) was calculated (Fig. 3). As seen in the presented figure, the highest M_{AB} values were recorded for Ivano-Frankivsk and Lviv oblasts, which correspond to pollutant emission levels. However, despite a slight difference in emission levels, the air basin load in Lviv oblast is nearly an order of magnitude lower than in Ivano-Frankivsk one. It should also be noted that Chernivtsi oblast, despite having the lowest emission levels, has an M_{AB} value comparable to those of Khmelnytskyi and Ternopil ones. At the same time, the emission indicators in these regions exceed those of Chernivtsi one by 1.5–2 times. A similar situation is observed when comparing Zakarpattia and Khmelnytskyi oblasts–lower emission levels correspond to a higher level of technogenic load on the air basin.

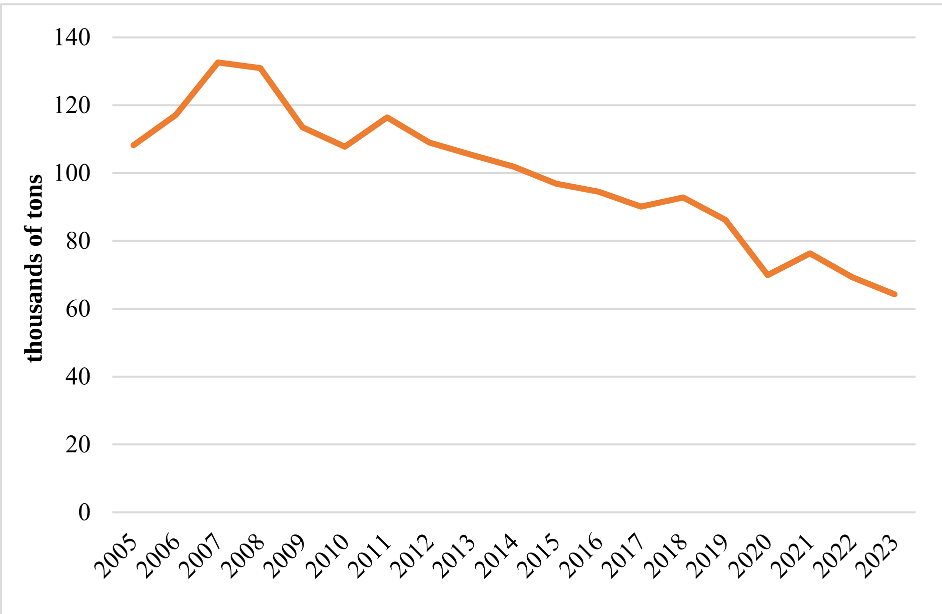

Fig. 2. Dynamics of pollutant emissions into the air basin of the regions of Western Ukraine in 2005–2023

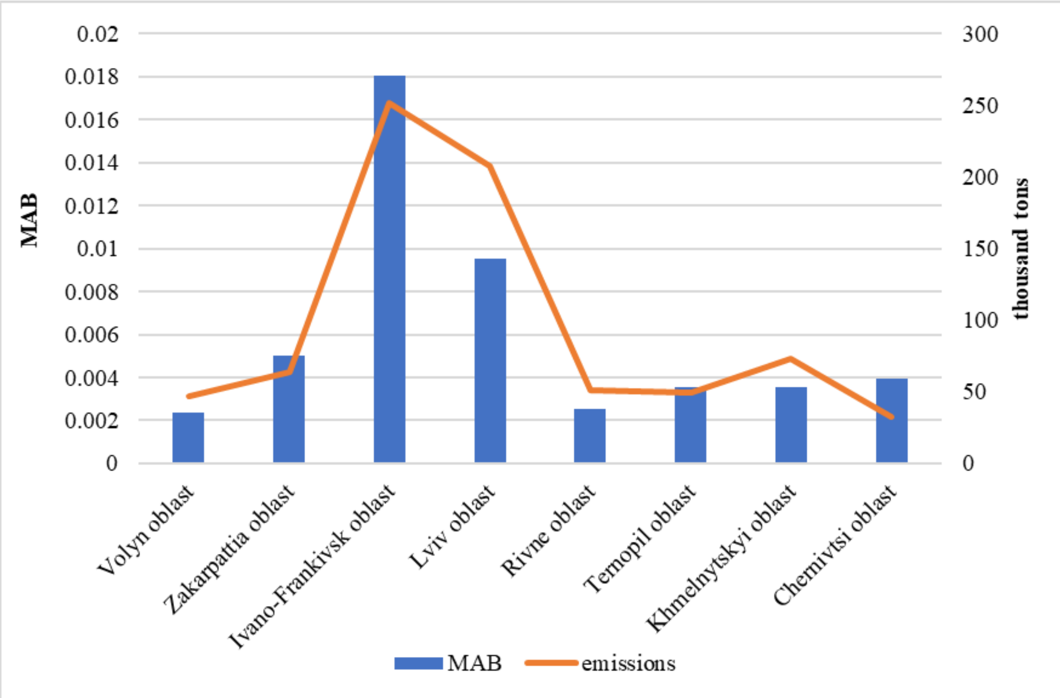

Fig. 3. Module of technogenic load on the air basin of the regions of Western Ukraine in 2005–2023

Fig. 4 presents the results of the calculation of the integral indicator of atmospheric air condition in comparison with the M_{AB}. As seen, the assessment results based on the I_{atm} indicator mostly correspond to the results obtained for the M_{AB} indicator, except for the data on Ternopil and Khmelnytskyi oblasts. This difference is due to the consideration of socio-economic and natural characteristics through the inclusion of the *I* coefficient. However, in general, both indicators provide similar results, indicating the possibility of using one of the methodologies depending on the available input data.

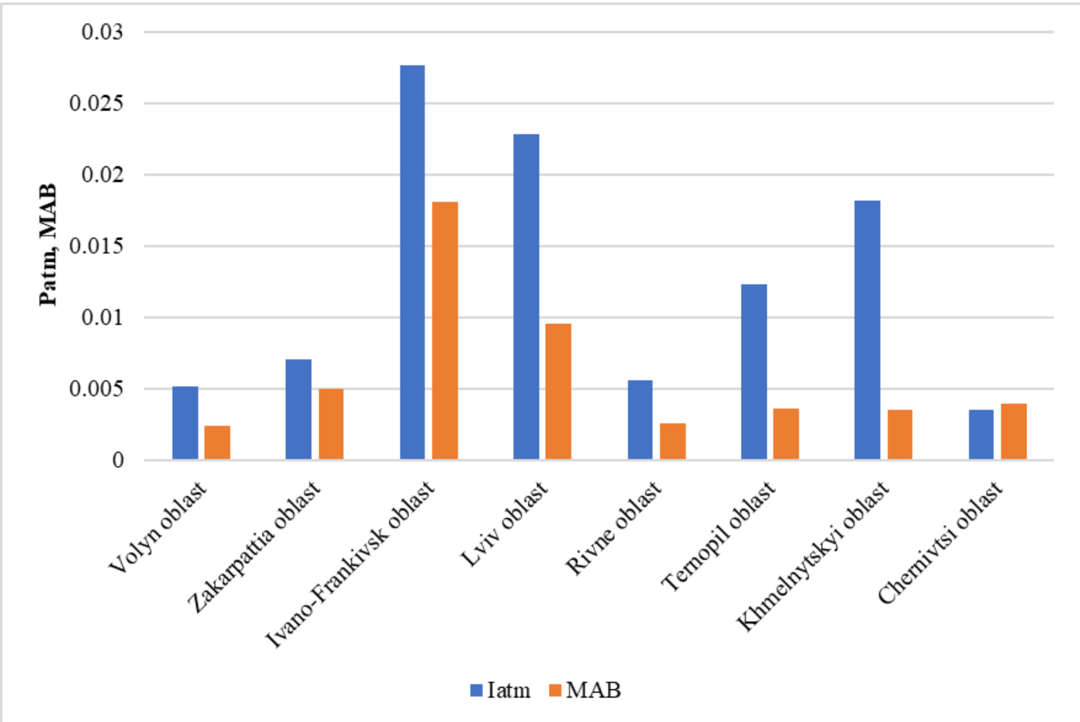

Fig.4. Indicators of technogenic load on the air basin of the regions of Western Ukraine in 2005–2023

Another stage of the investigation was determining the risk to human health due to atmospheric air pollution. The analysis was conducted for the period 2014–2023. At the first stage, the *HQ* indicator was calculated for each pollutant. A list of substances that could create the likelihood of developing non-carcinogenic effects on human health (*HQ* > 1) was identified. The results are presented in Table. As seen, nitrogen dioxide and formaldehyde were most frequently among such substances. Additionally, in certain regions (Volyn, Rivne, Chernivtsi), some specific pollutants posed a health risk to humans.

List of pollutants that contributed to the development of non-carcinogenic effects due to atmospheric air pollution in the regions of Western Ukraine

Region	Polluting substances	
	2014–2018	2019–2024
Volyn oblast	nitrogen dioxide, phenol, formaldehyde	nitrogen dioxide, phenol, formaldehyde
Zakarpattia oblast	nitrogen dioxide, carbon monoxide, formaldehyde	nitrogen dioxide, formaldehyde
Ivano-Frankivsk oblast	dust	nitrogen dioxide
Lviv oblast	dust, nitrogen dioxide, formaldehyde	dust, nitrogen dioxide, formaldehyde
Rivne oblast	hydrogen fluoride, formaldehyde	hydrogen fluoride, formaldehyde
Ternopil oblast	nitrogen dioxide	nitrogen dioxide
Khmelnytskyi oblast	nitrogen dioxide, formaldehyde	nitrogen dioxide, formaldehyde
Chernivtsi oblast	hydrogen chloride, formaldehyde	formaldehyde

The results of the assessment of the combined impact of pollutants on the possibility of developing non-carcinogenic effects for the regions of Western Ukraine are presented in Fig. 5. As seen in the figure, the highest indicators of combined impact are noted for cities such as Lutsk, Uzhhorod, Lviv, and Rivne. It should be noted that the number of indicators considered in the calculations varied slightly. However, for example, when considering 9 pollutants in Khmelnytskyi, the obtained total effect is significantly lower than in Lutsk, where 7 pollutants were considered. Additionally, in recent years, almost all regions have shown a tendency toward a slight decrease in pollutant concentrations, which contributes to reducing health risks for the population.

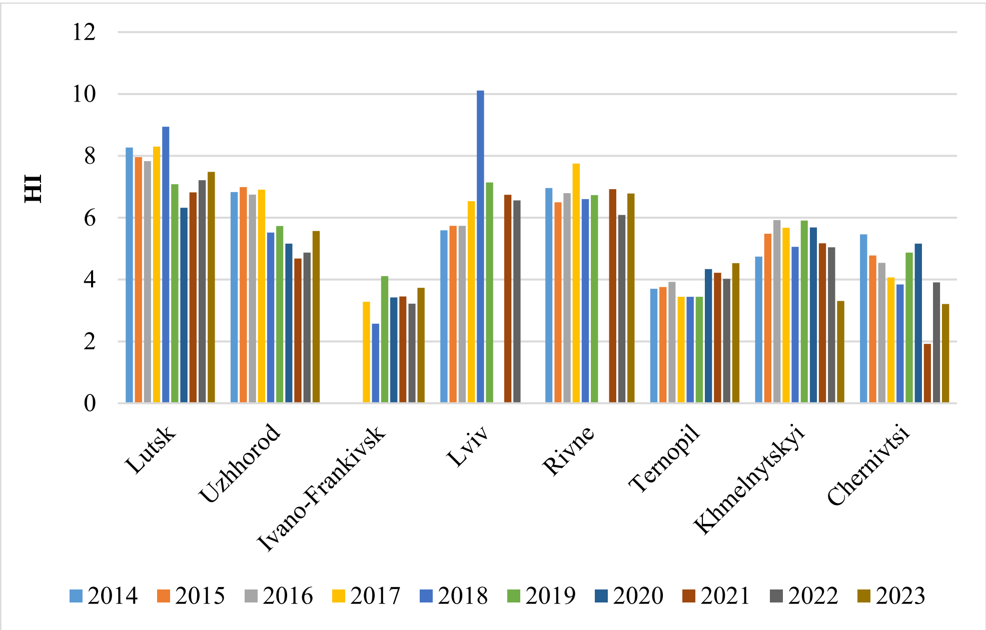

Fig. 5. Assessment of the combined impact of pollutants on the development of non-carcinogenic effects for the regions of Western Ukraine in 2014–2023

4. Conclusions

The investigation assessed the technogenic load on the air basin of the regions of Western Ukraine. Based on the conducted research, the following conclusions can be made:

1. The highest pollutant emission levels among the regions of Western Ukraine were observed in Ivano-Frankivsk and Lviv oblast, while the lowest were in Chernivtsi oblast.

2. The predominant sources of emissions in most regions, except for Ivano-Frankivsk, are mobile sources. A general trend of decreasing pollutant emissions has been noted.

3. The highest values of the M_{AB} indicator were observed in Ivano-Frankivsk and Lviv oblast, corresponding to pollutant emission levels; Chernivtsi oblast, despite having minimal emission levels, has an M_{AB} value comparable to Khmelnytskyi and Ternopil oblasts, where emission levels are 1.5–2 times higher; a similar situation is observed when comparing Zakarpattia and Khmelnytskyi oblasts.

4. The results of the assessment based on the I_{atm} indicator largely correspond to the results obtained for the M_{AB} indicator, except for two regions, which is due to the consideration of socio-economic and natural factors.

5. The substances most frequently associated with a potential risk of developing non-carcinogenic effects on human health were nitrogen dioxide and formaldehyde, as well as certain specific pollutants in Volyn, Rivne, and Chernivtsi oblasts.

6. The highest combined impact indicators were recorded for the cities of Lutsk, Uzhhorod, Lviv, and Rivne. In recent years, almost all regions have shown a slight decrease in pollutant concentrations, which contributes to reducing health risks for the population.

The overall analysis of the level of technogenic load on the air basin in the regions of Western Ukraine indicates a slight improvement in the indicators. However, due to the lack of complete and reliable data in some cases for 2022–2023, associated with the military situation, the obtained results should be considered as preliminary data for further use in scientific and practical activities.

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