Vol. 8, No. 3, 2023

CONDITION AND QUALITY OF THE AIR OF THE CHERNIVTSI REGION

Angelina Chugai, Maksym Nedostrelov, Kostiantyn Bratov

Department of Ecology and Environmental Protection,
Odesa State Environmental University,
15, Lvivska Str., Odesa, 65016, Ukraine
avchugai@ukr.net

https://doi.org/10.23939/ep2023.03.133

Received: 11.07.2023

Abstract. The question of rating of the condition of the air in the regions of Ukraine is very relevant. An important component is the choice of the optimal rating method. The purpose of the work is to review methodological approaches to the rating of the condition of atmospheric air (on the example of the city of Chernivtsi). The results of the calculation of *CAPI* and I_5 showed that the maximum was noted in 2017 due to abnormally high concentrations of phenol, the minimum was in 2018. The value of I_5 is fully correlated with the value of *CAPI*, which means the expediency of using I_5 in particular for rating. According to the value of I_5, the quality of the air is characterized by the level of "slightly polluted". Nitrogen dioxide, hydrogen fluoride and formaldehyde were included in the "three" priority pollutants. The value of I_n changes similarly to *CAPI*. In comparative analysis for individual regions, it can be used as an alternative indicator. The dynamics of changes in the index *AQI* for individual pollutants are similar to their time course. At index values of 100 %, the air quality is characterized as "poor", although this corresponds to the level of the *MRS*. According to indicators of sustainable development in the "Ecological systems" category, a significant deterioration of circumstances is noted, for the "Environmental load" category – a significant improvement in circumstances is noted. The condition of the air underwent positive changes until 2018. Since 2019, indicators have deteriorated.

Keywords: air, method of rating, danger index, pollution index, sustainable development.

1. Introduction

The question of rating of the condition of the air in the regions of Ukraine is very relevant. This problem became especially worsened with the start of military actions on the territory of Ukraine on February 24, 2022.

According to the Regional Report (Rehionalna dopovid, 2022) in 2021 Chernivtsi was included in the list of territories with a low level of atmospheric pollution. In recent years, due to the decline in production activity and the transition from solid fuels to gaseous fuels, there has been a decrease in emissions of pollutants from stationary sources. The main source of atmospheric air pollution in the Chernivtsi region is emissions from mobile sources, mainly motor vehicles. It should be noted that over the past 10 years, emissions from mobile sources have decreased by more than 2 times. This is a consequence of the building the bypass road for the city of Chernivtsi. According to experts, Chernivtsi remains one of the most clean cities in Ukraine.

Also, an important component of the rating of the condition of the air is the methodical part – the choice of the optimal rating method. An attempt to assess the quality of the air pool using different methods is given in the work (Chugai; Starchuk, 2011). The issue of methodological approaches to assessing the state of the air basin has also been considered by other authors, for example, by A. A. Petrosian, A. V. Pavlichenko and co-authors (Petrosian, 2015; Pavlichenko et al. 2019).

Thus, the purpose of the investigation was to review methodological approaches to the rating of the condition of atmospheric air, which is a relevant issue in the context of changes in the legislative framework in the field of atmospheric air protection. Such an overview of the methods of rating the quality of

For citation: Chugai, A., Nedostrelov, M., Bratov, K. (2023). Condition and quality of the air of the Chernivtsi region. *Journal Environmental Problems*, *8*(3), 133–141. DOI: https://doi.org/10.23939/ep2023.03.133

atmospheric air was done on the example of the city of Chernivtsi, as for the rating of the condition of the air – the Chernivtsi region as a whole.

2. Materials and Methods

The materials of Regional Reports, Environmental Passports on the level of atmospheric air pollution in Chernivtsi, as well as sources of anthropogenic influence and volumes of emissions of pollutants into the air of the region as a whole for 2012–2021 were used as initial data.

One of the methodological approaches to the rating of atmospheric air quality is the use of the integral rating method, which allows to provide a rating of the condition of the air of a separate district or settlement as a whole for certain pollutants based on the calculation of complex indicators. We considered three such methods (indices):

– air pollution index (*API*);

– pollution danger index (I_n);

– air quality index (*AQI, Australia*).

As you know, the unit *API* is calculated according to the formula:

$$API = (\frac{\overline{q}}{MPC_{da}})^{C_i}, \quad (1)$$

where $\overline{q}$ is the average concentration of the pollutant in atmospheric air, mg/m^3; C_i is a constant that takes the value 1.7; 1.3; 1.0; 0.9 respectively for 1; 2; 3; 4th class of danger pollutant and allows to reduce the degree of harmfulness of the *i* substance to the degree harmfulness of SO_2 (Chugai, Safranov, 2021).

According to the methodology, with $API \leq 1$ the quality of the air in terms of the content of a separate pollutant meets the sanitary and hygienic requirements.

On the basis of the obtained single *APIs*, it is possible to calculate complex indices of atmospheric pollution (*CAPI*) (Chugai, Safranov, 2021):

$$CAPI = \sum_{i=1}^{n} API_i. \quad (2)$$

A variant of *CAPI* is the I_5 index, which takes into account the unit *API* values of those five pollutants for which these values are the largest. Calculation of I_5 allows to classify the level of atmospheric air pollution according to the following gradations: $I_5 < 2.5$ – atmospheric air is clean; $I_5 = 2.5 – 7.5$ – slightly polluted; $I_5 = 7.6 – 12.5$ – polluted; $I_5 = 12.6 – 22.5$ – heavily polluted; $I_5 = 22.6 – 52.5$ – highly polluted; $I5 > 52.5$ – extremely polluted atmospheric air (Chugai, Safranov, 2021).

If we analyze *CIAP* and I_5, then *CIAP* takes into account all pollutants that are monitored in a certain settlement. At the same time, in a comparative analysis for different cities, the number of monitored pollutants may be different. Taking this into account, the I_5 indicator more objectively characterizes the condition of atmospheric pollution. It takes into account the 5 most significant pollutants, which in fact unifies the rating results. Also, the experience shows that polluting substances that are not included in the "first five" actually have an insignificant effect on the values of *CAPI* (Chugai, Safranov, 2021).

A. V. Priymak (Chugai, Safranov, 2021) proposed to use the "pollution danger index" as an *API*, which is calculated according to the formula:

$$I_n = \sqrt{\sum_{i=1}^{n} k_i^2}, \quad (3)$$

where k_i is an excess of the *MPC* of a specific pollutant (Chugai, Safranov, 2021).

Somewhat similar to the *API* calculation is the air quality index *AQI*, which is used in Australia. According to the methodology, the content of five pollutants is analyzed: O_3, NO_2, SO_2, *CO* and suspended substances:

$$I_P = (C_P / C_{Ps}) \cdot 100~\%, \quad (4)$$

where C_P is the pollutant concentration; C_{Ps} is the standard concentration of a pollutant (Chugai, Safranov, 2021).

According to the *AQI* values, five categories of atmospheric air quality are selected (Table 1).

The condition of the air can be rated from the perspective of sustainable development. Various methodological approaches can be used for this purpose. One of them is the rating based on the evaluation parameters, which are presented in the metric for measuring the processes of sustainable development (MMSD) (Stalyi rozvytok, 2020). Usually, the rating of sustainable development is carried out taking into account the economic, ecological and social and institutional development of the region. As for the environmental component, it is determined through the index of the environmental dimension (I_e) taking into account three categories of environmental policy: environmental systems (I_{SYS}); environmental load (I_{STR}); regional environmental management (I_{REG}). These categories consist of 13 indicators and 44 parameters for assessment (Stalyi rozvytok, 2020).

Table 1

Air quality categories by *AQI* value (Australia) (Chugai, Safranov, 2021)

Category	*AQI* range
Very good (*VG*) air quality	0–33
Good (*G*) air quality	34–66
Fine (*F*) air quality	67–99
Poor (*P*) air quality	100–149
Very poor (*VP*) air quality	≥ 150

3. Results and Discussion

In the city of Chernivtsi, monitoring of atmospheric pollution is carried out at 3 stationary observation points (Prohrama derzhavnoho monitorynhu, 2022). According to official data, the city constantly monitors the content of 9 pollutants: dust, sulfur dioxide, carbon monoxide, nitrogen dioxide, nitrogen oxide, phenol, hydrogen fluoride, hydrogen chloride and formaldehyde. It should also be noted that in 2012–2013, the content of benzo(a)pyrene was also monitored.

Figure 1 shows the results of calculating *CAPI* and I_5 according to data (Rehionalna dopovid, 2022; Rehionalna dopovid, 2013; Rehionalna dopovid, 2014; Rehionalna dopovid, 2015; Rehionalna dopovid, 2016; Rehionalna dopovid, 2017; Rehionalna dopovid, 2018; Rehionalna dopovid, 2020; Ekolohichnyi passport, 2020; Rehionalna dopovid, 2021). As can be seen, the maximum was noted in 2017 due to abnormally high concentrations of phenol. The minimum values were noted in 2018. If 2017 is not taken into account, then a decrease in the level of atmospheric air pollution during the investigation period is noted. In recent years, the indicators correspond to the indicators of the level of 2015–2016. The value of I_5 is fully correlated with the value of *CAPI*, which indicates the feasibility of using precisely I_5 to rate the condition of the air of a separate region.

According to the value of I_5, the quality of the air is characterized by the level of "slightly polluted" for the entire period of the investigation. At the same time, when defining I_5, the list of Pollutants that were included in the 5 priority ones was changed (Table 2).

The table shows that nitrogen dioxide, hydrogen fluoride and formaldehyde were among the "three" priority pollutants. In most years, phenol and hydrogen chloride were also prioritized. In some years, this list included dust (2018, 2020, 2021), carbon monoxide (2014), and benzo(a)pyrene (2012–2013). With regard to benzo(a)pyrene, taking into account the data for 2012–2013, it can be assumed that this substance had the opportunity to enter the "three" priority pollutants, provided that the observations were not stopped.

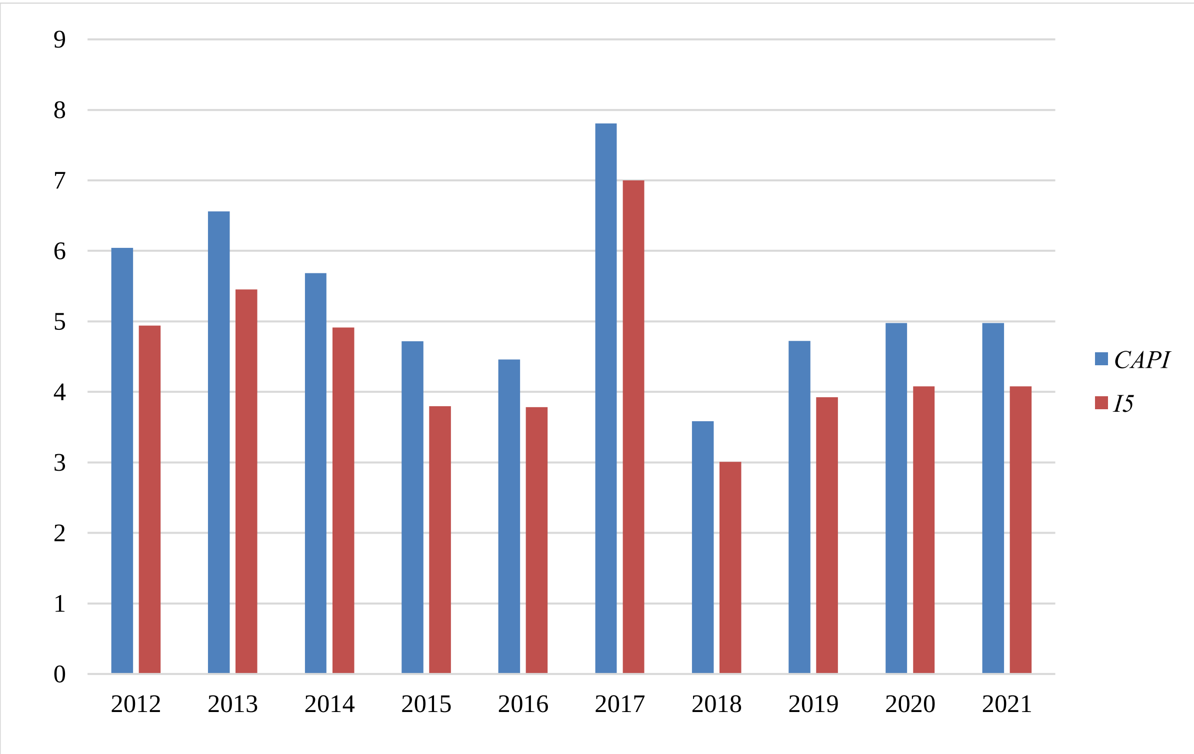

Fig. 1. Dynamics of changes in the comprehensive *API* of Chernivtsi in 2012–2021

Table 2

The list of pollutants that are taken into account when calculating I_5

Year	Dust	Carbon monoxide	Nitrogen dioxide	Phenol	Hydrogen fluoride	Hydrogen chloride	Formal-dehyde	Benzo(a)-pyrene
2012			+		+	+	+	+
2013			+		+	+	+	+
2014		+	+		+	+	+	
2015			+	+	+	+	+	
2016			+	+	+	+	+	
2017			+	+	+	+	+	
2018	+		+		+	+	+	
2019			+	+	+	+	+	
2020	+		+	+	+		+	
2021	+		+	+	+		+	

Fig. 2 shows the results of the calculation of the pollution danger index I_n. Taking into account the fact that the I_n indicator takes into account the content of all pollutants, it was compared with *CAPI*. As can be seen, the value of I_n changes similarly to the *CAPI* indicator. Although the danger class of the substance is not taken into account when calculating I_n, it can be used as an alternative indicator in the general comparative analysis of atmospheric air quality in individual regions.

As mentioned above, when calculating the *AQI*, the content of five pollutants, including ozone, is analyzed. Since monitoring of the ozone content in Chernivtsi is not carried out, we used one of the priority pollutants – formaldehyde.

The dynamics of changes in *AQI* for individual pollutants are similar to the dynamics of changes in single *API*s. The classification of air quality categories according to *AQI* values is presented in the Table 3.

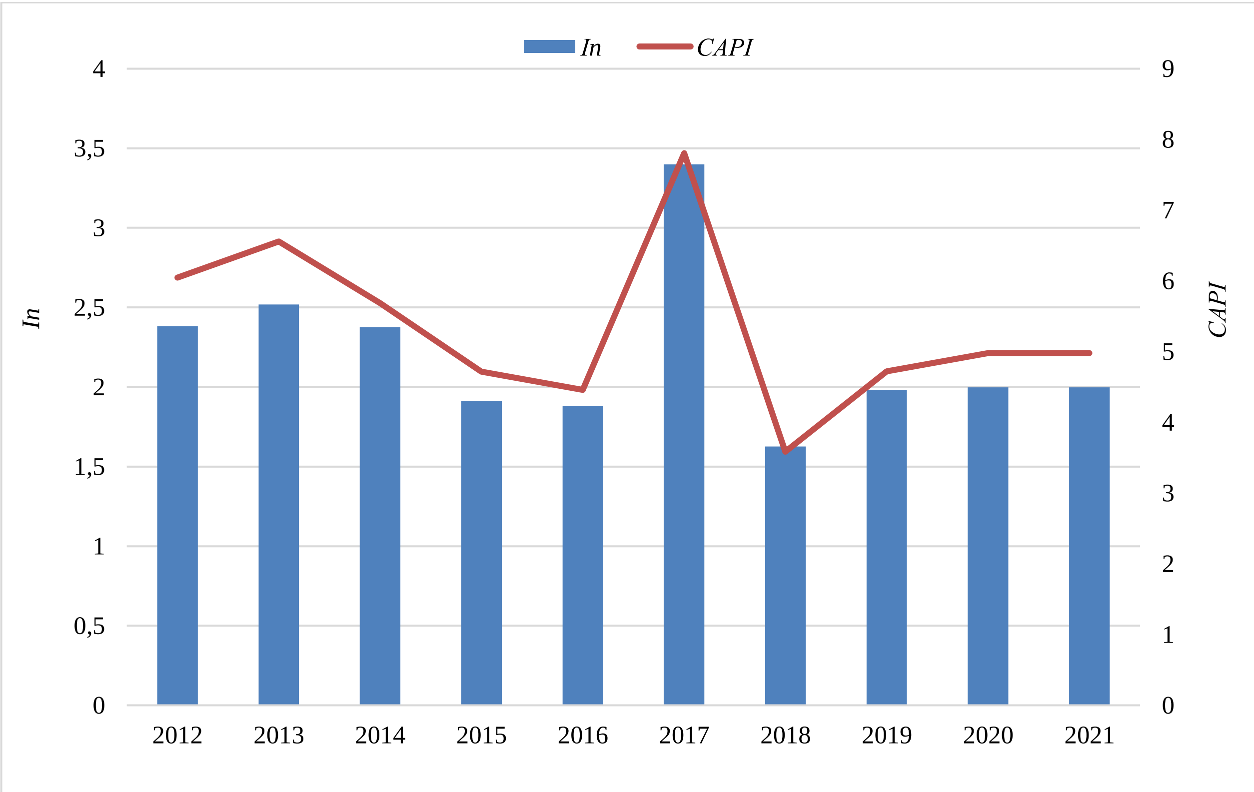

Fig. 2. Dynamics of changes in I_n and *CAPI* in Chernivtsi in 2012–2021

Table 3

Air quality categories by *AQI* value (Australia)

Year	Dust	Sulfur dioxide	Carbon monoxide	Nitrogen dioxide	Formaldehyde
2012	30 (very good)	6 (very good)	30 (very good)	75 (fine)	167 (very poor)
2013	30 (very good)	6 (very good)	30 (very good)	75 (fine)	167 (very poor)
2014	30 (very good)	6 (very good)	30 (very good)	80 (fine)	170 (very poor)
2015	30 (very good)	8 (very good)	30 (very good)	50 (good)	130 (poor)
2016	30 (very good)	4 (very good)	20 (very good)	60 (good)	110 (poor)
2017	33 (very good)	4 (very good)	20 (very good)	80 (fine)	100 (poor)
2018	30 (very good)	4 (very good)	10 (very good)	100 (poor)	100 (poor)
2019	50 (good)	7 (very good)	10 (very good)	100 (poor)	120 (poor)
2020	90 (fine)	6 (very good)	10 (very good)	80 (fine)	100 (poor)
2021	90 (fine)	6 (very good)	10 (very good)	80 (fine)	100 (poor)

As can be seen, according to the methodology of Australian scientists, the quality of atmospheric air in the city of Chernivtsi in terms of sulfur dioxide and carbon monoxide content is characterized by a single category of "very good", in terms of dust content – from "very good" to "fine", although according to the standards of Ukraine, all values meet the standards. The content of nitrogen dioxide corresponds in different years to the categories from "good" to "poor", and the content of formaldehyde – from "poor" (dominant) to "very poor". It should also be noted that with index values of 100 %, the air quality is already characterized as "poor", although this corresponds to the level of *MPC*.

The following parameters were used when rating the condition of the region's air according to indicators of sustainable development:

– in the category "Ecological systems" – average concentrations of nitrogen dioxide I_{NO2}, sulfur dioxide I_{SO2}, dust I_{TCP};

– in the "Environmental load" category – emissions of nitrogen oxides I_{NOX}, sulfur dioxide I_{SOT}, volatile organic compounds I_{VOC}, from transport I_{CAR}, stationary and mobile sources per 1 km^2 of I_{EKM} and per 1 person of I_{EPC};

– in the "Regional environmental management" category – the amount of actual funds for I_{FND} environmental protection measures.

It should be noted that the initial information was somewhat different. So, for example, in 2021 there is no information on emissions of pollutants. Also, in fact, due to the lack of investigations of emissions from mobile sources since 2016, almost all parameters of the "Environmental load" category have been calculated taking into account only emissions from stationary sources. These are indicators of emissions of individual pollutants, as well as the calculation of specific emissions per 1 km^2 and per 1 person.

The results of the rating are given in table. 4. As can be seen, in the "Ecological systems" category, the best conditions correspond to the indicators of the dust content in the atmospheric air. In the "Environmental load" category, the worst conditions for almost all indicators were observed in 2012. In recent years, the values of the parameters are close to the minimum, but, as mentioned above, this is due to the lack of data on Pollutants emissions from mobile sources. The "Regional environmental management" category, namely the indicator of financing of environmental protection measures, indicates a worsening of the situation during over the years of research.

Average index values were calculated for two environmental policy categories: I_{SYS} of the "Environmental Systems" category and I_{STR} of the "Environmental Load" category. The results are shown in Fig. 3–4.

Fig. 3 shows that in the category "Ecological systems" there is a significant deterioration of the conditions of sustainable development during the period of the study. The best conditions were observed in 2016. For the category "Environmental load" (Fig. 4), a significant improvement in the state of the air from the point of view of sustainable development is noted. However, under the conditions of availability of data on Pollutants emissions from mobile sources, the expected results would be somewhat worse.

The overall index of the ecological dimension I_e was also calculated in relation to the conditions of sustainable development of the air of the region (Fig. 5). As can be seen, in general, the condition of the air underwent positive changes until 2018. Since 2019, indicators have deteriorated, including due to a decrease in funding for environmental protection measures.

Table 4

Rating the condition of the air of the Chernivtsi region according to indicators of sustainable development 2012–2021

Indicator	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Policy category "Ecological systems" I_{SYS}										
I_{NO2}	0.5	0.5	0.6	0	0.2	0.6	1	1	0.6	0.6
I_{SO2}	0.5	0.5	0.5	1	0	0	0	0.75	0.5	0.5
I_{TCP}	0	0	0	0	0	0.05	0	0.33	1	1
Policy category "Environmental load" I_{STR}										
I_{NOX}	1	0.98	0.96	0.85	0.004	0.004	0.01	0.004	0	–
I_{SOT}	0.88	0.75	0.75	1	0.25	0.25	0.21	0.09	0	–
I_{VOC}	1	0.95	0.86	0.79	0	0	0.005	0.01	0.002	–
I_{CAR}	1	0.89	0.75	0.49	0.4	0.26	0.15	0	–	–
I_{EKM}	1	0.94	0.9	0.82	0.04	0.04	0.02	0.02	0	0
I_{EPC}	1	0.95	0.89	0.82	0.03	0.04	0.02	0.02	0.002	0
Policy category "Regional environmental management" I_{REG}										
I_{FND}	0.12	0.77	0.81	0.62	0.79	1	–	0	–	0.7

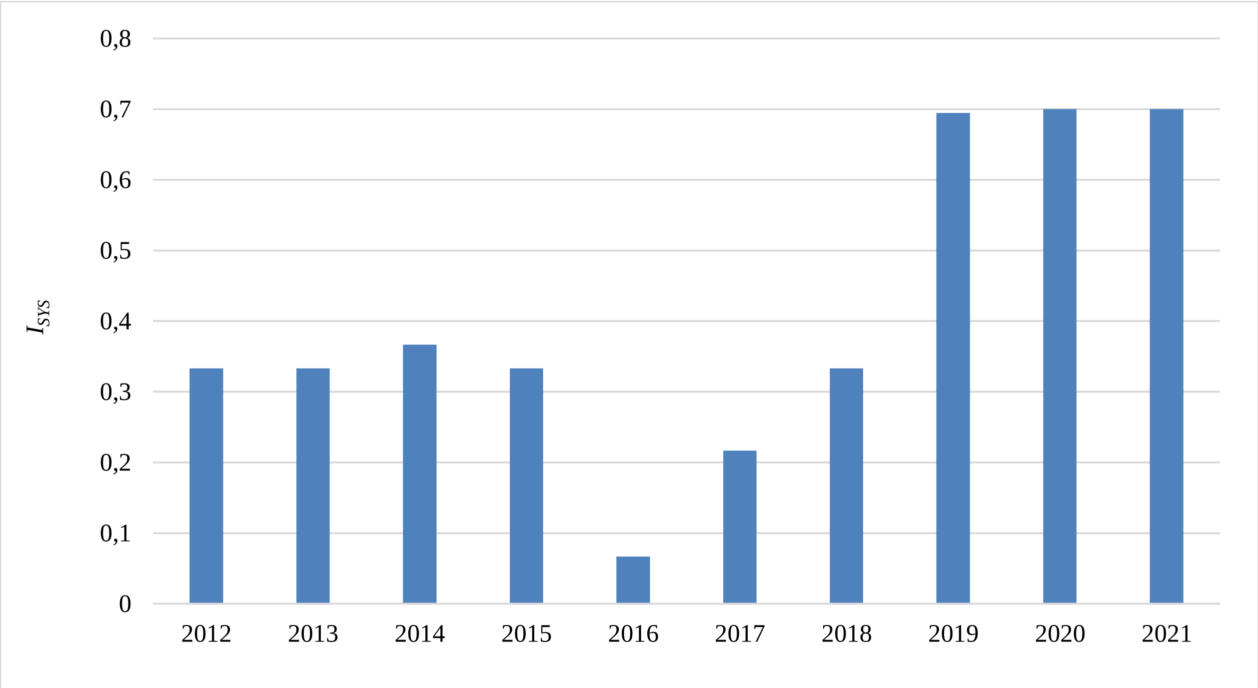

Fig. 3. Value of the I_{SYS} index of the "Ecological systems" category for the Chernivtsi region in 2012–2021

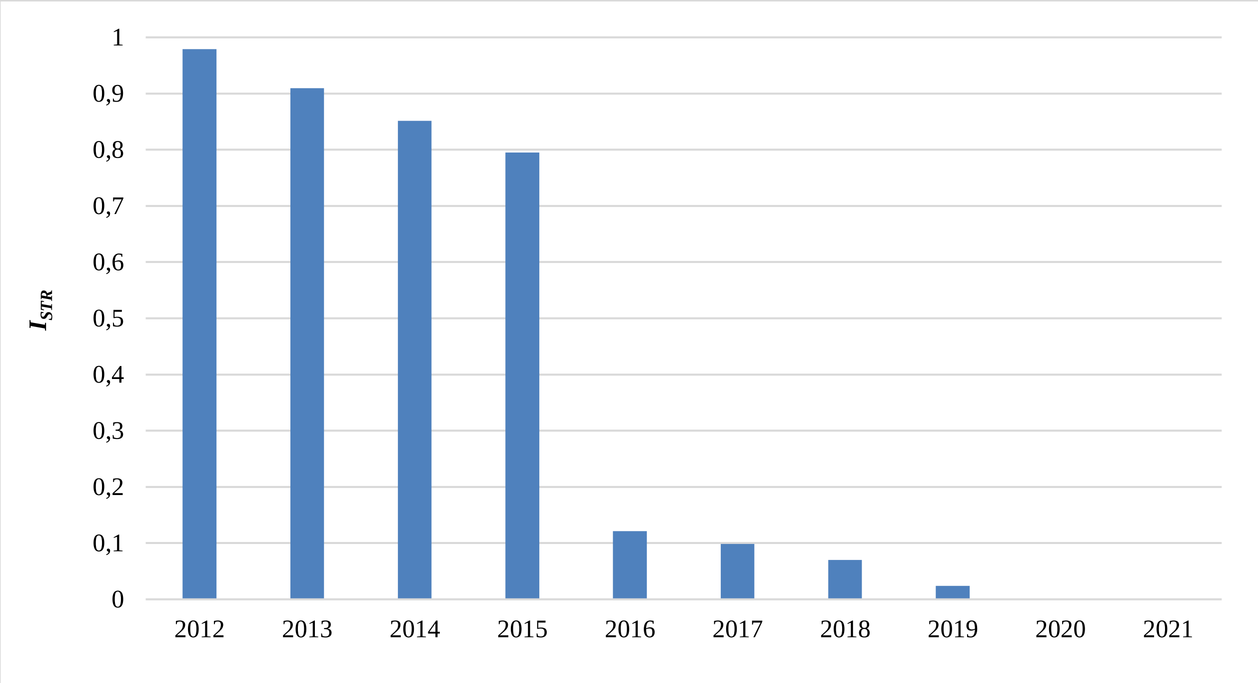

Fig. 4. The value of the I_{STR} index of the "Environmental load" category for the Chernivtsi region in 2012–2021

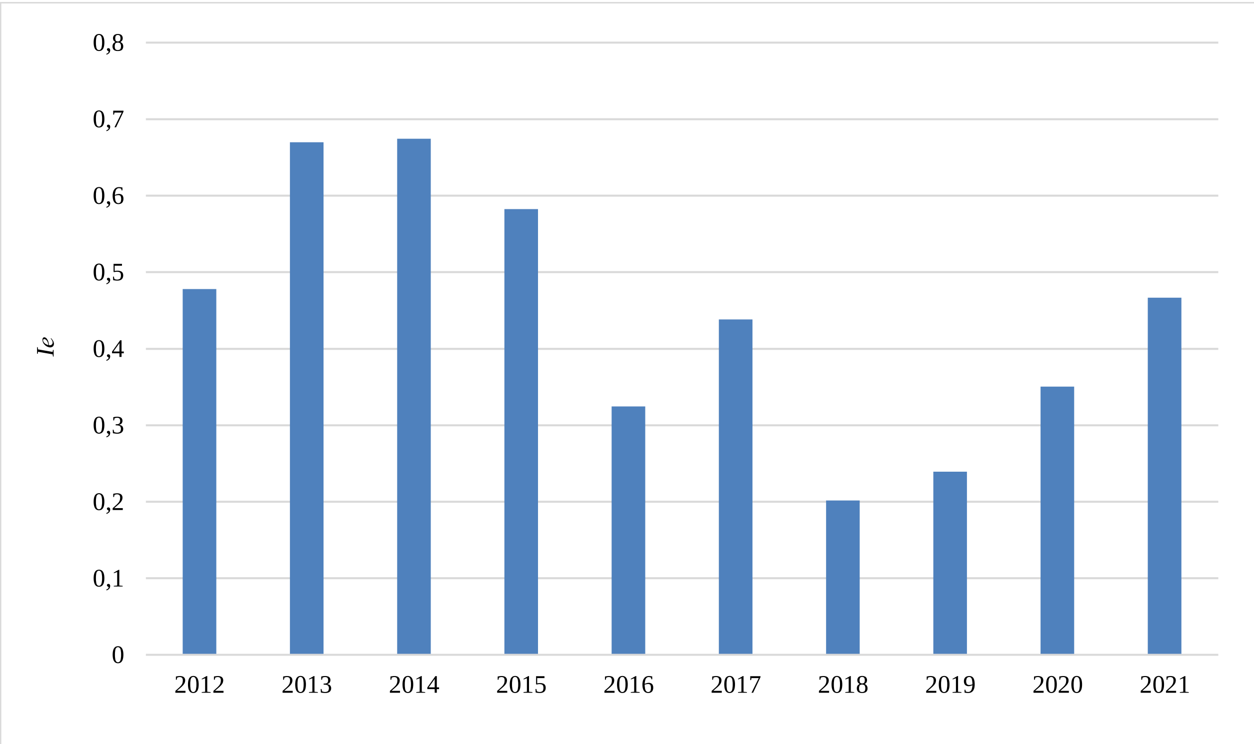

Fig. 5. The value of the index of the environmental dimension I_e for the Chernivtsi region in 2012–2021

4. Conclusions

As a result of the conducted research, the following conclusions can be drawn:

1) the results of the calculation of *API* and I_5 showed that the maximum was noted in 2017 due to abnormally high concentrations of phenol, the minimum was in 2018. In general, there was a decrease in the level of atmospheric air pollution during the investigation period. The I_5 value is fully correlated with the *CAPI* value, which indicates the expediency of using I_5 to rate the condition of the air of a separate region.

2) according to the value of I_5, the quality of the air is characterized by the level of "slightly polluted" for the entire period of the investigation. At the same time, during its calculation, the list of pollutants that were included in the 5 priority ones was changed. Nitrogen dioxide, hydrogen fluoride and formaldehyde were included in the "three" priorities. In most years, phenol and hydrogen chloride were also prioritized. In 2012–2013, this list included benzo(a)pyrene.

3) the value of I_n changes similarly to the *CAPI* indicator. When calculating I_n, the danger class of the substance is not taken into account, but it can be used as an alternative indicator in the general comparative analysis of atmospheric air quality in individual regions.

4) the dynamics of *AQI* changes for individual pollutants is similar to the time course of their concentrations. Atmospheric air quality in terms of sulfur dioxide and carbon monoxide is characterized by the "very good" category, and in terms of dust content – from "very good" to "fine", although according to the standards of Ukraine, all values correspond to the standards. The content of nitrogen dioxide corresponds to the categories from "good" to "bad", the content of formaldehyde – from "bad" (dominant) to "very bad". At index values of 100 %, the air quality is already characterized as "bad", although this corresponds to the level of the *MPS*.

5) according to the indicators of sustainable development, based on the average values of the indices for the two categories of environmental policy, it was found that in the category "Ecological systems" there is a significant deterioration of the conditions of sustainable development during the investigation period. The best conditions were noted in 2016. For the "Environmental load" category, a significant improvement in the condition of the air from the point of view of sustainable development is noted. Given the availability of data on pollutant emissions from mobile sources, the expected results would be somewhat worse.

6) the calculation of the overall index of the ecological dimension I_e in relation to the conditions of sustainable development of the air of the region showed that, in general, the condition of the air underwent positive changes until 2018. Since 2019, the indicators have deteriorated, including due to a decrease in funding for environmental protection measures.

In general, the condition of the air of Chernivtsi has significantly improved over the ten-year period. It is currently not possible to make a rate due to the lack of official information in connection with military actions on the territory of Ukraine. The considered methodological approaches can be used both for rating the condition in a separate region and for comparative analysis.

References

Chugai, A. V., & Starchuk, I. O. (2011). Porivnialnyi analiz rozrakhunku IZA za riznymy metodykamy. *Vestnyk Hydromettsentra Chernoho y Azovskoho morei, 2*(13), 34–41. Retrieved from http://eprints.library.odeku.edu.ua

Chugai, A. V., & Safranov, T. A. (2021). *Metody otsinky tekhnohennoho vplyvu na dovkillia*. Navchalnyi posibnyk. Odesa: Bukaiev Vadym Viktorovych. Retrieved from http://eprints.library.odeku.edu.ua/id/eprint/10029/1/ChyhayAV_MetOcTehnogenVplivy_2021.pdf

Ekolohichnyi pasport. Chernivetska oblast. 2019 rik (2020). Retrieved from https://bukoda.gov.ua/chernivecka-oda/structure/departament-regionalnogo-rozvitku/pasport-cherniveckoyi-oblasti

Petrosian, A. A. (2015). Do pytannia rozrobky metodychnykh pidkhodiv shchodo otsinky yakosti povitria ta zberezhenni hromadskoho zdorovia. *Hihiiena naselenykh mists, 66*, 47–52.

Pavlychenko, A. V., Buchavyi, Yu. V., Angurets, O. V., & Khazan, P. V. (2019). Perspektyvy vprovadzhennia systemy operatyvnoho informuvannia naselennia pro yakist atmosfernoho povitria promyslovykh mist za mizhnarodnymy standartamy. *Zbirnyk naukovykh prats NHU, 57*, 178–191. Retrieved from http://nbuv.gov.ua/UJRN/znpngu_2019_57_18.

Prohrama derzhavnoho monitorynhu u haluzi okhorony atmosfernoho povitria. Chernivetska (zona/ahlomeratsiia) (2022). Retrieved from https://bukoda.gov.ua/npas/pro-zatverdzhennya-programi-derzhavnogo-monitoringu-u-galuzi-ohoroni-atmosfernogo-povitrya-cherniveckoyi-zoni

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2012 rotsi (2013). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/ecology/reg-dop-che2012.pdf

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2013 rotsi (2014). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/ecology/reg-dop-che2013.pdf

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2014 rotsi (2015). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/ecology/reg-dop-che2014.pdf

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2015 rotsi (2016). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/ecology/reg-dop-che2015.pdf

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2016 rotsi (2017). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/ecology/reg-dop-che2016.pdf

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2017 rotsi (2018). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/ecology/reg-dop-che2017.pdf

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2019 rotsi (2020). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/ecology/reg-dop-che2019.pdf

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2020 rotsi (2021). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/ecology/ecology2020.pdf

Rehionalna dopovid pro stan navkolyshnoho pryrodnoho seredovyshcha v Chernivetskii oblasti u 2021 rotsi (2022). Retrieved from https://bukoda.gov.ua/storage/app/sites/23/uploaded-files/%20%D0%94%D0%BE%D0%BF%D0%BE%D0%B2%D1%96%D0%B4%D1%8C%202021.pdf

Stalyi rozvytok rehioniv Ukrainy (2020). Retrieved from http://nung.edu.ua/files/attachments/stalyy_rozvytok_regioniv_ukrayiny.pdf