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ANALYSIS OF THE STATE OF AIR POLLUTION IN INDUSTRIAL CITIES OF UKRAINE DURING THE WAR PERIOD (ON THE EXAMPLE OF ZAPORIZHZHIA CITY)

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INTRODUCTION

Zaporizhzhia is one of the most urbanized, industrial and environmentally unfavorable cities of Ukraine. The population of Zaporizhzhia lives in the conditions of constant air pollution by hazardous chemicals of technogenic origin. The crisis of technogenic load on the city is worsened by climatic features of the region and by the existing buildings. The city of Zaporizhzhia is located in climatic conditions characterized by unfavorable conditions for the dispersion of harmful emissions (temperature inversions, calms, etc.), which leads to the accumulation of emissions from enterprises in residential areas. The main enterprises of the city of Zaporizhzhia are located on an industrial area, which is located almost in the center of the city, air pollution over the main areas of the city occurs in almost any wind direction.

The relevance of the scientific work is as follows: control over the condition of the atmospheric air is one of the key links in the environmental monitoring system, as it provides information on the level of pollution of the component, which primarily, not indirectly affects the health of a large number of people. At the same time, the efficiency and completeness of state atmospheric monitoring is not always sufficient to solve the tasks of environmental management, emergency response, etc. Therefore, there is an obvious need to improve the organizational structure, methods and ways of monitoring the state of atmospheric air[1].

1. Air quality monitoring during martial law

Anthropogenic impact of air pollution is about 0.5 % of the total pollution by natural phenomena, but this type of pollution has the most negative impact.

Under conditions of long-term impact of sources of anthropogenic origin, environmental components that have a direct impact on the safety of life and quality of life of both humans and all living organisms are of particular importance.

[1] Бєлоконь К. В., Тулушев Є. О. Аналіз впливу технологій промислових підприємств та автотранспорту на стан екологічної безпеки атмосферного повітря (на прикладі м. Запоріжжя) : монографія. Запоріжжя : ВД «Гельветика», 2020. 230 с.

Emissions of harmful substances entering the atmosphere from anthropogenic sources are mixed, moved and washed out of it. Photochemical processes occur in the air basin, leading to the emergence of new compounds, sometimes more harmful than the original ones. Adequate analysis of air pollution levels is impossible without accurate determination of the amount of harmful contaminants present in the air. Data on the concentration of pollutants in the air are obtained at a network of control and measuring stations, which is part of the state environmental monitoring system.

In order to ensure proper air quality, an adequate system of environmental monitoring, in particular monitoring of the condition of atmospheric air, is of great importance.

Relations in the sphere of environmental monitoring are regulated by Article 22 of the Law of Ukraine "On Environmental Protection", the Resolution of the Cabinet of Ministers of Ukraine dated March 30, 1998 № 391 "On Approval of the Regulation on the State Environmental Monitoring System", in the field of atmospheric air – the Law of Ukraine "On Atmospheric Air Protection" (Article 32 "Monitoring in the field of atmospheric air protection"), in the field of atmospheric air – the Resolution of the Cabinet of Ministers of Ukraine № 827 "Some issues of state monitoring in the field of atmospheric air protection" dated August 14, 2019.

Since the beginning of the full-scale invasion of the Russian Federation troops into the territory of Ukraine, the environmental monitoring system has suffered significant negative impacts.

Until February 2022, the state air quality monitoring in the city of Zaporizhzhia was carried out by the Zaporizhzhia Hydrometeorology Center at five permanent stations for monitoring the state of environmental pollution in 3 districts of the city – Dniprovsky, Voznesenivsky, Oleksandrivsky, 4 of which are located on the left bank of the Dnipro, with a sampling frequency of 5 days a week, 3–4 times a day[2].

Sampling at the stations was carried out according to the approved program for the city of Zaporizhzhia and each station (taking into account the location, proximity to emission sources, other factors).

Observations were performed according to the full (01, 07, 13 and 19 hours) or shortened program (7 and 19 hours) throughout the year, except weekends and holidays. The locations of the observation stations and the list of pollutants are given in Table 1.

At all observation stations the content of the main pollutants was determined – suspended substances (dust), sulfur dioxide, carbon monoxide and nitrogen dioxide. The content of specific substances – hydrogen sulphide,

[2] Огляд стану забруднення навколишнього природного середовища на території України за даними спостережень національної гідрометслужби. Центральна геофізична обсерваторія ім. Срезневського URL: http://cgo-sreznevskyi.kyiv.ua/index.php?fn=u_zabrud&f=ukraine

phenol, hydrogen fluoride, hydrogen chloride, formaldehyde – was monitored at separate stations, taking into account the emissions of industrial enterprises located near the observation station, as well as in the areas of the busiest highways of the city[3].

Table 1

Location of observation stations in Zaporizhzhia and list of pollutants

Number of the observation station	Location of the observation station	Parameters to be monitored	Units of measure-ment	Frequency of monitoring
№ 9	2 Rekordna St.	dust, CO, soluble sulfates, heavy metals	mg/m^3	2 times per day
		CO_2, NO_2, hydrogen sulfide, hydrogen fluoride, formaldehyde		4 times a day
№ 10	25 Shevchenko Blvd.	dust, CO	mg/m^3	2 times per day
		SO_2, NO_2, phenol		3 times per day
		hydrogen sulphide		4 times per day
№ 11	1 Mira St.	dust, CO, heavy metals, benzo (a)pyrene	mg/m^3	2 times per day
		CO_2, NO_2, NO_x, hydrogen sulphide		3 times per day
		Phenol, formaldehyde		4 times per day
№ 12	24 Shkilna St.	dust, CO, CO_2, NO_2 heavy metals, benzo (a)pyrene	mg/m^3	2 times per day
		Phenol		3 times per day
		Hydrogen chloride		4 times per day

[3] Регіональна доповідь про стан навколишнього природного середовища у Запорізькій області у 2020 році. Запорізька обласна державна адміністрація, м. Запоріжжя, 2021. 276 с.

Since the environmental pollution observation system was formed 25–40 years ago, the state of the instruments for measuring the composition of the atmosphere under observation corresponds to the scientific and technical level of the 70s of the last century. Therefore, its technical capabilities are limited, and the system itself requires immediate modernization and replacement of measuring instruments. The existing observation network neither in its composition, nor in the list of measured parameters, nor in technical equipment does not meet the modern level, in particular, the requirements of Directive № 2008/50/EC on the monitoring of atmospheric air quality and Directive № 2004/107/EC on the concentrations of arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in the air.

The research of the atmospheric air pollution at the observation stations was conducted only in Zaporizhzhia city, other cities of the region are not covered by the network of observation stations.

Assessment of the state of air pollution is carried out by indicators of average monthly concentrations in multiples of exceedances of the established average daily maximum permissible limits for priority pollutants. Priority substances are those whose contribution to the balance of air pollution in the city is the largest.

In March 2022, sampling at the observation posts was not carried out, the approved sampling programs were not fully implemented due to a number of objective reasons – the danger of rocket attacks on the territory of the city, the physical absence of personnel due to mobilization and evacuation of the population, problems with transportation and logistics of conducting appropriate physicochemical analysis in the relevant laboratories of the Hydrometeorological Service of Ukraine.

However, since April 2022, the Zaporizhzhia Hydrometeorology Center has resumed a full range of sampling and established proper air monitoring in Zaporizhzhia at all existing observation stations. It should be noted that the mobile environmental monitoring laboratory of the State Institution "Zaporizhzhia Regional Center of Disease Control and Prevention" of the Ministry of Health of Ukraine also carried out monitoring visits under limited conditions.

However, even taking into account the changes in the organization of research, sampling was carried out in the amount that allows drawing conclusions about air quality.

The industrial complex of the city has also undergone significant impacts and changes. Some enterprises stopped their activities, some significantly reduced the volume of production. However, since May 2022, the enterprises have restored their capacities (Table 2)[4].

[4] Регіональна доповідь про стан навколишнього природного середовища у Запорізькій області у 2020 році. Запорізька обласна державна адміністрація, м. Запоріжжя, 2021. 276 с.

2. Methodology of air quality research in Ukraine

In our country, the main criterion for the level of air pollution is the established maximum permissible concentrations approved by the Ministry of Health. To assess the level of air pollution, single averaged data of pollution indicators to the corresponding maximum permissible concentration by the averaging period are used.

The Air Pollution Index (API) is calculated for individual pollutants to assess the contribution of individual impurities to the overall level of air pollution or comprehensively for several substances to compare this level in different cities. The value of the API can be used to judge the degree of air pollution and the dynamics of pollution[5, 6].

The total index of urban air pollution changes annually not only due to the emissions, but also as a result of taking into account the sum of the index of pollution of a different number of single substances. With different number of pollutants taken into account, only relative comparison of the city pollution is possible.

The pollution index has a significant drawback – it does not take into account the effect of the combined action of impurities (total effect), as well as a rigid matrix of calculation conditions.

Other drawbacks include the assumption that a person is negatively affected by the presence of any amount of impurities in the air. At the same time, according to the definition of the API, toxic substances do not have a harmful effect on humans (regardless of hazard class) at concentrations below the established API level.

Single averaged and one-time indicators of air pollution normalized for the API are single indexes of air pollution. To analyze the level of atmospheric air pollution in populated areas by individual impurities, the API (I) is used, which is calculated by the formula (1):

$$I = \left(\frac{\overline{q}}{MPC_{average}} \right)_i^{C_i}, \qquad (1)$$

where q is the average concentration of a pollutant in the atmospheric air, mg/m^3; C_i is a constant that takes the values 1.7, 1.3, 1.0, 0.9 for 1, 2, 3, 4th hazard class of the substance respectively, and is the reduction of the degree of harmfulness of the *i*-th substance to the degree of harmfulness of sulfur dioxide.

[5] Колесник В.Є, Павличенко А. В., Калініна К. Р. Екологічна класифікація якості атмосферного повітря за комплексними індексами його забруднення. *Геотехнічна механіка* : міжвід. зб. наук. праць. Дніпро : ИГТМ НАНУ, 2017. Вип. 137. С. 156–169.

[6] Доценко Л. В., Демиденко А. С. Порівняльний аналіз методів визначення рівня забруднення атмосферного повітря. *Екологічна безпека*. 2014. Вип. 2. С. 71–74.

Table 2

Production volumes of the largest enterprises of the main industrial area, thousand tons of products

Year	Production volumes, thousand tons / month	Ferroalloys (PJSC " Zaporizhzhya Ferroalloy Plant")	Titanium alloys (Zaporizhzhya Titanium and Magnesium Plant)	Graphite products (PJSC " Ukrgraphite")	Coke and chemical products (PJSC " Zaporozhkoks")	Steel (PJSC " Zaporizhstal")	Pig iron (PJSC " Zaporizhstal")
1	2	3	4	5	6	7	8
2020	January	15,458	0,544	2	98,979	251,386	102,144
	February	14,865	0,507	2,417	86,08	232,915	83,154
	March	17,883	0,505	3,731	98,994	202,547	87,366
	April	20,338	0,529	3,965	95,036	194,498	77,672
	May	24,177	0,446	4,292	96,779	223,857	109,258
	June	24,118	0,386	3,805	82,999	211,58	92,582
Total		117	2,917	19,985	558,867	1316,783	552,176
2021	January	16,27	0,485	4,759	89,731	238,244	104,362
	February	16,049	0,385	3,043	84,407	219,831	75,453
	March	18,849	0,421	5,457	92,742	245,134	88,436
	April	18,301	0,424	5,926	86,284	232,448	66,711
	May	18,715	0,444	5,437	97,709	233,772	48,499
	June	21,659	0,422	6,248	92,214	231,191	48,909
Total		**109,843**	**2,581**	**30,87**	**543,087**	**1400,62**	**432,37**
2022	January	24,667	0,305	3,523	91,307	225,572	103,873
	February	17,085	0,284	3,092	79,048	202,411	78,12
	March	0,526	0,118	0,163	4,902	26,15	0,466
	April	4,432	0,095	0,68	64,213	46,88	0,366
	May	5,347	0,027	1,255	82,831	104,59	37,469
	June	4,878	0	2,064	83,352	59,288	83,843
Total		**56,935**	**0,829**	**10,777**	**405,653**	**664,891**	**304,137**

This method of determining the air pollution index is based on the assumption that at the MPC level all pollutants have the same impact on human health, and with further increase in concentrations, the degree of their harmful effects increases at different rates, which depends on the hazard class of the substance. It is believed that the air quality in terms of the content of a

particular pollutant meets the requirements of sanitary and hygienic safety with an API ≤ 1.

In order to compare the level of air pollution in different cities, the Composite Index of Air Pollution (CAPI) is used. This indicator is a dimensionless function of the characteristics of the degree of air pollution by several substances, their mixture. Complex API is calculated by the formula (2), which takes into account l substances present in the atmosphere:

$$I_l = \sum_{i=1}^{l} I_i = \sum_{i=1}^{l} \left[\frac{\overline{q}}{MPC_{average}} \right]_i^{C_i} . \quad (2)$$

For each settlement, a list of five priority pollutants has been determined, according to which the air pollution index (API) is calculated.

As an integral assessment of the level of air pollution using the CAPI, the values of the unit indexes of the five pollutants (I_5) for which these values are the highest are used:

$$I_5 = \sum_{i=1}^{5} I_i . \quad (3)$$

According to the value of I5, four levels of pollution are established:

$I_5 < 5$ – low level;

$5 \le I5 > 7$ – increased level;

$7 \le I5 > 14$ – high level;

$I5 \ge 14$ – very high level.

The initial data for the analysis were:

– to assess the state of air pollution, the indicators of API and CAPI, average monthly concentrations of pollutants in multiples of exceeding the established average daily maximum permissible concentrations for priority pollutants were used;

– for correlation of air quality indicators with the determinant (determining factor) typical for Zaporizhzhia, the volumes of products of the 5 largest heavy metallurgy enterprises of the main industrial site of the city were used.

The determining factor affecting the air quality in Zaporizhzhia is the production capacity of 10 enterprises belonging to the 1st group and forming the basis (95 %) of the balance of air pollution. For this analysis, 5 enterprises of heavy metallurgy were selected, the emissions of which are dominant in the overall balance of gross (ton/year) emissions, which are located in the Voznesenivsky district of Zaporizhzhia on the main industrial area. Other

enterprises of the 1st group, which have a significant contribution to the balance of gross pollution, located in other districts, were not taken into account due to the lack of observation stations in these areas, the information from which is the basis for the calculation of the API and CAPI.

3. Analysis of changes in air quality in Zaporizhzhia city during the state of war

The assessment of the state of the atmospheric air for January-June 2020, 2021 and 2022 was carried out by the values of average monthly concentrations in multiples of exceedances of the average daily MPCs for priority pollutants, taking into account their maximum one-time and average daily maximum concentrations (Table 3)[7].

On average, every year in the air of Zaporizhzhia city, the Hydrometeorological Service records about 8 % of exceedances of MPC with small fluctuations.

Average concentrations in fractions of MPC for the period 2019–2022 show a certain stability with some fluctuations for dust, nitrogen dioxide, phenol and formaldehyde (Figure 1, red line – conditionally safe concentration of 1 MPC).

Table 3

Priority pollutants

Pollutant	Average daily maximum permissible concentrations, (mg/m^3)	Maximum one-time permissible concentrations, (mg/m^3)
Dust (suspended substances)	0,15	0,50
Sulfur dioxide	0,05	0,50
Carbon oxide	3,0	5,0
Nitrogen dioxide	0,04	0,2
Nitric oxide	0,06	0,40
Formaldehyde	0,003	0,035
Phenol	0,003	0,01
Hydrogen chloride	0,20	0,20
Hydrogen fluoride	0,005	0,02

In 2022, there is a downward trend in air pollution for all pollutants. This is especially evident for the pollutants of nitrogen dioxide and phenol. This is

[7] Пірогова І. М., Бєлоконь К. В., Єрьоменко В., Олійник О. Визначення рівня забруднення атмосфери м. Запоріжжя на основі індексу забруднення атмосфери. *Біоекономіка як ключовий фактор розвитку виробництва та екологізації промислового регіону* : Міжнародна науково-практична конференція. Запоріжжя : ІННІ ЗНУ, 2020. С. 392–395.

primarily due to the same rapid decrease in production capacities of the largest enterprises in Zaporizhzhia.

According to the reports of the Sreznevsky Central Geophysical Observatory for the period of 2016–2019, the values of CAPI in Zaporizhzhia fluctuate at the level of 8, which corresponds to the level of "dangerous".

The observation results show that the highest concentrations are observed for the following pollutants: general dust, nitrogen dioxide and oxide, phenol and formaldehyde (Tables 4, 5, Figures 2–5)[8].

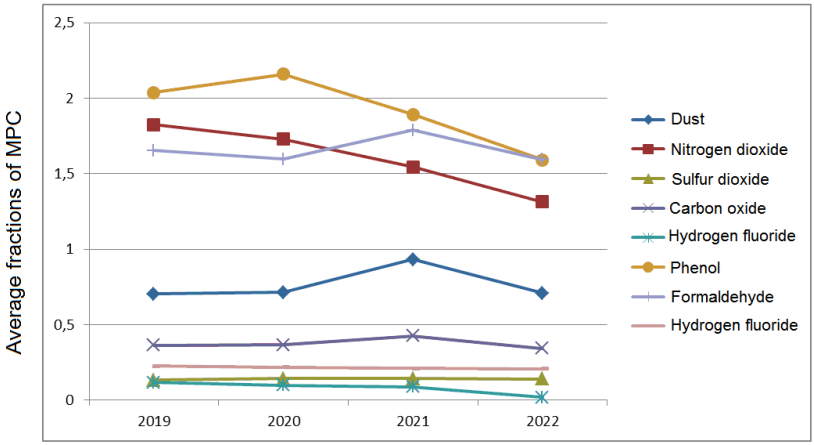

Fig. 1. Dynamics of average concentrations of pollutants in the atmospheric air of Zaporizhzhia, fraction of MPC

The average concentrations differ significantly from the maximum concentrations. For example, in 2020, the average concentrations for dust did not exceed the established MPCs and amounted to 0.7 MPC, but at the same time, the maximum concentrations were recorded at 1.4 MPC, for nitrogen dioxide, the average concentrations are 1.8 MPC, and the maximum values are 2.4 MPC. For formaldehyde, the average daily values are 1.6 MPC, and the maximum values recorded are 2 MPC[9].

[8] Бєлоконь К. В., Пірогова І. М. Аналіз та оцінка рівня забруднення атмосферного повітря м. Запоріжжя. *Збірник наукових праць Дніпровського державного технічного університету (технічні науки)*. 2021. Т. 1. № 38. С. 149–158.

[9] Регіональна доповідь про стан навколишнього природного середовища у Запорізькій області у 2020 році. Запорізька обласна державна адміністрація, м. Запоріжжя, 2021. 276 с.

Table 4

The highest average and maximum concentrations of pollutants (in multiples of MPC) in the air of Zaporizhzhia city for 2015–2022

Substance/period		dust	SO_2	NO_2	NO_x	CO	CH_2O	Phenol	HF	HCl
Annual average concentrations	2015	0,7	0,2	2,2	1	0,3	1,7	2	0	0,2
	2016	0,7	0,2	2	1	0,3	1,7	2	0	0,2
	2017	0,7	0,2	2,2	1	0,3	1,3	2	0	0,2
	2018	0,7	0,1	2	0,8	0,3	1,3	2	0	0,2
	2019	1,1	0,2	2,2	1	0,4	2	2,3	0,2	0,2
Average concentrations 1st half of the year	2020	0,7	0,1	1,7	0,9	0,4	1,6	2,2	0,09	0,2
	2021	0,9	0,1	1,5	0,8	0,4	1,8	1,9	0,09	0,2
	2022	0,7	0,1	1,3	0,7	0,3	1,6	1,6	0,02	0,16

Table 5

Average and maximum concentrations of pollutants (in multiples of MPC) in the atmospheric air of Zaporizhzhia city for 2020–2022

Name of pollutant	2020		2021		2022	
	average	max	average	max	average	max
Dust	0,7	1,4	0,9	1,7	0,7	1,3
Nitrogen dioxide	1,7	2,4	1,5	2,5	1,3	2
Nitric oxide	0,9	0,9	0,8	0,9	0,7	0,8
Sulphur dioxide	0,14	0,2	0,14	0,2	0,14	0,2
Hydrogen fluoride	0,1	0,2	0,1	0,2	0,02	0,06
Carbon monoxide	0,4	0,7	0,4	0,8	0,3	0,5
Phenol	2,2	3,1	1,9	2,5	1,6	2,2
Formaldehyde	1,6	2	1,8	2,1	1,6	1,9
Hydrogen chloride	0,2	0,3	0,2	0,2	0,17	0,2

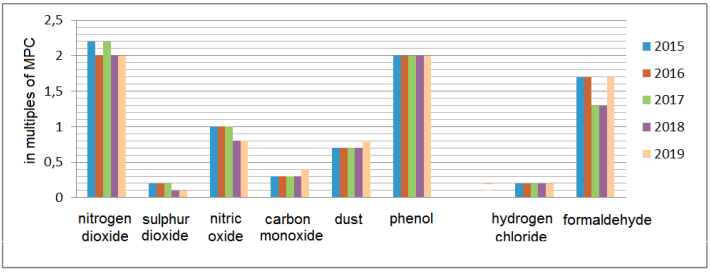

Fig. 2. Average annual concentrations of pollutants in the atmospheric air of the Zaporizhzhia city in multiples of MPC for 2015–2019

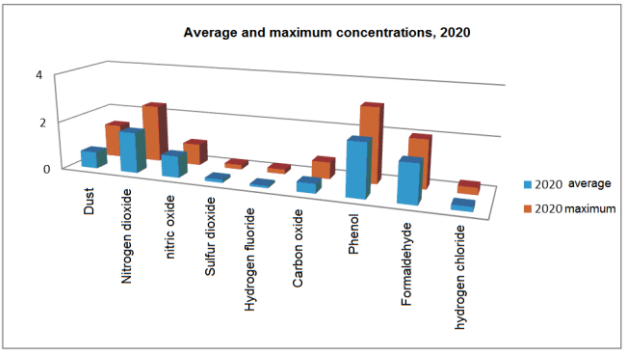

Fig. 3. Average and maximum concentrations of pollutants, 2020, in multiples of MPC

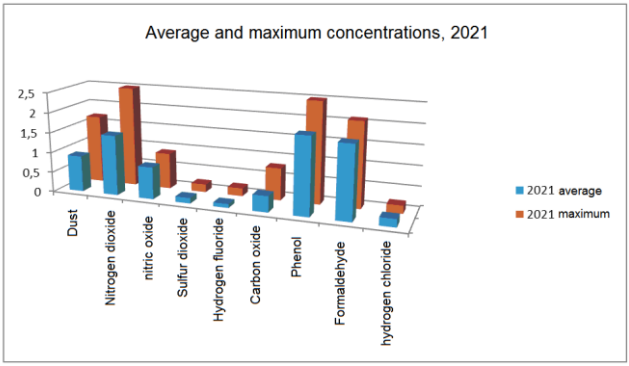

Fig. 4. Average and maximum concentrations of pollutants, 2021, in multiples of MPC

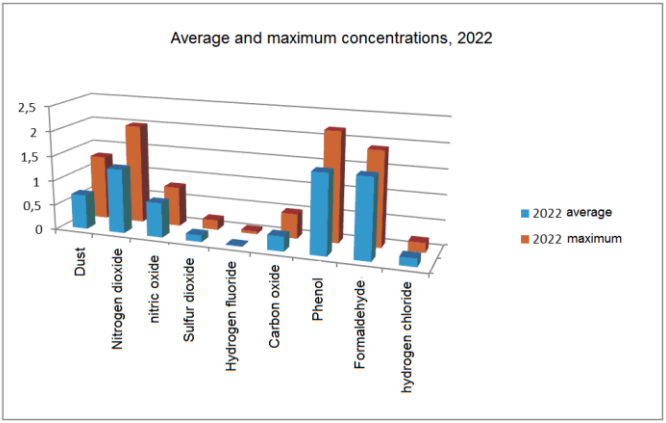

Fig. 5. Average and maximum concentrations of pollutants, 2022, in multiples of MPC

CAPI was calculated for the average daily concentrations of substances at each observation station in the city of Zaporizhzhia for the period of monitoring of 2020–2022 (as of 01.07.2022) (Table 6). The calculation of CAPI by observation stations was carried out for all concentrations of the studied substances, except for hydrogen sulfide due to the absence of an average daily MPC for hydrogen sulfide (Figure 6, yellow line – "increased level of air pollution", CAP I 5.0; red line – "dangerous level of air pollution", CAP I 7.0).

Table 6

Calculated CAPI for observation stations of the Zaporizhzhia Hydrometeorological Center

Year	Station 9	Station 10	Station 11	Station 12	Station 13
2020	3,0	5,9	9,7	5,7	1,8
2021	3,3	5,6	10,1	4,6	2,0
2022	2,7	4,6	8,2	3,9	1,6

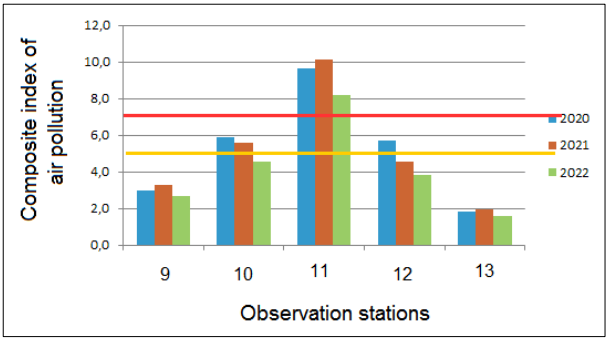

Fig. 6. Composite index of air pollution by observation stations of Zaporizhzhia city

The levels of I_n (integrated level of air pollution) differ depending on the area of the city and the location of the station, its remoteness from the sources of pollution. For example, the observation station № 13, located on the right bank of the city, shows the lowest pollution levels, which do not exceed 2 units, and the stations located in the city center in close proximity to the main industrial complex, reach values of 7 or more units. At the observation station № 11, which is the closest to the industrial complex, the complex index of air pollution is the highest and reaches more than 9 units (with a conditionally safe level of less tha n 5)[10].

However, a slightly different picture emerges when analyzing the data of monitoring studies of the state institution "Zaporizhzhia Regional Center of Disease Control and Prevention" of the Ministry of Health of Ukraine. The percentage of samples with exceedances is significantly different from the data of the Zaporizhzhia Hydrometeorology Center.

In the 1st half of 2021, the laboratory of the Zaporizhzhia Regional Center of Disease Control and Prevention did not carry out measurement visits due to lack of funding, in the second half of 2021 the mobile laboratory resumed research.

During the 1st half of 2020, 1188 atmospheric air samples were collected, deviations in 327 samples were found – 27.5 %. The WHO recommended safe concentrations of fine particles $PM_{2.5}$ were exceeded for 23 days, PM_{10} – 14 days. Exceedance of hygienic standards was caused by indicators – phenol (62.8 %) of the total number of deviations for the specified ingredient,

[10] Пірогова І. М., Бєлоконь К. В., Єрьоменко В., Олійник О. Визначення рівня забруднення атмосфери м. Запоріжжя на основі індексу забруднення атмосфери. *Біоекономіка як ключовий фактор розвитку виробництва та екологізації промислового регіону* : Міжнародна науково-практична конференція. Запоріжжя : ІННІ ЗНУ, 2020. С. 392–395.

hydrogen sulfide (62.2 %), formaldehyde (19.8 %), carbon disulfide (51.4 %), toluene (17.14 %), xylene (8.6 %).

In 2022, monitoring studies were conducted in January-June, but to a smaller extent than in pre-war 2020. A total of 1894 atmospheric air samples were analyzed, of which 241 samples (13 %) did not meet the normative indicators. The WHO recommended safe concentrations of fine particles $PM_{2.5}$ were exceeded for 23 days, PM_{10} – for 7 days. Exceedance of hygienic standards was caused by the following indicators – dust (33 % of the total number of deviations for the specified ingredient), phenol (28.3 %), hydrogen sulfide (16.2 %), formaldehyde (9.1 %), carbon dioxide (7.1 %), nitrogen dioxide (6 %), the excess of which was fixed in the range from 1.1 to 1.7 MPC (Figure 7).

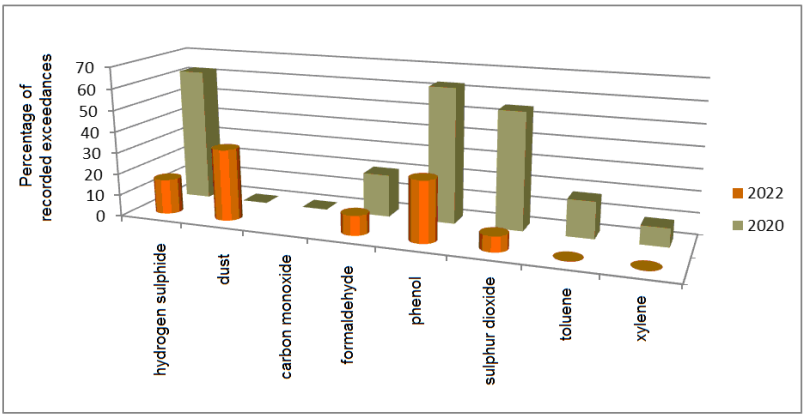

Fig. 7. Percentage of recorded exceedances by the mobile laboratory of the Zaporizhzhia Regional Center of Disease Control and Prevention of the Ministry of Health of Ukraine

To correlate the levels of air pollution with the determinant (production capacity), the analysis of correspondences for the main types of products of the 5 largest enterprises of the city, which are located on the main production area (Voznesenivsky district) of Zaporizhzhia city, was carried out. The enterprises were selected on the basis of the largest gross emissions of pollutants. The types of products are categorized by the main ones and by the specifics of the enterprise (for example, all products of PJSC "Zaporozhkoks" are combined into one type – coke products – coke, coke gas with conversion to tons, etc.)

It should be noted that other districts of the city (Khortytsky, Shevchenkivsky) also have powerful metallurgical complex production facilities and enterprises of the 1st hazard group. However, they are not taken into account for the current analysis, as there are no observation stations in these districts, the information from which is the basis for the calculation of the CAPI.

The determinant factor (production capacity) correlates with the levels of CAPI, provided that production capacity is reduced, the level of pollution is reduced accordingly.

Dynamics of changes in concentrations of pollutants and production volumes are shown in Figures 8 and 9.

Dynamics of changes in CAPI and production volumes are shown in Figures 10–12.

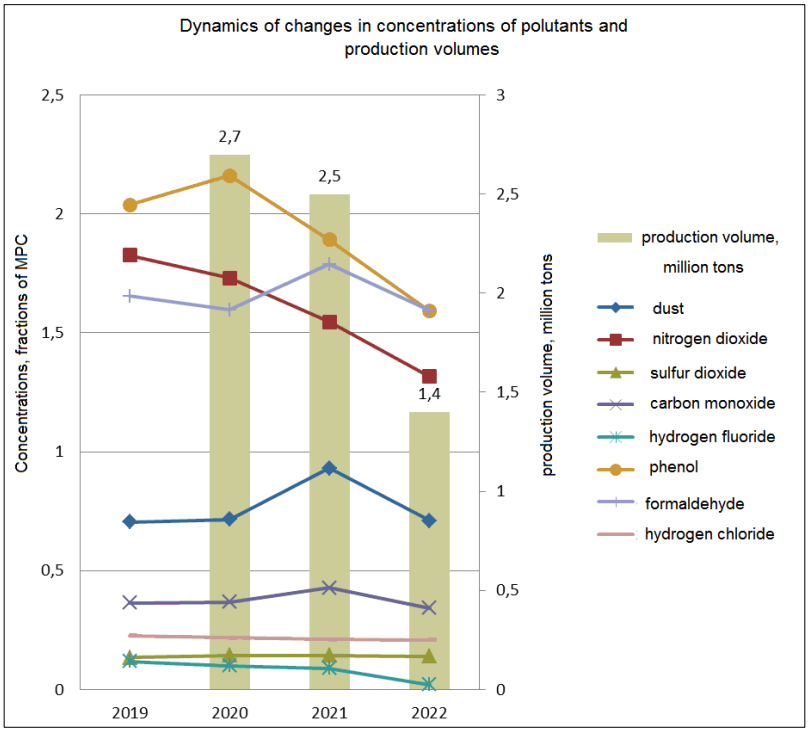

Fig. 8. Dynamics of changes in concentrations of pollutants and production volumes

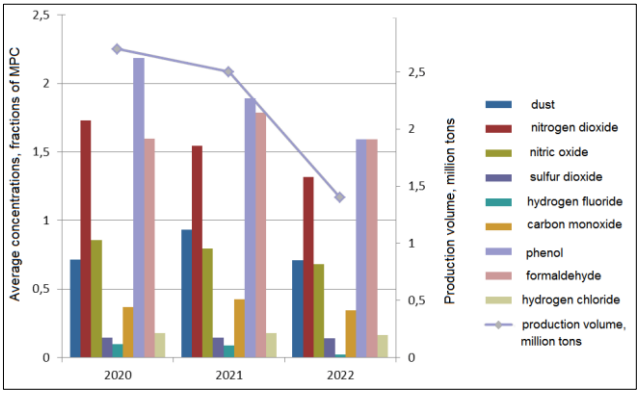

Fig. 9. Dynamics of changes in concentrations of polutants and production volumes

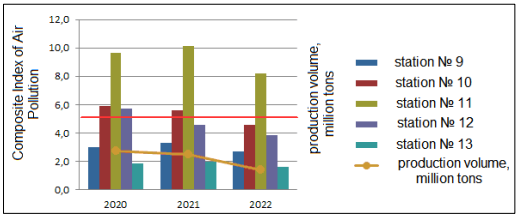

Fig. 10. Dynamics of changes in CAPI and production volumes by monitoring stations, red line – increased level of air pollution

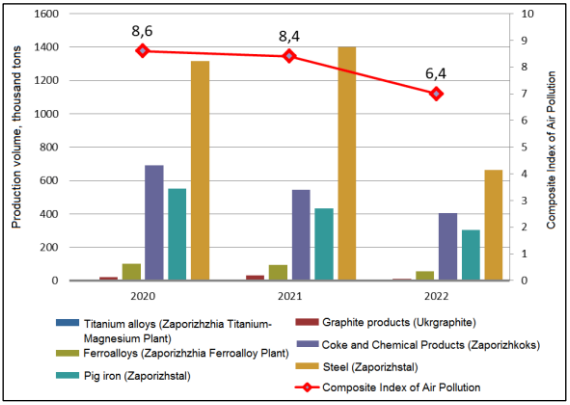

Fig. 11. Dynamics of changes in CAPI and production volumes by main enterprises

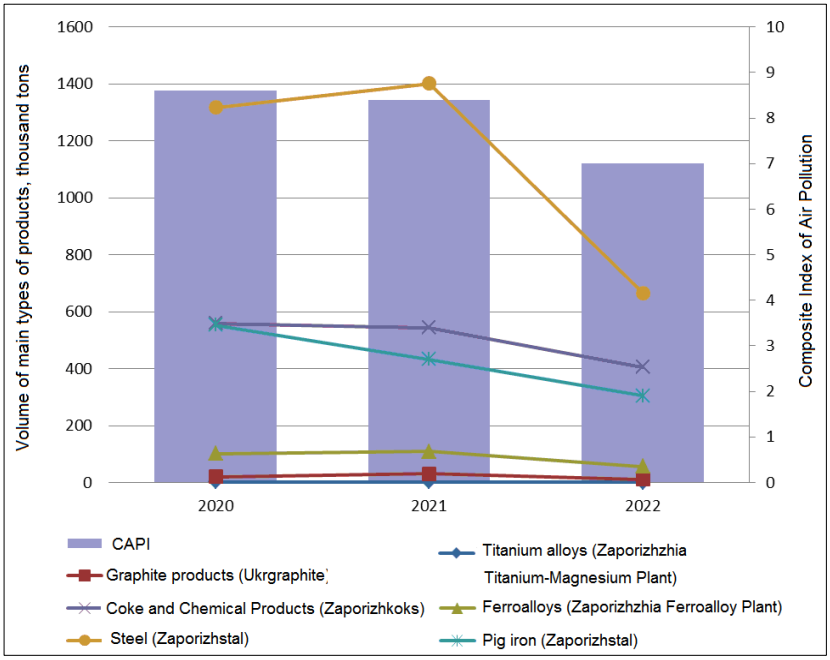

Fig. 12. Dependence of CAPI on production volumes

The monthly distribution of CAPI shows a certain cyclicity of processes – in January, a decrease in production capacity, the maximum peaks of production occur in March and May. However, it is impossible to analyze March 2022 due to the fact that in March 2022, the Zaporizhzhia Hydrometeorology Center did not carry out sampling at the observation stations.

As of 01.07.2022, almost all enterprises have restored their production capacities, except for steel production.

The dynamics of changes in CAPI and production volumes by months for the 1st half of 2022 is shown in Figure 13.

The impact of pollutant emissions from mobile sources is not determinant for the city of Zaporizhzhia according to numerous previous scientific studies, but in terms of gross indicators it is up to one third of the total pollution balance. At the time of the analysis, statistics for February-July 2022 are not available.

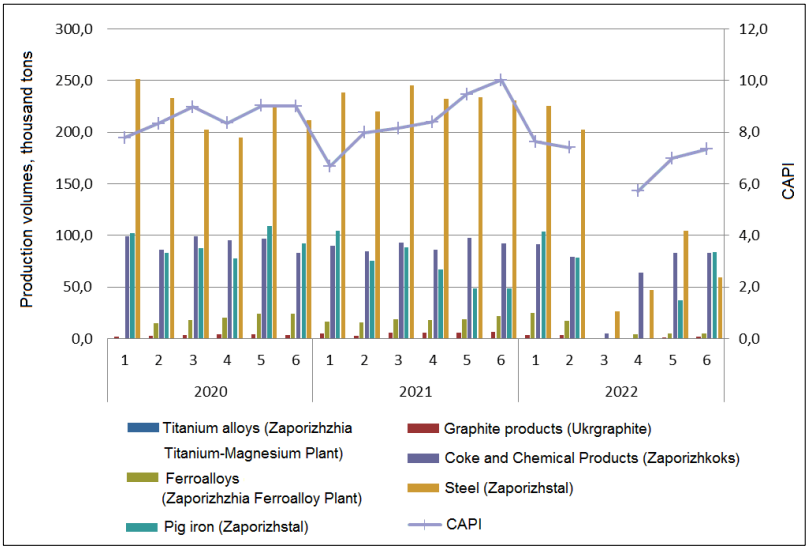

Fig. 13. Dynamics of changes in CAPI and production volumes by months of the 1st half of 2022

CONCLUSIONS

Production capacity is a determining factor of air quality. A decrease in production capacity leads to a decrease in pollutant concentrations. The analysis of the correspondence between the determining factor (production capacity) and the levels of CAPI showed that with a sharp decrease in production capacity, there is a decrease in the content of priority pollutants (except for hydrogen chloride and sulfur dioxide, the levels of which have not changed).

The discrepancy between the CAPI level in 2022 (quite high, reaching 6.4 units) and steel production (PJSC "Zaporizhstal" has a dominant contribution to the balance of gross pollution) can be explained by the following assumptions:

1) the resumption of production required a forced mode of raw materials and fuel use at the stage of production resumption;

2) the analysis is limited to the selected sample of the 5 most powerful enterprises in terms of gross pollution (according to long-term state observations);

3) emissions from low-emission sources of other industries are not taken into account. Mostly emissions of large enterprises are high-emitting, for better dispersion of large amounts of pollution, and observation posts measure

pollution in the surface layer of the atmosphere. It can be assumed that the level of air quality in the surface layer of the atmosphere is sufficiently influenced by low-emission sources of pollution – fast food establishments, various low-capacity boiler houses using solid fuel with pollution source heights up to 15 m;

4) presence of unaccounted and unreported emissions. Emissions from economic agents of the 3rd group (which have emission sources and technological equipment that emits pollutants into the air) – are not taken into account in the total gross indicators.

Of the total number of economic agents, small and medium-sized businesses report on the gross inflow of pollutants on average about 20 % of the total amount. It should be noted that even small business entities may carry out activities related to environmental pollution (e.g. heating boilers in shops, painting and welding, tire fitting installations at service stations, various solid fuel ovens for fast food, etc).

Since a significant part of economic agents is outside the area of statistical reporting, the real picture of technogenic impact is not currently reflected in statistical indicators.

It is advisable to investigate the impact of pollution from mobile emission sources (motor vehicles), provided that statistics on the volume of fuel sold and excise duty according to the fiscal service are available.

The air quality analysis system needs a more correct comparison. Currently, the analysis is carried out using data on gross pollution volumes (which in turn are determined by the capacity of production) and concentration levels of priority pollutants. For a more correct comparison, it seems advisable to conduct certain scientific studies to identify marker substances for each enterprise. For example, carbon monoxide emissions are dominant for the production of cast iron and agglomerate at PJSC “Zaporizhstal”, phenol is a marker (typical for this technology) for the production of graphite products, coke products. Considering the very high levels of exceedance of sulfur dioxide and hydrogen sulfide (obviously markers for the production of PJSC “Zaporozhkoks”), which are recorded by the mobile laboratory of the Zaporizhzhia Regional Center of Disease Control and Prevention of the Ministry of Health of Ukraine, the control of this substance should be systematic at the city level, since these substances have a powerful toxic effect on the health of residents, and the enterprise is located in close proximity to the residential area.

Under the conditions of war conditions, the air monitoring system needs to develop and use all available opportunities, including indicative measurements by public monitoring stations.

SUMMARY

The purpose of the scientific work was to analyze the level of air quality in Zaporizhzhia city for the 1st half of 2022 in comparison with the same periods of 2020 and 2021. For this analysis, air quality monitoring data for the last 3 years were used. As indicators of comparison, the volumes of production of the main types of products of large enterprises and the established for Ukraine indicator of the API (air pollution index), the concentration of pollutants in the atmosphere (by priority) were taken. It was determined that the state of the air monitoring system in the Zaporizhzhia city requires technical and qualitative reformation, the level of air pollution in the study period is high. Calculations of the Composite Air Pollution of Index (CAPI) at the posts showed their heterogeneity, the list of measured substances is not unified for all posts. The greatest contribution to the formation of CAPI is made by formaldehyde. The concentrations of nitrogen oxides, phenol and total dust are also significant. The highest level of the CAPI is observed at observation posts located in the zone of influence of the main industrial site. In other areas of the city, where there is industrial potential, observations are not carried out, it is impossible to assess the level of air quality according to the hydrometeorological service.

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