ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНІ ТЕХНОЛОГІЇ, МОНІТОРИНГ ТА ДІАГНОСТИКА В ЕНЕРГЕТИЦІ

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Artur Zaporozhets[1]*, PhD (Engin.), Senior Researcher, https://orcid.org/0000-0002-0704-4116
Vitalii Babak[1], Dr. Sci. (Engin.), Professor, https://orcid.org/0000-0002-9066-4307
Anastasiia Sverdlova[1], PhD (Engin.), https://orcid.org/0000-0001-8222-1357
Leonid Scherbak[1], Dr. Sci. (Engin.), Professor, https://orcid.org/0000-0002-1536-4806
Yurii Kuts[2], Dr. Sci. (Engin.), Professor, https://orcid.org/0000-0002-8493-947
[1]General Energy Institute of NAS of Ukraine, 172, Antonovycha Str., 03150, Kyiv, Ukraine
e-mail: info@ienergy.kiev.ua
[2]National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", 37, Prosp. Peremohy, 03056, Kyiv, Ukraine
e-mail: y.kuts@ukr.net
*Corresponding author: a.o.zaporozhets@nas.gov.ua

REVIEW OF THE STATE OF AIR POLLUTION BY ENERGY OBJECTS IN UKRAINE

Abstract. *Objective information about the state of air pollution is the basis for implementing measures to ensure conditions for the safe living of the population and improve the environmental pollution monitoring network. The purpose of the work is to study the impact of energy facilities (enterprises consuming different types of fuels) on atmospheric air pollution and its spatial and temporal distribution in cities and regions of Ukraine. The relevance of the work is confirmed by the fact that Ukraine, according to the World Health Organization, has the highest mortality rate from diseases caused by polluted air. The article considers general approaches to the functioning of the air pollution monitoring system in Ukraine and the features of the formation of the local air pollution index. The article discusses the most common pollutants generated at energy-intensive enterprises in Ukraine, in particular benzo(a)pyrene ($C_{20}H_{12}$), sulfur dioxide (SO_2), dust, carbon monoxide (CO), nitrogen oxides (N_xO_y), hydrogen sulfide (H_2S), carbon disulfide (CS_2), hydrogen fluoride (HF), ammonia (NH_3), phenol (C_6H_6O) and others. Statistical information about emissions of pollutants (CO_2, SO_2, NO_2, CO, PM_{10}, $PM_{2.5}$, PAHs, Zn, Pb, Cu, Cr, Ni, As) into the air from stationary sources of pollution for the period 1990–2018 was analyzed and visualized. The dynamics of chemical air pollution in different cities and regions of Ukraine are analyzed in detail. For some cities (Kyiv, Dnipro, Odesa, Kharkiv), energy-intensive enterprises and types of pollutants emitted into the air have been identified. It is shown that among the most polluted cities are Mariupol, Dnipro, Odesa, Kamianske, Kyiv, Kryvyi Rih, Lutsk, Lysychansk, Mykolaiv, Sloviansk, Kramatorsk, Rubizhne, Lviv, Zaporizhzhia, Lysychansk, Kherson, Kremenchuk, and among the most polluting regions are Donetsk, Dnipropetrovsk, Ivano-Frankivsk, Zaporizhzhya, Lviv, Vinnytsia, Kyiv, Cherkasy, Poltava. These regions need priority implementation of modern air pollution monitoring systems.*
Keywords: air pollution, chemical pollution, stationary sources, energy objects, pollution dynamics, maximum permissible concentration

1. Introduction

Atmospheric air is one of the most important components of the natural environment, therefore due attention should be given to the analysis of its quantitative and qualitative composition. Air pollution is one of the first places in terms of the degree of chemical danger to humans. The problem of air pollution is especially acute in urban areas. Urbanized areas are risk zones for public health, as the atmospheric air of these areas contains an increased volume of harmful impurities of anthropogenic origin. Such impurities can not only have a negative impact on the health and well-being of the population but also lead to the formation of smog under favorable conditions. That is why it is an urgent task to study the sources of the entry of various pollutants into the air and the characteristics of their spatiotemporal distribution in large cities. For Ukraine, this task has particular importance, because according to the World Health Organization data, Ukraine ranks first in the world in mortality from diseases caused by excessive content of harmful substances in the air [1].

At present, combustion processes associated with the activities of energy-intensive enterprises can be considered as the main source of atmospheric pollution. Impurities contained in the fuel, deviations from the stoichiometric composition of the «fuel-air» mixture during combustion, as well as too high or too low combustion temperatures, lead to an increase in the formation of pollutants such as carbon monoxide, sulfur and nitrogen oxides, soot, unburned hydrocarbons, etc. All these substances contribute to air pollution.

Despite a fairly diversified energy balance, energy-intensive enterprises, in particular, thermal power plants (TPPs), boiler houses, etc., consume about a third of the produced fuel. The share of fossil fuels (coal, peat, gas) used to generate electricity is more than 60%, and this trend tends to increase. Therefore, energy facilities, including TPPs as one of the largest consumers of energy resources, remain one of the largest environmental pollutants, especially air.

2. General approaches to air pollution monitoring in Ukraine

Atmospheric air pollution depends on emissions into the atmosphere, their specifics, and weather conditions. The level of atmospheric air pollution is determined by comparison with maximum permissible concentration (MPC), including their one-time and average daily values. One-time and average daily values of MPC of some pollutants, the concentrations of which are measured at stationary posts [2–5], are given in Table 1.

The data, given in Table 1, indicate that the greatest danger is caused by benzo(a)pyrene, which belongs to substances of the 1st hazard class. Other listed substances belong to 2–4 hazard classes.

To quantify air pollution in individual settlements, the atmospheric pollution index (API) is used, which is defined as the sum of the ratios of the actual concentrations of the five most important impurities to their average daily MPC [4]:

$$API = \sum_{i=1}^{n} \left(\frac{q_i}{MPC_{iMO}} \right)^{\alpha_s}, \qquad (1)$$

where n – the number of impurities taken into account in the calculation; q_i – concentration of the i-th substance; MPC_{iMO} – maximum one-time MPC of the i-th substance; α_s – the ratio of the insalubrity of the i-th substance to the insalubrity of a substance of the 3-rd hazard class ($\alpha_1 = 1.5$; $\alpha_2 = 1.3$; $\alpha_3 = 1$; $\alpha_4 = 0.85$).

According to the API value, the level of atmospheric air pollution is divided [4]: 1) clean air (API<2.5); 2) slightly polluted air (2.5≤API<7.5); 3) polluted air (7.5≤API<12.5); 4) heavily polluted air (12.5≤API<22.5); 5) highly polluted air (22.5≤API<52.5); 6) extremely polluted air (API≥52.5).

Assessment of atmospheric air pollution in Kyiv, Kyiv region, and other cities of Ukraine is carried out by the B. Sreznevsky Central Geophysical Observatory. In total, control of air pollution was carried out in 39 cities at 129 stationary posts of the monitoring network of hydrometeorological stations [6, 7].

22 pollutants were determined in the atmospheric air, including 8 heavy metals. The annual average concentration of formaldehyde in the cities, where the observation posts are located, was about 2.3 MPC_{DA}, nitrogen dioxide – 1.5 MPC_{DA}, and phenol – 1.3 MPC_{DA}.

According to [8], according to API in 2018, a very high level of air pollution was observed in

Table 1. MPCs for some pollutants in the air

№	Substance	Formula	Max. one-time MPC (MPC_{MO}), mg/m^3	Daily average MPC (MPC_{DA}), mg/m^3	Hazard class
1	Dust	–	0.5	0.15	3
2	Sulfur dioxide	SO_2	0.5	0.05	3
3	Carbon monoxide	CO	5	3	4
4	Nitrogen oxide	NO	0.4	0.06	3
5	Nitrogen dioxide	NO_2	0.085	0.04	2
6	Ammonia	NH_3	0.2	0.04	4
7	Formaldehyde	CH_2O	0.035	0.003	2
8	Hydrogen chloride	HCl	0.2	0.2	2
9	Hydrogen fluoride	HF	0.02	0.005	3
10	Benzo(a)pyrene	$C_{20}H_{12}$	–	10^{-6}	1

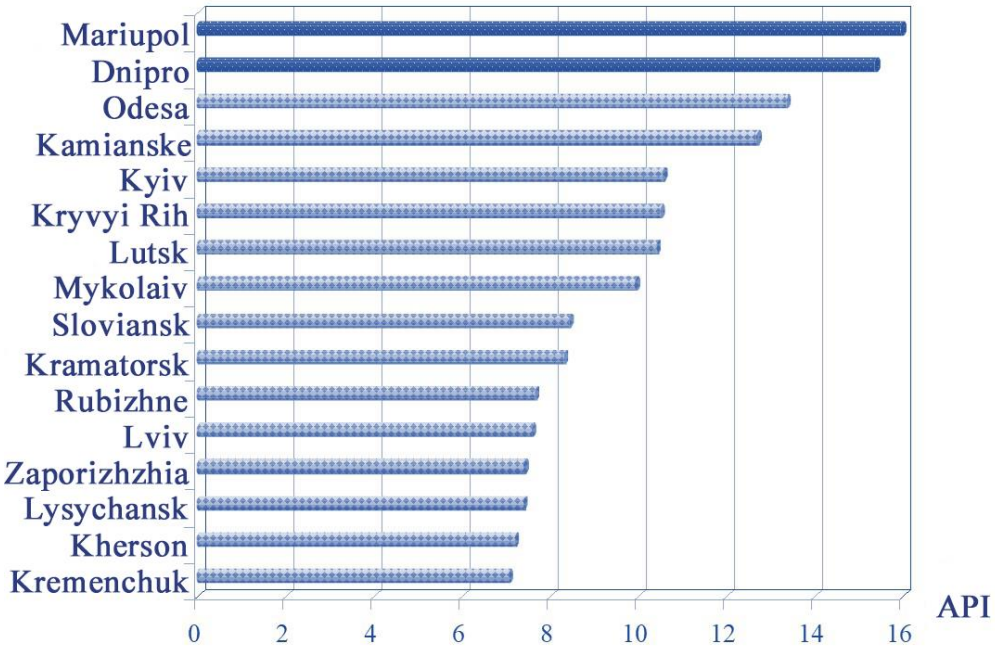

Fig. 1. API value in the most polluted cities of Ukraine in 2018

Mariupol and Dnipro; high – in Odesa, Kamianske, Kyiv, Kryvyi Rih, Lutsk, Mykolaiv, Sloviansk, Kramatorsk, Rubizhne, Lviv, Zaporizhzhia, Lysychansk, Kherson, Kremenchuk. The high level of air pollution in these cities is due to significant concentrations of phenol, nitrogen dioxide, formaldehyde, hydrogen fluoride, carbon monoxide, and suspended solids (dust) (Fig. 1).

Most of the cities with polluted and very polluted air are located in the Donetsk region – 3 cities, Dnipropetrovsk region – 3 cities, Luhansk region – 2 cities, and Poltava region – 1 city [9].

In 2018, there were also 3 cases of high atmospheric air pollution in Obukhiv city by carbon monoxide with a maximum concentration of 8.8 MPC_{MO}. There were no cases of extremely high air pollution in 2018 in the territory of Ukraine [10].

High average concentrations of formaldehyde were recorded in Mariupol – 6 MPC_{DA}; Dnipro – 5 MPC_{DA}; Mykolaiv, Odesa, and Kryvyi Rih – 4.7–3.7 MPC_{DA}; in 9 other cities – 3 MPC_{DA}. The excess of the average annual concentrations of nitrogen dioxide was recorded in Kyiv, Dnipro, and Kherson – 3.3–2.8 MPC_{DA}, and in 4 cities – 2.3 MPC_{DA}. Exceeding the concentrations of suspended solids at the level of 3.0–2.3 MPC_{DA} was recorded in Kryvyi Rih, Dnipro, Kamianske; phenol (C_6H_5OH) at the level of 2.3 MPC_{DA} in Kramatorsk, Kamianske, Sloviansk; carbon monoxide at the level of 1.8–1.3 Sloviansk in Rubizhne, Lysychansk, Odesa; hydrogen fluoride at the level of 1.6–1.4 MPC_{DA} in Odesa, Rivne [6, 10].

In recent decades, a slight decrease in API has been observed in Ukraine in some cities of Ukraine, which is associated with a decrease in the concentrations of benzo(a)pyrene, formaldehyde, ammonia, and nitrogen dioxide.

According to API, the overall level of atmospheric air pollution in Ukraine was 7.6 points in 2018 and was assessed as high. This indicator slightly increased compared to 2017 (7.2 API points) due to an increase in the average annual concentration of phenol.

3. Characteristics of some common pollutants in the air

Benzo(a)pyrene ($C_{20}H_{12}$) enters the atmosphere with emissions from non-ferrous and ferrous metallurgy, TPPsg, as well as during the operation of vehicles. Its highest concentration was observed in 1992–1994, when it reached the level of 10 MPC and more, primarily in the centers of the metallurgical industry. At present, the concentration of benzo(a)pyrene has decreased, which is associated with a decrease in atmospheric emissions from industrial enterprises, as well as an improvement in the quality of fuels. Still, quite significant concentrations of benzo(a)pyrene are observed in Zaporizhzhia, Sloviansk (2.7 MPC), Dnipro, and Ternopil (2.3 MPC).

Sulfur dioxide (SO_2) is a characteristic impurity contained in the emissions of chemical, metallurgical, and paper industries and significantly pollutes the air. Sulfur dioxide emissions contribute to the

formation of acid rain. High concentrations of this substance are observed in Odesa and Kyiv.

Dust is formed during the combustion of fuels, in industrial processes, as well as during soil erosion. The highest concentrations are observed in the eastern and southern regions.

Carbon monoxide (CO) is a characteristic impurity formed during the incomplete combustion of fossil fuels. As a rule, elevated concentrations of carbon monoxide are observed on the territory of TPPs, boiler houses, and metallurgical enterprises. Carbon monoxide is a compound that actively reacts with the constituent substances of the atmosphere and contributes to the creation of the greenhouse effect. High concentrations of carbon monoxide are typical for Rubizhne, Zaporizhzhia, Odesa, and Kyiv.

Nitrogen dioxide enters the atmosphere during the combustion of fossil fuels, as well as in the production of nitrogen fertilizers, paints, and synthetic fabrics. The highest concentrations of nitrogen dioxide are typical for Sloviansk (~3 MPC), Kyiv (2.5 MPC), Odesa, Dnipro, and Bila Tserkva.

Depending on the degree of oxidation, there are the following *nitrogen oxides*: NO, N_2O, N_2O_3, NO_2, and N_2O_5. The oxides N_2O_3 and N_2O_5 are solids, and the others are gases. Natural sources of nitrogen oxides are such natural phenomena as volcanic eruptions and lightning. Anthropogenic sources of nitrogen oxides entering the atmosphere are chemical industry enterprises, the production of explosives, mineral fertilizers, nitrate acid, bacterial decomposition of silage, etc. The largest amount of nitrogen oxides in the atmosphere comes from road transport. The dynamics of changes in the concentration of nitrogen oxides in the air during the day are associated with the intensity of vehicle traffic and solar radiation. So, during daylight hours, the concentration of nitrogen oxides in the air increases significantly due to the processes of photochemical oxidation of nitrogen. Nitrogen oxides are a dangerous pollutant due to their high toxicity and impact on atmospheric phenomena (acid rain, smog). During chemical processes in the atmosphere, nitrogen oxides lead to the destruction of the ozone layer.

Hydrogen sulfide and *carbon disulfide* are released into the atmosphere both individually and together with other sulfur compounds. The main sources of emissions are enterprises producing sugar, artificial fiber, coke-chemical, and oil refining industries. In the atmosphere, during interaction with other pollutants, these substances are oxidized to sulfur dioxide. The highest levels of hydrogen sulfide pollution were recorded in Toretsk, Mariupol, and Zaporizhzhia.

Hydrogen fluoride enters the atmospheric air together with emissions from non-ferrous metallurgy enterprises, mineral fertilizer plants, and construction industry enterprises. The excess of MPC is observed in Sloviansk (2.8 MPC), Zaporizhzhia, and Odesa (1.8 MPC).

Sources of pollution of *fluorine compounds* are industrial companies producing aluminum, glass, steel, enamels, ceramics, and phosphate fertilizers. Fluorine-containing substances enter the atmosphere as gaseous compounds – hydrogen fluoride or dust of calcium and sodium fluoride. These compounds have a toxic effect.

Chlorine compounds enter to the atmosphere from chemical enterprises producing pesticides, hydrochloric acid, soda, bleach, organic dyes, and hydrolytic alcohol. The toxicity of chlorine depends on both the type of compound and its concentration.

Ammonia is contained in the emissions of chemical industry enterprises, in particular, those specializing in the production of mineral fertilizers. An increase in the concentration of this pollutant is typical for Cherkasy (3 MPC), Kamianske (1.8 MPC), and Mariupol (1.5 MPC).

Phenol enters the atmosphere with emissions from ferrous metallurgy enterprises. An increase in the concentration level is typical for Odesa (2 MPC), Kamianske, Toretsk, Zaporizhzhia (1.7 MPC), and Sloviansk (1.3 MPC).

4. Analysis of air pollution in cities and regions of Ukraine

Further information is given about the nature of pollution in some cities of Ukraine, including using the data [6, 11–29].

Kyiv. According to the State Statistics Service of Ukraine, 2.966 million people live in Kyiv (on December 1, 2019). The area of the city is about 890 km^2.

The total amount of emissions into the atmosphere of the city, according to the Main Department of Statistics in Kyiv, has sharply decreased in recent years: in 2014 – 214.2 thousand tons; 2015 – 171.0 thousand tons; 2016 – 34.3 thousand tons; 2017 – 45.5 thousand tons; 2018 – 29.2 thousand tons.

The main source of air pollution in Kyiv is road transport. It is the cause of about 83% of emissions. TPPs, enterprises in the machine-building, chemical, chemical-pharmaceutical, light, food, and construction industries have a lower level of pollution. Among the main enterprises-sources of emissions, the following can be distinguished: CJSC «Ukr-Kan-Power» (TPP-4), TPP-5, TPP-6, «Energia» plant, OJSC «Ukrplastyc», OJSC «Korchevatsky

Combine of Building Materials and Structures», Darnytsia car repair plant.

Nitrogen dioxide is the most polluting substance in Kyiv. The average annual concentration of this substance in recent years is about 2.5 MPC. Concentrations of formaldehyde (3–1.3 MPC), benzo(a) pyrene (1–1.2 MPC), and phenol (1–1.3 MPC) are also significant.

Significant differences in the location and specifics of industrial enterprises, as well as the location of highways, leading to the fact that the total level of air pollution and its specificity in individual areas differ significantly.

Thus, the atmospheric air near the observation points located at the intersection of Peremogy Avenue and Academician Tupolev St. The proximity of the observation post to the highway makes it possible to determine that the atmospheric air in this area is very polluted with benzo(a)pyrene, nitrogen dioxide, and carbon monoxide. The area within the Bessarabian market is also close to this level of pollution. Carbon monoxide predominates among pollutants. The main reason for the pollution of this area is a large number of cars and significant traffic jams in front of traffic lights.

In general, the greatest air pollution is observed in the central part of the city; the cleanest air is observed within forest park zones, especially in the western part of the city.

In recent years, the level of air pollution in the city has remained stable. Compared to the beginning of the 90s, it has significantly decreased, which is associated with a reduction in the number of industrial enterprises, a decrease in emissions from enterprises, an improvement in the quality of fuel materials, and the construction of new transport solutions.

Dnipro. The population is about 1 million people. The main industries that affect the level of air pollution in the city are mechanical engineering, ferrous metallurgy, and electric power industry. The enterprises that have the greatest impact on air quality include Dnipro Metallurgical Plant, PJSC «Dnipro Pipe Plant», Prydniprovska TPP, JSC «INTERPIPE», JSC «Dniprocoks», JSC «Dniproshina», PJSC «Dniprovazmash», JSC «Dnipro Paint Plant», PJSC «Dniprovsky Oil Extraction Plant». The substances, that are most polluted the air, in the city are nitrogen dioxide, formaldehyde, and benzo(a)pyrene. The average annual concentration of formaldehyde is about 3 MPC, benzo(a)pyrene – 2 MPC.

Odesa. About 1 million people live in the city. The greatest impact on atmospheric air quality makes by the next industries: chemical, oil refining, mechanical engineering, electric power engineering, and building materials. The total number of enterprises that in the course of their activity influence the state of the atmospheric air in the Odesa region is about 3,000. In 2018, 18.3 thousand tons of harmful substances from stationary sources entered to the air of the region, which is 50% more than in 2017. Among the enterprises, that emit the largest volume of pollutants, are CJSC «Odescement», TPP-1, SE «Odesa Sea Trade Port», and Odesa Oil Refinery. The most polluted part of the city is the northern part, where the most powerful industrial enterprises are concentrated. The air in the city is most polluted with formaldehyde (5 MPC), nitrogen dioxide (2 MPC), phenol (2 MPC), and hydrogen fluoride (2 MPC).

Kharkiv. The population is about 1.5 million people. Mechanical engineering is the most influential industry on air pollution. The main source of air pollution in the city is road transport. Among the stationary sources of air pollution, are energy enterprises (TPP-3, TPP-5), mechanical engineering («Kharkiv Machine-Building Plant», «V. O. Malyshev Plant»), building industry. According to the data of the Main Department of Statistics in the Kharkiv region, emissions of pollutants into the air from stationary sources in 2018 were 44.7 thousand tons (in 2017 – 45 thousand tons, in 2016 – 100.2 thousand tons). The decrease in the volume of emissions of polluting substances into the atmospheric air is due to the decrease in the volume of enterprises' production of the energy industry, in particular, Zmiivska TPP (10.5 thousand tons in 2018, 34.1 thousand tons in 2017).

According to the data of the State Statistics Service of Ukraine, in 2018, the volume of emissions of pollutants was 3866.7 thousand tons (for comparison, in 2017 – 3974.1 thousand tons, in 2016 – 4498.1 thousand tons), at the same time, the volume of emissions from stationary sources in 2018 was 2508.3 thousand tons (for comparison, in 2017 – 2584.9 thousand tons, in 2016 – 3078.1 thousand tons). The volume of emissions of carbon dioxide, which has the greatest impact on the greenhouse effect, was 126.4 million tons in 2018, which is 2% more than last year. At the same time, since 2008, there has been a clear tendency in Ukraine to reduce emissions of pollutants and carbon dioxide into the atmosphere (Figs. 2, 3).

Figs. 4–7 also provides data about emissions of various pollutants into the air during 1990–2018.

Dnipropetrovsk and Donetsk regions are the leaders among Ukrainian regions in terms of pollutants emissions into the surrounding air from stationary sources of pollution (Fig. 8). In particular,

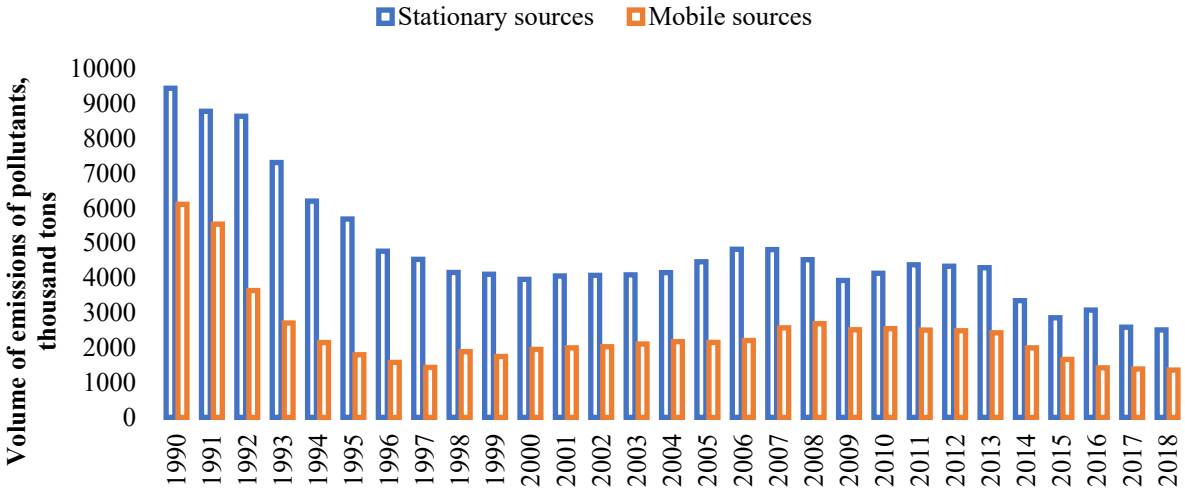

Fig. 2. Total emission of pollutants into the air in the period 1990–2018 in Ukraine

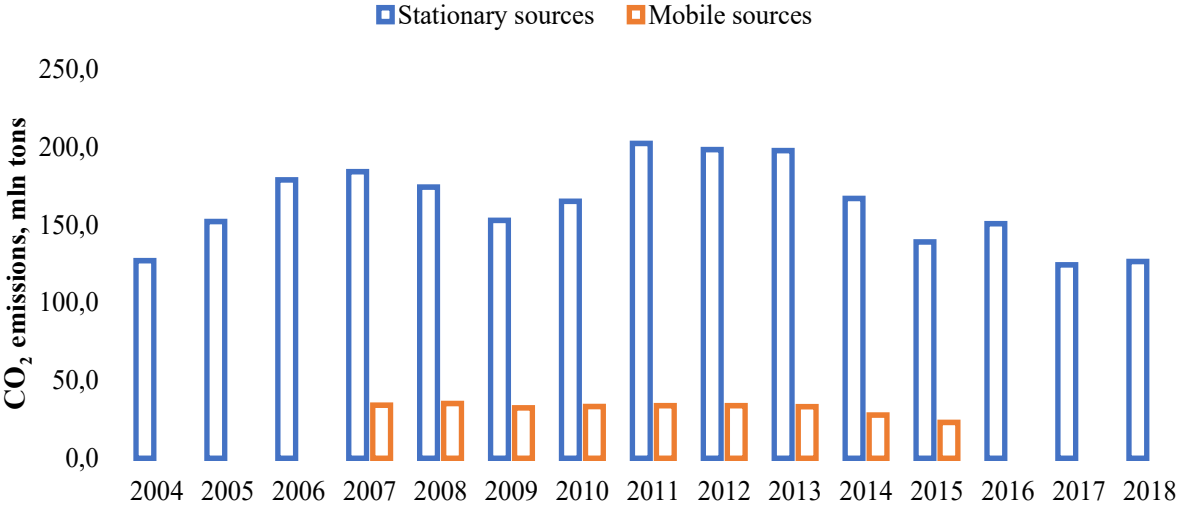

Fig. 3. Carbon dioxide emission into the air in the period 2004–2018 in Ukraine

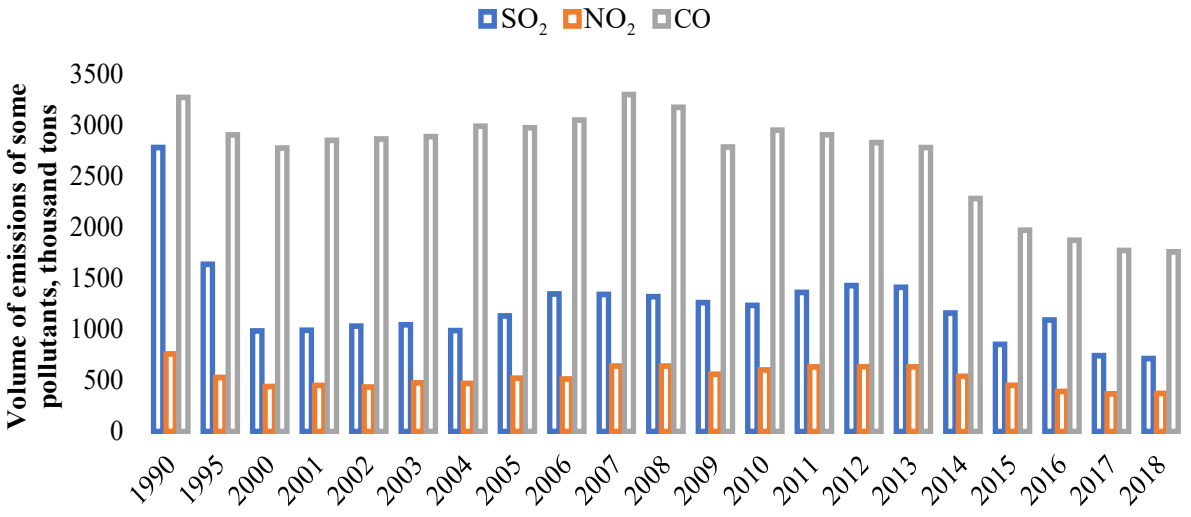

Fig. 4. Emissions of sulfur dioxide, nitrogen dioxide, and carbon monoxide into the air in Ukraine in 1990–2018

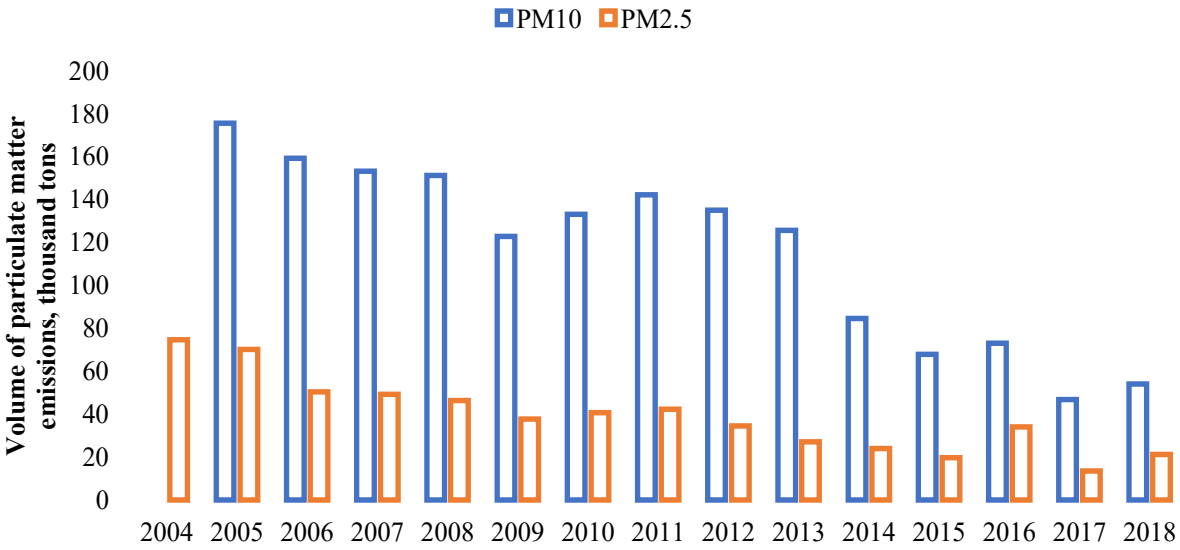

Fig. 5. Emission of dust (PM10, PM2.5) into the air in Ukraine in 2004–2018

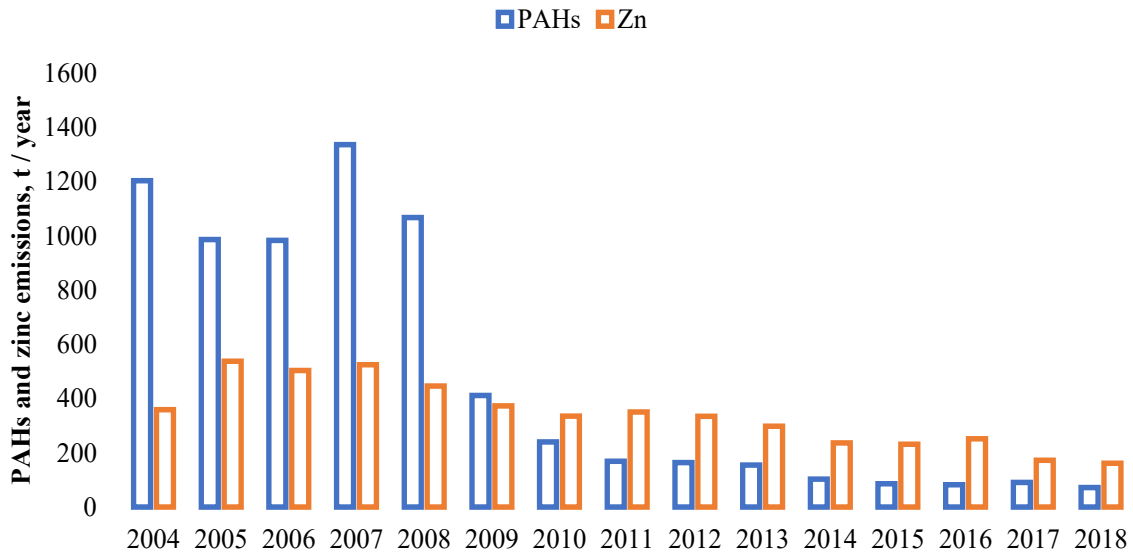

Fig. 6. Emissions of polycyclic aromatic hydrocarbons and zinc into the air in Ukraine in 2004–2018

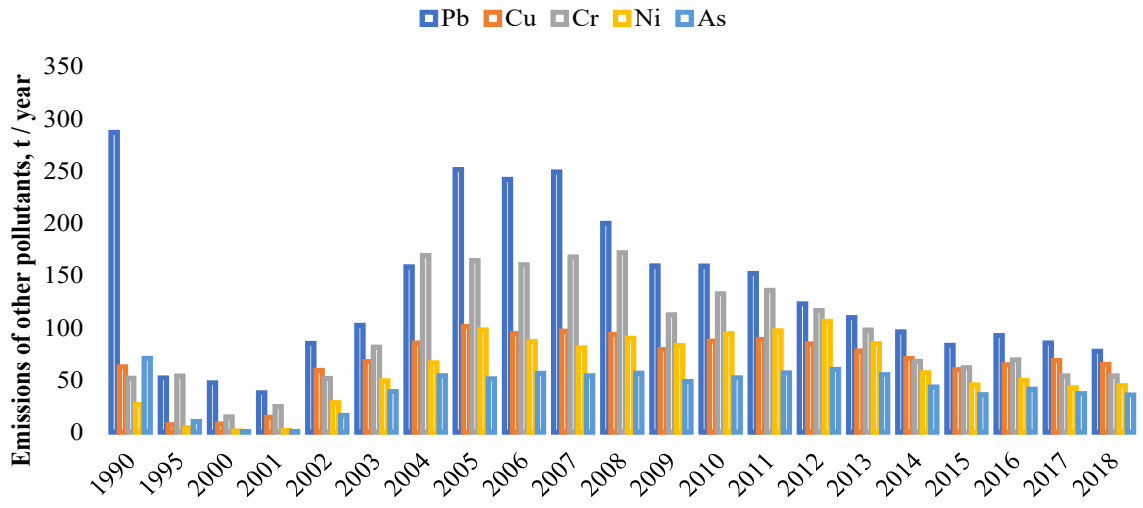

Fig. 7. Emissions of plumbum, cuprum, chromium, nickel and arsenic into the air in Ukraine in 1990–2018

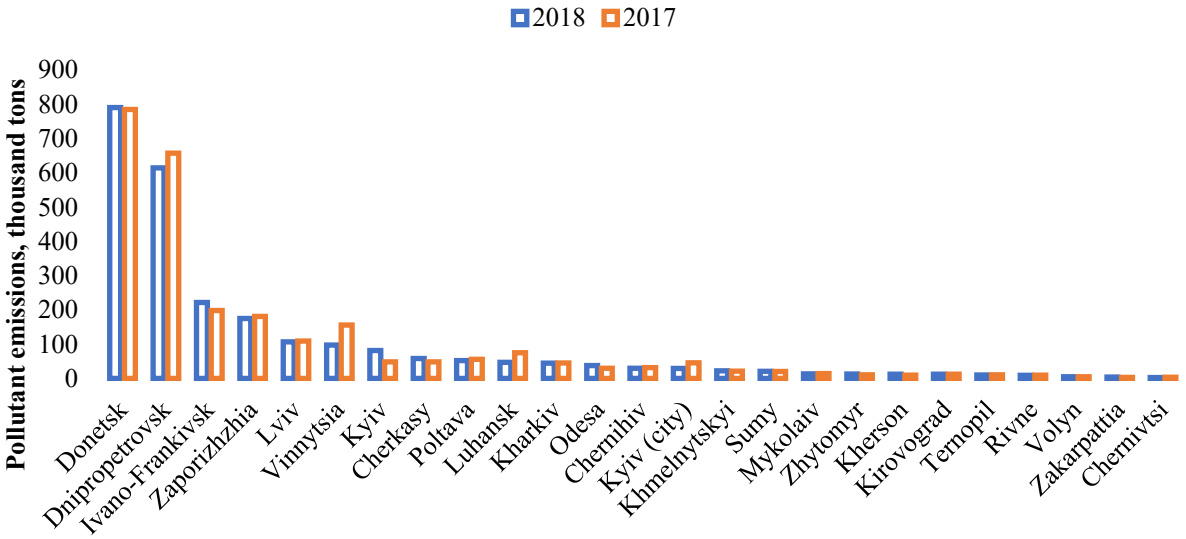

Fig. 8. Volume of emissions of pollutants from stationary sources by Ukrainian regions in 2017–2018

in 2017 657.3 and 784.8 thousand tons were emitted by the above regions.

Compared to the previous year, an increase in emissions into the atmosphere was recorded in 10 regions: Kyiv region (68.6%), Kherson region (29.1%), Odesa region (26.4%), Zhytomyr region (25.5%), Zakarpattia (24%), Cherkasy (19.8%), Ivano-Frankivsk (11.6%), Khmelnytskyi (4.8%), Sumy (2.1%), Donetsk (0.7%).

Table 2 shows 10 regions that had the greatest impact on air pollution in 2018.

In general, in 2018, there was 59.3 kg of pollutant emissions into the atmosphere by each inhabitant of Ukraine. In the territorial context, there were

Table 2. Top air-polluted Ukrainian regions in 2018

Region	Volume of emissions, thousand tons	% of total national emissions
Donetsk	790.2	31.5
Dnipropetrovsk	614.3	24.5
Ivano-Frankivsk	221.4	8.8
Zaporizhzhia	174.7	7.0
Lviv	106.7	4.3
Vinnytsia	97.3	3.9
Kyiv	81.3	3.2
Cherkasy	57.9	2.3
Poltava	52.1	2.1
Luhansk	46.7	1.9

Table 3. Dynamics of pollutants emissions into the atmospheric air in the cities of Ukraine, thousand tons

City	2010	2011	2012	2013	2014	2015	2016	2017	2018	% of total in 2018
Mariupol	364.3	382.4	330.4	333.8	289.4	249.6	257.3	288.2	316.6	12.60
Kryvyi Rih	395.0	358.6	354.6	351.8	327.4	327.0	342.9	323.9	267.4	10.7
Burshtyn	146.8	198.7	174.7	182.7	199.8	198.0	168.5	160.1	182.9	7.3
Kurakhove	123.9	166.2	148.4	166.0	125.0	112.7	126.4	154.7	139.2	5.5
Kamianske	108.5	124.7	116.4	115.5	105.0	101.0	90.5	57.8	103.3	4.1

4.35 tons of pollutants per square kilometer of the country's territory. Among settlements, the greatest anthropogenic load (more than 100 thousand tons of pollutants) was experienced by 5 cities in Ukraine, shown in Table 3. The total volume of emissions of pollutants into the atmospheric air of these cities was 40.2%.

In 2018, about 11 thousand industrial enterprises emitted pollutants into the atmospheric air. 2508.3 thousand tons of pollutants entered the atmosphere from them, which is 3% less than in 2017.

The main air pollutants in Ukraine are enterprises of the processing and mining industries, supply of electricity, gas, steam, and conditioned air, the total emissions of which make up more than 92% of the total emissions from stationary sources.

Among the types of economic activity, the largest share of pollutant emissions (excluding carbon dioxide emissions) falls on the supply of electricity, gas, steam, and conditioned air – 39.4%.

The processing industry is the second in terms of emissions of pollutants into the atmosphere. It accounts for 35.2%. At the same time, the share of metallurgical production is 29%. Extractive industry and quarrying account for 17.7% of the total amount of emissions into the atmosphere.

Research on the impact of various industries on atmospheric air pollution remains an urgent task [30–33].

5. Conclusions

The study of current regulatory acts and domestic scientific publications showed that morally outdated informative parameters that do not meet modern requirements for speed and accessibility are used for the quantitative assessment of air pollution in Ukraine. At the same time, even with the use of API, significant excess concentrations of various pollutants in the air are recorded in Ukraine, in particular sulfur oxides, nitrogen oxides, phenol, formaldehyde, hydrogen fluoride, carbon monoxide, dust, and others. Statistical information about emissions of pollutants (carbon dioxide, sulfur dioxide, nitrogen dioxide, carbon monoxide, dust, PAHs, zinc, plumbum, cuprum, chromium, nickel, arsenic) into the air from stationary sources of pollution for the period 1990–2018 was analyzed and visualized. It is shown that some of the most polluted cities are Mariupol, Dnipro, Odesa, Kamianske, Kyiv, Kryvyi Rih, Lutsk, Lysychansk, Mykolaiv, Sloviansk, Kramatorsk, Rubizhne, Lviv, Zaporizhzhia, Lysychansk, Kherson, Kremenchuk. Typical sources of emissions of various pollutants (benzo(a)pyrene, sulfur dioxide, dust, carbon monoxide, nitrogen dioxide, nitrogen oxides, hydrogen fluoride, hydrogen sulfide, carbon disulfide, ammonia, phenol, etc.) and their distribution in individual cities are considered. It is shown that among the regions that pollute the air the most are: Donetsk, Dnipropetrovsk, Ivano-Frankivsk, Zaporizhzhya, Lviv, Vinnytsia, Kyiv, Cherkasy, Poltava. These regions need priority implementation of modern air pollution control systems.

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ОГЛЯД СТАНУ ЗАБРУДНЕННЯ ПОВІТРЯ ОБ'ЄКТАМИ ЕНЕРГЕТИКИ В УКРАЇНІ

Артур Запорожець[1]*, к.т.н., ст.досл., https://orcid.org/0000-0002-0704-4116
Віталій Бабак[1] , д.т.н., професор, https://orcid.org/0000-0002-9066-4307
Анастасія Свердлова[1], к.т.н., https://orcid.org/0000-0001-8222-1357
Леонід Щербак[1], д.т.н., професор, https://orcid.org/0000-0002-1536-4806
Юрій Куц[2], д.т.н., професор, https://orcid.org/0000-0002-8493-947
[1]Інститут загальної енергетики НАН України, вул. Антоновича, 172, 03150, м. Київ, Україна
e-mail: info@ienergy.kiev.ua
[2]Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», проспект Перемоги, 37, 03056, м. Київ, Україна
e-mail: y.kuts@ukr.net
*Автор-кореспондент: a.o.zaporozhets@nas.gov.ua

Анотація. *Об'єктивна інформація про стан забруднення атмосферного повітря є основою для здійснення заходів щодо забезпечення умов для безпечного проживання населення та вдосконалення мережі моніторингу забруднення довкілля. Мета роботи – дослідження впливу об'єктів енергетики (підприємств, що споживають різні види палив) на забруднення атмосферного повітря та його просторово-часовий розподіл у містах та регіонах України. Актуальність роботи підтверджується тим, що Україна, за даними Всесвітньої організації з охорони здоров'я, має найвищу смертність населення від хвороб, спричинених забрудненим повітрям. У статті розглянуті загальні підходи щодо функціонування системи моніторингу забруднення повітря в Україні, особливостей формування локального індексу забруднення повітря. В статті розглянуто найпоширеніші забруднюючі речовини, що генеруються на енергоємних підприємствах України, зокрема бенз(а)пірен ($C_{20}H_{12}$), діоксид сірки (SO_2), пил, монооксид вуглецю (CO), оксиди азоту (N_xO_y), сірководень (H_2S), сірковуглець (CS_2), фтористий водень (HF), аміак (NH_3), фенол (C_6H_6O) та ін. Проаналізовано та візуалізовано статистичну інформацію щодо викидів забруднюючих речовин (CO_2, SO_2, NO_2, CO, PM_{10}, $PM_{2,5}$, ПАР, Zn, Pb, Cu, Cr, Ni, As) у повітря від стаціонарних джерел забруднення за період 1990–2018 рр. Детально проаналізовано динаміку хімічного забруднення повітря в різних містах та областях України. Для деяких міст (Київ, Дніпро, Одеса, Харків) визначено енергоємні підприємства та типи забруднюючих речовин, які вони викидають у повітря. Показано, що одними з найбільш забруднених міст є Маріуполь, Дніпро, Одеса, Кам'янське, Київ, Кривий Ріг, Луцьк, Лисичанськ, Миколаїв, Слов'янськ, Краматорськ, Рубіжне, Львів, Запоріжжя, Херсон, Кременчук, а до областей, що найбільше забруднюють повітря, належать: Донецька, Дніпропетровська, Івано-Франківська, Запорізька, Львівська, Вінницька, Київська, Черкаська, Полтавська. Ці регіони потребують першочергового впровадження сучасних систем моніторингу забруднення повітря.*

Ключові слова: забруднення повітря, хімічне забруднення, стаціонарні джерела, об'єкти енергетики, динаміка забруднення, гранично-допустима концентрація.

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