

# Ecological Problems of Ukraine Related to Urbanization, Migration and State of War

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**Abstract** The environmental situation in Kyiv has changed as a result of the transformation of industry and its territorial structure, the role of motor vehicles. Therefore, the study of the impact of urbanization on the environmental conditions of Kyiv during the development of the post-industrial economy is topical. The aim of the research is to identify territorial specifics of environmental changes in Kyiv in the period of the post-industrial economy development in 2000-2022. General regularities and specifics of the urbanization of Kyiv and other major cities of the world in the post-industrial period were determined. The assessment of changes of sources and types of environmental pollution caused by urbanisation was conducted, which allowed estimating specifics of the post-industrial ecological conditions at a macro level, using statistical indicators of urbanisation. The methodology of the assessment of ecological usage intensity and efficiency of urbanisation reorganisation of Kyiv was developed, a comparative analysis of the urbanisation level from stationary sources and the level of ecological intensity of the use of industrial zones. Key features of dynamics and territorial structure of influence of automobile and aviation transport in Kyiv were distinguished. The methodology of complex assessment of

the environmental quality change in municipal areas was applied. The practical significance of the work consists in the development of the system of ecological assessment of urbanization, which can be used to create the ecological-urban development concept of Kyiv, as well as in teaching courses and the development of practical tasks on the city ecology.

**Keywords** Urbanisation, Factors of Influence on the Environment, Big Cities Ecological Problems

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## 1. Introduction

In large cities of the world, the transformation of the economy structure, industry, population's employment causes a change of an anthropogenic influence and internal differences in the city's ecological conditions. Along with the fact that in recent years, Ukraine has faced a sufficient number of problems, such as: the war since the beginning of 2014, and the significant escalation of the military conflict since the beginning of 2022. In addition, the COVID-19 epidemic has had a significant impact on

urbanization since the beginning of 2019, when people had to resettle in places to ensure proper medical care [1]. In the post-Soviet period, industrial production was reduced, the functioning of production areas and the policy of the Kyiv authorities in the sphere of their reorganization was changed. Location and power of the anthropogenic influence sources is the basis for a change of territorial structure of pollution, while a complex analysis of their transformation allows one to reveal the points of the greatest ecological tension of the development of urban planning measures [2].

Over the past five years, the analysis of Ukraine's atmospheric air situation showed that the environmental crisis continues to develop and spread, covering an increasing part of the country's territory. This is facilitated by the following factors: 1) almost complete absence of investments in environmental protection measures in all branches of industry both by the Government of Ukraine and foreign companies; 2) weak control, and sometimes its complete absence along with virtual irresponsibility for nature damage caused by any kind of economic activity; 3) an increase in the number and strength of technogenic accidents due to the total destruction of equipment and outdated production technologies; 4) an extremely low level of environmental education and public awareness [3].

These trends give an idea of the environmental condition and how it has changed due to the growth of technologies and the European partnership conditions. However, they do not reveal the country's internal ecological situation due to urbanisation. Environmental problems of modern cities are caused by intensive processes of urbanization, accompanied by increasing load on natural resources, as well as the appearance of significant volumes of production and household waste, which reduce the possibilities of natural system self-improvement [4]. Accordingly, the problem of urban agglomerations further development, which have arisen in the process of urbanization and have faced threats of ecological character, has become topical.

Assessing the urbanization scale, one can confidently say that the modern world is developing mainly by the vector of the city organization of social life. At the same time, the rapid growth of urban agglomerations is accompanied by serious environmental problems, which have resulted from unthought urban processes and irrational use of natural resources [5]. In order to understand the specifics of urbanization and its impact on the urban environment, it is necessary to understand the dynamics of this process and the factors that lead to the violation of ecological balance in the system of nature – economy – society.

In order to determine the current state of the city of Kyiv, it is necessary to study the meteorological factors that are decisive and have an impact on the spread of pollutants in the studied territory. Variations in meteorological parameters affect the formation of specific atmospheric

conditions, classes of atmospheric stability, which determine the conditions for the spread of pollutants [6].

Within the framework of philosophical knowledge, there were two basic approaches to urbanization. One comes from the ideas of Montesquieu, who considers urban life to be the highest level of civilization development. According to N. F. Reimers, "an urban system (city) is an unstable natural-anthropological system consisting of architectural-building objects and sharply disturbed natural ecological systems" [7]. Another one is represented by Russo, who negatively assesses the development of cities, which are purely artificial entities, the embodiment of "a soulless machine civilization".

The presence of such opposite assessments gives grounds to consider the urbanization a complicated and controversial process, which, on the one hand, is an objective evolutionary way of society development, connected with technological progress and creation of more comfortable living conditions; on the other hand, it leads to overpopulation of the city and to an increase in the load on the natural zone. The challenges caused by urbanization are topical for Ukraine as well. For example, in 1897 in Ukraine the share of the urban population was about 13%, while in the middle of 60s of the 20th century this indicator passed symbolic 50% "urban equator" [8]. The decline of the Ukrainian countryside and the movement of young people to the country's big cities, migration of the population in connection with war problems led to an increase in construction sphere both in Kyiv and in other large cities of Ukraine, such as: Odesa, Lviv, Dnipro. Therefore, the impact of urbanization on the ecological conditions of large cities is topical.

## 2. Materials and Methods

The aim of the research is to determine the territorial specifics of environmental changes in Kyiv during the period of the post-industrial economy development in 2000-2022. In accordance with the aim, the following tasks were set:

1. The identification of typical and unique regularities of changes of the ecological component of the city environment quality in Kyiv and other major cities of the world in the post-industrial period and urban planning.
2. The assessment of changes in anthropogenic influence of different sources, types and levels of environmental pollution in Kyiv in the period 1990-2022 and the identification of directions and mechanisms of the reduction of their negative influence.
3. A comprehensive assessment of changes in the level of anthropogenic influence of industrial zones in Kyiv in 2000-2022.

4. The development of methodology and estimation of ecological efficiency of production zones transformation in Kyiv in the post-industrial period.
5. The identification of key directions of reorganization and territorial changes of the intensity of industrial zones use in Kyiv.
6. The identification of the specifics of change in mobile pollution sources intensity and its territorial specific features.

The research object is the environmental situation in Kyiv during the period of post-industrial economy development and urbanization. The research subject is structural and territorial specific features of the environmental change in Kyiv during urbanization.

### 3. Results and Discussion

First of all, it is necessary to consider the ecological situation of Kyiv and the influence of urbanisation on the general state of the capital. The analysis of approaches to a definition of urbanization, irrespective of a formal definition, as the basis for transformation of the traditional economic model is the priority development of human potential, knowledge and information, deep structural and technological changes and observance of ecological restrictions. Thus, the formation of a post-industrial economy model does not affect the ecological situation due to the transition to the industry with lower environmental pollution, the development of industries that are demanding to the ecological state of the territory (tourism, science, health care, culture, education). Characteristic features of the transformation of atmospheric pollution from stationary sources in the post-industrial period are the following:

- 1) during economic growth, first there is a decrease in gross, and then absolute emissions into the atmosphere;
- 2) the reduction of dependence of the emission volumes on the dynamics of gross regional product and industrial production;
- 3) the improvement of fuel quality and the reduction of emissions, increasing the role of housing and communal services (utilities), including waste recycling systems, in the emissions structure from stationary sources until the transition to renewable energy sources;
- 4) an increase of the level of catching and neutralization of pollutants;
- 5) the simplification of the structure of substances released.

In the developed countries, the key source of influence is the mobile sources of atmospheric pollution, which is caused by the increase of requirements for mobility of the population in the post-industrial period. However,

emissions of pollutants from mobile sources are gradually decreasing. On average, the volume of motor vehicle emissions decreased by 23% in 1990–1998, by 40% in 1998–2008, and by 30% in 2008–2018, mainly due to increased requirements for an engine and fuel quality, as well as to the development of transport infrastructure. In most of the reviewed countries, in 1990 and 1998 emission figures differ the least significantly, later emissions are reduced more dynamic and have an impact on the incredible growth of the transition to electric vehicles that do not pollute the environment. However, even during this period, emissions increased in Turkey, the Czech Republic, New Zealand and Australia, while in Portugal, Poland, Greece, Italy, Slovakia decreased more slowly than the average. Considering a general trend of most countries to reduce the reduction of gross pollution from motor vehicles even in the light of the growth of the fleet, the pace of this reduction is different. For example, in less developed countries, even growth is often observed. In Kyiv, in 1998–2018 the emissions rose by 40% [9].

A similar trend, though less evident, is typical for Ukraine and a number of other countries in 2021 as compared to 2008. Currently, the dynamics of emissions from mobile sources in Kyiv is closer to those of the post-Soviet countries than the European ones. On average, the countries of post-Soviet space experienced an increase in municipal waste by 21% over the period 1990–2021. However, the waste rate per person is decreasing by 4.2%, except for Austria, Canada, Denmark, Greece, Iceland, South Korea, the Netherlands, Sweden, and Switzerland. Estonia has the biggest reduction in waste per ton, reaching 37%. In most countries (except for Spain and Turkey), the volume of recycled waste increased to 500% over the period of 1990-2015. Higher figures are characteristic of Eastern Europe, Iceland, Portugal and Italy due to the low base effect. The development of green areas in global cities is an important trend, aimed not only at the development of the urban environment, but also at increasing the profitability of projects in the adjacent territories. Common features for all cities are the following ones: the priority for the creation of green zones on the waterfront and in central areas, the adoption of a system of laws protecting green planting, the reorganization of industrial territories taking into account the necessity of expansion of green areas.

These projects are very important and effective for improving the environmental condition of the state, but when the country is in a state of war, all economic resources are directed to defense against the aggressor, while environmental problems become secondary to the state. But we are citizens of a country in which people are trying to grow a healthy nation, which is impossible with the deterioration of ecology. Currently in countries that are not in a state of war, in big cities roofs and vertical landscaping are currently developing in order to solve ecological problems of the city and protect people from noise and polluting substances. The share of the population

of cities living under the influence of fine-dispersed particles (PM<sub>2.5</sub>) 15 µg/m<sup>3</sup> is the most important indicator of the condition of the urban environment. The fine-dispersed particles are mainly combustion products and organic particles that can cause serious health problems. According to the World Health Organization (hereinafter – WHO), the average annual level of PM<sub>2.5</sub> should be no more than 10 µg/m<sup>3</sup>. In general, this figure is 1,4–1,8 times higher in the largest cities than on average in the country [10].

In 1998, about 100% of the population of Brussels, Berlin, Paris, Vienna, London, and New York suffered from increased doses of PM<sub>2.5</sub>. Madrid was distinguished against the general background, with only 13% of the population suffering from increased doses. This indicator improved gradually in most metropolitan cities. However, it remained almost unchanged in Vienna and Santiago, while it decreased only by 17% in Berlin. This figure almost halved in Paris and Brussels, and decreased almost to zero in Madrid, London and New York. The Environmental Policy Stringency Index (EPS) is defined as the degree, according to which the environmental policy determines the direct and indirect cost of pollution or environmentally harmful effects. It is an assessment of the severity of the 14 environmental policy instruments (taxes, laws, licensing activities), primarily related to climate and air pollution. The index varies from 0 (not strictly) to 6 (the highest measure of stringency). The index covers 28 post-Soviet countries and 5 BRICS countries during the period 1990-2021 [11].

Countries that are members of the Organization for Economic Cooperation and Development have a higher level of Environmental Policy Stringency than those that are not members of the Organization. In the OECD countries, the increase in the Environmental Policy Stringency was observed mainly in the middle of 2000, while in other countries, the growth is somewhat less pronounced and relates to early 2010. At the moment, there is no single approach to reducing losses in water supply and waste recycling in global cities, although there is general understanding of the need to address these problems.

The post-industrial period in the development of Kyiv has common features of the environmental situation with other big cities. However, the specifics of a multi-million city, which has historically been formed as a large scientific and production centre, determine the specific features associated with both inherited industrial development and later steps in post-industrial development. In the beginning of 2000, the share of service industries in the capital's gross regional product (hereinafter – GRP) was 74%, and it reached 81% by 2010. Kyiv is mainly characterized by the service economy, despite significant development of its industry in recent years.

In Kyiv, the transition to a post-industrial type of development had common features, typical of most big

cities as follows:

- de-industrialization and an increase in the share of high-tech industries, which contributes to the reduction of pollution volumes, often leading to expansion of the spectrum of polluting substances and the appearance of non-critical pollutants;
- an increase in pollution from housing and communal services, a change of fuel balance towards more ecological types of fuel and stationary non-industrial sources;
- changes in the structure and the volume of solid waste generation;
- enhancing the role of road transport [12].

In the post-Soviet period, industrial production in Kyiv was reduced. Simultaneously, the impact of the industrial complex on the environmental situation in the city has decreased. In Kyiv, in 2016 emissions decreased 4 times as compared to 1990, and 1,6 times as compared to 2000, with the country's overall decline being 2% and 9% respectively. In Kyiv, in 2020 the share of emissions into the atmosphere from stationary sources decreased to 6%, which was due not only to the growth of the car, but also to the reduction of production. The rate of emission reductions is gradually slowing down, while industrial production is declining. In Kyiv, the volume of energy emissions decreased more than in the entire Ukraine due to the change in the fuel balance structure, with 96,7% being gas fuel, and the transition to electric engines. The energy consumption by industrial production is one of the lowest among regions of Ukraine. In the capital, the reduction rates of emissions from oil processing were above the average Ukrainian. In the period of 1990-1995 years, emission reductions were achieved by all ingredients, since 1995, after the transition to gas, mainly by means of NO<sub>x</sub> emissions. In 2005–2016, the most significant (by 59%) reduction of solid substances emissions happened. Thus, sulphur dioxide and volatile organic compounds (VOCs) reduced twice. The volume of carbon dioxide emissions increased as a result of the reduction of the share of captured and neutralized pollutants by gas-dust units from 56 to 40%. To achieve further reductions in emissions will be technologically difficult and costly.

The environmental situation in Kyiv is determined mainly by the influence of motor transport (93.4% of emissions into the atmosphere). The most important feature of the formation of the level of atmospheric pollution in Kyiv in recent years has been the change of trends. Thus, against the background of the growth of the number of cars, pollution is being reduced. This trend was observed in Kyiv even before. The most important changes in the structure of influence factors took place in the post-industrial period. During the Soviet period, despite the low road load level, the correlation coefficient between the increase in the level of motorization and the change in the level of emissions was 0,65. During the period of the increase of a number of cars in 1990-1996, the correlation

coefficient was also statistically significant (061), although it was somewhat reduced due to the simultaneous action and positive factors [13].

These trends give an idea of the ecology state and how it has changed over the past 20 years in connection with the technological growth and relationship conditions with their European partners, but do not reveal the internal ecological state of the country in connection with urbanization. Urbanization of Ukraine mainly occurs in connection with the outflow of people from the countryside because there are no jobs where people can provide themselves with decent living conditions. In addition, the fact that doctors do not want to work in rural areas (especially during epidemics such as COVID -19), which leads to the fact that young people choose to move to big cities instead of building a life in the village. Recently, young people are increasingly focused on the European Union and try to study there or, if they do not have the opportunity to study, then to find employment. According to the analysis of indicators, only 12% of young people return from EU countries. In most cases, the reasons are problems with the law, when this happens not at the expense of one's own desire, but as a result of the person's deportation or if there are personal reasons for returning.

In Ukraine, the share of the urban population is 74%. In Ukraine, more than 20 million people live in cities. By 2050, the share of urban population in developed countries will grow from 75% to 86% on average, while its share in developing countries will increase from 45% to 66%. More than 160 cities in the world have a population of more than 1 million people. The largest cities in the world, each of them having more than 10 million people (such as Mehiko, Tokio, Sao Paulo, Buenos Aires, Shanghai, Seoul, Istanbul, Mumbai, Karachi, Delhi, Manila, Dhaka, New York). People want to go to the city, although there they can not always find the means to support their existence, because cities are not able to provide all jobs, housing, water, sanitary and other at least elementary convenience and living conditions. The problems of the city are connected, first of all, with its unfavorable ecological situation. The health of the inhabitants of the city is significantly affected by the urban environment. From a medical-biological point of view, the impact of environmental factors in the urban environment is acceleration (general increase in growth and mass of people compared to previous generations) [14].

The cause of acceleration is sufficient and full-fledged food, violation of biorites (the prolongation of a day due to electric lighting, numerous professions connected with innership at night, variable working schedule, maintenance of a night way of life, etc.); allergy (the violation of the immune system caused by the appearance of new substances – pollutants which a person has not previously been exposed to in the process of evolution); growth of cancer diseases (radioactive contamination, contents of carcinogens in atmospheric air, water and food, action of strong electromagnetic fields; obesity (eating, hygiene); biological tendencies of lifestyle (drug addiction, alcoholism, smoking) computer addiction and internet dependence) [15].

The city consists of several functional zones as follows: industrial ones, which are the main pollutants of the environment; residential areas (areas of concentration of neighborhoods, houses, administrative buildings, etc.) and forest-park zones. There are numerous city parks, squares, and green plantings around residential buildings. In contrast to natural forest communities and forest parks, urban green plantations are not self-regulating systems and require constant care. Today, there are 400 large industrial cities on the planet. Specific emissions are presented in Table 1.

Their emissions include aero-technologic (2.5 billion t/year); aerosol (1 billion t/year); solid waste (3 billion t/year); liquid waste (more than 500 km<sup>3</sup>/ year).

Over the past 100 years, the need for cities in water has increased by 10 times, while in such large cities as Paris, Rome, Moscow, Berlin, New York, this need has increased more than 100 times [16]. Accordingly, the discharge of industrial and communal sewage, which purification is one of the most serious and unsolved problems in the modern world, is growing.

Motor transport is the main source of air pollution in large cities. It accounts for between 40 and 90% of all pollution. The exhaust gases of cars contain carbon oxides (II) SO and (IV) CO<sub>2</sub>; nitrogen oxides NO<sub>x</sub>, sulfur oxides SO<sub>x</sub>, carbon dioxide C<sub>x</sub>H<sub>y</sub>, other organic compounds, soot, as well as lead compounds Pb, which add to gasoline. (Today, many industrially developed countries do not allow the connection of lead to gasoline.) The atmosphere receives 20 or more times more harmful substances when the engine is idling, the vehicle is accelerating and braking than when the vehicle is moving at a constant speed [17].

**Table 1.** Specific emissions of pollutants in kg/t

Type of fuel	CO	CH	Nox	TЧ	SO <sub>2</sub>
Gasoline (cars)	233	33.5	16.37	-	0.6
Gasoline	233	56.9	16.37	-	0.6
Diesel fuel	41.5	6.93	29.6	3.85	5
Natural gas	92	30.8	23.2	-	-

Motor transport as a factor of ecological condition (together with traffic jams and noise) is becoming more and more differentiated, as transport becomes rather uniform. In the dynamics of air emission density from motor transport for the last 16 years as follows:

- On 40% of the territory, the density of polluting emissions remained unchanged (varies within 1000-3000 t/km<sup>2</sup> year);
- On average, throughout Kyiv there is a process of reducing the overall level of density of harmful substances entering the atmosphere of the city;
- practically all areas of the increased density of pollutants, which are in the atmosphere, are located only within the limits of influence of motor highways;
- the areas of the largest density are close to the city's highways, and even to the radial highway on the periphery of the capital;
- there is a decrease in amplitude of fluctuations of emission density in the atmosphere (by 1.5 times), which allows us to speak about a reduction of differences in pollution of the city's natural environment.

In general, during the period under consideration from 1992 to 2022 years there was a "wash" of pollutants from the motor transport territory of Kyiv. In 1992, in polluted air there was a very high concentration of pollutants, while in 2016 the general decrease in concentration of pollutants can be noticed, apart from the redistribution of harmful substances from motor transport [18]. For air transport, the increase in the frequency of flights is largely compensated by the improvement of the technology and types of vessels, the strengthening of air emission standards and requirements to the level of noise pollution, but compensation does not lead to a reduction of the level of influence adequate to the requirements of the post-industrial society. The issue of reducing noise pollution is even more urgent today than reducing emissions, which is realized much more effectively. Noise pollution is increased due to an increase in car speed and the expansion of the car park, as well as insufficient attention to construction of noise protection screens on large highways and non-use of special types of asphalt and its low quality. The pollution from air transport is caused by changes in the fleet of aircraft related to strengthening of noise and emission regulations in post-industrial countries, as well as a ban on flights over the territory of the capital [19]. Thus, only areas adjacent to the airport zones are prone to noise pollution, mainly in the Boryspil airport. As in the case of industry, the reduction of noise pollution from aviation due to the renewal of the fleet is up to 2020. In general, it is too early to talk about success in

solving the problems of noise pollution in the capital. The biggest emission level is in Kyiv airports is Boryspil, the smallest one is Chaika. The worst environmental situation is typical for Zhulyany at the expense of its old fleet of airplanes.

In the capital of Ukraine Kyiv, before the COVID-19 epidemic, 90% of harmful emissions were from motor vehicles. Combustion gases that are formed from mixing with oxygen are the main reason for respiratory and cardiovascular diseases [20]. The release of carbon dioxide in the atmosphere occurs under the influence of sunlight in which nitrogen monoxide is oxidized by atmospheric oxygen to nitrogen dioxide. The most important thing is that nitrogen dioxide is able to absorb ultraviolet rays and produce smokefog during this process. There is a conversion of NO to NO<sub>2</sub> on the formula [21]. At the same time, the toxicity changes twice as much as in NO. At the same time, the physical acting is manifested by the presence of acid concentrations in moist air with the formation of aerosols and a decrease in the size of a liquid drop as a result of evaporation in dry warm air. Solid and liquid particles are able to combine or absorb gaseous substances. Reactions of synthesis and decomposition, oxidation and reduction occur between gaseous components of VG and atmospheric air. Some processes of chemical transformations start directly when the emission enters the atmosphere, others in the presence of favorable conditions. Carbon monoxide diffuses quickly in the atmosphere and, as a rule, does not create a high concentration. Soil microorganisms intensively absorb it. In the atmosphere, it can oxidize to CO<sub>2</sub> in the presence of strong oxidants: O, O<sub>3</sub>, free radicals.

An experiment was conducted for the calculation of harmful emissions in the city Kyiv, average traffic intensity in a mixed flow during the day with an interval of 4 hours was determined by the formula:  $N = \frac{1}{3}(N_1 + N_2 + N_3) \frac{un}{n}$  where  $N_1 + N_2 + N_3$  are indicators of morning, afternoon and evening traffic intensity.

Table 2 shows indicators of fuel consumption for a certain range of cars.

We use guide to determine the carrying capacity of highways, taking into account points. 1.5 SNIP 2.05.02-85 for calculating traffic intensity and carrying capacity.

The mass pollutants which get into the atmosphere is determined by traffic intensity and expressed in unit of mass per unit of time and distance in a general formula:

$$G = \sum_{t=1}^n (Gt Nt) kg/km * h, \quad (1)$$

where G - average fuel consumption for this type of car, kg/km; n - average estimated traffic intensity for this type of car, unit/h. Table 3 shows the influence coefficient on specific emissions.

**Table 2.** Indicators of fuel consumption for a certain range of cars

	Type of vehicle	Fuel consumption, l/km	Fuel density, kg/l	Average operational fuel consumption, kg/km
1	Gasoline cars	0.09	0.77	0.07
2	Diesel cars	0.08	0.84	0.07
	Gas cars	0.05	0.4	0.03
3	Electric cars	0	0	0
4	Gasoline lorries (up to 5 tons)	0.16	0.77	0.12
5	Gasoline lorries (above 5 tons)	0.33	0.77	0.25
6	Diesel lorries	0,34	0.84	0.29
7	Gasoline minibuses	0.16	0.77	0.12
8	Diesel minibuses	0.11	0.84	0.09
9	Buses (gas)	0.09	0.6	0.08
10	Gasoline buses	0.37	0.77	0.28
11	Diesel buses	0.28	0.84	0.24

**Table 3.** Influence coefficient on specific emissions of pollutants according to technical condition of cars

Type of fuel	CO	CH	Nox	TCh	SO <sub>2</sub>
Gasoline (cars)	1.5	1.5	0.9	-	1
Gasoline	1.7	1.8	0.9	-	1
Diesel fuel	1.5	1.4	0.95	1.8	1
Natural gas	1.7	1.8	0.9	-	-

The majority of thermal power plants (TPPs) and combined heat and power (CHP) work on natural fuel. When burning coal, gas, oil products, sulphur and nitrogen oxides, a large amount of carbon dioxide, carbon oxides and solid particles enter the atmosphere. Different industrial enterprises, depending on their profile, besides the above-mentioned compounds, pollute the atmosphere with a whole range of other chemical compounds. Special filters, which install factory tubes, allow to significantly reduce the amount of harmful emissions into the atmosphere. A lot of dirt gets into the air when burning debris. Of these pollutants, dioxins are the most dangerous. According to modern technologies, before burning garbage it is necessary to sort it (separately paper, plastic products, etc.), which in most cases is not performed. During separate burning of each type of waste, an individual technology is applied. In such a way, much less dioxins and other pollutants come into the atmosphere. It is known that dioxins are not released from the human body for a long time, and gradually accumulate in the organism. The air of large cities is also polluted by dust. The effect of dust on human health depends on its physical and chemical properties such as its chemical composition, air concentration, size of particles (dispersion), their hardness, etc. Fine dust with particle sizes from 2 to 5 microns is the most dangerous for human health. These particles of dust

are in the air and get into a person's respiratory system. Dust causes respiratory tract diseases [22].

According to international experts, Kyiv has very negative indicators of air pollution and environment. Kyiv is an example of a city of strong geochemical pollution, the entire historical center of which is contaminated with heavy metals (zinc, lead, cadmium, copper, nickel, chromium). Heavy metals are also found in soil, wood leaves, grass lawns, sand-pit and scorched leaves. According to the content of heavy metals, the soil is classified as "extremely dangerous". The average content of zinc is 16 times higher than the background value, copper – 14 times, lead – 12 times, chromium – 5 times, cadmium – 4 times. The main source of heavy metals is not only motor transport and industrial enterprises, but also the old covering of walls of deteriorating buildings. Mineral paints are a mixture of heavy metal oxides or salts of the complex composition, first of all, lead. Painted surfaces are the secondary source of pollution of atmospheric air with toxic dust. The old plaster has mixed asbestos, playing the role of carcinogen in the environment.

The environmental situation in Kharkiv, as in other cities of the country, is far from perfect. Kharkiv is the second most populous (1.4 million people) and an industry-oriented city in Ukraine. Negative factors include air pollution, overpopulation, noise. All these factors lead

to the deterioration of the quality of life and health of Kharkiv citizens. In particular, the increase is observed by such indicators as carbon monoxide, volatile organic compounds, etc. For example, the maximum permissible concentration of nitrogen dioxide, which is contained in the exhaust gases of cars, is 20 times higher [23]. In Kharkiv, one person accounts for 60 – 75 kg of harmful substances.

The situation is somewhat better in Odessa, Kherson, Mykolayiv, with the help of the winds from the Black Sea. The category of "dirty environment" for atmospheric air and water objects is characterized by constant excess of pollution values above the established norms. One-time extreme pollution or excess of norms dozens of times is possible. This category includes the whole territory of Kharkiv and its suburbs, which are highly polluted by sulphur. Organic compounds (oil products, synthetic detergents, pesticides, phenols, etc.) are located within the city. Soil contamination with heavy metals (copper, nickel, cobalt, mercury, chromium) is observed in residential areas. Soil contamination with nitrates in suburban areas is connected with excessive mineral fertilizers [24].

In Ukraine, there are several large landfills of solid household waste, which are formed annually in the amount of 1700 thousand tons due to the activity of the population, organizations and enterprises of the city. In May 2012, the city government adopted a regional target program for the management of solid domestic and industrial waste in Ukraine for the period 2012-2020 [25]. The health of city residents is significantly affected by pollution, electromagnetic fields, ionizing radiation. Noise pollution is one of the forms of environmental pollution, which consists of increasing the noise level above the natural background and acts negatively on the person and other living organisms. The noise level is measured in decibels (decibels (dB), which represents the level of sound pressure). Noise of 20-30 dB (natural noise background) is almost harmless for a person. Noise can be household, industrial, transport, street traffic, aviation, etc.

The main source of urban noise is industrial enterprises such as power plants, compressor stations, metallurgical plants. The noise of motor transport is also significant. Environmental noise is one of the kinds of physical pollution of the environment, which consists of increasing the noise level above the natural background and acts negatively on the person and other living organisms [26]. The allowable noise level limit for a person is 80 dB. The sound of 130 dB causes pain, and at 150 dB it becomes

unbearable. The permissible noise of street traffic near the walls of houses should be 50 in the daytime, and 40 dB at night. The overall noise level in residential premises should not exceed 40 dB in daytime and 30 dB at night. Kyiv ranks fifth among the world's noisiest cities: The average noise level in the city is higher than normal (60 dB), surpassed only by Moscow, Tolyatti, Athens and Paris [27].

At present, according to the World Health Organization, the noise irritation is referred to as important causes of sleep disorder, the emergence of chronic fatigue syndrome, drowsiness, decreased mental activity, growth of cardiovascular diseases, impaired vision [28].

An increase in the number of cars leads to a sharp increase in noise pollution. The noise of large cities reduces life by 8–10 years. The biggest cities of Ukraine such as Kyiv, Odesa and Dnipro were explored to determine noise fluctuations. The research was conducted on streets where vehicles move at a constant speed and at a distance of 50 m from the intersection as the vehicle is the biggest noise pollutant of almost all big cities and it generates 60–80% of noise in residential areas. According to scientists, the acoustic comfort is considered to be 55 dB at a distance of 25-30 m [29].

The obtained data indicates that the tolerance of noise fluctuations is exceeded 10 dB on the explored territory. Sound indicators are from 65 to 81 dB. During the research, the microphone was located along the sidewalk at a distance of 8 m from the measurement point and at a height of 1.5 m.

The time for measuring the noise indicators of the traffic flow of more than 200 transport in different directions was 3 minutes. Using a noise meter with an arrow sound level indicator, the interval between sound level readings was 3 s. The level indicators were taken according to the indicators of the device arrow at the time of counting in the amount of 1 dB.

Indicators exceeded the maximum sound level and equal 65 dB. According to the obtained data, indicators are from 60 to 85 dB. Environmental indicator and noise pollution indicator in Kyiv are presented in Table 4.

Research of Kyiv testifies the exceeding of the normative maximum indicators of sound levels for the territory of the microdistrict from 2 to 11 dBA.

The next city is Odesa. The main sources of noise pollution are the main street network, the port area, the railway and the airport "Odesa". Environmental indicator and noise pollution indicator in Odesa are presented in Table 5.

**Table 4.** Environmental indicator and noise pollution indicator in Kyiv, as of 2022

Point of observation, address	Noise level, LAeq, dB
Residential building, Naberezhno-Rybalska Str / Elektrikyv Str	62
Mykhailivska Str. (territory of KGB)	64
Ushynskoho str. / Chokolibsky boulevard	79
Average across the city	68,3

**Table 5.** Environmental indicator and noise pollution indicator in Odesa, as of 2022

Point of observation, address	Noise level, LAeq, dB
Residential building, Bocharova / Dobrovolskoho Str.	72
Higway Peresypsky bridge	73
Pastera / Olhiivska Str. (territory of Odesa city clinical hospital No. 9)	57
Average across the city	67,3

**Table 6.** Environmental indicator and noise pollution indicator in Dnipro, as of 2022

Point of observation, address	Noise level, LAeq, dB
Residential building, Pavla Chubynskoho str. / Yalytsevyi lane	57
Sviatoslav the Brave/ Korolenka Str. (territory of KGB)	71
Aeroportivska Str	82
Average across the city	68,3

Analysis of the acoustic conditions on the street network is based on the survey data of the traffic intensity considering freight and public transport flow at an average speed.

Similar data are obtained in Dnipro. Almost the entire territory of Dnipro has a significant impact of traffic noise. Environmental indicator and noise pollution indicator in Dnipro are presented in Table 6.

According to the adverse consequences of noise, its level should not exceed 55 dB, a safe noise level is recommended to be 80 dB on city highways. But according to obtained results, almost all zones are partially or completely included in the zone of acoustic discomfort.

The acoustic discomfort is 82-92 dBA and can reach 100 dBA in cities with a large concentration of cars and on highways where the noise level is increased. People have nervous disorders, impaired speech, mental and psychological disorders and also serious consequences. Such conditions prevent a full rest and disrupt sleep.

Accordingly, an exceeding the permissible noise level is 2-12 dB according to the data of the research. Thus, citizens live and work in a condition of emotional and physical tension that is associated with constant acoustic discomfort.

An increase in the number of cars leads to a sharp increase in noise pollution. The noise of large cities reduces life by 8–10 years. Noise protection allows reducing the negative influence of noise of a large city on the human body. This is a set of measures to reduce noise such as the installation of sound-isolating housings on equipment, various silencers, acoustic screens, noise-protection zones, glass packages in windows, laying of noise-absorbing road surface, bushes along highways, etc. There are a lot of electromagnetic fields (EMF): Video-TVs, VCR-computers, radio-TVs, computers, radio-recorders, computers. radio receivers and radio transmitters, used by a person in everyday life in urban

conditions.

Radio-location and radio-cell television stations, transformer stations, power-generating units, high-voltage power lines, tram and trolley-bus lines, telephone lines laid under the ground, television, electric cable networks, heat, water-sewerage and other power substations are big sources of strong EMF in the city. There are also zones with electric current fields in the city. A created intensity of EMF tens and even hundreds times exceeds the natural electromagnetic background of the suburban green zone or rural area. In cities, electromagnetic fields (especially high-voltage power lines) pose a serious risk to health, because they can cause cancer, leukemia, brain tumors, sclerosis and other serious diseases for prolonged exposure to humans. Electrostatic fields also affect humans significantly. Electric charges accumulate on the surface of such materials as linoleum, plastic tiles, carpets, curtains, wallpaper, varnishing and polished surfaces (the potential of the field can reach 3-10 thousand V) [30].

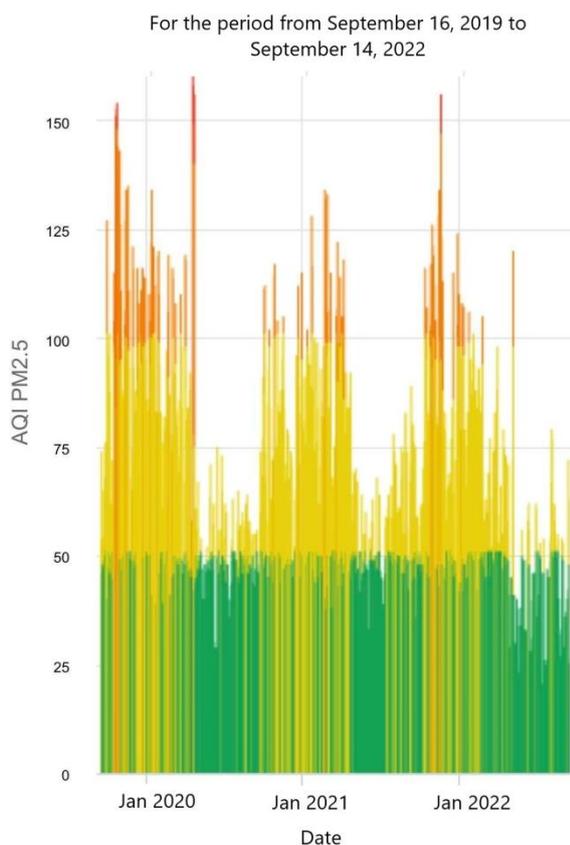
A human body receives long-lived natural radionuclides through air, food and water. Natural radiation does not harm a person. In medicine, radiation is used for diagnosis and treatment of diseases. Radioactive radiation is used in medicine and scientific research, but the excess of permissible doses leads to the emergence of malignant neoplasms and genetic mutations. It is obvious that radioactive contamination of a number of large metropolitan areas can significantly exceed the natural background and even natural anomalies. It should be remembered that even relatively small but constant radioactive radiation exposure is a genetic danger. Moreover, the radiation dose is summed up and can reach critical values. To protect big cities, to preserve and improve the environment, labour and rest for people, there is a system of measures, that is, sanitary-ecological control, which includes the assessment of the environment’s quality in the following way:

- the determination of noise, vibration, electromagnetic and ionizing radiation (radon), radioactive contamination and their compliance with acceptable norms;
- the control of air space and its compliance with requirements concerning contents of dust, allergens, pathogenic microbes, unpleasant odours, heavy metals, organic substances, sulphur oxides, nitrogen, carbon, can, acid and radioactive precipitations;
- control of water objects and their compliance with the requirements concerning the content of heavy metals, organic substances, oil products, synthetic compounds, mechanical impurities, pathogenic microorganisms, acids, etc.;
- the control of geochemical contamination in soils, including snow cover [31].

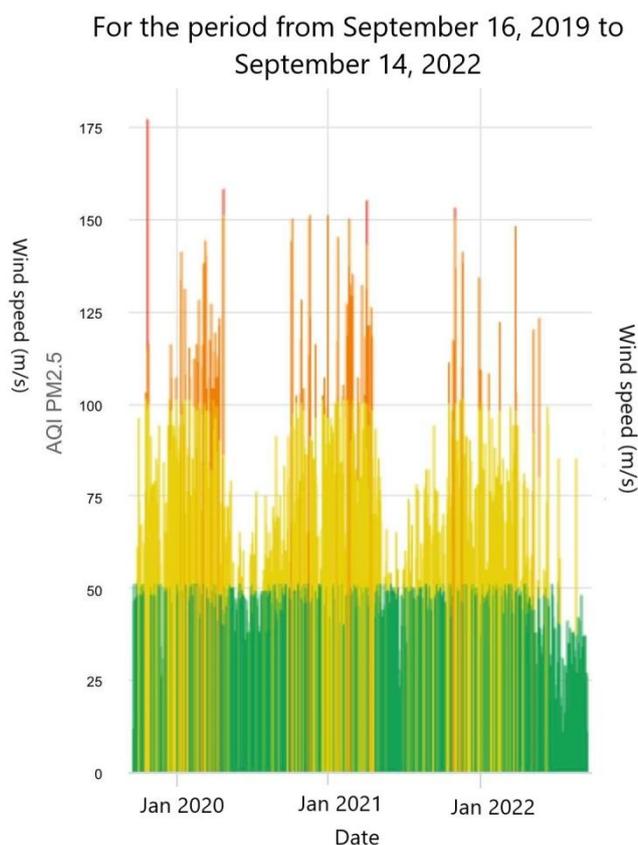
In big cities of Ukraine, the situation regarding the waste of production and consumption is connected with a steady increase of waste volumes coming into the environment, and, as a result, the accumulation of industrial and domestic waste. The dynamics of waste generation is represented by the following indicators: from 2707,596 thousand tons in 2012 to 3367,312 thousand tons in 2016,

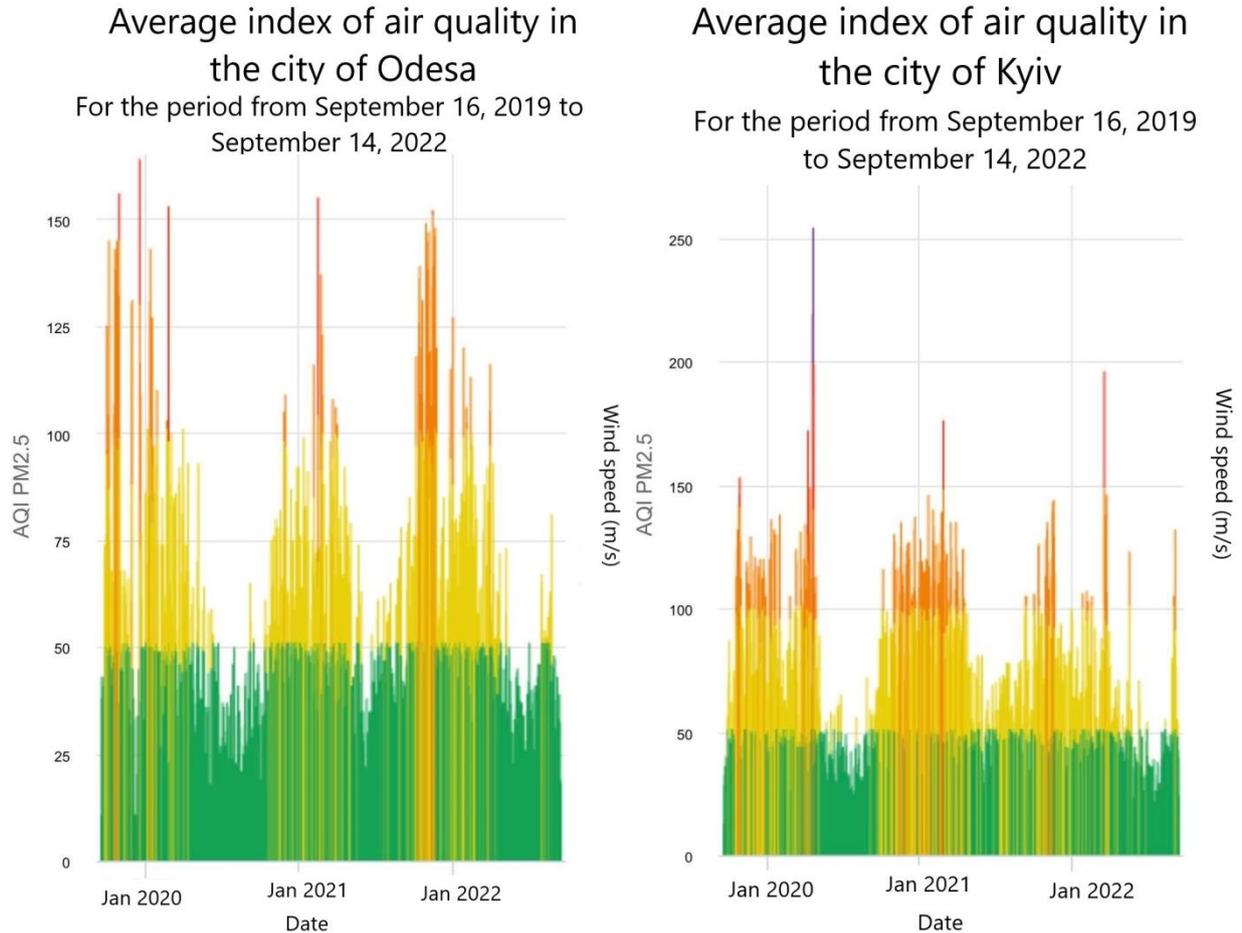
of which about 60% of all waste is collected and produced by housing, while 40% comes from enterprises, institutions and organizations. In Kyiv, the increase in waste per capita is 4-6% annually. The problem of formation and liquidation of natural and unauthorized dumps, which are usually located on the slopes of beams, yards, other areas with reduction of relief and high penetration of the ground, as well as direct exits to reservoirs and in the Black Sea or direct proximity to residential areas, is also acute. Thus, only in 2021 about 200 such dumps were found in Kyiv, where more than 50 thousand tons were placed, not classified by the composition of waste. The estimated area of natural landfills is about 95 hectares of urban land. Among the regional ecological problems, the preservation of urban lands quality takes a special place, because it is the soils that record emission of pollutants and their actual distribution in the components of the city territory. This problem is especially urgent for the city of Dnipro and Kharkiv as large industrial centres, 16% of the total area being the total area of industrial zones. More than one third of Dnipro territory (about 35%) is characterized by a different degree of dangerous pollution. More than 30% of the land resources of Kharkiv are characterized by different dangerous levels of heavy metals maintenance.

### Average index of air quality in the city of Dnipro



### Average index of air quality in the city of Kharkiv





**Figure 1.** Air quality index in the largest cities of Ukraine for the period 2019-2022 (Dnipro, Kharkiv, Odesa, Kyiv)

In Figure 1, you can see how the state of the air has changed over the past three years in the territory of Ukraine in three cities with a population of approximately 1,000,000, and, accordingly, in the capital Kyiv [32]. According to SaveEcoBot – Ukraine's only ecological chatbot. From which it can be seen that, after all, the city of Kyiv, which is the capital, has the worst level of air pollution, which is affected accordingly by the number of people, the level of motorization and the construction industry.

At the same time, the landscaping of the large cities of Ukraine is smaller than the standard value: each person has 10,8 m<sup>2</sup> green plants on average, the standard being 25,0 m<sup>2</sup>. Today, Kyiv consumes more oxygen than it is produced by urban green plants. The weaknesses of the environmental situation in Kyiv are as follows:

- 1) a difficult environmental situation in all areas (air, water, soil, greening, a large amount of industrial and household waste);
- 2) the disparity of environmental and economic priorities in the field of natural resources and environmental protection;
- 3) high complex toxic load on the human body;

- 4) underaccounting of factors of ecological education in solving problems of natural resource use and environmental protection, a low level of population's ecological culture.

There are the following threats to Kyiv caused by its environmental situation:

- 1) a high probability of technogenic accidents, especially during ecologically unfriendly production;
- 2) a high probability of transborder transport of pollutants in air and water;
- 3) inadequate funding of environmental programs.

For Kyiv, the reduction of air pollution can be achieved both by reducing the number of emissions of waste gases and ash, and more expedient planning, and in particular, a mutual allocation of settlement zones and sources of emissions into the atmosphere, taking into account the prevailing direction and strength of wind; the organization of sanitary protection zones and so-called buffer zones located between industrial complexes, main buildings of the heat station and residential city blocks; a choice of well-ventilated slopes for construction, which are not inclined to inversion and accumulation of air pollution.

Industrial zones of Kyiv occupy more than 58% of the coastal front (more than 35 km), covering the long lanes of exits from residential areas to the bank of the Dnipro River. Due to the peculiarities of the linear-band planning structure, the most pressing issues related to the placement of the industry on the valuable coastal territories are at the top of the agenda. The situation in Kyiv has been such that the concentration of industrial facilities on average exceeds the maximum permissible level accepted by the European Union. One of the directions of the urban development strategy in Kyiv is the reorganization of production areas, which envisages the development of a general production areas reorganization strategy. Despite the fact that in Kyiv the process of using the territories of former industrial enterprises for residential and commercial development is still under development, examples of such redevelopment already exist.

For a modern Ukrainian city, the task of reconstruction and improvement of former industrial zones and undeveloped areas is becoming more and more important due to the creation of compact residential areas. On the map of the city, many factories occupy free land, characterized by a large area and located in its central parts.

During the rapid growth of Kyiv, many enterprises were located in the residential area. In the city, historically industrial and communal areas occupy a significant part of the coastal strip and make it difficult to reach the Dnipro river. In many respects, this is caused by the significant air and underground water pollution in the city.

## 4. Conclusions

The peculiarities of post-industrial development of Kyiv are reflected in the reduction of the specific pollution of the early 2000s and gross pollution of the atmosphere and water sources since 2007. However, unlike the steady trends of other global cities, in Kyiv a small growth of absolute indicators of all types of pollution has recently begun. For Kyiv, the most urgent problems are unresolved problems of utilization of solid municipal waste and formation of green zones. In 2021, several different trends appeared, in comparison with 2000. The industrial structure of pollution has been simplified as much as possible, but increasing diversity of stationary non-industrial sources often leads to expansion of the spectrum of polluting substances, appearance of non-critical pollutants, as well as (together with diversification of sources of heat supply) contribute to reduction of internal homoc differentiation.

The volume of emissions from the thermal power station is stable, but the decentralization of heat supply is increasing, as many stationary non-industrial sources have autonomous heating systems. In addition, the level of alternative energy is growing. Almost all of the industrial area areas have significant development potential. A policy on industrial zones should be based on a comprehensive assessment of their impact on the environment and its

changes. Most of the reorganization projects pay insufficient attention to landscaping.

With the basic trend of reducing the level of influence of all types of transport due to the improvement of technologies, the role of transport in the pollution of the urban environment is increasing. Motor transport has become the main factor in reducing the territorial differentiation of the environmental situation in Kyiv. The level of influence of civil aviation is decreasing, but this trend does not affect small and private aviation. The post-industrial transformation of the branch and territorial structure of the economy not only reduces the volume, intensity and toxicity of anthropogenic influence, but also shows the internal differences of the environment.

Applying to the legislation of the European Union, namely, Germany, Austria, Spain, for experience of criminal-legal protection of ecology, has allowed to reveal some shortcomings in the criminalization of ecological encroaching. In order to eliminate them, it is proposed to supplement the Criminal Code of Ukraine with a note that will help to eliminate the presence of certain gaps in criminal environmental protection from noise, vibration and harmful radiation, without creating an additional criminal law. Review the procedure of environmental impact assessment, environmental safety regulations during design, placement, construction, reconstruction, commissioning, operation and liquidation of enterprises, structures, moving means and other objects, if it has created a danger for life, health of people or the environment. The biggest problems that arise in Ukraine today are related to migration in connection with military actions, which, accordingly, leads to the decline of the Ukrainian countryside.

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