

**MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
VASYL STEFANYK CARPATHIAN NATIONAL UNIVERSITY**



Co-funded by the
European Union

Faculty of Natural Sciences

Khatsevych O.M., Mykytyn I.M., Fedorchenko S.V., Kurta S.A.

AIR QUALITY MONITORING: EUROPEAN EXPERIENCE

MANUAL

developed within the framework of the project

101127251 – MEOEU – ERASMUS - JMO -2023- HEI - TCH - RSCH



Ivano-Frankivsk, 2026

UDC 504.06.

*Recommended for publication by the Academic Council of the Faculty of Natural Sciences as a textbook for students of higher educational institutions
(Minutes of the Academic Council meeting No. 5 of January 22, 2026)*

Authors:

Khatsevych O.M. – Ph.D., Associate Professor of the Department of Chemistry, Faculty of Natural Sciences, Vasyl Stefanyk Carpathian National University (Ivano-Frankivsk);

Mykytyn I.M. – Ph.D., Associate Professor of the Department of Chemistry, Faculty of Natural Sciences, Vasyl Stefanyk Carpathian National University (Ivano-Frankivsk);

Fedorchenko S.V. – Ph.D., Associate Professor of the Department of Chemistry, Faculty of Natural Sciences, Vasyl Stefanyk Carpathian National University, Ivano-Frankivsk;

Kurta S.A. – Doctor of Technical Sciences, Professor of the Department of Chemistry, Faculty of Natural Sciences, Vasyl Stefanyk Carpathian National University (Ivano-Frankivsk).

Reviewers:

Olexandra Abrat – Ph.D, Associate Professor of the Department of Biochemistry and Biotechnology, Faculty of Natural Sciences, Vasyl Stefanyk Carpathian National University;

Liubov Soltys – Ph.D, Associate Professor of the Department of Chemistry, Faculty of Natural Sciences, Vasyl Stefanyk Carpathian National University.

Air Quality Monitoring: European Experience (2nd edition): manual [text] / *Khatsevych O.M., Mykytyn I.M., Fedorchenko S.V., Kurta S.A.* / Faculty of Natural Sciences; Vasyl Stefanyk Carpathian National University. – Ivano-Frankivsk, 2026. – 150 p.

The manual is intended for students majoring in E3 "Chemistry" and natural sciences who are studying the following courses: "Monitoring of Chemical Parameters of the Atmosphere," "Air Quality Monitoring: European Experience," "Air Quality Control," "Environmental Chemistry," "Ecology," and "Atmospheric Chemistry." It may be used by full-time and part-time students to carry out research work and solve scientific and applied problems related to the study of the ecological state of atmospheric air and the possibilities of its monitoring. The textbook contains theoretical material and the results of experimental research. It highlights information about the approaches of European Union countries to monitoring environmental objects as well as the processes of harmonizing Ukrainian environmental monitoring with European requirements. Studying the material in the manual will contribute to the promotion of European environmental principles and the right to a safe living environment, providing course participants and the public with accurate and up-to-date information on the state of atmospheric air quality and methods used for its monitoring.

“Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or [name of the granting authority]. Neither the European Union nor the granting authority can be held responsible for them.”

© Khatsevych O.M., Mykytyn I.M., Fedorchenko S.V., Kurta S.A., 2026

© Vasyl Stefanyk Carpathian National University, 2026

CONTENTS

Introduction	5
Chapter 1. Main sources of pollution and pollutants of the atmosphere in Europe	6
1.1. Air quality status in Europe	6
1.2. EU actions to improve ambient air quality	8
1.3. Sources of air pollutant emissions in the EU and actions to reduce them	14
1.4. The impact of air pollution on health in Europe	21
1.5. The impact of air pollution on the state of ecosystems in Europe	25
Chapter 2. Comparative analysis of European and Ukrainian environmental legislation, policy, and practice	29
2.1. Specific features of legal support for environmental monitoring in international law and EU legislation	29
2.2. Legal principles for the functioning of the State Environmental Monitoring System in Ukraine. National priorities	35
2.3. Analysis of institutional support the implementation of state environmental monitoring	39
Chapter 3. Monitoring air pollution in the EU using one European country as an example	42
3.1. Air pollution monitoring in the Czech Republic	42
3.2. Pollutant registers (PRTR systems in the EU and Ukraine)	44
3.3. An example of air quality improving in the Ostrava/Karviná/Frýdek-Místek agglomeration	47
3.4. Environmental inspection system in the Czech Republic	49
Chapter 4. The current environmental permitting system in the EU	52
4.1. Overview of the environmental permitting procedures in the EU	52
4.2. Environmental permitting process in the Czech Republic	57
4.3. Environmental permits in Ukraine	62
Chapter 5. Technical support for air quality monitoring in the EU	66
5.1. Approaches to air quality monitoring	66
5.2. Organisational and logistical aspects of ambient air quality monitoring	67
5.3. Modern methods and means of air pollution control	72
5.4. Application of sensors to air quality monitoring	79
5.5. Air quality monitoring systems in Poland.	81

Chapter 6. European EEA-EU experience in air quality indices calculation and implementation practices for real-time public information on air pollution and population health risks	83
6.1. Logistics and technical support for air quality monitoring.	83
6.2. European and Ukrainian experience in calculating air quality indices.	88
6.3. AIR measurements in Ukraine and Ivano-Frankivsk	93
6.4. Ukrainian state information resources developed to display information on monitoring of environmental objects	97
Chapter 7. Cooperation with civil society institutions in the European State Monitoring System. The role of public monitoring	100
7.1. Civil society	100
7.2. Involving public organizations in environmental governance	103
7.3. Strengthening environmental governance through capacity building of non-governmental organizations	104
7.4. The role of civil society organizations in facilitating community-level monitoring	107
7.5. Air quality monitoring and management – public participation in decision-making	110
7.6. Main problems of practical application of citizens' rights	118
Chapter 8. Air quality and other environmental objects under emergency conditions	125
8.1. The impact of the Russian war in Ukraine on the environment	125
8.2. Environmental and economic damages from Russian military aggression for the world and Ukraine	132
References	142

Introduction

The Association Agreement between Ukraine and the EU requires Ukraine to reform its national environmental monitoring and control system and ensure compliance with environmental legislation. Legislative and regulatory changes must comply with international legal documents that are binding in Ukraine (including relevant EU legislation) as well as with national legislation. Within the professional sphere and society, it is necessary to promote the dissemination of innovations in environmental monitoring and to bridge the gap in knowledge, skills, and competencies relative to European standards.

Currently, there is insufficient information among students and society about the environmental status of environmental objects (water, air), the possibilities for their monitoring, and the understanding of environmental safety and the right to it.

The aim of this manual and the corresponding course is to promote European environmental principles and the right to safe living environment, providing the public with accurate and up-to-date information. The material in the manual will introduce students to the European Union's approaches to monitoring environmental objects and the processes of approximation of Ukrainian environmental monitoring to European requirements. It is designed to foster in students an active environmental stance grounded in European values, as well as the knowledge and skills necessary to address climate change, which will be important for the future of sustainable growth and European cohesion.

Air pollution is the most significant environmental health hazard in Europe, causing cardiovascular and respiratory diseases that lead to the loss of healthy years of life and, in the most serious cases, premature death.

The assessment indicates that air quality standards are commonly exceeded throughout the EU, with pollutant concentrations significantly surpassing the latest World Health Organization (WHO) recommendations.

CHAPTER 1.

Main sources of atmospheric pollution and air pollutants in Europe.

1.1. Air quality status in Europe.

Air pollution is defined as the presence in the atmosphere of one or more pollutants, such as dust, vapors, gas, fog, odors, smoke, or steam, in quantities and over durations that may be harmful to human health.

Over the past decades, air pollution in Europe has steadily declined, however it remains the most significant environmental health threat in the region, causing disease, reducing quality of life, and leading to preventable deaths. In addition to health problems, air pollution can have a significant impact on Europe's economy through increased healthcare expenditures, reduced life expectancy, and the loss of working days across various sectors. It also damages vegetation and ecosystems, water and soil quality, and local ecosystems.

According to the European Environment Agency's (EEA) new report, “The European environment 2025”, the overall environmental situation in Europe remains unsatisfactory. The EEA has published a report on the state of the environment every five years since 1995, as required by its regulations. The report was prepared in close cooperation with the EEA's European Environment Information and Observation Network (Eionet), drawing on the extensive expertise of Eionet's leading environmental experts and scientists from 32 EEA member countries and six cooperating countries. The report provides thorough, science-based conclusions on how European Union countries should respond to complex challenges such as climate change, biodiversity loss, and air and water pollution.

The report highlights that the European Union is a global leader in efforts to address climate change, having reduced greenhouse gas emissions and the use of fossil fuels, and doubling the share of renewable energy sources since 2005. Significant progress has also been achieved over the past 10-15 years in improving air quality, increasing waste recycling, and enhancing resource efficiency. Progress in a number of factors supporting the transition to sustainable development, such as innovation, green employment, and sustainable finance, also provides a reason for hope.

However the overall state of Europe's environment remains unsatisfactory, especially its nature, which continues to face degradation, overexploitation, and biodiversity loss. The consequences of accelerated climate change are also an urgent concern. The outlook for most environmental trends is worrying and poses serious risks to Europe's economic prosperity, security, and quality of life.

The EU has established air quality standards to reduce the risks associated with air pollution. The current EU standards were set in the ambient air quality directives of 2004 and 2008 (EU, 2004) (EU, 2008). The World Health Organization (WHO) published its air quality guidelines levels in 2021. These guidelines set concentration levels that are lower than the EU limit and target values and are intended to prevent significant impacts of air pollution on human health. The report "The European environment 2025" presents an analysis of the latest officially recorded pollutant concentrations in Europe for 2023 and 2024 compared to the current and future (2030) EU limit values, as well as the stricter levels established by the World Health Organization.

Directive (EU) 2024/2881 on ambient air quality and cleaner air for Europe (recast) (EU, 2024) entered into force on December 10, 2024, marking an important milestone in efforts to further reduce air pollution. The Directive establishes new and revised air quality standards that are to be achieved by January 1, 2030. Member States are granted a two-year period to adopt and transpose the laws, regulations, and administrative provisions.

Air quality in Europe has improved significantly over the past few decades for most of the 12 air pollutants that are subject to legislative air quality limits under EU law:

- particulate matter PM_{2.5},
- particulate matter PM₁₀,
- sulfur(IV) oxide SO₂,
- nitrogen(IV) oxide NO₂,
- ozone O₃,
- carbon (II) oxide CO (carbon monoxide),
- lead Pb,
- arsenic As,
- cadmium Cd,
- nickel Ni,
- benzene C₆H₆,
- polycyclic aromatic hydrocarbons.

For certain pollutants, such as benzene and cadmium, European countries already comply with the air quality standards established under European Union legislation. Positive improvements can also be seen for other air pollutants such as SO₂, CO, lead, arsenic, or nickel. Nevertheless, in a significant number of locations across the EU, concentrations of other pollutants exceed current standards, as well as the stricter values established by the WHO.

Conclusions on the state of air quality in Europe:

1. EU air quality standards are still not fully complied with across Europe, despite steady overall improvements.

2. Since 2011, all countries have reduced the exposure of urban population to particulate matter PM_{2.5}, which are the most harmful pollutant in terms of health. Nevertheless, the vast majority (94%) of the EU's urban population continues to be exposed to PM_{2.5} concentrations that exceed the level set by the World Health Organization. This implies an increased risk of health effects associated with this pollutant, such as respiratory and cardiovascular diseases, and the need for additional measures to reduce the associated health risks. Achieving the recently revised EU limits set for 2030 will help reduce these health impacts and bring air quality levels closer to those recommended by WHO in the coming years.

3. In many places, pollutant concentrations in the air are already below the new EU standards set for 2030. However, in order to achieve compliance with these new standards everywhere, and based on current progress, additional air quality improvement measures are likely to be needed, especially in cities.

1.2. EU actions to improve ambient air quality.

The European Union's "Green Deal" or "Green Course," launched in December 2019, set the objective of making Europe the first climate-neutral continent by 2050. That is, a place where all greenhouse gas emissions caused by human activity will be absorbed by ecosystems and carbon capture and storage technologies.

The Green Deal is a roadmap that includes strategies for developing a sustainable, clean, safe, and healthy Europe. It consists of an action plan aimed at making the EU economy more resilient by turning climate and environmental challenges into opportunities across all sectors. The EGC covers all sectors of the

economy, including transport, energy, agriculture, construction, and industry. Action Plans have been developed for different sectors.

Within the framework of the European Green Deal, the European Commission committed to further improving air quality and bringing EU air quality standards more in line with WHO recommendations. This commitment was reflected in the Zero Pollution Action Plan, which sets out a vision for 2050 of reducing air, water, and soil pollution to levels that are no longer considered harmful to health and natural ecosystems. In addition, the Zero Pollution Action Plan introduced targets for 2030, two of which focus specifically on air quality and aim to:

- reduce the health impacts (premature deaths) of air pollution by more than 55% compared to 2005;
- reduce the proportion of EU ecosystems where air pollution threatens biodiversity by 25% compared to 2005.

Directive (EU) 2024/2881 on ambient air quality and cleaner air for Europe (EU, 2024) is a key element for achieving the European Union's ambitious pollution targets for 2050. The Directive introduces a number of significant changes.

1. Air quality standards that provide enhanced protection.

The revised Directive significantly strengthens air quality standards, bringing them more closely into line with WHO recommendations. For example, it reduces the annual limit value for fine particulate matter (PM_{2.5}) by more than half and introduces new, stricter exposure reduction targets for NO₂, aligning the average exposure targets with WHO annual guideline levels established by the World Health Organization (WHO, 2021).

Recognizing that some Member States may face challenges in achieving the new air quality standards, the revised Directive includes flexibility mechanisms. Under certain conditions, it is possible to request a postponement of the achievement of the new air quality standards.

2. More extensive air quality monitoring and modeling.

Assessment thresholds determine when continuous measurements are required. These have been lowered in line with WHO guidance levels, meaning that additional monitoring stations will be required across Europe. The revised Directive also expands the scope of monitoring to include previously unregulated pollutants, such as ultrafine particles, aerosol black carbon, and ammonia. A new concept of "super sites" has been introduced. These are monitoring sites where

additional pollutants of concern will be measured in both rural and urban areas, providing important scientific data for a better understanding of their impact on human health and the environment, as recommended by the WHO.

The concept of "hot spots" has also been introduced. It identifies areas with particularly high levels of pollution that require special monitoring efforts. In addition, there is a specific obligation to measure excess pollution levels (UEP) at hot spot locations.

Air quality modeling will play a more significant role in air quality assessment, helping to determine the spatial representativeness of air quality monitoring stations. Furthermore, the use of modeling will become mandatory for assessing the extent to which air quality standards are exceeded.

3. More effective implementation measures, improved public information, and continuous improvement.

The revised Directive also strengthens compliance and enforcement measures. To ensure compliance, Member States must develop air quality roadmaps prior to the entry into force of the 2030 standards if the limit or target values for 2030 are exceeded between 2026 and 2029. These strengthened air quality plans are intended to increase efficiency in addressing and preventing exceedances of EU air quality standards.

Public information must now include mandatory air quality indicators and data on health impacts, especially for vulnerable groups. Member States are required, for example, make information on symptoms associated with air pollution peaks and protective behavior publicly available.

Citizens affected by air pollution can also claim compensation if EU air quality legislation is violated. Improved enforcement also includes new provisions on access to justice, compensation, and penalties.

The revised Directive represents a significant milestone in Europe's efforts to address air pollution, however further efforts will be needed across the European Union to achieve continued improvements in air quality and to attain the levels recommended by the WHO. To ensure continuous progress, the revised Directive provides for periodic reviews. The first is scheduled for December 31, 2030, with subsequent reviews every 5 years.

The revised Directive (EU) 2024/2881 (EU, 2024) introduces stricter air quality standards for most pollutants compared with the Directive 2008/50/EC on ambient air quality (EU, 2008). Most of the revised air quality standards have

been aligned with the WHO’s interim targets prior to the adoption of WHO guideline levels (WHO, 2021).

Below is a comparative analysis of the standards of the Air Quality Directive 2008/50/EC (EU, 2008) and the revised Directive (EU) 2024/2881 (EU, 2024) for the most significant air pollutants.

1. PM₁₀ – the daily limit value (DVL) for 24-hour concentrations of PM₁₀ has been reduced from 50 µg/m³ to 45 µg/m³, while the permitted number of exceedances allowed per year has been reduced from 35 to 18 days. Likewise, the annual limit value (ALV) has been halved from 40 µg/m³ to 20 µg/m³.

Below is a map of PM₁₀ concentration levels in 2023 relative to the EU's annual limit value for 2030. In 2023, 74% of reporting stations had concentrations below the 2030 ALV. In eight Member States (Denmark, Estonia, Germany, Ireland, Latvia, Lithuania, Luxembourg, and the Netherlands), concentrations were below the ALV 2030 at all stations in 2023. Moreover, all measured PM₁₀ levels in Iceland, Switzerland, and Andorra (non-EU members) were below the 2030 ALV in 2023.

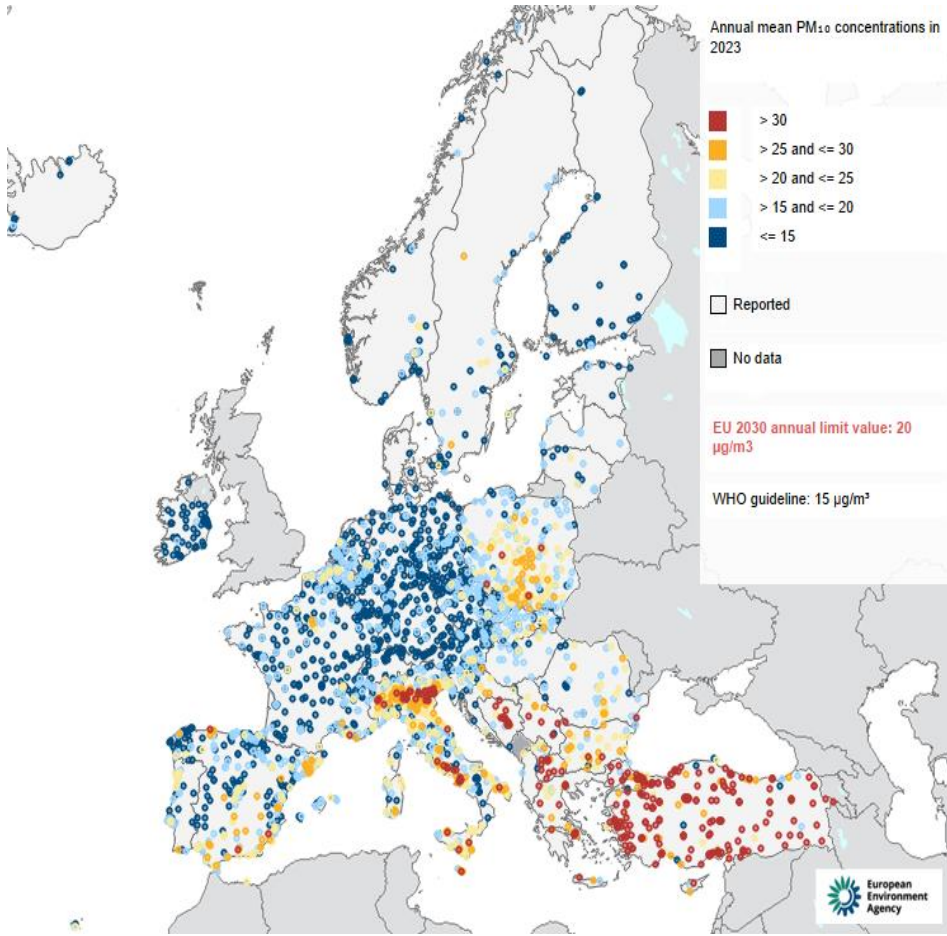


Fig. 1. Map of PM₁₀ concentrations in 2023 relative to the EU's 2030 annual limit value.

2. PM_{2.5} – a new daily limit value (DLV) of 25 µg/m³ has been introduced, with a maximum exceedance of 18 days per year. In addition, the annual limit value (ALV) has been reduced from 25 µg/m³ to 10 µg/m³.

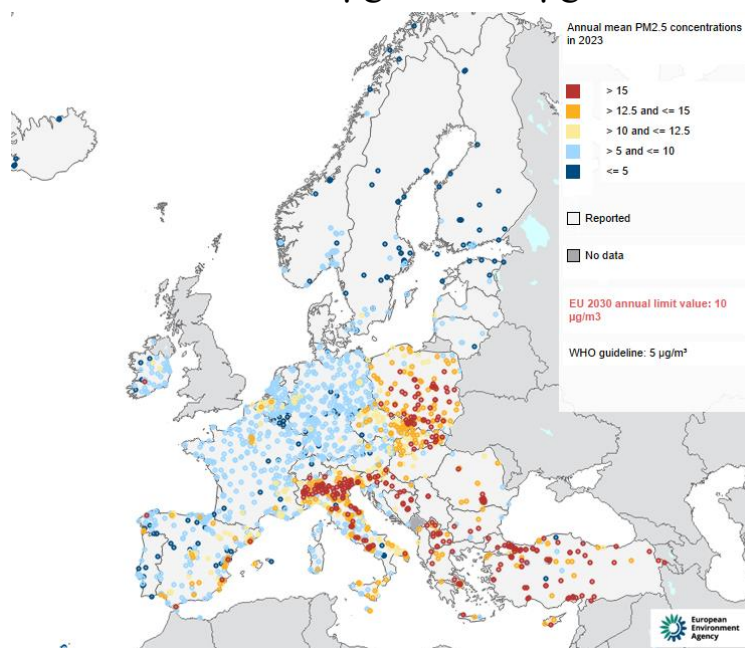


Fig. 2. Map of PM_{2.5} concentrations in 2023 relative to the EU annual limit value for 2030.

In 2023, concentrations were below the 2030 ALV at 69% of reporting stations. In 11 Member States (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, and Sweden), all reporting stations recorded concentrations below the 2030 ALV in 2023. PM_{2.5} levels in Andorra, Iceland, and Switzerland were below the 2030 ALV in 2023.

3. O₃ – the target value for ozone concentrations for the protection of human health, defined as the maximum 8-hour daily average, remains at 120 µg/m³, but the permitted number of exceedance days per year has been reduced from 25 to 18 days, averaged over 3 years. The long-term ozone target to protect human health has been aligned with the WHO's short-term recommended value for ozone to protect human health, 100 µg/m³, which is to be achieved by January 1, 2050.

In 2023, 71% of reporting stations had concentrations below the 2030 threshold. In seven Member States (Ireland, Latvia, Sweden, Finland, Estonia, Denmark, and Lithuania), all reporting stations recorded concentrations below the 2030 target value at all reporting stations in 2023. O₃ levels in Norway,

Albania, and Andorra were also below the 2030 threshold at all reporting stations in 2023.

4. NO₂ – the hourly limit value (HLV) remains unchanged (200 mg/m³), however, the revised Directive allows only three exceedances per year (instead of 18 exceedances permitted under the 2008 Directive). A new daily limit value (DLV) has been included in the 2024 Directive at a level of 50 µg/m³, whereas the 2008 Directive did not define a daily limit value. In addition, in the revised Directive, the annual limit value (AVL) has been halved from 40 µg/m³ to 20 µg/m³.

In 2023, 98.5% of reporting monitoring stations recorded NO₂ concentrations below the 2030 HLV. All stations in 23 Member States reported concentrations below the 2030 limit value in 2023. By contrast, only four Member States (Belgium, Greece, Italy, and Spain) each reported one monitoring station exceeding the HLV. All other reporting countries had concentrations below the 2030 HVL in 2023, except for Turkey.

Data on other pollutants indicate that a significant proportion of reporting air quality monitoring stations already recorded concentrations below the 2030 standards, particularly with regard to short-term standards. The largest number of stations with concentrations already below the revised air quality standard is observed for CO, C₆H₆ and SO₂. Overall, among all pollutants, SO₂ made the largest reduction, with average concentrations declining by more than 60% between 2005 and 2021.

However, challenges remain in maintaining concentrations below the AVL, especially for PM and NO₂, where concentrations at some stations significantly exceeded the 2030 standards. Overall, NO₂ levels decreased by about 38% over the same period, although there are notable differences between countries. PM₁₀ concentrations declined by 42% between 2005 and 2021, with a similar trend observed for PM_{2.5}.

Air quality levels vary across Europe depending on the pollutant.

The more ambitious air quality standards set by the revised Directive imply that Member States will need to further reduce emissions of air pollutants in order to achieve compliance by 2030. According to the Fourth Clean Air Outlook (EC, 2025), ambient concentrations of air pollutants are expected to decrease over time. However, under the baseline scenario, it is projected that 87% of the EU population will still be exposed to PM_{2.5} levels exceeding the WHO recommended level of 5 µg/m³ in 2030.

This analysis is limited to currently existing monitoring stations, although their number is expected to increase by 2030 to comply with the new regulatory requirements. Air quality monitoring networks and air quality control zones may also be adjusted to comply with the revised Directive.

The revised standards are not mandatory until 2030, consequently, air-pollution levels may improve in certain European regions before that date.

1.3. Sources of air pollutant emissions in the EU and actions to reduce them.

Air pollutants can be of natural, anthropogenic, or mixed origin, depending on their sources or the sources of their precursors. In addition, air pollutants can be classified as primary and secondary. Primary pollutants are emitted directly into the atmosphere, whereas secondary pollutants are formed in the atmosphere from pollutant precursors through chemical reactions and microphysical processes.

The main primary air pollutants include: particulate matter (PM) with a diameter of 10 micrometers and 2.5 micrometers and less (PM₁₀ and PM_{2.5}), black carbon (BC), sulfur oxides (SO_x), nitrogen oxides (NO_x), ammonia (NH₃), carbon monoxide (CO), methane (CH₄), non-methane volatile organic compounds (NMVOCs), including benzene, as well as certain metals and polycyclic aromatic hydrocarbons, including benzo[a]pyrene (BaP).

The main secondary air pollutants include: PM, ozone (O₃), nitrogen dioxide (NO₂), and several oxidised volatile organic compounds (VOCs). The key precursor gases for secondary PM are: sulfur dioxide (SO₂), NO_x, NH₃, and VOCs.

PM₁₀ refers to particulate matter with a diameter of 10 micrometers or less, consisting of sulfates, nitrates, ammonia, sodium chloride, black carbon, mineral dust, or water. PM₁₀ is emitted mainly from the combustion of solid fuels for domestic heating, although industrial activities, agriculture, and road transport are also important sources. Some PM₁₀ originates from natural sources such as sea salt, Saharan dust, or volcanic activity, while some (secondary PM) are formed in the atmosphere as a combination of different gases (e.g., ammonia and nitrogen dioxide). Concentrations exceeding the EU daily limit value for PM₁₀, are mainly observed in Italy and in several Eastern European countries. In many Central and Eastern Europe countries, solid fuels such as coal and wood are

widely used for domestic heating, as well as in some industrial facilities and power plants. This is the main reason for the exceedances in Central and Eastern Europe, together with older vehicle fleet.

PM_{2.5} – refers to particulate matter with a diameter of 2.5 micrometers or less. These particles are mainly emitted from the combustion of solid fuels for domestic heating, industrial activities, and road transport. Similar to PM₁₀, they can also originate from natural sources and be formed in the atmosphere. In this regard, agricultural ammonia emissions contribute significantly to their formation.

Concentrations of PM_{2.5} exceeding the EU annual limit value are observed in Italy, Turkey, and most Western Balkans countries.

Ozone (O₃) is a pollutant formed in the atmosphere as a result of chemical reactions in the presence of sunlight between nitrogen oxides, CO, and volatile organic compounds (VOCs), including methane (which is also a powerful greenhouse gas). Emissions of these precursor gases come from anthropogenic sources, while VOCs also have significant biogenic sources. Ozone is additionally transported to Europe from other parts of the northern hemisphere and the upper atmosphere. In 2023, the highest ozone concentrations were observed in the eastern Mediterranean, Italy, the Iberian Peninsula, and Central Europe.

The main source of nitrogen dioxide (NO₂) is road transport, which emits NO₂ at the ground level, mainly in densely populated areas, contributing to its impact on the population. Other important sources include combustion processes in industry and energy supply. Exceedances of the annual limit value were found in many Turkish cities and in some large cities with high traffic intensity.

Benzo(a)pyrene (BaP) is a carcinogenic pollutant emitted mainly through the combustion of coal and wood for residential heating and, to a lesser extent, from industrial installations and the burning of agricultural waste. The highest concentrations have been observed in Italy and Eastern Europe, where the use of coal and other solid fuels for residential heating is widespread.

The economic sectors contributing to air pollutant emissions vary depending on the pollutant; differences between Member States arise due to variations in national economic structures.

The European Green Deal has helped to make Europe's industry greener and more digital. Recently, the revision of the Industrial Emissions Directive and the new Industrial Emissions Portal Regulation (IEPR) aim to encourage large

European industries towards decarbonisation, zero pollution, a circular economy, and innovation. It is expected that the strengthening of the EU Air Quality Directive will further support this development by aligning pollution limits closer with the World Health Organization's health recommendations.

The National Emission Ceilings (NEC) Directive (2016/2284/EU) is one of the legislative instruments under the European Green Deal (EC, 2019). The NEC Directive entered into force on December 31, 2016. Supporting the ambition of zero pollution, it contributes to achieving a toxin-free environment and to reaching the 2030 air pollution related targets.

The Directive sets national emission reduction commitments for 2020-2030 for five key air pollutants: nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulfur (IV) oxide (SO₂), ammonia (NH₃) and fine particulate matter (PM_{2.5}). These pollutants deteriorate air quality, leading to significant negative impacts on human health and the environment.

Under the NEC Directive, Member States are required to develop and implement National Air Pollution Control Programs (NAPCPs) that contribute to the successful implementation of air quality plans developed in accordance with the EU Air Quality Directive. These programmes must include emission reduction measures in relevant sectors to ensure compliance with national commitments. NAPCPs should work in connection with other policies, such as climate change mitigation. Ensuring policy coherence enhances the impact of government intervention.

To ensure that the emissions information provided by Member States is consistent within the EU and aligned with international requirements, the NEC Directive requires Member States to follow methodologies agreed by the UN Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (LRTAP Convention) (Air Convention). The Directive also requires Member States to apply the EMEP/EEA Air Pollutant Emission Inventory Guidebook when preparing their national emission inventories.

The European Commission (EC) is currently reviewing the NEC Directive (EC, 2024). The assessment, which will be completed by December 31, 2025, will determine the extent to which the Directive has achieved its objective of protecting human health and the environment by reducing national emissions of the five key air pollutants.

The European Environment Agency (EEA) holds annual briefings that assess Member States' progress in meeting their emission reduction commitments for 2020-2029 under the NEC Directive. Data for 2023 were reported by Member States in 2025. This data indicate that 19 Member States complied with their emission reduction commitments for all five key air pollutants for the 2020-2029 period. Meanwhile, eight Member States failed to meet their emission reduction commitments for at least one of the five main air pollutants. For almost a quarter of Member States, reducing NH₃ emissions remains the most important challenge.

Since 2005, NH₃ emissions have decreased only slightly in many Member States, and in some cases have even increased. This highlights the need for more effective policies to reduce emissions in the agricultural sector, which is the main source of NH₃ emissions in the EU. Agricultural practices aimed at reducing NH₃ emissions include improvements in fertiliser application techniques and manure management, as well as optimisation of livestock feeding rations.

Efforts needed to fulfill national commitments in order to reduce emissions of other pollutants from 2030 onwards should be carried out in the following directions:

1. PM_{2.5} – Twelve (12) Member States have already met their commitments to reduce PM_{2.5} emissions by 2030 in 2023. However, the combustion of solid biomass and fossil fuels for residential heating still contributes significantly to PM_{2.5} emissions in some Member States. Therefore, improving insulation and modernizing heating systems, as well as installing low-emission boilers or transiting to cleaner fuels, remain key measures for reducing PM_{2.5} emissions. In addition to further efforts in the energy sector, there is also scope for further emission reductions in the manufacturing and extractive industries, as well as in the road transport sector. This includes emissions from internal combustion engines and from tire and brake wear in vehicles.

2. NO_x – Ten (10) Member States have already met their NO_x emission reduction commitments for 2030 by 2023. However, 17 Member States will need to further reduce their NO_x emissions. Efforts to reduce NO_x emissions are particularly required in the road transport and energy supply sectors.

3. NMVOCs – Sixteen (16) Member States have already met their 2030 emission reduction commitments in 2023. As the manufacturing and extractive sector are the main sources of emissions, there is potential to focus NMVOC reduction measures on industrial sectors.

4. SO₂ – Progress in reducing SO₂ emissions has been more positive compared to other pollutants overall, with only two Member States facing difficulties in meeting their emission reduction commitments for 2030. Energy supply is the main source of SO₂ emissions in the EU, while the manufacturing and extractive industry is the second largest source of emissions.

Figure 3 provides a visual representation of the five main air pollutant sources represented in the NEC Directive.

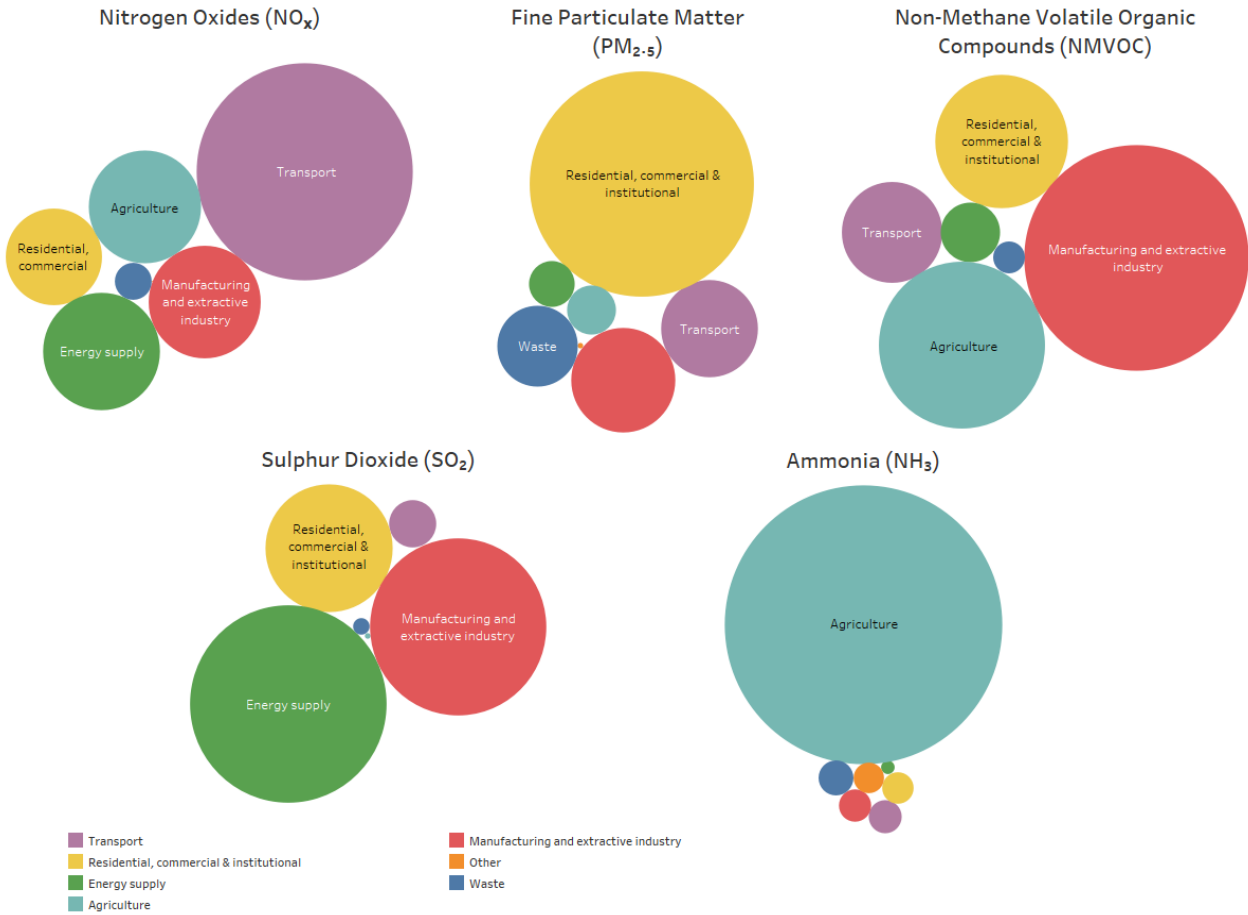


Fig. 3. Sectors and activities contributing to the five regulated air pollutant emissions in EU Member States

In 2023, there was a slight decrease in total air pollutant emissions across Member States, continuing the overall downward trend observed since 2005 (Fig. 5).

Between 2005 and 2023, emissions of PM_{2.5} and PM₁₀ declined by 38% and 36%, respectively. SO₂ emissions decreased by 85%. Significant reductions were also observed for NO_x (53%), black carbon (BC, 50%), carbon monoxide (CO, 47%), and non-methane volatile organic compounds (35%). Remarkably, NH₃

emissions decreased by only 17%, representing the smallest reduction among all pollutants.

From 2005 to 2023, emissions of nickel (Ni) and arsenic (As) decreased by 73% and 68%, respectively. By contrast, emissions of mercury (Hg), lead (Pb), and cadmium (Cd) declined by 57%, 46%, and 43%, respectively. BaP emissions decreased by only 28%.

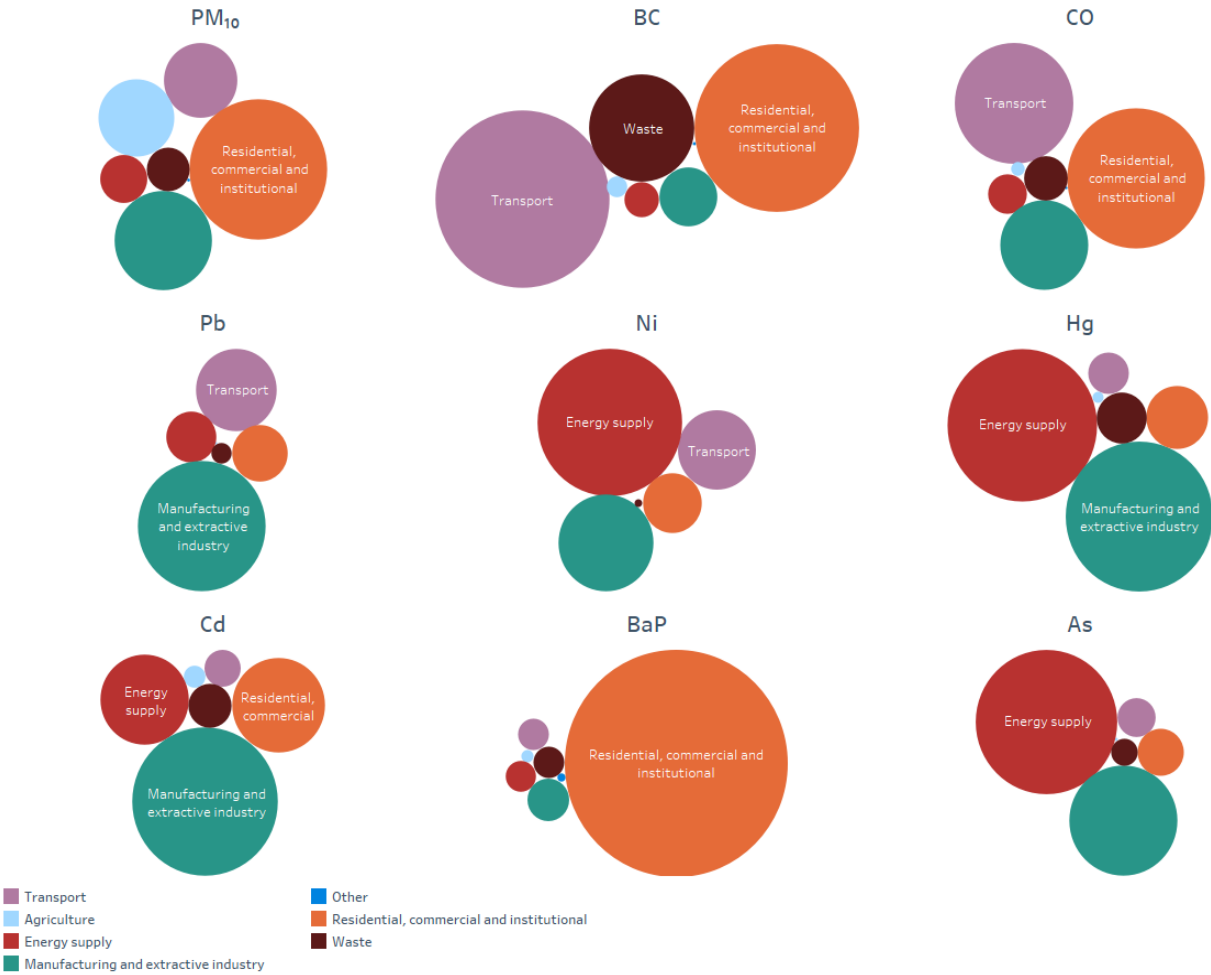


Fig. 4. Sectors and activities contributing to emissions of other air pollutants in EU Member States in 2023

Air pollutant emissions in EU member states decreased between 2005 and 2023, while GDP increased by 32%. This represents a significant absolute decoupling of emissions from economic activity over the 2005-2023 period. Absolute decoupling occurs when an environmental impact variable, such as air pollutant emissions, remains stable or declines while GDP increases. Decoupling emissions from economic activity leads to a reduction in air pollutant emissions

per unit of GDP produced annually. This outcome may arise from a combination of factors such as tighter regulation and policy implementation, fuel switching, technological improvements, and increases in energy or technological efficiency.

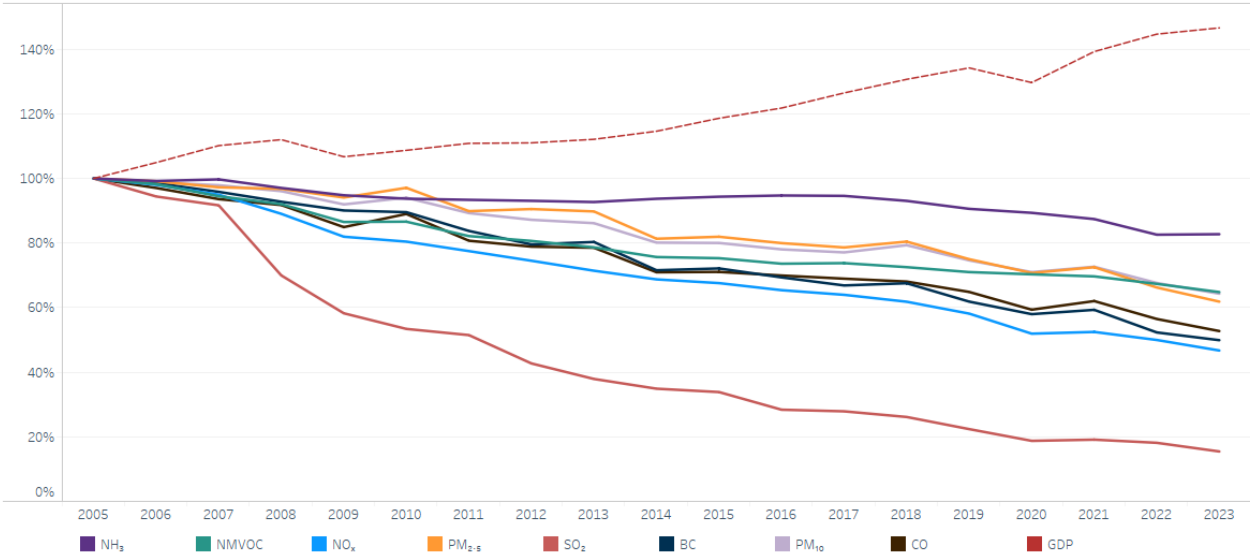


Fig. 5. Trends in emissions of NH₃, NMVOC, NO_x, SO₂, primary PM_{2.5}, primary PM₁₀, BC, and CO in the EU from 2005 to 2023

Therefore, according to data provided by EU Member States in 2025 on their emissions for 2023, the main results achieved by the EU and its Member States in reducing emissions of air pollutants regulated by the National Emission Reduction Commitments Directive (EU/2016/2284) are as follows:

1. In 2023, 19 Member States have complied with their national emission reduction commitments for the 2020-2029 period for each of the five main air pollutants. By contrast, eight Member States failed to meet their commitments for at least one pollutant.
2. The reduction of ammonia (NH₃) emissions represents the biggest challenge: six Member States need to reduce emissions even further in order to meet their emission reduction commitments for 2020-2029.
3. The most progress has been achieved in reducing sulfur (IV) oxide (SO₂) emissions, with 25 Member States already meeting their emission reduction commitments for 2030.
4. Almost all Member States will face a significant challenge in meeting the more stringent emission reduction commitments for 2030 and beyond for almost all air pollutants.

1.4. The impact of air pollution on health in Europe.

European Union legislation has led to significant improvements in air quality. The percentage of urban residents exposed to pollutant levels exceeding legal limits established to protect human health declined between 2000 and 2023, particularly for particulate matter and nitrogen dioxide (NO₂). However, poor air quality remains a concern.

The latest estimates of the health impacts on EU population resulting from long-term exposure to the most dangerous air pollutants – fine particulate matter, NO₂ and ozone – based on data up to 2023, are summarized in the following conclusions:

1. Although significant progress has been made in reducing air pollution, 95% of urban Europeans are still exposed to air pollutant concentrations that exceed World Health Organization (WHO) recommendations. More than 94% of urban residents are exposed to dangerous levels of fine particulate matter (PM_{2.5}).

2. Reducing air pollution to WHO recommended levels could have prevented 182,000 deaths related to exposure to fine particulate matter (PM_{2.5}), 63,000 from exposure to O₃, and 34,000 from exposure to NO₂ in the EU in 2023.

3. For some diseases caused and/or exacerbated by air pollution, such as asthma, the main consequence is poor health. For others, such as ischemic heart disease and lung cancer, it is premature death.

4. New evidence suggests that air pollution may also contribute to the development of dementia. The estimated burden of dementia is higher than that of other related diseases.

5. Countries in Eastern and Southeastern Europe are most affected by air pollution due to high pollution levels.

Although there are many toxins that negatively affect health, the pollutants with the most compelling evidence for public health concern are particulate matter (PM), carbon monoxide, ozone, nitrogen dioxide (NO₂), and sulfur dioxide SO₂. Fine particulate matter is a particularly important source of health risks because these very small particles can penetrate deep into the lungs, enter the bloodstream, and spread to organs, causing systemic damage to tissues and cells.

The main route of exposure to air pollution is through the respiratory tract. Inhalation of these pollutants leads to inflammation, oxidative stress, immunosuppression, and cell mutagenicity throughout the body, affecting the lungs, heart, brain, and other organs, and ultimately leading to disease.

Almost every organ in the human body can be affected by air pollution. Due to their small size, some air pollutants are able to enter the bloodstream through the lungs and circulate throughout the body, leading to systemic inflammation and carcinogenicity.

Air pollution poses a risk for all-cause mortality, as well as the development of certain diseases. Specific diseases that are most closely associated with exposure to air pollution include stroke, ischemic heart disease, chronic obstructive pulmonary disease, lung cancer, pneumonia, and cataracts (only household air pollution).

There is also compelling evidence linking exposure to air pollution with an increased risk of adverse pregnancy outcomes (i.e., low birth weight, small size for gestational age), other types of cancer, diabetes, cognitive impairment, and neurological diseases.

Health problems in both children and adults can arise from either short-term or long-term exposure to air pollutants. The levels and duration of exposure that may be considered "safe" depend on the pollutant as well as on the associated health effects. For some pollutants, there are no threshold levels below which adverse effects do not occur.

For example, short-term exposure to high levels of particulate matter can lead to reduced lung function, respiratory infections, and asthma exacerbations. Whereas long-term or chronic exposure to fine particulate matter increases the risk of developing diseases with a longer onset, such as certain non-communicable diseases, including stroke, heart disease, chronic obstructive pulmonary disease, and cancer.

Air pollution is a cause of morbidity and premature death. People who suffer from diseases related to exposure to air pollution bear a burden in terms of personal suffering, as well as significant costs to the healthcare sector.

The "environmental burden of disease" concept is used to assess the overall health damage caused by air pollution. The burden of disease can generally be measured using four indicators, including mortality and morbidity:

1. Years lived with disability (YLD) – an indicator, which assesses the amount of healthy life lost due to disability or disease. It was originally developed by Harvard University for the World Bank and is now increasingly used in the health sector, including by the WHO.

2. Attributable Deaths (AD) – the number of causal deaths that occur due to a specific disease or group of diseases and are associated with a specific risk.

3. Years of life lost (YLL) – an indicator that estimates the amount of healthy life lost due to premature death caused by a disease or group of diseases; it represents an estimate of the average number of additional years that people in a population could have lived, statistically, if they had not died before reaching a certain statistical life expectancy.

4. Disability-adjusted life years (DALY) – the combined indicator of mortality and morbidity representing years of life adjusted for disability. DALY corresponds to one year of healthy life lost due to disease or injury. DALY is obtained by summing YLL and YLD for the same disease or group of diseases (Fig. 6). Thus, DALY is a standardized indicator of health consequences resulting from both the number of people affected by a disease and the number of people who have died from it.

The assessment of the environmental burden of disease for the most dangerous air pollutant – PM_{2.5} – can be summarized as follows:

1. In 2023, 182,000 deaths in the EU-27 countries were caused by PM_{2.5} concentrations exceeding the WHO recommended level of 5 µg/m³. This resulted in a loss of 1,914,000 years of life (YLL).



Fig. 6. DALY – a social indicator of morbidity or disability burden among the population

The number of premature deaths decreased by 57% between 2005 and 2023, indicating progress toward the objective of the Zero Pollution Action Plan for 2023.

The highest absolute number for all-causes deaths in 2023 was observed in Italy, Poland, and Germany (in descending order). However, the highest relative

impact (years of life lost per 100,000 population aged 30 years and above) was observed in Bulgaria, Greece, and Romania, in descending order.

The lowest relative impact (years of life lost per 100,000 population aged 30 years and above) due to PM_{2.5} was observed in countries located in northern and north-western Europe, including Iceland, Finland, Sweden, Estonia, and Norway (in ascending order of disease burden).

The total burden of disease (including mortality and morbidity components) attributable to long-term PM_{2.5} exposure for specific diseases, is shown in the diagram (Fig. 7).

The results indicate a downward trend in the burden of disease caused by PM_{2.5} in Europe, partly due to a sharp decline in population exposure to this pollutant (concentrations decreased from 11.4 µg/m³ in 2022 to 10.2 µg/m³ in 2023, corresponding to a 10.5% reduction). This decrease is the result of the implementation of EU, national, and local policies aimed at improving ambient air quality (e.g., EU Ambient Air Quality Directive) and reducing air pollutant emissions (e.g., National Emission Ceilings Directive). These policies have contributed to a 38% reduction in emissions of fine particulate matter between 2005 and 2023. This reduction has been particularly significant in electricity and heat production sector, domestic fuel use, and road transport. Looking at specific primary sources of PM_{2.5}, it can be concluded that the reduction in emissions from residential heating in the EU has been particularly significant.

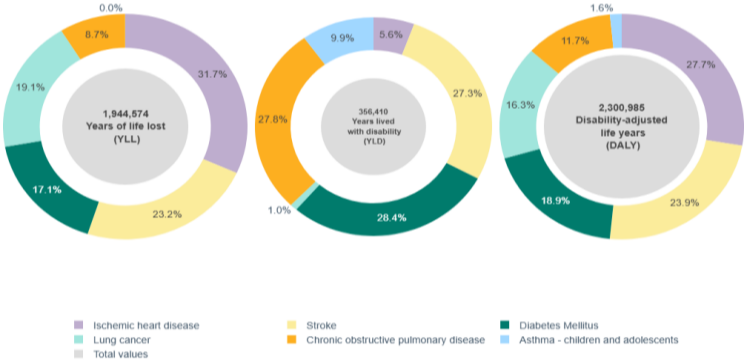


Fig. 7. Disease burden (YLL, YLD, DALY) attributable to PM_{2.5}, differentiated by disease

1.5. The impact of air pollution on the state of ecosystems in Europe.

Air pollution negatively affects both terrestrial and aquatic ecosystems, deteriorating the environment and reducing biodiversity. Vegetation is also

affected by major air pollutants. Different pollutants harm the ecosystem health in different ways.

The main conclusions of the report "Air Quality in Europe 2024" regarding the impact of major air pollutants on vegetation are as follows:

1. Atmospheric nitrogen increases nutrient load on habitats. In 2022, 73% of EU-27 ecosystems exceeded the critical load for eutrophication. The Zero Pollution Action Plan target of achieving a 25% reduction by 2030 (compared to 2005 levels) is now unlikely to be met.

2. In 2022, almost a third of Europe's agricultural land was affected by ground-level ozone (O_3) concentrations above the threshold set for vegetation protection in the EU's Ambient Air Quality Directive. This led to crop damage, reduced yields, and economic losses.

3. O_3 also damages other types of vegetation, thus affecting biodiversity. In 2022, 62% of the total forest area across 32 EEA member countries exceeded the critical levels set for the protection of forests.

4. Significant reductions in sulfur dioxide (SO_2) emissions over the past decades have largely solved the problem of acidification.

Let's look at the impact of major air pollutants on vegetation. The analysis is based on both modeled estimates of overall impact and measurements obtained from monitoring stations in rural areas.

Ground-level ozone (O_3) is a secondary air pollutant formed by the reaction of other pollutants, known as precursors (nitrogen oxides (NO_x) and volatile organic compounds, including methane), in the atmosphere under the influence of sunlight. Ozone damages crops, forests, and plants by slowing growth, reducing yields, and affecting biodiversity and ecosystem services. For instance, evidence of ozone's impact on crop yields highlights a reduction in wheat and potato yields, with losses in 2022 estimated at €1.3 billion for wheat and €680 million for potatoes across Europe.

Certain air pollutants settle on the surface of the earth, contributing to the degradation of receiving ecosystems. Nitrogen deposition on terrestrial and aquatic environments is mainly caused by ammonia from agricultural activities and NO_x from combustion processes. Excessive amounts of nitrogen inputs to ecosystems lead to several negative effects. In aquatic ecosystems, it contributes to eutrophication, which is characterized by algal blooms and reduced oxygen availability due to excess nutrients. In sensitive terrestrial ecosystems, such as meadows and pastures, exceedance of critical loads for nitrogen deposition may

cause the loss of sensitive species, increased growth of species that benefit from high nitrogen levels, and changes in ecosystem structure and functioning.

SO₂ can also have significant negative effects on ecosystems. Deposits of SO₂, as well as NO_x and NH₃, can lead to changes in the chemical composition of soils, lakes, rivers, and marine waters. This may result in acidification, which disrupts ecosystems and leads to biodiversity loss. The main sources of SO₂ are industrial activities and energy supply.

Heavy metals are toxic pollutants that can be transported over long distances in the atmosphere and settled in ecosystems. They accumulate in soils and are subsequently bioaccumulated (i.e. the substance accumulates in the body throughout its life) and biomagnified within the food chain (i.e. the concentration of substances in animal tissues gradually increases through the food chain). The main sources of heavy metals are manufacturing and extractive industries, energy supply, and road transport.

The European Environment Agency (EEA) report on the state of Europe's water resources states that "Europe's water resources continue to be affected by chemicals, mainly through atmospheric pollution from coal-fired power stations and diffuse pollution from agriculture." Countries report that the main factors contributing to surface water pollution are related to contamination from diffuse sources, such as atmospheric deposition (52%).

Air quality standards for the protection of vegetation.

The Ambient Air Quality Directives establishes standards for the protection of vegetation from air pollution, including a target value and long-term objective for ozone, as well as critical levels for NO_x and SO₂ (Table 1). The revised 2024 Ambient Air Quality Directive reiterates the previously agreed standards for the protection of vegetation from air pollution and the national commitments concerning the minimum number of monitoring locations. It also introduces standards that are more in line with World Health Organization's recommendations for the protection of human health.

Risk assessments and compliance assessments with critical levels for the protection of vegetation focus mainly on rural areas. As stated in the revised Ambient Air Quality Directive (EU, 2024), such assessments should also take into account and complement the requirements of the National Emission Reduction Commitments Directive regarding the monitoring of the impact of air pollution on terrestrial and aquatic ecosystems and regular reporting on such impacts. In accordance with the Convention on Long-range Transboundary Air

Pollution, known as the UNECE Air Convention, a critical level for ozone impact for the protection of forests has also been established. The various standards are presented in Table 1.

Table 1.

Air quality standards for the protection of vegetation

Pollutant	Averaging period	Standard type and concentration	Comments
O ₃	AOT40 ^(a) accumulated over May to July	EU target value: 18,000µg/m ³ per hour EU long-term objective: 6,000µg/m ³ per hour	Averaged over 5 years ^(b)
	AOT40 ^(a) accumulated over April to September	Critical level for the protection of forests: 10,000µg/m ³ per hour	Defined under the UNECE Air Convention
NO _x	Calendar year	EU critical level: 30µg/m ³	
SO ₂	Winter	EU critical level: 20µg/m ³	1 October to 31 March
	Calendar year	EU critical level: 20µg/m ³	

Impact of ground-level ozone on vegetation.

Air pollution from ground-level ozone damages vegetation. Ozone enters plant leaves, reducing photosynthesis, slowing plant growth, and increasing its vulnerability to pests and diseases. At the ecosystem level, high levels of ground-level ozone can cause a loss of species diversity and lead to changes in ecosystem structure and habitat quality. In industrial agriculture, ozone reduces crop yields and forest growth.

The revised EU Ambient Air Quality Directive 2024 sets January 1 2050, as the deadline for achieving the long-term objective of 6,000 µg/m³ per hour, which corresponds to the critical ozone level for crop protection as defined by the UNECE Convention on Long-range Transboundary Air Pollution. In 2022, only 11.2% of the total agricultural area of the EEA countries achieved this long-term objective. Exceedance of the critical level is associated with an increased risk of vegetation damage due to O₃ exposure.

Impact of NO_x and SO₂ on vegetation.

The impact of NO_x and SO₂ on vegetation can also be assessed using monitoring data provided to the EEA in accordance with the Ambient Air Quality Directive.

The annual critical level for the protection of vegetation from the effects of NO_x (annual average value of 30 µg/m³) was exceeded in 2022 at only 6 of the 393 rural background pollution stations reporting: one in Italy, one in the Netherlands, and four in Turkey. In most European countries, NO_x levels are estimated to be below the critical level for protecting vegetation. Regarding SO₂, the critical level (annual average value of 20 µg/m³) was exceeded at only one

station in Bosnia and Herzegovina out of 287 rural background stations that reported data for 2022.

Heavy metals.

Heavy metals emitted into the air are transported over long distances in the atmosphere and deposited in ecosystems. Heavy metals are toxic, and their persistence in ecosystems leads to their bioaccumulation within the food chain. In addition, the deposition of heavy metals in marine waters contributes to the presence of metals in marine organisms. Nine hazardous substances were monitored, including cadmium, lead, and mercury, and all exceeded the safe threshold limits established for human health protection).

An analysis of heavy metal concentrations in EU agricultural soils (JRC, 2024) conducted in accordance with the Sewage Sludge Directive indicated that 19% of samples exceeded the maximum permissible values for at least one heavy metal. According to a recent report on the state of Europe's water resources, atmospheric deposition also contributes to widespread mercury pollution, affecting 49% of surface waters.

Acidification.

Deposition of sulfur dioxide (SO₂), nitrogen oxides (NO_x), and ammonia (NH₃) alters the chemical composition of soils, lakes, rivers, and marine waters, leading to acidification. The impact of low pH values on freshwater and forest soils includes the release of toxic metals and the loss of nutrients, leading to fish mortality and forest decline, respectively.

Significant reduction in SO₂ emissions over recent decades has successfully addressed the problem of acidification. Between 2005 and 2022, SO₂ emissions in the EU-27 decreased by 81% (EEA, 2024b). The European Monitoring and Evaluation Program (EMEP), which models deposition data, estimates that exceedances of critical loads for acidification due to nitrogen and sulfur were identified in only 3.3% of European terrestrial ecosystems in 2022 (EMEP, 2024). Hot spots occurred in the Netherlands and along the borders with Germany and Belgium, as well as in small parts of southern Germany and the Czech Republic.

CHAPTER 2.

Comparative analysis of European and Ukrainian environmental legislation, policy, and practice.

2.1. Specific features of legal support for environmental monitoring in international law and EU legislation.

EU policy and legislation in the field of ambient air are systematic and have a long history. In general, the field of ambient air quality is very closely linked to climate change regulation. Some EU acts in this field are systematic and can be considered as separate mechanisms. Most legal acts related to fuel quality (except for sulfur content in fuel) are currently under the responsibility of DG CLIMA (The European Commission's Directorate-General for Climate Action) and are therefore not included in this section. Although some of these acts are included in the "Ambient Air Quality" section of Annex XXX to the Association Agreement. In addition, a significant number of legal acts concern greenhouse gas emissions from the transport sector (around 20 acts), which also belong to climate change sector (in particular, the new Regulation No. 2019/631 on establishing CO₂ emission standards for passenger cars and light commercial vehicles).

This area includes six main EU acts, along with a number of additional ones, and is closely linked to certain international agreements in this field, to which the EU is a party (such as the Convention on Long-range Transboundary Air Pollution and a number of associated protocols). It remains relevant and is undergoing significant changes as part of the implementation of the European Green Deal.

The European Union's "Green Deal" or "Green Course" is a program launched in December 2019, which promises to make Europe the world's first climate-neutral continent by 2050. That is, a place where all greenhouse gas emissions caused by human activity will be absorbed by ecosystems and technologies for carbon capture and storage.

The European Green Deal is a roadmap that includes strategies for developing a sustainable, clean, safe, and healthy Europe. It consists of an action plan aimed at making the EU economy sustainable by transforming climate and environmental challenges into opportunities across all sectors. The EGC covers

all sectors of the economy, including transport, energy, agriculture, construction, and industry. Action Plans for various sectors have been developed (Fig. 8). Each part of the plan sets out the EU's approved targets for 2030, which are important to achieve in order to reach the overall goal.

Over the past decades, the EU has taken decisive action to address climate change, resulting in a reduction of emissions by more than 30% in 2020 compared to 1990 levels. This is mainly the result of increased use of renewable energy sources and reduced consumption of carbon-intensive fossil fuels. Improvements in energy efficiency and structural changes within the economy have also contributed to these achievements.



Fig. 8. European Green Deal

Even more ambitious objectives have now been set: including a net reduction of greenhouse gas emissions of 55% by 2030 and the achievement of climate neutrality by 2050. This will require even greater emission reductions through a transition from fossil fuels to clean renewable energy, stopping deforestation, using land sustainably, and restoring nature until we reach a point where greenhouse gas emissions into the atmosphere are balanced by the capture and storage of these gases in forests, oceans, and soil.

The Ambient Air Quality Management Unit brings together several acts whose scope of application relates to ambient air protection in general.

Key legal acts:

- Directive (EC) 2024/2881 (EC, 2024) of the European Parliament and of the Council of October 22, 2022 on ambient air quality and cleaner air for Europe (consolidated text);
- Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (consolidated text);
- Directive (EU) 2016/2284 of the European Parliament and of the Council of December 14, 2016, on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC [4].

The key regulatory act within this block (and for the field of ambient air protection as a whole) is Directive 2024/2881 on ambient air quality and cleaner air for Europe, the main objective of which is to bring EU standards closer to WHO's recommendations. The update to the Directive also aims to strengthen provisions on air quality monitoring and modeling, as well as on the development of air quality plans in order to help local authorities to achieve cleaner air. The European Commission has published a proposal for the revision of the Ambient Air Quality Directive, with the following main changes:

- stricter pollution thresholds, more closely aligned with the new limits set by the World Health Organization,
- strengthening of the right to clean air and improving access to justice,
- Current legislation does not include provisions enabling citizens to claim compensation for health damage caused by air pollution; the new rules will bring more effective penalties and opportunities for compensation in case of violations of air quality rules.
- Enhanced air quality monitoring rules to support preventive action and targeted measures.
- Requirements to improve air quality modeling, especially in areas where air quality is poor.
- improved public access to information.

The above measures are aligned with other legislative proposals, such as the revision of the Industrial Emissions Directive and the recent proposals on Euro 7

emission standards for road vehicles, which will contribute to achieving more stringent air quality standards.

In parallel, the European Green Deal also provides more stringent requirements to address air pollution from sources such as agriculture, industry, transport, buildings, and energy sector. In the European Green Deal, the European Commission has committed to further improving air quality and to aligning EU air quality standards more into line with WHO's recommendations. This commitment was reflected in the Zero Pollution Action Plan, which sets out a vision for 2050 to reduce air, water, and soil pollution to levels that are no longer considered harmful to human health and natural ecosystems. In addition, the Zero Pollution Action Plan established targets for 2030, two of which focus on air quality and aim to:

- reduce the health impacts of air pollution (premature deaths) by more than 55% compared to 2005;
- reduce the proportion of EU ecosystems where air pollution threatens biodiversity by 25% compared to 2005.

Stricter air quality standards will also contribute to the achievement of the European Cancer Plan objectives. Air pollution is a well-known cause of cancer in Europe, particularly lung cancer (EEA, 2022).

Since the 1980s, the EU has adopted a stringent air quality policy implementing legislation aimed to reduce emissions of air pollutants. The relevant directives also define common methods for monitoring, assessing, and informing the public about ambient air quality across the EU. A network of over 4,000 air quality monitoring stations provides reliable, objective, and comparable information on air quality.

The National Emissions Reduction Commitments (NEC) Directive (2016/2284/EU) is one of the legislative instruments under the European Green Deal that supports the ambition of zero pollution to achieve a clean environment. The NEC Directive entered into force on December 31, 2016. It aims to ensure air quality levels that do not harm human health or the environment. The directive sets national commitments to reduce emissions for the period 2020-2030 for five major air pollutants: nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulfur (IV) oxide (SO₂), ammonia (NH₃) and fine particulate matter (PM_{2.5}). These pollutants deteriorate air quality, leading to significant negative impacts on human health and the environment.

From 2020 to 2029, the emission reduction obligations set out in the Directive reflect the commitments for EU Member States under the 2012 Gothenburg Protocol, as amended. From 2030 onwards, more ambitious obligations will apply, aiming to halve the health impacts of air pollution compared to 2005 levels. It is particularly critical for achieving the 2030 air pollution targets under the Zero Pollution Action Plan. To meet these objectives, it is essential that EU Member States fulfil their respective emission reduction commitments set for 2020-2029 and 2030 onwards under the NEC Directive.

Under the NEC Directive, Member States are required to develop and implement National Air Pollution Control Programs (NAPCPs), which should contribute to the successful implementation of air quality plans developed in accordance with the EU Ambient Air Quality Directive. These programmes include measures to reduce emissions in the relevant sectors to meet national commitments. These NAPCPs have to operate in coordination with other policies, such as climate change mitigation measures. Ensuring coherence between policies enhances the impact of government intervention.

The Directive introduces a number of new reporting requirements for Member States. These are specified in Annex I to the Directive and include annual information on emissions of a number of pollutants:

- five key air pollutants: NO_x, NMVOC, SO₂, NH₃ and PM_{2.5};
- other pollutant: carbon monoxide (CO);
- in addition to PM_{2.5}, also PM₁₀ and, where available, black carbon (BC) and total suspended particulates (TSP);
- heavy metals cadmium (Cd), lead (Pb) and mercury (Hg) and, where available, additional heavy metals arsenic, chromium, copper, nickel, selenium and zinc;
- persistent organic pollutants (POPs), including selected polycyclic aromatic hydrocarbons (PAHs), dioxins and furans, polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB).

The NEC Directive emphasizes the importance of regular reporting by Member States on air pollutant emission inventories in order to assess progress in reducing air pollution in the EU and to determine whether Member States are complying with their commitments. Under the NEC Directive, Member States must report emissions inventories annually, starting from 1990, and in the case of PM_{2.5}, starting from 2000 onwards. The EEA conducts annual briefings on the

status of reporting under the NEC Directive, assessing progress in the fulfilment of these legal obligations.

To ensure that the emissions information provided by Member States is consistent within the EU and aligned with international requirements, the NEC Directive requires Member States to adhere to methodologies agreed by the UN Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution LRTAP (Air Convention). The Directive also requires Member States to use the EMEP/EEA manual on air pollutant emission inventories when preparing their inventories.

Directive 2004/107/EC regulates pollution by certain heavy metals (arsenic, cadmium, mercury, nickel) and polycyclic aromatic hydrocarbons. In order to implement Directives 2024/2881/EC and 2004/107/EC, the Joint Implementing Decision 2011/850/EC on the mutual exchange of information and the reporting on ambient air quality was adopted. Both directives are closely linked to international agreements ratified by the EU (the Convention on Long-Range Transboundary Air Pollution and its associated protocols).

Policies and measures aimed at reducing emissions in EU countries focus on three key air pollutants – fine particulate matter, nitrogen oxides and ammonia – which are reported by Member States in accordance with the National Emission Reduction Commitments Directive. Appropriate actions are expected in three sectors that contribute significantly to air pollution, namely transport, energy, and agriculture.

The situation in Ukraine.

This area is subject to legal regulation in Ukraine. Two legal acts included in the commitments under the Association Agreement have been the subject of active efforts by the Government in recent years.

In recent years, the Government and the Verkhovna Rada have made certain efforts to implement individual EU acts in this area, which is part of the commitments under the Association Agreement. At the same time, the full implementation of EU law in this area will still require long period of time due to a lack of human, institutional, and financial resources (in particular, for the development of an ambient air quality monitoring system in accordance with the requirements of the relevant Directives). It will also require accession to (ratification of) all international agreements in this area to which the EU is a party, in particular within the framework of the Convention on Long-range

Transboundary Air Pollution. The implementation of Directive 2016/2284 will require entirely new efforts.

2.2. Legal principles for the functioning of the State Environmental Monitoring System in Ukraine. National priorities.

The foundation for the establishment and operation of the state environmental monitoring system is Article 50 of the Constitution of Ukraine, which guarantees everyone the right to free access to information about the state of the environment, as well as the right to disseminate it.

In recent years, the Government and the Verkhovna Rada have made certain efforts to implement individual EU legal acts in this area, which is part of the obligations under the Association Agreement.

On March 20, 2023, the Verkhovna Rada of Ukraine adopted the government bill No. 7327 "On the State System of Environmental Monitoring, Information on the State of the Environment (Environmental Information) and Information Support for Environmental Management." According to the new law:

the state environmental monitoring system is a system for observing, collecting, processing, analyzing, storing, and exchanging information about the state of the environment, its impact, as well as forecasting its changes, and developing scientifically based recommendations for effective management decisions in Ukraine to ensure the achievement of the Sustainable Development Goals.

The state environmental monitoring system includes the following subsystems:

- a) ambient air monitoring;
- b) water monitoring;
- c) land and soil monitoring;
- d) forest monitoring;
- e) monitoring of biological and landscape diversity;
- e) monitoring in the field of waste management;
- f) geological environment monitoring;
- f) monitoring of the impact of physical factors (temperature, noise, vibration, ionizing and non-ionizing radiation).

The procedure for the functioning of the State Environmental Monitoring System and its subsystems is established by the Cabinet of Ministers of Ukraine.

State authorities vested by law with the power to carry out environmental monitoring are responsible for implementing such monitoring, publishing the environmental information obtained as a result of such monitoring, and ensuring access to this information in accordance with the law.

This European integration document is intended to reform the State Environmental Monitoring System. The law integrates 18 legislative acts of Ukraine with the principles of environmental monitoring, sets a certain framework, and initiates an important reform in the field of monitoring all components of the environment: water, air, soil, forests, flora, fauna, waste management, geological processes, etc.

The new system must comply with international environmental management standards, including the requirements and directives arising from the Ukraine-EU Association Agreement. The system will be compatible with similar systems in other countries and integrated into the European monitoring system of all environmental components coordinated by the European Environment Agency.

Under the current legal framework, each of the above-mentioned subsystems of the State Environment Monitoring System requires the establishment of specific legislative and regulatory instruments for the organisation and implementation of monitoring of the state of environmental objects.

In particular:

- The Law of Ukraine "On the Protection of Atmospheric Air" and Resolution of the Cabinet of Ministers of Ukraine No. 827 of August 14, 2019, "On Certain Issues of Implementing State Monitoring in the Field of Atmospheric Air Protection " define the order and procedure for monitoring in the field of ambient air protection.

- The Water Code of Ukraine and Resolution of the Cabinet of Ministers of Ukraine No. 758 of September 19, 2018, "On Approval of the Procedure for State Water Monitoring " – regulate the procedure for state water monitoring,

- The Land Code of Ukraine and the Law of Ukraine "On Land Protection" together with Resolution of the Cabinet of Ministers of Ukraine No. 661 of August 20, 1993, "On Approval of the Regulations on Land Monitoring" define the procedure for land monitoring 1.

In contrast to these three subsystems, others have not been properly developed, as the following legislative acts:

- Forest Code of Ukraine;
- Law of Ukraine "On the Plant World";
- Law of Ukraine "On the Animal World";
- Law of Ukraine "On the Ecological Network of Ukraine";
- Law of Ukraine "On the State Biosafety System for the Creation, Testing, Transportation, and Use of Genetically Modified Organisms";
- Law of Ukraine "On the Nature Reserve Fund of Ukraine";
- Law of Ukraine "On Waste"

define the relevant monitoring subsystems as an integral part of the State Environmental Monitoring System and indicate the need to establish procedures for implementing the relevant areas of monitoring. However, they have not received adequate regulatory support in the form of procedures (regulations) for the implementation of such monitoring.

Thus, Ukraine has established the basic principles for the organization and functioning of the State Environmental Monitoring System and has regulated the procedure for monitoring individual subsystems.

The State Environmental Monitoring System is based on the use of existing organizational structures of monitoring entities and operates on the basis of a unified regulatory, organizational, methodological, and metrological framework, combining the component parts and the unified components of this system.

In recent years, the regulatory and legal framework in the field of environmental protection and monitoring has been actively developed and updated. Ukraine is a party to more than 70 international bilateral and multilateral agreements, the implementation of which requires the use of environmental data and forecasting of environmental changes. In this regard, the development of the State Environmental Monitoring System should be carried out taking into account both the requirements of EU legislation and the requirements of bilateral and multilateral agreements.

An active impetus was given by Ukraine's ratification of the Association Agreement with the European Union, the European Atomic Energy Community and their member states in 2014. According to Article 361 of this Agreement, cooperation aims to preserve, protect, improve and restore the environmental quality, protect public health, ensure the prudent and rational use of natural resources, and encourage measures at the international level to address regional and global environmental problems, including in the areas of climate change mitigation and ambient air quality management.

The Association Agreement between Ukraine and the EU requires Ukraine to reform its national environmental monitoring and control system and to ensure compliance with environmental legislation. Legislative and regulatory changes must comply with international legal instruments that are binding in Ukraine (including relevant EU legislation) as well as with national legislation. The Association Agreement between Ukraine and the EU contains an exhaustive list of EU legal acts that Ukraine must comply with.

Under the Association Agreement, Ukraine is required to implement a number of EU directives in the field of environmental protection, including Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control). This process involves and requires a number of changes, including:

- legislative changes (in particular, the preparation and implementation of best available technologies – BAT);
- technical changes (e.g., identification of facilities requiring integrated permits and establishment of a register of pollutants);
- organizational changes (in particular, ensuring public access to information and participation in environmental decision-making).

The Ministry of Economy, Environmental Protection, and Agriculture of Ukraine has also initiated a reform of state environmental control, which is part of its obligations to the EU under the Association Agreement. The future reform envisages for the establishment of a single state environmental control body. However, there are currently many state bodies in Ukraine that control the state of the environment.

State environmental control and state environmental monitoring differ in their purpose, scope, and functions. These systems should complement each other. Monitoring provides knowledge, while control ensures accountability.

State environmental monitoring system

Purpose: to obtain objective, systematic information about the state of the environment. This involves observation, measurement, analysis, and forecasting.

Implemented by:

- Hydrometeorological Service
- Ministry of Environmental Protection and Natural Resources
- Ministry of Health, State Emergency Service, scientific institutions, and other relevant bodies

Scope includes:

- measurement of air, water, and soil pollution

- biomonitoring (plants, animals)
- radiation and climate monitoring
- Establishment of databases for environmental policies, reports, forecasts

State environmental control

Purpose: to ensure compliance with environmental legislation. This includes supervision, inspections, detection of violations, and application of sanctions.

Implemented by:

- State Environmental Inspectorate of Ukraine (SEI)
- other regulatory bodies, such as water management, forestry agencies, etc.

Scope includes:

- scheduled and unscheduled inspections of enterprises
- control over permits (emissions, discharges, waste, etc.)
- investigations of environmental incidents
- prosecution of data administered by the European Environment Agency.

2.3. Analysis of institutional support the implementation of state environmental monitoring.

The regulation on the State Environmental Monitoring System defines the following entities as responsible for its implementation:

Ministry of Economy, Environment Protection and Agriculture of Ukraine (Ministry of Environment)

Ministry of Health

Ministry of Internal Affairs of Ukraine (MIA)

Ministry of Development of Communities and Territories of Ukraine (Ministry of Infrastructure)

Central executive bodies subordinated to the Ministry of Environment:

State Agency of Forest Resources of Ukraine (State Forestry Agency)

State Agency of Water Resources of Ukraine (State Water Agency)

State Service of Geology and Subsoil of Ukraine (State Geology Service)

State Agency of Ukraine for the Management of the Exclusion Zone (SAUEZ)

Central executive bodies subordinated to the Ministry of Internal Affairs:

- State Emergency Service of Ukraine (SES)

Central executive bodies subordinated to the Ministry of Agrarian Policy:

- State Service of Ukraine for Geodesy, Cartography and Cadastre (State Geocadastre)

- State Agency for Melioration and Fisheries of Ukraine (State Fisheries Agency)

Other central executive bodies, authorities, institutions, and organizations

- State Space Agency of Ukraine (SSAU)

Executive authority of the Autonomous Republic of Crimea for environmental protection and natural resources (on the territory of the Autonomous Republic of Crimea), as well as environmental protection departments of regional and city state administrations

- Accreditation, standardization, and metrology bodies

In addition to the central executive bodies and institutions mentioned above, **scientific institutions**, particularly those within the National Academy of Sciences of Ukraine and their territorial branches — participate in environmental monitoring activities, along with enterprises, institutions, and organisations under their jurisdiction, including regional-level entities.

Aspects of institutional support for the State Environmental Monitoring System (SEMS) and other related types of state monitoring are presented in Table 2.

Table 2.

Institutional support for SEMS and other related types of state monitoring.

State environmental monitoring system				Other types of monitoring		
Provides for coordination by the Ministry of Environment						
Monitoring in the field of atmospheric air protection	Water monitoring (surface and groundwater)	Land monitoring	Biodiversity monitoring	Monitoring of aquatic biological resources	Social and hygienic monitoring	Monitoring of drinking water quality and technical condition of centralized drinking water supply and wastewater facilities
UGMS (Hydrometeorological Service) as part of the State Emergency Service of Ukraine under the leadership of the Ministry of Internal Affairs of Ukraine			Institutions under the leadership of the Ministry of Environment,	The State Fisheries Agency under the leadership of the	Public Health Center under the leadership of the	City water utilities under the methodological guidance of the Ministry of
Public Health	Under State Water Agency	The State Geocadastre and				

Center under the leadership of the Ministry of Health			the State Institute of Soil Protection under the leadership of the Ministry of Agrarian Policy	as well as the NAS of Ukraine	Ministry of Agrarian Policy	Ministry of Health	Regional Development
		State Geological Survey of Ukraine		Forest monitoring: State Forestry Agency under the leadership of the Ministry of Environment			
Regional state administrations		State Agency of Ukraine for Exclusion Zone Management					
Executive committees		Sea: Ukrainian Scientific Center for Marine Ecology					

CHAPTER 3.

Monitoring air pollution in the EU using one European country as an example.

3.1. Air pollution monitoring in the Czech Republic.

Air quality monitoring in the Czech Republic is regulated by Act No. 201/2012 Coll. on Air Protection. According to this Act, not only air quality but also pollution levels (emissions) are assessed. Air quality is monitored through a network of automatic observation stations of the Czech Hydrometeorological Institute (ČHMÚ), which is subordinated to the Ministry of the Environment. The monitoring system was established in the 1990s and underwent major changes in 2015 (thanks to funding from the Environmental Management Programme). The monitoring assesses the concentrations of substances that are defined by legislation and for which limits are set (based on EU standards). Namely:

- dust aerosol/suspended particulate matter PM₁₀, PM_{2.5}, and in some areas PM₁;
- SO₂, CO, NO/NO₂, O₃;
- Volatile organic compounds (benzene);
- Heavy metal content in PM₁₀ – As, Pb, Cd, Ni;
- Content of PM₁₀ particles – expressed as benz(a)pyrene.

The substances measured at a specific station are selected according to the specifics of the area. The set of substances varies for different monitoring stations and may sometimes include additional chemical elements. Data collected through the monitoring network are stored in the Air Quality Information System (ISKO) of the Czech Hydrometeorological Institute. Other organisations, including companies, also store information in this system. ISKO data is evaluated annually and the results are published in the report "Air Pollution in the Czech Republic", which is available online and for public access. The annual report contains infographics and raw data presented in tables. The operator of the pollution source ensures the emissions monitoring in accordance with the Air Protection Act. The Act precisely specifies which substances need to be monitored. The operating permit clearly states what substances to measure, where and how. Certain substances are measured continuously (suspended particulate matter, sulphur oxides, nitrogen oxides, chlorine compounds, fluorine compounds,

carbon monoxide, volatile organic compounds, sulphates), while others are determined by interval measurements (e.g. heavy metals contained in PM₁₀). Continuous measurements are carried out at large emission sources, while emissions from smaller sources are estimated by calculation. The operator reports the measurement results to the authorities electronically through the Integrated Reporting System (ISPOP). The Ministry of Economy of the Czech Republic conducts an annual emissions inventory for selected substances and assesses their dynamics. The aggregated data are published in environmental reports and yearbooks. Monitoring may also include inspections of companies subject to so-called "integrated licensing". The Ministry of the Environment manages the Integrated Prevention Information System, which provides information on emission limits established for a specific source or information on compliance with these limits (companies must submit an annual report on compliance with the conditions under their integrated permit). Information on air quality and emissions is used for air quality modelling in computer models (using software developed by the Czech Hydrometeorological Institute ČHMI). Thanks to, computer modelling it is possible to generate data on air quality throughout the Czech Republic and estimate the size of the area where limit values have been exceeded. To level out the values of unfavourable dispersion conditions, five-year averages are used (maps generated from this information are freely available on the Internet). If the limit values are exceeded in a particular region, environmental protection measures are taken. The National Emission Reduction Programme in the Czech Republic, which is updated every four years, serves as a tool for reducing emissions and improving air quality. If air pollution limits are exceeded only in a specific area (the republic is divided into smaller units for the purpose air quality assessment), the Ministry of Economy develops an Air Quality Improvement Programme for that sector in cooperation with the relevant region. These programmes are also regularly updated. An Air Quality Improvement Programme can be developed for both small regions and cities. An example for the Ostrava/Karviná/Frýdek-Místek agglomeration can be found in this publication. The Czech Republic has also developed a medium-term Air Quality Strategy for improving air quality. The strategy identifies the main current problems and presents ways to solve them. The Strategy was prepared at the request of the European Commission, as it allows a basis for the justification of funds from the European Air Protection Fund. Air quality monitoring in the Czech Republic has been carried out for over 50 years. It is worth noting that due

to the development of lignite-fired power plants in the 1960s and 1970s, the Czech Republic had to address serious air quality issues. The territory of Northern Bohemia was one of the most polluted in Europe. Since then, air quality has improved significantly. The example of Ostrava shows that the situation can be improved even in industrial areas.

3.2. Pollutant registers (PRTR systems in the EU and Ukraine).

Emissions registers were introduced with the main purpose to ensure public access to data regarding the emissions and transfers of certain pollutants from enterprises with a significant environmental impact. Experience shows that this is a good preventive measure and that disclosure of information leads to a pollution reduction. To achieve this goal, it is sometimes sufficient to change the technology or replace the problematic substance with a less harmful one. For example, Knauf Krupka eliminated using formaldehyde in the manufacture of thermal insulation and started using starch as a binding agent.

The EU has integrated pollution registers at both the EU and national level. The first information was submitted to the European Pollutant Release and Transfer Register (E-PRTR) in 2007.

Reporting on air, water and soil pollution, as well as wastewater transfers, is regulated by Regulation 166/2006/EC105 provided that the pollution exceeds the threshold values for registered substances (the list of substances is included in Annex II to the Regulation).

Reporting is conducted on an annual basis. The E-PRTR publishes significantly more information than the European Pollutant Emission Register (EPER), which had been in operation until then (see Table 3).

The Czech Integrated Pollution Register (IPR) was established in 2003 by Act No. 76/2002 Coll. on Integrated Prevention. Government Decree No. 386/2003 Coll. approved the final form of the register. This register was created and supplemented not on the basis of the EU model, but on the model adopted in the United States, where the concept of a pollutant register was first introduced. The first data were entered into the IPR in 2004 (72 substances). In 2008, the Register was partially aligned with the E-PRTR. The number of substances to be reported was expanded, but unlike the E-PRTR (where reports are provided only for certain industries), all companies that exceed the established emissions limits for of certain substances report their emissions and transfers to the IPR. Thus, the

information in the IPR is more comprehensive than in the E-PRTR. This is due to the adoption of the American system as a model, which tracks more substances than the EU register. Czech companies must also monitor and report the content of certain substances in waste. In addition, the Czech register tracks emissions of styrene and formaldehyde (93 substances in total).

Table 3.

Comparative analysis of the URWUWAP (Unified Register of Water Users and Water Abstraction Points) and the E-PRTR (Unified Electronic Register of Pollutant Release and Transfer)

	URWUWAP	E-PRTR
Form of the law on the creation of the register	European Commission decision	Rules of Procedure of the European Parliament and of the Council
Number of substances in the register	50	91
Number of activities to be monitored	56	65
Air emissions	Yes	Yes
Discharges into water bodies	Yes	Yes
Soil pollution	No	Yes
Transfer with wastewater	Yes	Yes
Emergency resets	No	Yes
Amount of waste generated	No	Yes
Diffuse sources	No	Yes
Installations covered by the Integrated Pollution Prevention and Control Directive	Yes	No
Reporting frequency	3 years	annually
Approximate number of reporting enterprises	12,000	50,000

In 2017, 1,332 companies reported emissions of pollutants subject to accounting, and 2,359 companies reported the waste generated. A company that fails to report pollution generated may be fined (up to 500,000 CZK). Compliance with this requirement is monitored by the Czech Environmental Inspectorate. In addition to the IPR, there is another PRTR in the Czech Republic. It was created on the initiative of the non-profit organisation “Arnika” with the aim of making the data submitted to the IPR more accessible to the public. On the website <https://zncistovatel.cz>, you can select the "top ten" companies with the highest emissions levels not only within the Czech Republic, but also in individual regions. Companies can be sorted by their impact on the environment or public health. The programme can be used to create graphs showing long-term trends. Detailed data on specific substances are not available.

What does the Integrated Pollution Register offer?

- streamlining of available information on the emissions and transport of pollutants subject to monitoring (solving the problem of duplication and lack of data in a "unified format")
- Effective data management (electronic reporting, verification of data completeness and accuracy, data presentation)
- Effective public control over sources of hazardous substances and monitoring of the reduction of environmental impact.

Why is an Integrated Pollution Register needed? The experience of the United States shows that an open IPR is:

- a starting point for anyone who wants to find information about the state of the environment in which he/she lives,
- an opportunity for the public to initiate a dialogue with companies operating within the city/municipality and its surrounding areas,
- an opportunity for business leaders to improve technology, eliminate malfunctions, achieve cost savings and provide information to the public,
- a basis for trade union negotiations regarding the improvement of working conditions,
- a source of information for government and international organizations for the effective protection of the environment and the public,
- a basis for regional/local authorities and municipalities to develop emergency response plans, monitor pollution and ultimately improve legislation,
- a basis for developing appropriate measures to protect human health in the vicinity of industrial accidents, for the emergency response system

(information on substances used in production that is not available in the Czech IPR is important),

- an important tool for risk management and prevention of damage to property and agriculture for public authorities.

3.3. An example of air quality improving in the Ostrava/Karviná/Frýdek-Místek agglomeration.

The Ostrava/Karviná/Frýdek-Místek agglomeration is located in the Upper Silesian coal basin, which covers most of Poland. It is one of the most urbanized and industrialized areas in Central Europe. In this agglomeration, unlike other regions of the Czech Republic, emissions mainly originate from large-scale organized sources. The main industries are coal mining and processing, as well as iron and steel production. The region has a population of over 800,000 (on the Czech side). Air quality in the agglomeration is measured at more than 20 points/locations. Concentration monitoring is carried out for all substances for which limit values have been set. In this region, limit values for dust (PM₁₀, PM_{2.5}) and polyaromatic hydrocarbons (benzo(a)pyrene) were exceeded. Unlike other regions, high levels of air pollution were observed throughout the entire calendar year, not just during the winter (when pollution increases due to domestic heating). Tools for improving air quality in the agglomeration The Ostrava/Karviná/Frýdek-Místek agglomeration has been struggling with atmospheric pollution for a long time. This is due to its geographical location, historical development, and the fact that in the past, air pollution was not considered a major problem (Ostrava became an industrial centre in the 1950s). There are two metallurgical plants located here — Liberty House, formerly ArcelorMittal Ostrava, and Třinecké železářny (Třinec Metallurgical Plant). Their total annual production volume is 1.8 million tonnes of coke, 3.6 million tonnes of iron, and 4.3 million tonnes of steel (2017 data). Currently, air quality in the region is significantly better, but not ideal. Local physicians are concerned about the impact of pollution on public health. The annual level of particulate matter (PM₁₀) usually exceeds the standard value at only one monitoring station, however during 24-hour measurements, the dust concentration is usually exceeded at all stations. The concentration of benz(a)pyrene exceeds the limits several times over. The authorities are taking measures to address the situation.

The air quality improvement programme for the region is regularly updated. Such programmes must be developed for each area where air quality does not meet the standards. The scope of the programme is regulated by law. The programme analyses the situation and develops appropriate measures. Both the programme and its updates must undergo a Strategic Environmental Assessment procedure. The participation of public and non-profit organizations plays an important role in this process. To facilitate this, they must be granted access to information. Due to the proper functioning of the Integrated Pollution Register (IPR/PRTR) in the Czech Republic, non-profit organizations can monitor and record cases of exceedances of emission limits from large-scale sources. Public organizations in the Czech Republic can participate in the process of issuing integrated permits for certain factories and have the opportunity to comment on and make proposals for air quality improvement programmes.

Thanks to EU membership, the right to a clean environment is guaranteed by the courts. In this region, public organizations have filed a lawsuit against the state, alleging that the measures taken are insufficient and that there is no clear timetable for their implementation. The case concerned a complaint against the adopted air quality improvement programme. At the end of 2017, the Supreme Administrative Court ruled that the complaint was justified. Therefore, the Ministry of the Environment will have to supplement the measures.

Results achieved

- Based on a 2010 resolution of the Parliament of the Czech Republic, the Ministry of the Environment prepared a report on the situation in the region. Funds from EU operational programmes were used to implement the proposed measures.

- An air quality improvement programme was developed and updated for the agglomeration. Similar programmes have also been developed in some large cities within the region. The programme is subject to public consultation and some ineffective measures may be challenged in court (see above).

- Sources of pollution and their share in total volume of emissions have been identified.

- Measures have been taken to reduce emissions from large sources; other projects are being implemented. Between 2002 and 2011, dust emissions decreased by approximately 50%.

- Emission limits values have been established for plastics production and metalworking industries until 2020. These limits also include fugitive emissions from industrial facilities (data for 2015 showed that fugitive dust emissions can be more than 100% higher than direct emissions measured at an organized source).

- Within the framework of the National Emission Reduction Programme (NERP), measures have been taken to reduce emissions from both small-scale sources (household heating) and transport.

- Cooperation with Poland has been established. Analysis has shown that transboundary dust transfer leads to an increase in air pollution levels in the region of 30-50%, depending on the distance from the border. On the other hand, between 5 to 30% of the pollution in the border area of Poland comes from the Czech Republic.

3.4. Environmental inspection system in the Czech Republic.

Environmental inspections in the Czech Republic are carried out by the Czech Environmental Inspectorate (CEI). The Inspectorate was established in 1991 under the Act on the Czech Environmental Inspectorate and its powers in the field of forest protection. The CEI is a state body (Czech: "organizační složka") and is subordinate to the Ministry of the Environment (Table 4-5).

The CEI structure includes a head office and regional inspectorates, the number of which has been 10 since 1995. The head office serves as the executive, organizational and methodological body within the CEI structure. The role of the CEI within the public administration system of the Czech Republic is fully in line with its legal definition. The main mission of this specialized administrative body is to supervise compliance with environmental legislation, covering all components of the environment (water, air, waste, nature and forests). Thus, the CEI carries out prevention, supervision and control, as well as imposing sanctions in the field of environmental protection.

The CEI conducts (i) scheduled inspections, (ii) inspections upon request (citizens' complaints, information in the media, etc.) and (iii) monitoring of industrial accidents. The work of the Inspectorate is determined by an annual activity plan. In general, 40-45% of each inspector's working time is scheduled in advance. The rest is allocated to addressing current annual tasks (e.g.

conducting unscheduled inspections, inspecting operations at certified sites, monitoring the implementation of official emission measurements, etc.).

Inspectors have the right to access facilities (with or without prior notice), the right to examine documentation, take measurements, suspend facility operation, impose fines or decide on measures to remedy malfunctions.

According to the legislation, the CEI is an administrative body of first instance, i.e. its decisions are final either upon the expiration of the appeal period for the entities against which the proceedings are conducted (or in the case of an appeal against the decision of the appellate body – the Ministry of the Environment).

The Ministry makes second-instance decisions in its departments located in Prague and regional cities (České Budějovice, Plzeň, Chomutov, Liberec, Hradec Králové, Brno, Olomouc and Ostrava). After consideration by the appellate body, the first instance decision issued by the CEI may be confirmed or annulled. The case is then either returned for reconsideration or dismissed.

The legal proceedings may be terminated or modified, but never to the detriment of the accused party. If an individual considers their rights to have been violated by a decision of the State Administration Department (in Czech, “odbor výkonu státní správy”), they may apply to the administrative court to have the decision annulled or declared invalid.

Table 4.

Overview of the powers of the Czech Environmental Inspectorate

	Powers of the Czech Environmental Inspectorate	Air	Water	Waste	Nature	Forests
Sphere	Inspections, reviews, investigations	X	X	X	X	X
Supervision	Fines for individuals	X	X	X	X	X
	Fines for legal entities	X	X	X	X	X
	Limitation or shutdown of a production process or enterprise	X	X		X	X
Control	Measures to eliminate deficiencies	X	X	X	X	X
	Dealing with old environmental problems		X			
	Documenting accidents and collaborating to resolve them	X	X	X		
	Confiscation of rare species					
	Confiscation of animals and goods	X			X	
Sanctions	Fines for emissions (wastewater discharge, groundwater use)		X			
Statements	Statements and expert opinions for other government bodies	X	X	X	X	X
Suggestions	Working with proposals	X	X	X	X	X

Table 5.

Overview of the activities of the Czech Environmental Inspectorate in 2017

Number of inspectors	396
Number of checks	15,864
Orders issued (legally)	10,249
Total amount of fines in legal order (CZK)	113,051,685

CHAPTER 4.

Modern Environmental Permitting System in the EU.

4.1. Overview of the environmental permitting procedure in the EU.

For decades, the European Union has been striving to improve air quality by controlling emissions of harmful substances into the atmosphere and integrating environmental protection requirements into the industrial and energy sectors. Both legislative acts (the 1985 EIA Directive, the 1996 Directive on Integrated Prevention and Control, and the 2010 Industrial Emissions Directive, including amendments and additions) and policy instruments have been developed, such as:

□ the Seventh Environmental Action Programme "Living well, within the limits of our planet" 2013 – this action programme sets a long-term goal for the EU: to achieve "a level of air quality that does not give rise to significant negative impacts on and risks to human health and the environment". Achieving this goal requires effective policies for maintaining clean atmospheric air, as well as cooperation and measures at the global, European, national and local levels.

□ Clean Air Programme for Europe (CAPE), 2013 – the goal is to ensure full compliance with existing legislation by 2020 and to further improve air quality in Europe so that by 2030 the number of premature deaths is halved compared to 2005.

□ The First Clean Air Outlook, 2018 – published by the European Commission; it concluded that the measures adopted in 2013 are expected to exceed the health impact reduction targets by 2030, as envisaged by the Clean Air Programme for Europe. However, it also recognizes that in the short term, there is an urgent need for decisive action at all levels of government to ensure that the objectives of the Ambient Air Quality Directives are achieved.

The EU's efforts to improve air quality consists of the following areas:

1. Establishing ambient air quality requirements, as defined in the Ambient Air Quality Directives (EU, 2004, 2008).

2. Setting national emission reduction targets, as specified in the National Emission Ceilings Directive (EU, 2016).

3. Approval of emission limit values and energy efficiency requirements of major sources of air pollution (ranging from vehicle emissions to industrial

sources). The latter are defined in EU legislation regulating industrial emissions (in particular, the Industrial Emissions Directive).

Industrial production processes account for a significant share of total pollution in Europe. This is due to emissions of pollutants into the atmosphere, wastewater discharges and waste generation. To address this issue, in 2010 the EU adopted the Industrial Emissions Directive (IED). Approximately 52,000 installations carrying out the industrial activities listed in Annex I to the Directive must operate in accordance with **an environmental permit** (issued by the authorities of the Member States). This permit must contain conditions established in accordance with the principles and provisions of the Directive.

The Industrial Emissions Directive, as the EU's main instrument regulating pollutant emissions from industrial installations, provides for an integrated (comprehensive) approach to environmental permits. The table below summarizes the main advantages of integrated pollution prevention and control.

The integrated approach considers the environmental performance of an enterprise as a whole. In particular, the following aspects are assessed: emissions to air, water and soil pollution, waste generation, raw material use, energy efficiency, noise, accident prevention, site restoration after closure, etc.

Table 6.

Comparison of integrated and fragmented approaches to Environmental Permitting

Best overall solutions	Integrated approach	Comprehensive review of the company's activities - best methods for controlling the overall impact of production processes on the environment
	Fragmented approach	A permit that regulates pollution in one aspect (e.g., reducing air pollution) may lead to side effects in other areas (e.g., increasing water pollution)
Efficiency	Integrated approach	Reduces administrative costs — for both regulators and businesses
	Fragmented approach	The permitting process can be complex, time-consuming, and inefficient due to fragmentation across different agencies.
Pollution prevention	Integrated approach	Comprehensive and comprehensive assessment of sites is likely to prevent contamination

	Fragmented approach	Control limited to the source of contamination (the pipe) may leave issues unresolved at other stages of production.
Sustainability	Integrated approach	Taking into account such aspects of a company's operations as the use of natural resources, the generation and processing of waste, as well as the impact on the environment, helps to achieve sustainability in the long term.
	Fragmented approach	Neglecting or giving little consideration to other aspects of a business's operations can lead to short-term or inconsistent sustainability.
Public participation	Integrated approach	Stakeholders have been given access to a comprehensive environmental impact assessment. This promotes public participation and a comprehensive dialogue between industry and other stakeholders
	Fragmented approach	Requires participation in several separate and time-consuming permitting processes

Under the fragmented approach currently applied in Ukraine, emissions into the environment (water, air, soil) and permits for the operation of the main facility are considered separately at different levels of government, and usually by different agencies.

The EU has been practicing an integrated approach since the early 1980s. The table below shows how this approach evolved until it was enshrined in legislation.

Table 7.

Development of the integrated approach in the European Union

Environmental programs of the European Commission	EIA Directive	Directive on integrated prevention and control	Industrial Emissions Directive
The need to move from the traditional	The first piece of legislation to cover	The first directive to define the	Optimizes and emphasizes the

<p>fragmented (sector by sector) approach to integrated pollution prevention and control has been identified; no definition of an integrated approach ^{a)}.</p>	<p>various aspects of an enterprise's impact and a holistic (rather than sectoral) approach to environmental protection; the concepts of integrated pollution prevention or control are not used^{b)}.</p>	<p>concept of integrated pollution prevention or control ^{c)}.</p>	<p>principles contained in the Integrated Prevention and Control Directive.</p>
--	--	---	---

Development of the integrated approach in the European Union:

a) the first four environmental programmes of the European Commission between 1982 and 2010. Eberhard Bohne, "The Quest for Environmental Regulatory Integration in the European Union," Kluwer Law International;

b) Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment. The Directive has been amended three times: by Directive 97/11/EC of 3 March 1997, Directive 2003/35/EC of 26 May 2003 and Directive 2009/31/EC of 23 April 2009;

c) Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (IPPC). After several amendments, a codified version was issued in the form of Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control. It was later replaced by **Directive 2010/75/EU** of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).

The Industrial Emissions Directive merged the Integrated Pollution Prevention and Control Directive and six sector-specific directives into a single directive with the objective of streamlining the interaction between these legal instruments and providing a clear definition of its provisions. It is based on the following pillars:

1. Integrated approach – permits must include comprehensive environmental indicators of the enterprise. This includes emissions to air, water and land, waste

generation, raw material use, energy efficiency, noise, accident prevention and site restoration after closure.

2. Use of **best available techniques (BAT)** – conditions for permitting a certain amount of emissions must be developed on the basis of the best available techniques. The European Commission facilitates the process of interaction between experts from Member States, industry and environmental organizations. This process results in the identification of BAT and the development of BAT Reference Documents (BREFs). The European Commission adopts these BAT conclusions at the legislative level. They then serve as a benchmark for the establishment of permit conditions.

3. Flexibility – in certain cases, authorities may set less stringent emission limits if achieving the emission levels specified in BAT would result in costs that are disproportionately higher than the environmental benefits.

4. Monitoring – Member States must establish a system of environmental inspections and develop plans for their implementation. Site visits take place at least once every one to three years (a risk-based approach is applied).

5. Public participation: the public has the right to participate in the decision-making process and receive information of its consequences, and shall have access to permits and monitoring reports.

Member States report pollutant emission volumes to the European Pollutant Release and Transfer Register (E-PRTR or PRTR). The PRTR is a publicly accessible register that provides environmental information on major industrial activities.

The Industrial Emissions Directive pays considerable attention to BAT reference documents when developing permit conditions. Since BATs must be enshrined in legislation and be mandatory, it is expected that the implementation of BATs will be more clearly specified in environmental permits. Since BAT is a dynamic concept that evolves over time, permits must be updated with the primary objective of promoting a continuous reduction in the industrial impact on the state of the environment. The Industrial Emissions Directive outlines detailed rules for reviewing permits and provides a compulsory review of permit conditions within four years of the publication of BAT conclusions.

The Industrial Emissions Directive clearly explains the legal status of BAT. It also describes the roles of all participants in the information exchange process to achieve a high-quality result and ensure that BAT principles are applied in the implementation of the Directive. The Directive establishes conditions for

monitoring compliance with permit conditions. These include risk-based inspections and specify the minimum frequency of site visits.

The Industrial Emissions Directive strengthens the public's right to access information and, in particular, to participate in decisions concerning deviations from BAT conclusions within the process of integrated pollution prevention and control, as well as the use of the internet to create publicly accessible opportunities.

In 2022, the Commission adopted proposals for the revision of the IED and E-PRTR. The proposals aim to improve the Directive by placing greater emphasis on the efficiency of energy, water and material use, as well as their reuse, and by encouraging the use of safer, less toxic or non-toxic chemicals in industrial processes.

The revision of the IED provides a framework for EU industrial operations that is in line with the European Green Deal and the Zero Pollution Action Plan.

The European Green Deal – all 27 EU Member States have committed to making the EU the first climate-neutral continent by 2050, and have therefore pledged to reduce emissions by at least 55% by 2030 compared to 1990 levels. On 12 May 2021, the European Commission adopted the EU Action Plan "Towards Zero Pollution of Air, Water and Soil" (and its annexes) – a key outcome of the European Green Deal.

4.2. Environmental Permitting Process in the Czech Republic.

The process of integrated pollution prevention and control in the Czech Republic is regulated by the Act on Integrated Pollution Prevention and Control (implementing the Industrial Emissions Directive).

2. Ministry of the Environment – formulates environmental policy in the field of air, water and soil protection. (The Ministry of the Environment issues environmental permits only for facilities with significant negative transboundary impacts) [11].

3. Ministry of Agriculture – formulates agricultural policy in accordance with the Act on Integrated Pollution Prevention and Control.

4. Czech Environmental Inspectorate – monitors compliance with the Integrated Pollution Prevention and Control Act and imposes sanctions.

5. Czech Environmental Information Agency (CENIA) – provides expert opinions for the authorities responsible for issuing integrated permits.

6. State Environmental Fund – controls and manages financial subsidies for environmental initiatives; reports to the Ministry of the Environment.

7. Regional authorities – responsible for issuing integrated permits.

The process of issuing **integrated permits** is decentralized in the Czech Republic. With the exception of environmental permits for facilities with negative transboundary impacts (which are issued by the Ministry of the Environment), integrated permits are issued at the regional level. It should be noted that policy related to integrated permits is formulated at the national (ministerial) level. Furthermore, it should also be noted that despite the involvement of several state bodies (ministries, inspectorates, agencies) in the process of integrated pollution prevention and control, their competences are clearly defined and do not overlap.

In the Czech Republic, as well as in other EU Member States that have implemented the Industrial Emissions Directive (and related processes), only industrial and agricultural activities (energy, metal production and processing, mineral industry, chemical industry, waste management and other operations such as animal husbandry) that exceed the limit values, require an integrated permit. Other enterprises that do not exceed these threshold values may obtain an integrated permit on a voluntary basis. It should be noted that the main intention is not to license all industrial and agricultural activities, but only those with high pollution potential.

In order to **obtain an integrated permit**, an enterprise submits an application to the relevant regional authorities [18]. The application must comply with the legal requirements, and the application template is established in the regulatory documents.

The requirements **for an integrated permit** application are included in Article 4 of the Act on Integrated Pollution Prevention and Control. This is a rather complex document. In addition to identifying the applicant and the industrial or agricultural facility, it must contain a fairly detailed description of the operation, processes and technologies used, sources of emissions and measures for emission monitoring and waste prevention. Mandatory operating conditions must be described. The application must be accompanied by a package of supporting documents (e.g. zoning permit, relevant administrative decisions, etc.). If the facility uses, produces or discharges hazardous substances that may contaminate the soil or water, in accordance with Article 4a of the Integrated Pollution Prevention and Control Act, the applicant must submit a baseline report

(in Czech, "základní zpráva"). The report must be prepared by a competent person for approval by the regional authority. The report helps to determine the degree of soil or water contamination so that the state of the environment can be compared with the state in which it will remain after the final completion of the activity.

After receiving the application, the regional authority assesses its completeness within 20 days of the submission date. If the application is incomplete, the regional authority requests that its recertification and sets a deadline for this correction (usually from one week to 30 days). The integrated permitting process is suspended until the clarifications are made.

In the Czech Republic, public hearings are not a mandatory part of the integrated permit issuance process, as it is mainly carried out through the exchange of written correspondence and documentation. According to the Act on Integrated Pollution Prevention and Control, public hearings in the form of public meetings are mandatory only if a participant in the procedure requests this within their comments on the application. Such cases are rare. Unlike judicial proceedings, most administrative procedures are conducted without public hearings. The regional authority usually holds hearings on its own initiative in exceptionally complex cases that require a lot of clarification and where testimony from all relevant stakeholders and from the first person can be guaranteed at the same time.

In order to assess the application, the regional authority may, in addition to its own review, consult a **"competent person"** (in Czech, "odborně způsobilá osoba") for an opinion on the application of BAT or, in exceptionally complex cases, for the review of the entire application. A competent person (in Czech, "odborně způsobilá osoba") is a legal or natural entity possessing relevant knowledge in areas within the scope of the Integrated Pollution Prevention and Control Act (e.g. application of BAT, emission limits, environmental legislation, etc.). Competent persons are authorised by the Ministry of the Environment to provide expert opinions and are included in the official register of competent persons approved by the Ministry. If necessary, regional authorities can either contact a company from the Ministry of the Environment's list or (more often) contact CENIA, the sole competent authority that provides expert opinions to state authorities free of charge.

A key aspect of the integrated permit process is the determination of mandatory operating conditions and emission limits for a particular industry

based on BAT principles. When determining BAT, regional authorities take into account the aspects specified in Annex 3 to the Integrated Pollution Prevention and Control Act. Regional authorities conduct comparative analysis between the proposed technologies, production and production processes with BAT, in particular regarding the emission of pollutants into the atmosphere. The decision on the use of BAT is made by the regional authority (namely, the relevant official). Although the regional authority has the legal mandate to determine BAT, when setting emission limits and deciding on the granting of an integrated permit, the regional authority must consider the circumstances of each case individually in order to establish reasonable conditions for its operation.

The decision of the regional authority regarding obtaining an integrated permit may be appealed within 15 days of its adoption. Once the decision becomes legally binding, it is published on the official notice board (and online) within 30 days.

The conditions set out in the permit for industrial and agricultural activities are mandatory. In accordance with the Act on Integrated Pollution Control and Prevention, the enterprise must submit an annual report to the regional authority, in which it must describe in detail the fulfilment of the conditions specified in the integrated permit. At least once every eight years, the regional authority checks whether there have been any changes in circumstances that could lead to a change in the mandatory conditions of the integrated permit.

If, within this eight-year period, production and the technologies used change in a way that allows for a reduction in the environmental impact of production, regional authorities usually apply stricter conditions to the enterprise's operations in order to motivate investment in newer, more environmentally friendly technologies.

If an enterprise does not comply with the conditions of the integrated permit, the regional authority or inspectorate usually issues compliance orders before imposing fines. The fines are extremely high.

Depending on the severity of the violation of the Integrated Pollution Prevention and Control Act and the conditions of the integrated permit, the fine may range from 2 to 10 million CZK (approximately 70,000 to 350,000 EUR) and may be imposed repeatedly, which could lead to the closure of the enterprise.

The inspection authority (Czech Environmental Inspectorate) checks not only compliance with the conditions of the integrated permit, but also general compliance with the Integrated Pollution Prevention and Control Act. Each

calendar year, the inspection authority prepares a plan for facilities covered by the Integrated Pollution Prevention and Control Act, on the basis of which it prepares a plan for standard control inspections. The interval between individual monitoring inspections is determined on the basis of a systematic assessment of the environmental risks posed by the facility and ranges from one (highest risk) to three years (lower risk).

Currently, there are approximately 1,708 facilities to inspection by the regulatory authority (more precisely, its regional units). Upon the requirement for an additional or more extensive audit, the inspection authority sometimes conducts unscheduled inspections (e.g., in the event of an industrial accident or public complaint) as well as repeated on-site inspections (e.g., in case of a serious violation of the conditions of the integrated permit). Data from 2017 show that 488 inspections were carried out.

The Ministry of Environmental Protection maintains an Integrated Pollution Register, a nationwide information system that is an integral part of a unified environmental information framework. This system allows the public to obtain free and unrestricted access to information in accordance with the Integrated Pollution Prevention and Control Act. The open database allows searching for operators, issued integrated permits, BAT assessments, and information regarding current integrated permitting procedures, etc. Furthermore, the system also serves as a functional archive of published documents relating to integrated permits in general, and in particular, they disclose the process of integrated pollution control and prevention. The Ministry has authorised the Czech Environmental Information Agency to manage the Integrated Pollution Register as a public accessible database. Within this framework, enterprises are required to report information concerning both regulatory emissions and those exceeding established limit values.. If a company fails to report or submits false information, it may be fined up to 500,000 CZK (approximately 25,000 EUR).

In the Czech Republic, most large-scale industrial and agricultural facilities have undergone the process of obtaining integrated permits. Although there are sometimes bureaucratic delays requiring a large amount of documentation, the process of issuing integrated permits in the Czech Republic is an effective procedure. It is regulated by a well-structured legislative framework (the Integrated Pollution Prevention and Control Act) with a clear distribution of rights and obligations of interested parties, guarantees the procedural rights of participants, and a clear enforcement mechanism.

4.3. Environmental permits in Ukraine.

Ukraine currently has a fragmented environmental permitting system, characterized by a large number of permits to regulate different types of pollution (air emissions, water discharge and waste generation), which are issued by different agencies. This system is costly and creates an administrative burden for both the authorities and enterprises. Moreover, the permitting process does not take into account the overall impact of the installation on the environment. Environmental permits are usually limited to setting emission limit values, without taking into account other operational conditions, such as energy efficiency, use of raw materials and water, emergency preparedness, reporting and notification of accidents, etc.

In terms of emissions into the atmosphere, enterprises in Ukraine are divided into three groups:

a) the first group — facilities that are registered with the state and have production or technological equipment for which the best available techniques and management methods must be implemented;

b) the second group consists of facilities that are registered with the state and do not have production or technological equipment requiring the implementation of the best available techniques and management methods;

c) the third group — facilities that are not included in the first and second groups.

Existing capacities. Permits for emissions into the atmosphere for enterprises in groups II and III are issued by regional state administrations, while permits for group I are issued by the Ministry of Environmental Protection and Natural Resources (MEPR). The MEPR has the right to revoke any permit approved by regional authorities. In practice, these permits are often issued by bodies that are not competent in environmental matters. For example, permits for air pollutant emissions for the Kharkiv Coke Plant, a coal and coke processing facility, were issued by the Environmental Protection Agency of the Kharkiv Regional State Administration instead of the Ministry of Environmental Protection and Natural Resources and without conducting an environmental audit.

Permits for Group I are issued for seven years, for Group II for 10 years, and for Group III for an unlimited period of time. Permits are issued free of charge.

Procedure. At the beginning of the procedure for obtaining an environmental permit, the enterprise must conduct an emissions inventory. The enterprise can do this independently or hire an external company. The emissions inventory must contain information about all existing sources of emissions, types of pollutants and installed measuring equipment.

All this information is then presented in an emissions inventory report. This report is an important document as it contains the parameters for calculating the environmental and technical characteristics of the facility. The report is not publicly available as it may contain sensitive (including financial) information. The report is submitted to the relevant authority (according to the above-mentioned classification and their geographical/administrative location), and the company begins to prepare documentation to justify the volumes of pollutant emissions into the atmosphere.

At the same time, the enterprise is required to publish a notice of its intention to obtain a permit for emissions in the local media. However, it is not specified what kind of media these should be. In practice, such announcements are published in small local newspapers, which are often not accessible to the general public.

After the announcement of the company's intention to obtain an emission permit, the public has 31 days to submit comments and objections to the relevant regional state administration. In practice, this is difficult to do because the information that would need to be commented on (the emissions inventory report and the materials justifying these emissions) is not publicly available, and the process of justifying emission volume may take up to six months after the publication of the stated intention. At the end of the 31-day period, the relevant regional state administration usually declares that no public comments/objections have been received. The Ministry of Health (or its territorial body) gives its approval and the documentation package is submitted to the relevant permitting authority (depending on the group and geographical/administrative location) for the issuance of the permit.

Within 30 days of receipt, the competent authority reviews the documentation package. If the authority has comments/remarks, the package is returned to the enterprise for the necessary amendments/additions. If there are none, the relevant authority issues a permit.

The permit contains the following conditions:

- emission volumes into the ambient air;

- technological process requirements;
- BAT or, more precisely, emission limit values;
- Methods of reducing atmospheric emissions;
- Methods of monitoring compliance with the permit conditions.

The volume of emissions into the atmosphere approved in the permit is calculated on the basis of documentation submitted by the enterprise. These documents are prepared either by the plant itself or by outsourcing companies. The determination of the permitted emission volumes specified in the permit is based on documents from business entities that are included in the authorised list of the Ministry of Environmental Protection and Natural Resources.

In Ukraine, a number of standards for emission volumes and concentrations are used.

Maximum Permissible Concentration (MPC) is the concentration of a pollutant in the air that is safe for human health, as determined by the Ministry of Health.

Maximum Permissible Emissions (MPE) are the amount of a pollutant that must not exceed the established limit value per unit of time, provided that the concentration of the pollutant at the boundary of the sanitary zone does not exceed the MPC for that substance. MPE standards are developed by the Ministry of Environmental Protection and Natural Resources for specific types of equipment.

Technological Emission Limit Values (TELVs) are the maximum permissible emission volumes approved by the Ministry of Environmental Protection and Natural Resources for specific technological processes that do not fit within the MPE standard.

Both MPE and technological emission limit values are mandatory for the relevant enterprises.

New industrial enterprises, expansion/reconstruction of existing enterprises. According to the Law "On the Protection of Ambient Air", new, reconstructed or expanded industrial facilities must obtain permits under the EIA procedure, which is regulated by the Law "On Environmental Impact Assessment" (EIA Law). Article 3 of the EIA Law contains a list of activities subject to the mandatory EIA procedure.

The new EIA procedure contains a number of improvements over the former "environmental expertise procedure". The current EIA procedure covers a greater number of facility types and activities. More importantly, the EIA considers and

assesses the transboundary impact of a project. Furthermore, a unified EIA register has been established, and making all submitted information freely available to the public via the Internet. The EIA Law also introduced a post-project monitoring procedure. The public can provide comments and suggest specific monitoring and control measures to be included in the final permit. Such monitoring is applied when it is provided by the EIA conclusion to identify any differences and deviations between the predicted impact levels and the effectiveness of measures designed to prevent and reduce environmental pollution. The EIA procedure consists of the following steps:

- submission of the notification of the planned activity subject to EIA (both online and offline);
- preparation of the EIA report;
- public consultations;
- obtaining an EIA conclusion;
- decision on the implementation of the planned activity;
- post-project monitoring (if specified in the EIA conclusion).

Sanctions that may be imposed on business entities for violating the terms of the permit are also being expanded: temporary prohibition and termination of the enterprise's operations.

Public participation. The public has the right to access information about the process of obtaining emission permits and the permits themselves in accordance with the Law “on Access to Public Information”. Under this Law, public authorities are obligated to disclose information they have at their disposal. However, the success of such inquiries remains low; while authorities sometimes respond, they often fail to provide permits or relevant information. Even when they do, the information is often incomplete or takes a long time to be released. Furthermore, regarding the publication of permits and other information, there is no equivalent in Ukraine to the Pollutant Release and Transfer Register under European legislation. Public consultations on EIA procedure are required by law, but they are often not held in practice. Even when conducted, comments and suggestions from the public are not taken into account. Although the new EIA Law has increased the transparency and openness of the permitting process for new, reconstructed, or expanded industrial facilities, the current environmental permitting process for operating industrial facilities still lacks a clear and effective regulatory framework. This would prevent biased decision-making and guarantee the rights of relevant stakeholders.

CHAPTER 5.

Technical support for air quality monitoring in the EU.

5.1. Approaches to air quality monitoring.

The main structural elements of international ambient air quality monitoring are:

- The existence of an extensive network of monitoring stations.
- Methodologies for measuring key air quality indicators, accompanied by monitoring of meteorological conditions.
- Systems for collecting, analysing and transmitting data on ambient air quality.
- Strategies for supporting and developing the monitoring system.
- Communication tools regarding the state of ambient air quality.

Approaches to air quality monitoring include a wide range of organisational, human resource, technical, material and other logistical solutions that involve significant financial costs. These approaches can be divided into the following groups:

1) terrestrial and surface-based monitoring methods, which include both automated and semi-automated sensors for continuous monitoring of atmospheric air and water resources, as well as methods that involve field visits and conducting research directly at monitoring stations (observation points). This group also includes photo and video recording using UAVs and the organisation of stationary photo and video surveillance;

2) The use of remote sensing methods of land or water surface involves obtaining satellite images with the required resolution, followed by their decryption and interpretation. This group of methods also involves the use of photo and video recording using UAVs.

Air quality monitoring at stationary sites is the main tool provided by the Ambient Air Quality Directive (AAQD) to verify compliance with limit or target values for certain air pollutants that have been set to protect human health.

There are two main types of monitoring sites: those where the highest concentration is measured with a risk of overall population exposure over a certain period, and locations where more general exposure is measured.

To ensure comparability across Europe, the AAQD specifies criteria for the location and number of monitoring sites. In addition, these criteria must ensure a certain representativeness of the results, as their number is limited, including due to financial constraints.

5.2. Organisational and logistical aspects of ambient air quality monitoring.

EU Member States, at all relevant levels, shall designate competent authorities and bodies responsible for:

- ambient air quality assessment;
- approval of measurement systems (methods, equipment, networks and laboratories);
- ensuring the accuracy of measurements;
- analysis of assessment methods;
- coordination within their territory, where Community-wide quality control programmes are organised by the Commission;
- cooperation with other Member States and the European Commission.

Where necessary, the competent authorities and bodies shall comply with the provisions of Section C of Annex I to Directive 2008/50/EC.

Ambient air quality assessment shall be carried out for sulphur dioxide, nitrogen dioxide and nitrogen oxides, ozone, particulate matter, lead, benzene and carbon monoxide.

5.2.1. Assessment criteria.

1. Member States shall assess ambient air quality in relation to the above-mentioned pollutants in all their zones and agglomerations in accordance with the criteria set out in Annex III to Directive 2008/50/EC.

2. In all zones and agglomerations where the levels of pollutants exceed the upper assessment threshold established for those pollutants, fixed measurements shall be used to assess ambient air quality. Such fixed measurements may be supplemented by modelling or indicative measurements to ensure that adequate information on the spatial distribution of ambient air quality is obtained.

3. In all zones and agglomerations where the level of pollutants is below the upper assessment threshold established for these pollutants, a combination of

fixed measurements and modelling methods or indicative measurements may be used to assess ambient air quality.

4. In all zones and agglomerations where the level of pollutants is below the lower assessment threshold established for those pollutants, the use of modelling or objective assessment methods, or a combination of both, shall be sufficient for the assessment of ambient air quality.

5. In addition to the assessment, measurements shall be carried out in rural areas, distant from significant sources of air pollution. The objective is to obtain, as a minimum, information on the total mass concentration and concentrations of individual chemical components of fine particulate matter (PM_{2.5}). Such measurements shall be carried out annually and shall take into account the following criteria:

(a) one sampling point shall be established per 100,000 square kilometres;

(b) each Member State shall establish at least one measuring station, or may, in agreement with neighbouring Member States, establish one or more joint measuring stations covering the relevant neighbouring areas in order to achieve the necessary spatial distribution;

(c) where necessary, monitoring shall be coordinated through the monitoring strategy and measurement programme of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP);

Member States shall inform the Commission of the measurement methods used to measure the chemical composition of fine particulate matter (PM_{2.5}).

5.2.2. Network and observation stations.

Member States shall establish zones and agglomerations throughout their territory. Air quality assessment shall be carried out in all zones and agglomerations.

1. Sampling points

1. The location of sampling points for the measurement of sulphur dioxide, nitrogen dioxide and nitrogen oxides, particulate matter (PM₁₀ , PM_{2.5}), lead, benzene and carbon monoxide in ambient air shall be determined using the criteria set out in Annex III.

2. In each zone or agglomeration where fixed measurements are the sole source of information for air quality assessment, the number of sampling points

for each relevant pollutant shall not be lower than the minimum number of sampling points specified in Section A of Annex V.

3. For zones and agglomerations where information from fixed measurement sampling points is supplemented by information from modelling or indicative measurements, the total number of sampling points specified in Section A of Annex V may be reduced to 50%, provided that the following requirements are met:

(a) the additional methods provide sufficient information to assess air quality in relation to limit values and alert thresholds as well as to adequately inform the public;

(b) the number of sampling points to be installed, and the spatial distribution of other methods are sufficient to establish the concentration of the relevant pollutant in accordance with the data quality objectives specified in Section A of Annex I, and to enable the assessment results to meet the criteria defined in Section B of Annex I.

The results of modelling or indicative measurements shall be taken into account in assessing air quality in relation to limit values.

4. The application of the criteria for the selection of sampling points in Member States shall be monitored by the European Commission with a view to promoting the harmonised application of these criteria throughout the European Union.

2. Reference measurement methods.

In order to ensure that collected air pollution data is sufficiently representative and comparable across the Member States, it is important that standardised measurement methods and common criteria for the number and location of measurement points are used for the assessment of ambient air quality. In addition to direct measurements, other methods may also be used to assess ambient air quality, and it is therefore necessary to define criteria for the use and required accuracy of such methods.

The EU monitoring system uses reference measurement methods and criteria set out in Sections A and C of Annex VI to Directive 2008/50/EC. Other measurement methods may be used under the conditions set out in Section B of Annex VI.

Reference methods for assessment of pollutant concentrations.

1. Reference method for the measurement of sulphur dioxide.

The reference method for measuring sulphur dioxide is described in standard EN 14212:2005 "Ambient air quality – Standard method for the measurement of sulphur dioxide concentration by ultraviolet fluorescence".

2. Reference method for the measurement of nitrogen dioxide and nitrogen oxides.

The reference method for measuring nitrogen dioxide and nitrogen oxides is described in standard EN 14211:2005 "Ambient air quality – Standard method for the measurement of nitrogen dioxide and nitrogen monoxide concentrations by chemiluminescence".

3. Reference method for the sampling and measurement of lead.

The reference method for lead sampling is described in Part 4 of Section A of this Annex. The reference method for measuring lead is set out in standard EN 14902:2005 "Ambient air quality - Standard method for the measurement of Pb/Cd/As/Ni in the PM₁₀ fraction of suspended particulate matter".

4. Reference method for the sampling and measurement of PM₁₀.

The reference method for the sampling and measurement of PM₁₀ is defined in standard EN 12341:1999 "Ambient air quality – Determination of the PM₁₀ fraction of suspended particulate matter – Reference method and field test procedure for the demonstration of equivalence of measurement methods".

5. Reference method for the sampling and measurement of PM_{2.5}.

The reference method for the sampling and measurement of PM_{2.5} is specified in standard EN 14907:2005 "Ambient air quality - Standard gravimetric measurement method for the determination of the mass fraction of PM_{2.5} of suspended particulate matter".

6. Reference method for the sampling and measurement of benzene.

The reference method for measuring benzene is described in Parts 1, 2 and 3 of standard EN 14662:2005 "Ambient air quality – Standard method for the measurement of benzene concentrations".

7. Reference method for the measurement of carbon monoxide.

The reference method for measuring carbon monoxide is set out in standard EN 14626:2005 "Ambient air quality – Standard method for the measurement of carbon monoxide concentrations by non-dispersive infrared spectroscopy".

8. Reference method for the measurement of ozone.

The reference method for measuring ozone is described in standard EN 14625:2005 "Ambient air quality – Standard method for the measurement of ozone concentration by ultraviolet photometry".

Reference measurement methods for major pollutants (sulphur dioxide, nitrogen dioxide and nitrogen oxides, benzene, carbon monoxide, particulate matter (PM10, PM2.5), ozone) provide for the possibility of measuring their levels in automated mode. For other pollutants on the list of priority substances (arsenic, cadmium, nickel, benzo(a)pyrene), the Procedure for State Monitoring in the Field of Ambient Air Protection defines reference methods that involve sampling and subsequent analysis by chemical laboratories.

In addition, in accordance with the requirements of the EU Ambient Air Quality Directives, modelling methods should be used where possible to enable the interpretation of concentration data depending on their geographical location. The use of measurement data in combination with data on pollutant emissions, geographical and meteorological indicators can serve as a basis for calculating the collective risk exposure for the population living in the relevant area.

In order to control the quality of ambient air quality assessment, and to guarantee measurement accuracy and compliance with data quality objectives, the relevant competent authorities and structures of EU Member States ensure that:

- all measurements carried out in connection with the assessment of ambient air quality are traceable in accordance with the requirements set out in Section 5.6.2.2. ISO/IEC 17025:2005,
- institutions operating monitoring networks and individual stations establish quality assurance and quality control systems that provide for regular maintenance in order to ensure the accuracy of measuring devices,
- an established quality assurance/quality control procedure for data collection and reporting processes, and that the institutions designated to perform this task actively participate in relevant quality assessment programmes at Community level,
- national laboratories, if designated by the relevant competent authority or organisation, which participate at the European Community level in intercomparison of pollutants regulated by this Directive, are accredited in accordance with EN/ISO 17025 by 2010 for the reference methods specified in Annex VI. Such laboratories are involved within the territory of Member States in the coordination of quality assessment programmes organised by the Commission at the European Community and shall coordinate, at national level, the corresponding implementation of reference methods and the confirmation of the equivalence of non-reference methods.

Confirmation of equivalence.

1. A Member State may use any other method which it can demonstrate to produce results equivalent to any of the methods specified in Section A or, in the case of particulate matter, any other method which the Member State can demonstrate to be compatible with the reference method. In such cases, the results obtained by using alternative method shall be adjusted in order to obtain results equivalent to those that would have been obtained using the reference method.

2. The Commission may require Member States to prepare and submit a report confirming equivalence.

3. In assessing the acceptability of the report, the Commission shall refer to its guidelines on equivalence confirmation (to be published). If Member States have used interim factors in order to approximate equivalence, such factors shall be confirmed or amended with reference to the Commission's guidelines.

4. Member States shall ensure, where appropriate, that such adjustments are also applied to data from past measurements in order to achieve better data comparability.

Standardisation.

For gaseous pollutants, the volume shall be standardised to a temperature of 293 K and an atmospheric pressure of 101.3 kPa. For particulate matter and substances analysed in particulate fractions (e.g. lead), the sample volume shall reflect the atmospheric conditions in terms of temperature and atmospheric pressure at the time of measurement.

Introduction of new equipment.

All new equipment purchased for the implementation of the provisions of this Directive shall comply with the reference method or its equivalent by 11 June 2010.

All equipment used for fixed measurements must comply with the reference method or its equivalent by 11 June 2013.

Mutual recognition of data

When conducting type approval to confirm that equipment meets the performance requirements of the reference methods specified in Section A, the competent authorities and bodies designated in accordance with Article 3 shall accept test reports issued in other Member States by laboratories accredited to the EN ISO 17025 standard for carrying out such testing.

5.3. Modern methods and means for air pollution control.

5.3.1. Remote sensing of the Earth.

One of the key approaches to environmental monitoring is observation using remote sensing of the Earth. The use of remote sensing allows obtaining of the information about the state of the environment and its components at the international, regional and local levels. Data obtained through remote sensing can be combined with data from ground-based observation methods, as well as with modelling methods, which allows for a comprehensive assessment of the state of the environment, forecasting, and tracking changes in its dynamics.

Among the best examples of international observation and decision-making systems using remote sensing of the Earth is the European Union's Copernicus programme. It provides all stakeholders (countries) with timely and accurate geospatial information obtained from Earth observation satellites and other sources. This data is necessary for the effective elimination of the consequences of natural disasters, man-made emergencies, and addressing humanitarian crises.

The Copernicus programme was established in 2011 and became fully operational in 2014. The space component of the Copernicus information system is served by a set of specialised satellites of the Sentinel family and supporting missions (existing commercial and public satellites). Sentinel satellites are specifically designed to meet the needs of Copernicus services and their users. Since the launch of Sentinel-1A in 2014, the European Union has embarked on a programme to deploy a family of nearly 20 satellites into orbit by 2030.

This programme offers information services based on Earth observation satellite data and local data (non-space-based data). The programme is coordinated and managed by the European Commission. Copernicus is implemented in partnership with EU Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU agencies, Mercator Océan and countries with signed international agreements. Talking about the data dissemination policy under the Data Access Programme, Copernicus is attracting increased interest. In this context, the EU is seeking opportunities to share data for the benefit of the Copernicus programme. Thus, the fastest way to gain access Copernicus data that requires authentication is to offer to share local observations from Ukraine. On

25 May 2018, the State Space Agency of Ukraine and the European Commission signed a Cooperation Agreement on data access and the use of Sentinel satellite data of the Copernicus Programme. In exchange, the SSAU provides free open access to data from its own satellites for use within the Copernicus programme. Information services are provided to authorised users of the Copernicus programme free of charge via open access. This applies only to data with low and medium spatial resolution.

Depending on their access level, users can work with raw data from direct observations or use the results of processing and forecast calculations in a convenient format. Detailed user instructions are provided for working with raw data streams from direct observations, which describe the data structure and format.

Copernicus also collects information from in situ systems (local data), such as ground-based stations, which deliver data obtained by a multitude of sensors located on land, at sea or in the air. As a result, the modelling of processes in the atmosphere, oceans, and on the Earth’s surface is based not only on satellite observation data but also on data from local terrestrial, atmospheric, and marine measurement systems. The main purpose of in situ observation data is to refine satellite observation data and to support the periodic calibration of satellite monitoring systems.

As a result of data processing and modelling, various current and forecast thematic maps are created, features and anomalies are identified, and statistical data can be reviewed and refined.

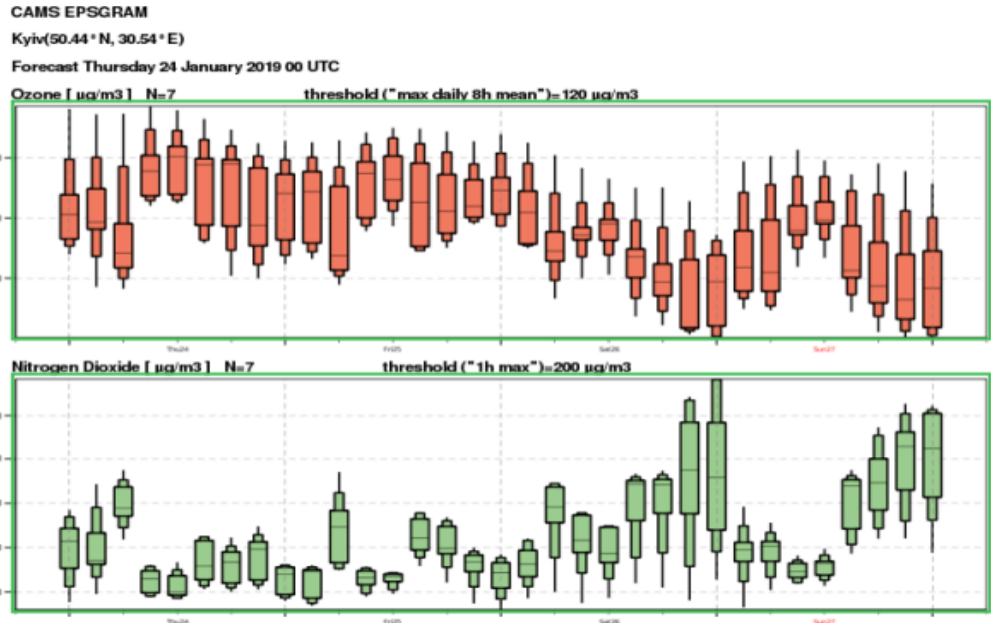


Fig. 9. Example of satellite data.

The information obtained by the system is optimised through six thematic streams of Copernicus services:

1. Atmosphere Monitoring Service (CAMS).
2. Marine Environment Monitoring Service (CMEMS).
3. Land Monitoring Service (CLMS).
4. Climate Change Service (C3S).
5. Copernicus Security Service.
6. Copernicus Emergency Management Service (EMS). The Copernicus Emergency Management Service (EMS) provides all participants involved in the management of natural disasters, technological emergencies and humanitarian crises with timely and accurate geospatial information obtained from satellite observation data and local (in-situ) data sources.

The Copernicus EMS service consists of two components:

1. Mapping service.
2. Early warning systems.

The mapping service (Copernicus EMS-Mapping) provides the above-mentioned entities (mainly civil protection authorities and humanitarian aid organisations) with maps based on satellite imagery. The service began operating on 1 April 2012, with scientific support provided by the European Commission's Joint Research Centre (JRC).

The products generated by the service can be used in the form of digital or printed maps, or can be combined with other data sources (e.g. in the form of digital feature sets in a Geographic Information System) to support geospatial analysis and decision-making processes by emergency management authorities. Copernicus EMS-Mapping can support all stages of the emergency management cycle: preparedness, prevention, disaster risk reduction, emergency response and recovery.

The Early Warning System of Copernicus EMS consists of three different systems:

- The European Flood Awareness System (EFAS), which provides data regarding current and forecasted floods across Europe with a forecast of up to 10 days;
- The European Forest Fire Information System (EFFIS), which provides near real-time and historical data on forest fires and forest fire regimes within Europe, the Middle East and North Africa;

- The European Drought Observatory (EDO), which provides drought-relevant information and drought prevention for Europe.

The Global Flood Awareness System (GloFAS), the Global Wildfire Information System (GWIS) and the Global Drought Observatory (GDO) complement the early warning framework at the global scale.

The Copernicus EMS service provides information free of charge to authorised users only, operating both in emergency mode and in non-emergency modes. These services support emergency management activities not requiring immediate response (delay of one to three hours).

The Copernicus space observation system is based on the use of observation data from six satellite families: Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-4, Sentinel-5, and Sentinel-6. Each satellite family consists of two or four satellites. Some of the satellites have already been launched into orbit, while others are still in the development phase or are undergoing launch preparation.

CAMS is one of six services that make up Copernicus, the European Union's Earth observation programme. The basic concept of Copernicus is to provide information regarding air quality and atmospheric composition both within and beyond Europe based on satellite and ground-based (in-situ) observations combined with forecasting models.

Copernicus provides users with data through various services. These include the Climate Change Service (C3S) and the Atmosphere Monitoring Service (CAMS), both managed by the European Centre for Medium-Range Weather Forecasts (ECMWF). The Copernicus Atmosphere Monitoring Service (CAMS) provides continuous data and information on the atmospheric composition.

The main tasks of Copernicus Atmosphere Monitoring are: describing the current state of the atmosphere; providing forecasts for several days; analysing retrospective data from recent years. The service supports many applications in various fields, including public health, environmental monitoring, renewable energy sources, meteorology and climatology.

CAMS services focus on five main areas:

1. Air quality and atmospheric composition.
2. Ozone layer and ultraviolet radiation.
3. Waves and surface currents.
4. Solar radiation.
5. Impact on climate.

The service provides daily information on the overall atmospheric composition using monitoring and forecasting components such as greenhouse gases (carbon dioxide and methane), reactive gases (e.g. carbon monoxide, nitrogen oxides, sulphur dioxide), ozone and aerosols. Furthermore, it provides a practical real-time analysis and 4-day forecasts, as well as reanalysis of European air quality. These outputs enable the continuous assessment of the ambient air quality; it also provides public and private organisations involved in the use of solar energy with relevant and accurate information on solar radiation resources on the Earth's surface, which is important in areas such as public health, agriculture and renewable energy sources.

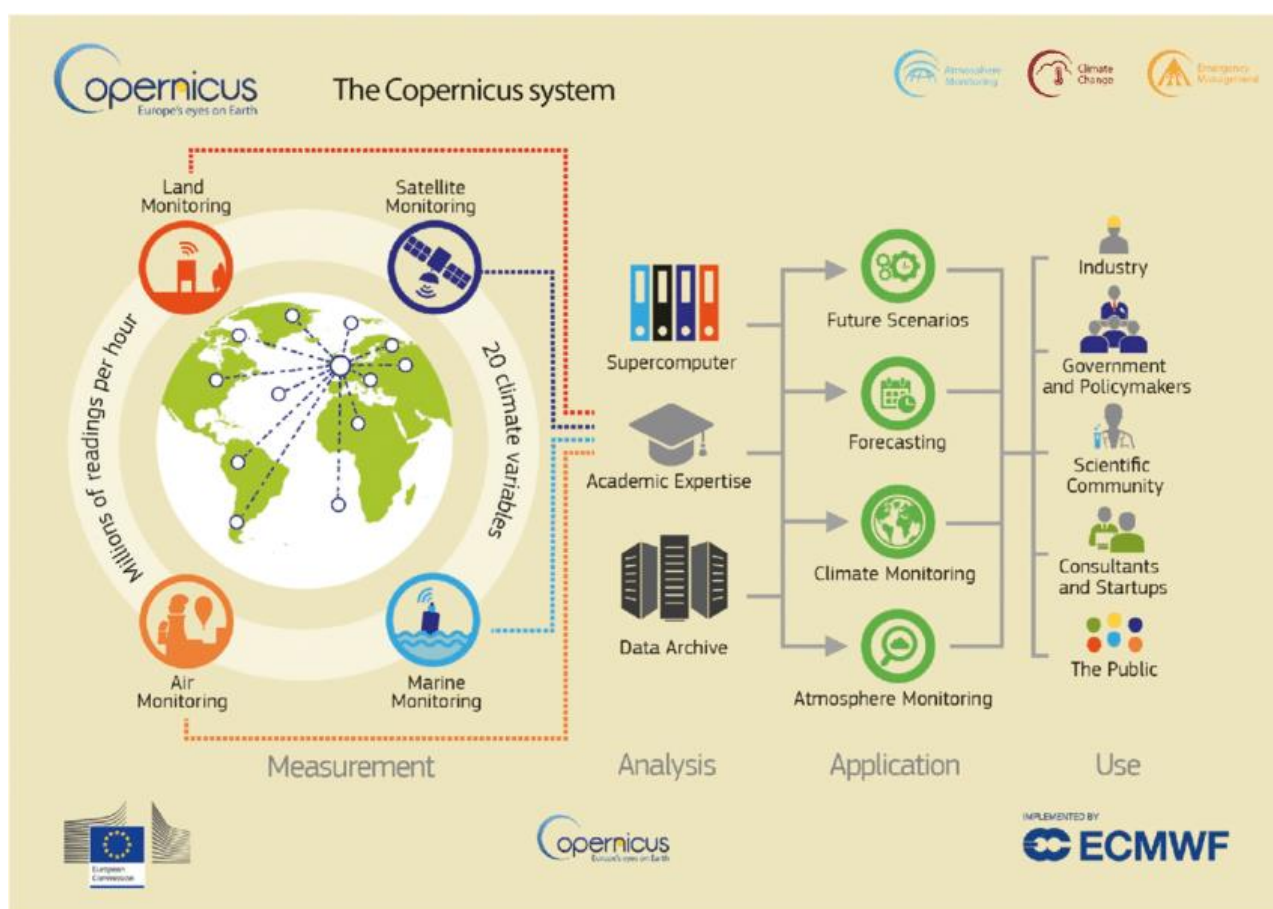


Fig. 10. Organisation of the Copernicus system

All information is provided free of charge and without restrictions in order to raise awareness of the state of the atmospheric environment among politicians, businesspeople and citizens.

The CAMS service is based on seven modern air quality models developed across Europe:

- 1) CHIMERE by INERIS (France),

- 2) EMEP by MET Norway (Norway),
- 3) EURAD-IM by the University of Cologne (Germany),
- 4) LOTOS-EUROS by KNMI and TNO (Netherlands),
- 5) MATCH by SMHI (Sweden),
- 6) MOCAGE by METEO-FRANCE (France),
- 7) SILAM by FMI (Finland).

In addition to these, there is also the ENSEMBLE model, which is a combination of all the above models. Data from this model is available for the whole Europe (25°W-45°E, 30°N-70°N).

CAMS is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission. ECMWF is an independent international organisation supported by 34 countries. It is both a research institute and a 24-hour operational service, that produces and distributes numerous weather forecasts for its Member States.

To ensure the operation and further development of CAMS, ECMWF collaborates with many service providers across Europe. In doing so, CAMS combines the expertise and infrastructure that exists in Europe to provide a range of services that are unmatched by any other organisation in the world. CAMS is implemented through the European Centre for Medium-Range Weather Forecasts (ECMWF) and with the support of more than 30 organisations located across Europe. Air quality information is assessed using the European Air Quality Index, which complies with the EEA definition. The index is calculated for the five most important air pollutants regulated by European legislation: O₃(ozone), NO₂(nitrogen dioxide), SO₂ (sulphur dioxide), PM_{2.5} and PM₁₀ (particulate matter with a diameter of less than 2.5 micrometres and 10 micrometres, respectively). For each pollutant, the index value ranges from 1 (good) to 5 (very poor). The European Air Quality Index is calculated separately for different air pollutants based on their concentrations (depending on the air pollutant, either as a daily average or immediately). Higher concentrations correspond to higher index value. The European Air Quality Index is represented by an integer, corresponding to five concentration ranges specific to each pollutant. The overall hourly European Air Quality Index is defined as the highest value of the five individual pollutant indices calculated for the same time. For example, if the O₃, NO₂, SO₂, PM_{2.5} and PM₁₀ indices are 1, 3, 1, 2 and 2 respectively, the average index will be 3. The overall daily European Air Quality Index is the highest value of the overall hourly European Air Quality Index for

that day. The overall daily European Air Quality Index is reported in the news on the Euronews channel.

CAMS can also provide forecast data. Just like a weather forecast, this information is based on advanced mathematical models and reflects physical laws in combination with past observations. As a result, forecasts may occasionally be inaccurate. However, an assessment of the last six months of 2017 showed that the forecasts were accurate within one index value (either higher or lower by one) in more than 98% of cases.

The data it provides is obtained using a computational grid with horizontal cells approximately 10 km by 10 km, which means that they cannot reflect local effects (such as a road with heavy traffic within a few hundred metres, etc.). In large cities, the values provided by CAMS also reflect the concentrations of the so-called "urban background", corresponding to areas of the city that are not affected by local sources such as traffic directly (e.g. inside a large park or in a residential area). It is expected that areas affected by local sources may have higher concentrations of NO₂, PM_{2.5}, PM₁₀ and SO₂ and lower concentrations of O₃.

5.4. Application of sensors to air quality monitoring.

The expansion of commercial availability of micro-sensor technology is facilitating the rapid adoption of low-cost sensors for air quality monitoring by both community science initiatives and public authorities. One of the advantages of using LCS is the increase in spatial coverage when monitoring air quality in cities and remote locations.

In general, public authorities want to increase the density of monitoring measurements and often want to rely on low-cost sensors as they cannot afford enough air quality monitoring stations (AQMS)²⁷. Low-cost sensors can provide real-time measurements at a lower cost, allowing broader spatial coverage than current reference methods for measuring air pollutants.

Furthermore, air pollution monitoring using reference measurement methods requires skilled operators to maintain and calibrate the measuring devices. Conversely, low-cost sensors are designed for autonomous operation, allowing unskilled users to monitor air quality without the need for additional technical expertise. Many institutions responsible for regulatory monitoring air quality, as well as local authorities, are considering incorporating low-cost

sensors into their routine measurement methods to complement reference measurement monitoring. However, the lack of comprehensive and accessible information for comparing the performance of low-cost sensors and the wide range of commercial offerings make it difficult to select the most appropriate low-cost sensors for monitoring purposes. To classify and understand sensor deployment, a distinction should be made between a single sensor detector manufactured by an original equipment manufacturer (hereinafter referred to as OEM or OEM sensors) and sensor systems (SSys). The latter includes OEM sensors along with a protective enclosure, sampling system, power supply, electronic equipment, and software for data collection, analogue-to-digital conversion, processing, and transmission. Hereinafter, both OEM and SSys are referred to as low-cost sensors (LCS). From a user perspective, SSys are ready-to-use systems for immediate deployment, while OEM users need to add hardware/software components for meteorological protection, data storage, data transmission, data compatibility, as well as overall LCS calibration. The application of LCS is of great interest to public science initiatives. Thus, small and medium-sized enterprises offer SSys that can be used by citizens who want to monitor air quality in a selected environment.

Currently, there are hundreds of LCS commercially available on the market, ranging in price from a few hundred to several thousand euros. At the same time, current scientific literature contains independent information on the performance of sensor systems relative to reference measurements for approximately 110 sensor systems. In fact, the data quality from low-cost sensors is often questionable. It is influenced by atmospheric conditions, pollutant concentration levels and, therefore, the location where measurements are taken.

There are only a few commercially available sensor systems that, according to studies, demonstrate high correlation with reference measurements (coefficient of determination, R^2 , above 0.75 and a regression line slope within 1 ± 0.5) and a total price lower than 3,000 euros. Information on such studies was obtained from research institutes that have LCS testing programme, e.g. the California Air Resources Board – Air Quality Sensor Performance Evaluation Centre (AQ-SPEC), the European Union’s Joint Research Centre (EUJRC) and the US Environmental Protection Agency (USEPA). Other information was taken from peer-reviewed journals that tested different types of sensors through empirical studies. The conclusion from this market analysis is that the only one sensor system meets the requirements of multi-pollutant monitoring, raw data

accessibility, full transparency of all data processing, and availability of sensor system performance evaluation with a high coefficient of determination (>0.85). This system was identified as the AirSenseEURv.2.

These LCS for monitoring gaseous air pollutants are grouped into four categories based on operating principles and technologies based on:

- metal oxide sensors,
- electrochemical or amperometric sensors,
- non-dispersive infrared absorption (NDIR)
- photoionisation detectors.

In particular, metal oxide sensors consist of a metal oxide (resistive or semiconducting MeO), whose resistance or conductivity changes under the influence of oxidising gas(es). The reaction of such gases with heated MeO leads to the capture and accumulation of electrons on the sensor's surface, creating a negative charge that acts as a barrier to electrons, thus changing the conductivity. Conductivity changes are usually proportional to the concentrations of oxidising gases in the ambient air and can be controlled by an external circuit. MeO-LCS are capable of measuring non-methane hydrocarbons, CO, carbon dioxide (CO₂), NO, NO₂ and O₃.

5.5. Air quality monitoring systems in Poland.

Air pollution monitoring in Poland is part of the National Environmental Monitoring System. Poland is required to produce an annual air quality report in accordance with the Convention on Long-range Transboundary Air Pollution and the Protocol to this Convention on EMEP financing.

Measurements are carried out at State Environmental Monitoring stations established by the Chief Inspectorate for Environmental Protection, in cooperation with other organisational units subordinated to the Ministry of Climate and Environment as well as units subordinated to the Ministry of Health (including the State Sanitary Inspection and the Central Institute for Labour Protection).

Furthermore, in compliance with the provisions of Directive 2004/107/EC of the European Parliament and of the Council on arsenic, cadmium, nickel, mercury and polycyclic aromatic hydrocarbons in ambient air, part of the measurements consists of assessing the background pollution of the air with heavy metals and polycyclic aromatic hydrocarbons. While in accordance with

the provisions of Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe, part of the research is aimed at providing comprehensive data on the atmospheric concentration and chemical composition of PM_{2.5}.

The total number of air quality monitoring stations in Poland is 287, including 213 automatic or semi-automatic stations. The monitoring programme is set by the EMEP Steering Body. The following measurements are carried out at Polish stations: measurements in the gas phase of SO₂, NO₂, O₃; in aerosols: SO₄²⁻, NO₃⁻, NH₄⁺, Cl⁻; in atmospheric precipitation: SO₄²⁻, NO₃⁻, NH₄⁺, Cl⁻, Na⁺, Ca²⁺, K⁺, Mg²⁺, electrolytic conductivity, and pH. Furthermore, specialized measurements of heavy metals are conducted at the stations in Łeba and the Borecka Forest.

In addition, the station in the Boretska Forest measures PM₁₀ and heavy metals (As, Cd, Cr, Cu, Ni, Pb, Zn), polycyclic aromatic hydrocarbons (benzo(a)pyrene, benzoanthracene, benzofluoranthene, benzofluoranthene, benzofluoranthene, dibenzoanthracene, indeno(1,2,3-cd)pyrene) as well as PM_{2.5}, organic and elemental carbon, as well as measurements of CO₂, and Hg in the air and polycyclic aromatic hydrocarbons in total precipitation.

The results of hourly automated air pollution measurements are available on the Air Quality portal in the “Current Measurement Data” module as well as in the “Air Quality in Poland” mobile applications. The results of manual measurements of the content of benzo(a)pyrene, lead, arsenic, cadmium and nickel in PM₁₀, PM_{2.5} particulate matter become available approximately 1-1.5 months after sampling period.

CHAPTER 6.

European EEA-EU experience in air quality indices calculation and implementation practices for real-time public information on air pollution and population health risks

6.1. Logistics and technical support for air quality monitoring.

Organization of ambient air quality monitoring.

Ambient air pollution ranks as the primary threat, in terms of chemical hazard to humans, causing negative environmental consequences for ecosystems, and has a direct negative impact on vegetation and fauna, as well as on water and soil quality.

Global and regional observation and monitoring systems for ambient air pollution in developed countries are organized in accordance with UN recommendations. These recommendations were developed in the 1970s.

The main structural elements of international ambient air quality monitoring are:

- The presence of an extensive system of monitoring stations.
- Availability of a methodology for measuring key air quality indicators along with meteorological monitoring.
- Availability of a system for collecting, analyzing and transmitting data on the state of ambient air quality.
- Availability of a strategy for system maintenance and development.
- Availability of communication tools regarding ambient air quality status.

The organization of monitoring involves controlling the dispersion of harmful impurities both within the atmosphere itself and across the integrated "atmosphere - hydrosphere - lithosphere - biosphere" system. For this activity, the following is required:

1. Information on existing and prospective sources of atmospheric pollution (taking into account the economic development of the region).
2. Characteristics of pollutants (toxicity, physicochemical properties).
3. Hydrometeorological data.
4. Results of previous researches (retrospective analysis).
5. Data on atmospheric pollution in other areas, regions and countries.

Each country independently determines the list of pollutants to be monitored.

In Ukraine, ambient **air pollution monitoring** has been carried out since the early 1960s. The air quality monitoring system in Ukraine is gradually being updated to align with European standards, in particular the requirements of EU Directives included in the so-called "Green" European integration course.

Key new or updated aspects that are being implemented or planned to be include:

- harmonization with EU Directives
- unified state environmental monitoring system
- new priority pollutants (prioritizing the monitoring of PM_{2.5} and PM₁₀ (fine particulate matter) – one of the main health risks)
- automated air monitoring stations (AMS)
- gradual replacement of DSTU

So, Ukraine has not yet abandoned old standards, but is actively integrating modern, European approaches. This transition is being facilitated through projects such as APENA (it was carried out in the Ivano-Frankivsk region, the Delegation of the European Union to Ukraine is implementing pilot climate change adaptation strategies and corresponding implementation plans with European Union funds), and within the framework of the EU Association Agreement.

Currently, monitoring of APL (atmospheric pollution levels) in cities and residential areas of Ukraine is still carried out in accordance with DSTU 4219:2003 “Nature Protection. Atmosphere. Rules for Air Quality Control in Residential Areas”. However, it is gradually **being updated** to meet European standards:

- emphasis on data quality, sources of measurement uncertainty, calibration control, in particular, more accurate measurement of pollutant concentrations;
- health risk assessment;
- introduction of **air quality indices (AQI)** according to European classification scales;
- public access to data online.

In many regions of Ukraine (especially pilot ones, such as Ivano-Frankivsk), automatic stations are being installed that:

- comply with EU accuracy standards;
- transmit data to a unified electronic data portal.

In February of this year, Ivano-Frankivsk began cooperation with Finland in the field of air quality within the framework of the UFAIR project. The goal of the project is to establish an effective air quality monitoring system that will comply with European requirements. This project is being implemented with the support of the Finnish Metrological Institute and is funded by the Ministry of Foreign Affairs of Finland. The total project budget exceeds 650,000 euros. One of the key stages of the project is the installation of modern air quality monitoring stations in large cities of Ukraine. Ivano-Frankivsk is among the selected cities where the establishment of a city background monitoring station is planned. The installation of such a station will allow monitoring the level of air pollution by 16 indicators, compared to 4–5 parameters currently monitoring. Several potential locations for the station have already been identified, and the final decision will be made by a working group. The Ivano-Frankivsk monitoring station will be only part of a large-scale environmental project, which will be implemented over four years in four regions of Ukraine.

An automated air quality monitoring system of the Kyiv City State Administration is already operating in Kyiv, which includes 46 indicative sensors and 7 reference monitoring stations. According to the results of an independent inspection by experts from the Finnish Meteorological Institute, the relevant stationary monitoring stations in the capital are equipped with modern equipment that meets EU criteria. All Kyiv City State Administration stations are certified.

At the national level, air quality monitoring in Ukraine is carried out by:

- The Center for Disease Control and Prevention of the Ministry of Health of Ukraine provides monitoring of ambient air quality in residential and recreational areas, including in highway zones, sanitary and hygienic zones, as well as on territories of educational insitutuions, healthcare facilities, etc. In addition, ambient air quality analysis can be conducted based on citizens' complaints.

- Ukrainian Hydrometeorological Center (UGMC) of the State Emergency Service of Ukraine.

- Environmental protection units of regional and municipal state administrations are designated as air quality management bodies, which ensure coordination of air quality monitoring and air quality management within the territory of a zone or agglomeration. They monitor sources of industrial emissions into the atmosphere (pollutant concentration, including radionuclides).

Such monitoring will help raise environmental awareness among residents and respond to changes in ambient air quality in a timely manner.

In conditions of limited state resources, and due to the lack of state or municipal sensors in many settlements, a community-based initiative for public air quality monitoring has emerged in Ukraine. The expertise and skills of public organizations are often critically needed to resolve individual issues. In many cases, they provide operational information about the ambient air status. They monitor fine particulate matter, which is not yet tracked by state monitoring bodies. In some settlements, this is the only source of such information.

The involvement of civil society organizations and close cooperation with the public align with both the letter and spirit of the Aarhus Convention, which Ukraine has ratified. Public monitoring is **an indicative (approximate) indicator** of air pollution that the public can rely on. This enables citizens to analyze the indicators and evaluate the environmental situation in the city on a daily basis.

Monitoring devices used within the community are uncertified, however empirical evidence suggests that civic monitoring results do not report higher pollution levels than the certified stations operated by the Kyiv City State Administration (KCSA). Certification only increases the cost of these devices that are designed as low-cost solutions specifically for citizens.

The wider commercial availability of micro-sensor technology has facilitated the adoption of low-cost air quality sensors by both citizen science initiatives and governmental agencies. One of the advantages of using low-cost sensors for monitoring is the increased spatial coverage when monitoring air quality in cities and remote locations.

In general, public authorities want to increase the density of monitoring networks and often rely on low-cost sensors, as the deployment of sufficient number of reference air quality monitoring stations (AQMS) is financially unfeasible. Low-cost sensors can provide real-time measurements at a lower cost, allowing broader spatial coverage. In addition, air pollution monitoring using **reference measurement methods** requires skilled operators to maintain and calibrate the complex measuring devices. In contrast, low-cost sensors are expected to be self-operating, allowing unskilled users to monitor air pollution without the need for advanced technical knowledge.

Many institutions responsible for air quality monitoring for regulatory purposes, as well as local authorities, are considering incorporating low-cost

sensors into their routine measurement methods to supplement monitoring of reference measurements.

The existing air pollution monitoring network in Ukraine includes stationary, route-based and mobile (flare) monitoring posts.

An observation post is a selected location (point of the terrain) where a pavilion or a vehicle equipped with appropriate instruments is placed. A stationary monitoring post is designed to ensure regular air sampling for the purpose of further laboratory analysis and continuous recording of pollutant concentrations using automatic gas analyzers. At these observation posts, air sampling for analysis can be carried out both manually and automatically (using an ANKOS-AG system designed for continuous monitoring of spatial and temporal variations in air pollution and meteorological parameters. These systems are equipped with automatic sampling systems and automatic gas analyzers for pollutant determination.

There are a number of methods for conducting analysis to determine air pollution:

1. **Express methods** for rapid determination of harmful substances in indoor air – automatic devices and portable devices with manual air sampling are used. Automatic devices can be used for express monitoring in a periodic or continuous mode. Such devices are divided into gas analyzers and gas detectors. Both types share the following features: rapid registration of the pollutant concentrations and the mandatory provision of a signal (visual or auditory) about the excess of the pollutant content in the air.

2. **Laboratory** – a selected air sample is analyzed in a laboratory using chemical or physicochemical methods (photometric, chromatographic, mass spectrometric, etc.). These methods can be used to determine the amount of pollutant concentrations in the air with sufficient accuracy, but they require significant time.

Regular observations at fixed monitoring stations are carried out according to one of four observation programs: full, incomplete, reduced, daily. This allows assessing the dynamics of air pollution and identifying affected areas.

The existing network of air monitoring stations makes it possible to monitor air pollution in populated areas, identify the impact of pollution sources on specific territories; determine the dynamics of atmospheric pollution, identify territories with a tendency to increase air pollution, and at the same time identify hazardous sources of emissions.

6.2. European and Ukrainian experience in calculating air quality indices.

6.2.1. The concept of air quality index.

The basic chemical indicators of air pollution need to be converted into an indicator that shows the relationship between observational data and public health consequences.

There is international experience from the US Environmental Protection Agency (**EPA, USA**) - a department in the US federal government, which was established to protect human health and the environment, as well as the US Environmental Protection Agency). There is also European experience from European Environment Agency (**EEA EU**). **European Environment Agency** provides independent environmental information. Both agencies have developed methodologies for calculating Air Quality Indices (AQI) and for applying them in order to promptly inform the population about air pollution and risks to public health. The **AQI** was developed by the US Environmental Protection Agency and is used in many countries around the world. **Air quality index (AQI)** is a measure used **by governmental authorities** in different countries to communicate the current level of ambient air pollution to the public. If the index increases, a significant portion of the population will face serious health consequences. Different countries have their own air quality indicators according to different national standards.

AQI

1-50	Clean air. You can ventilate and spend time actively outdoors.
51-100	Acceptable air quality. No cause of concern; this is a normal indicator.
101-150	Unhealthy air for sensitive groups. Individuals with cardiovascular or respiratory conditions, as well as children, are advised to limit outdoor activities.
151-200	Unhealthy air quality. Outdoor activities should be avoided; indoor ventilation should be suspended.
201-300	Very unhealthy air quality. Windows should be kept closed; where possible, air purifiers should be used.
from 301	Hazardous air quality. Protect yourself by turning on an air purifier or humidifier.

The Air Quality Index allows monitoring air quality indicators in real time in countries that have implemented real-time data transmission protocols.

In general, higher AQI values correspond to higher levels of air pollution and indicate more negative impact on human health. What are the AQI air quality levels?

Certain European countries also have their own indices. In particular, the British Daily Air Quality Index, used by UK government, has a 10-point scale divided into 4 parts, where (1) is taken as the lowest value with the minimal health hazard, while (10) indicates the highest level of pollution and is most hazardous to health.

Ukraine will introduce a new procedure for informing the population about air quality according to key indicators using the air quality index. The corresponding order of the Ministry of Environment Protection dated 24 March 2025 No. 590 was registered with the Ministry of Justice of Ukraine on April 7 under No. 536/43942. The document approves the Procedure for Public Information on Air Quality Based on Key Indicators Using an Air Quality Index in Ukraine. According to the Ministry, this represents an important step towards ensuring free public access to information about air quality in Ukraine in a format adapted for users.

the Procedure establishes the following elements:

- list of air pollutants for determining the quality index,
- concentration ranges for each pollutant,
- color-coded and textual index indicators,
- recommendations for the population.

It is noted that the Air Quality Index for any pollutant is defined as:

"Very poor",

"Poor",

"Unsatisfactory",

"Satisfactory",

"Acceptable",

"Good".

At the same time, the concentration ranges used for the Air Quality Index are determined based on the regulatory values of the levels for each pollutant, taking into account the WHO recommendations on air quality as well as the European Air Quality Index. The Ministry has emphasized that the Procedure is

being developed in alignment with the European Air Quality Index, published on the official website of the European Environment Agency (EEA). Subsequently, the Ukrainian Air Quality Index will also be presented on the EEA platform.

6.2.2. European Air Quality Index.

Air quality information across EU Member States is assessed using the European Air Quality Index, which is defined by the EEA (<https://www.eea.europa.eu/themes/air/air-quality-index>).

The European Air Quality Index allows users to better understand the air quality where they live, work or travel. By displaying up-to-date information for Europe, users can get an overview of the air quality in certain countries, regions and cities.

The index assesses air quality based on five indicators:

- particulate matter (PM_{2.5} and PM₁₀ – suspended particles with a diameter of less than 2.5 micrometers and 10 micrometers, respectively),
- ground-level ozone (O₃),
- nitrogen dioxide (NO₂),
- sulfur dioxide (SO₂).

Each of the indicators is assessed in accordance with standards established by European Union Directives (<http://ec.europa.eu/environment/air/quality/standards>.) EU legislation defines ambient air quality standards for both short-term (hourly or daily) and long-term (annual) air quality levels. As the standards differentiate between long-term and short-term indicators, the Air Quality Index provides regarding short-term air quality. It does not reflect the long-term air quality status, which may vary significantly. The standards for long-term levels are stricter than for short-term levels, as prolonged exposure to pollutants can have serious health consequences.

The Air Quality Index is not a tool for verifying compliance with ambient air quality standards and cannot be used for this purpose.

The European Air Quality Index is calculated for different air pollutants separately by concentration (depending on the air pollutant, on an average per day or immediately). The index value increases proportionally with the concentration levels. For each pollutant, the index value ranges from 1 (good) to 5 (very poor). The European Air Quality Index is represented by an integer corresponding to five concentration ranges characteristic of each pollutant.

By default, the air quality index displays the atmospheric conditions for the last 3 hours. Users can select any specific hour within the previous 48 hours and view the forecast for the next 24 hours.

The index bands are complemented by health-related messages that include recommendations both for the general population and for sensitive population groups, including adults and children with respiratory conditions, as well as adults with heart disease.

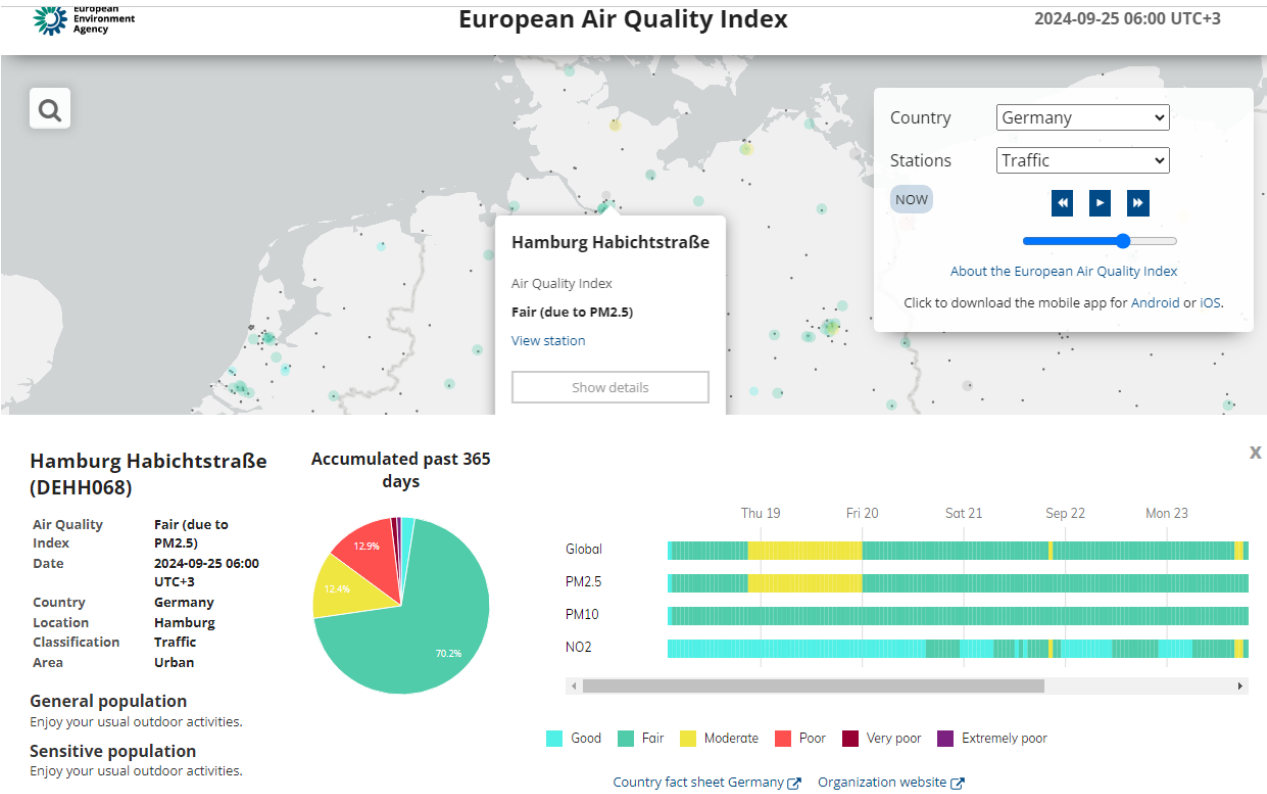


Fig. 11. Visual representation of the European Environment Agency Air Index

Air quality index calculation methodology

The index is calculated hourly using data from more than 3,500 air quality monitoring stations across Europe. The calculation relies on up-to-date hourly data officially provided by EEA (European Economic Area) Member States, supplemented where necessary with modelled air quality data from the EU’s Copernicus Atmosphere Monitoring Service (CAMS) (<http://atmosphere.copernicus.eu/>).

The index allows citizens to use an interactive map to check air quality at the station level based on five key pollutants that harm human health and the environment. The circles and dots on the map indicate the locations of air quality

monitoring stations, while color coding reflects the air quality at a specific hour at that station.

When you click on a monitoring station on the map, a pop-up window appears with the following additional information:

1. Station name and air quality index recorded at that station for the specific time.
2. The "View Station" option, which determines the location of the monitoring station using Google Maps.
3. "Show details" option with brief information about the station; air quality index and relevant health advice for the general population and sensitive population groups; links to air quality information in the country where the station is located as well as to the website of the authority responsible for reporting pollutant concentrations for that station, and presents two graphs.

The values indicated when you hover over the horizontal chart show the hourly AQI index, hourly concentrations for NO₂, O₃ and SO₂, as well as the 24-hour average concentration of PM measured at the station or filled in the blank over the last 7 days. The pie chart indicates the number of days corresponding to a certain air quality levels, indicated by the corresponding index color bands, over the last 365 days.

The user can filter the selection by country and station type. The monitoring stations are classified according to the predominant emission sources: traffic, industrial and background stations (where the pollution level is independent of either traffic or industrial activities). The user can view all stations, only traffic-related stations, or only non-traffic stations (i.e., industrial and background stations).

Resources used to develop and maintain the air quality index calculation system.

The system was developed jointly by the European Environment Agency (EEA) and the European Commission's Directorate-General for the Environment with the aim to inform both citizens and public authorities about the latest air quality in Europe.

From a technological point of view, the map is an adaptation of the Mapbox JavaScript library. Other libraries were also used for additional functions. The index itself does not allow downloading data for analysis and serves only as a communication tool. However, it contains links to primary data that can be downloaded from another resource.

In addition, the Agency provides detailed information on the mechanisms and tools of the monitoring system, and it also pays attention to communication with key stakeholders.

The European Environment Agency also publishes a range of information related to air quality, including:

EU air pollution webpage: <https://www.eea.europa.eu/en/topics/in-depth/air-pollution>

Real-time air quality: latest air quality measurements: <https://www.eea.europa.eu/data-and-maps/explore-interactive-maps/up-to-date-air-quality-data>

Key air quality statistics for major air pollutants: view maps: <https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics>

6.3. AIR measurements in Ukraine and Ivano-Frankivsk.

6.3.1. LUN City AIR.

In Ukraine, air quality monitoring is carried out, among others, by the Ukrainian public air quality monitoring system LUN Misto AIR. This is a Ukrainian public air quality monitoring system established to improve the environmental situation in the country. The project was developed through a collaboration between the teams of the Ukrainian IT company LUN and Taras Shevchenko National University of Kyiv, Faculty of Radiophysics, Electronics and Computer Systems.

Stations are located throughout the city and monitor the ambient air quality in real time. The devices measure pollutants that are particularly harmful to human health - the concentration of PM₁, PM_{2.5}, PM₁₀. These ultra-fine particles are not visible to the naked eye, and their source is primarily combustion processes – car exhaust emissions, smoke from chimneys, fires.

Real-time indicators are displayed on the interactive map, in Telegram and Viber chatbots, and in a widget for iOS. LUN Misto AIR services are available on both mobile devices and computer.

The monitoring stations are transferred to the city free of charge, and maintenance is also free of charge.

6.3.2. SaveEcoBot

The SaveEcoBot project is the only public ecological system in Ukraine that combines data on the current state of the environment, pollution levels, polluters, and environmental protection tools. It is a volunteer project of the Save Dnipro initiative group .

On the website <https://www.saveecobot.com/> you can find:

- interactive map of background radiation levels.
- detailed information on the state of the radiation background in regions and settlements.
- air quality map displaying wind direction and speed.
- air quality data from each monitoring station and data for settlements.
- analytics and an interactive map of fires in Ukraine with details for each region.
- environmental tax analytics.
- statistics on the results and the performance of the environmental inspection.

The chatbot provides convenient access to the following types of information:

- monitoring of the EIA register (Environmental Impact Assessment), which reflects the stages of the environmental assessment procedure for planned activities of enterprises.
- data on permits for emissions of harmful substances into the atmospheric air by stationary sources of pollution, including enterprises of groups 1, 2 and 3.
- data on special permits for the use of subsoil.
- data on permits for special water use.
- data on licenses for hazardous waste management.
- information about business entities that have tax debt.
- data on licenses for the production of especially hazardous chemicals.
- data on waste declarations.

On March 25, the Save Dnipro NGO and **the Ministry of Environmental Protection and Natural Resources of Ukraine** signed a Memorandum of Cooperation.

The purpose of continuing cooperation is to develop effective cooperation in all areas of mutual interest to both the Ministry and the SaveDnipro NGO. These include monitoring of atmospheric air quality, monitoring of the radiation,

compensation of damage to the Ukrainian environment affected by the consequences of the war, digitalization of administrative services, etc.

In particular, the following has already been done:

- a template for complaints about environmental pollution has been established, which allows users of the SaveEcoBot chatbot to file a complaint to public authorities within a few clicks;
- collection and transfer of background radiation monitoring data from the SaveEcoBot system to the national EcoThreat system has been established;
- the organization, within the Ukrainian delegation to the COP29 World Climate Conference, of a presentation of a virtual reality (VR) video demonstrating the environmental damage inflicted on Ukraine as a result of Russian military actions.

6.3.3. EcoCity SMOG ALARM map – implementation of the Ukrainian air quality index.

Currently, citizens across most regions of Ukraine, using a network of more than 250 automated monitoring stations of the All-Ukrainian EcoCity public air quality monitoring network, can use air quality monitoring maps on the eco-city.org.ua website and the updated reborn.eco-city.org.ua website.

EcoCity has created the first Ukrainian air quality monitoring map, where any user can view air pollution levels in real time. The team manufactures monitoring stations of its own design. These devices can be installed anywhere with Wi-Fi or Ethernet connection. The stations can measure dozens of different pollutants, using different variations of sensors for different conditions and monitoring tasks.

The EcoCity project has been around for over seven years and is constantly evolving and growing. It has grown from a few simple stations in Ivano-Frankivsk into a large-scale network covering Ukraine and monitoring over 20 different air pollutants, including NO₂, SO₂, CO, CH₂O, H₂S, NH₃, O₃, Cl₂, HF. EcoCity was developed and is supported by the Clean Air for Ukraine programme with the support of the Czech NGO “Arnika”.

On September 4, 2024, the official presentation of the updated **EcoCity** air quality monitoring website, **Reborn, took place.**

The platform assesses four groups of pollutants:

- Particulate matter

- Primary gases
- other gases
- background radiation

The highest index is given priority and is displayed in the central part, marked with the corresponding color on the map. Humidity, atmospheric pressure, and air temperature are also measured.

Among the main innovations, there is a user-friendly search for stations on the map, the ability to view air quality data in different regions and detailed pollution level statistics, which allows users to receive the most accurate information about air quality in real time. A search for cities by name has appeared, responding to high user demand that had previously been unmet.

Users can access the statistics page, which shows a list of regions, that can be sorted by name, allowing them to check which region is currently more polluted. There is an opportunity to see the average air quality indicators for a specific region that are currently recorded there. Health-related recommendations corresponding to different pollution levels are available, helping users understand potential impacts on public health.

Another innovation is the ability to see the indicators for the last 48 hours at each station. This makes it possible to compare data from the last two days: whether current conditions are better or worse than those recorded a week or a month ago.

6.3.4. Radiation background of the Carpathian region.

On the official website of the Ivano-Frankivsk Regional Center for Disease Control and Prevention, users can track information about background radiation indicators. The natural background radiation indicators for the Carpathian region are not more than 0.32 $\mu\text{Sv/h}$. <https://if.cdc.gov.ua/statistics-and-monitoring/>

6.3.5. Waste sorting.

There are also resources that support the initiation and further development of household waste sorting practices, enabling citizens to contribute to environmental protection.

1. Sortui (sortui.org.ua)

This is a free mobile application developed by MacPaw that helps sort over 130 types of household waste. It provides tips on preparing recyclables materials for recycling and shows the nearest collection points in over 20 cities in Ukraine.

2. Ukraine without waste (nowaste.com.ua)

This is a non-profit organization that educates about waste sorting and recycling. They have their own sorting station in Kyiv and offer recycling services. In addition, it conducts educational events and provide the opportunity to send waste for recycling by postal services.

3. Educational website for children (elpom.com.ua)

An interactive resource designed to educate children how to sort waste. It contains games, coloring materials, and guides that can be used both in household or in educational institutions.

4. EcoPolitic (ecopolitic.com.ua)

EcoPolitic is an information portal that publishes news and tips on an environmentally responsible lifestyle, including articles on waste sorting and separate waste collection.

6.4. Ukrainian state information resources developed to display information on monitoring of environmental objects.

6.4.1. “EcoSystema” Platform.

“EcoSystema” is the only nationwide automated information and analytical online platform in the field of environmental protection, which was developed and implemented in partnership between the Ministry of Environmental Protection and Natural Resources, the Ministry of Digital Transformation, with the support of the USAID/UK aid project “Transparency and Accountability in Public Administration and Services/TAPAS”. The national environmental platform "EcoSystema" was established to ensure that every citizen of Ukraine has up-to-date, reliable information about the state of the environment and natural resources. In addition, the platform enables transparent, efficient, and user-friendly interaction between the public and governmental authorities.

The project includes:

- monitoring data on the condition of air, water, and soil in settlements;
- all registers maintained by the Ministry of Environment and Natural Resources, as well as central government bodies that we coordinate;
- a full range of online services for citizens and businesses with current updates on topics, reporting calendars, and newsletters.

The developers of "EcoSystema" wanted to provide the following benefits for platform users:

- to provide centralized access to relevant information, eliminating the need to navigate multiple websites, submit formal information requests, and wait for responses, and to reduce uncertainty regarding the reliability of data sources;

- to establish transparent, constructive, and user-friendly interaction between the public and public authorities, minimizing unnecessary administrative and bureaucratic barriers;

- to enable rapid and convenient access to public services, while ensuring accountability and integrity in the performance of duties by public officials.

The following services are available, in particular, for monitoring environmental objects:

- e-Environment. All information from institutions that monitor the environment in various areas is collected here - air, water, soil, etc. It enables users to verify data contained in state registries and to access official environmental information in a user-friendly, transparent, and efficient manner, without unnecessary administrative burden.

- e-Air. This is an electronic service for convenient access to information on permitted emissions into the atmosphere with the function of obtaining such a permit. Users can verify whether an enterprise holds a valid permit for pollutant emissions, identify the responsible environmental auditor, and access other relevant regulatory information. In addition, the service allows users to submit documents for obtaining a permit; register a report on the inventory of pollutant emission sources; issue an environmental auditor certificate, and use other administrative services.

- e-Water. This is an electronic system for registration of water users and monitoring pollution of water bodies. It contains information on major polluters of water bodies, issued permits for dredging activities, and authorized works on lands of the water fund within coastal protection zones along seas, bays, estuaries, internal marine waters, and the territorial sea. The system enables users to obtain an online permit for special water use and submit annual reports.

- e-Waste. This is an electronic system for accounting and monitoring waste in Ukraine. It includes registers of waste disposal sites, reports on waste disposal and information about enterprises that have the right to work with hazardous waste, as well as those permitted to produce especially hazardous chemicals. In addition, the system provides online access to administrative services such as submission of waste declaration, processing documents for transboundary waste transportation, issuance of licenses for conducting

economic activities in hazardous waste management or licenses for the production of especially hazardous chemicals.

- e-Ecocontrol. This is an electronic system of environmental control. This service enables users to report suspected violations of environmental legislation to the competent authorities and to access information on scheduled and unscheduled inspections carried out by the State Environmental Inspectorate, including the results of such inspections.

- e-Environmental Impact Assessment. This electronic system supports the implementation of environmental impact assessment. Users have access to data from the Environmental Impact Assessment Register, an information and analytical system for calculating environmental risks, and related administrative services.

6.4.2. Open data portal.

On the website <https://diia.data.gov.ua/about> you can get information about various aspects of state's life. This data are very valuable, and a large part of it should be accessible and open to business, startups, government officials, journalists, and the public. Open data helps to monitor the work of state bodies, improve state services, and create new services.

The issue of environmental pollution is important for 93% of Ukrainians. Thanks to Resolution No. 835, state authorities have opened dozens of registers in the field of environment: data on the quality of surface waters, licenses for hazardous waste management, permits for emissions into the atmosphere, permits for subsoil use and special water use, and many others. Publishing government data on the Unified State Portal of Open Data in free access is the first step toward transparency. The data should be easy to understand even for non-specialists. Therefore, based on this data, developers create user-friendly digital services that make it easier for citizens to access information about the state of the environment, the presence of pollutants and potentially dangerous objects that may affect public health, residential location choices, and other areas of life.

This web resource was made possible by the support of the American people through the United States Agency for International Development (USAID) as well as through financial support from the United Kingdom government (UK aid). At the present, the portal operates in a pilot mode.

CHAPTER 7.

Cooperation with civil society institutions in the European State Monitoring System. The role of public monitoring

7.1. Civil society.

State activities that have an impact on the environment should be carried out with the participation of a wide range of stakeholders, including government, business and civil society. A strong civil society is a key factor for positive change. Civil society is mainly represented by non-governmental organizations.

Civil society organizations (CSOs) should be key players in any decision-making process that may affect the environment. The capacity and strength of local CSOs are essential to ensure accountable and sustainable natural resource management, inclusive socio-economic development, and equitable distribution of costs and benefits. Democratic, transparent, and accountable governance systems and practices are essential for achieving sustainable natural resource management through effective environmental monitoring.

What is civil society?

In its broadest sense, civil society is characterized as a sphere of social life that is public but excludes government activity (Meidinger, 2001). Michael Bratton describes civil society as a social interaction between households and the state, characterized by community cooperation, voluntary associational structures, and networks of public communication (Bratton, 1994). The term “civil society” is commonly used to classify individuals, institutions, and organizations that aim to advance or express a common purpose through ideas, actions, and demands on governments (Cohen and Arato, 1992); Membership in civil society is quite diverse: ranging from individuals to religious and academic institutions as well as groups that focus on specific issues, such as non-profit or non-governmental organizations. The structure may vary depending on the country, for example, civil society may include local and international non-governmental organizations, various charities, various religious organizations, associations, and other social groups. In the field of environmental monitoring, NGOs are the most prominent players, so they form the main focus of this assessment.

The United Nations Conference on Environment and Development declared the need to consult with non-governmental organizations, to take steps to improve existing ones or, where they do not exist, to establish mechanisms and procedures within each agency - to draw on the experience and views of non-governmental organizations in the development, implementation and evaluation of environmental policies and programmes. (UN, 1994: Chapter 27)

The world's most famous non-governmental organizations (NGOs) in the field of environment.

- Greenpeace. An international non-governmental organization with the goal of "ensuring the Earth's ability to nurture life in all its diversity."

- Center for Ecological Research and Environmental Conservation at the Earth Institute. An analytical center for sustainable development at Columbia University.

- Earth Island Institute. Founded by David R. Brower, it functions as an environmental umbrella organization, empowering individuals and groups to develop environmental initiatives.

- Earth Justice. An environmental organization headquartered in San Francisco that engages in litigation on environmental issues.

- Environmental Defense Fund. Focuses on global warming, ecosystem restoration, oceans, and human health.

- World Wildlife Fund. Works on conservation of endangered species and ecosystems, taking into account human needs.

- Naturefriends International. A global environmental umbrella organization.

- Global Footprint Network. An international analytical organization that provides ecological footprint tools for policy and decision-making in a resource-constrained world.

- International Union for Conservation of Nature. An alliance of governmental and civil society organizations to provide knowledge and tools that ensure human development, economic growth, and nature conservation.

- Nature conservation. An environmental organization that protects lands and waters that are ecologically important to nature and people.

- Natural Resource Conversation Council. An international environmental advocacy group with hundreds of lawyers, scientists, and policy experts.

- Wetlands International. A global non-profit organization dedicated to the conservation and restoration of wetlands.

- World Agroforestry Centre. Generates knowledge about the benefits of agroforestry to develop policies and practices to improve livelihoods and environmental benefits.

- World Wildlife Fund. An international organization for the conservation of nature.

A number of government delegations at international conferences now include NGO representatives, and they actively present the views of their organizations.

One of the most important roles that NGOs can play in the global environment is to provide timely information on critical issues. Governments often turn to NGOs to fill research gaps in order to make effective decisions. Some NGOs, have established their mandates around the role of information provider. These groups are dedicated to producing accurate, and up-to-date research. Since governmental and intergovernmental bodies often lack analytical capacity or are hampered by bureaucratic constraints and other obligations, NGOs can focus on a dynamic research agenda and quickly address emerging issues.

The Global Ecosystem Assessment by NGOs is integrated with local environmental reporting. NGOs and other non-governmental organizations such as academic and research institutions are major contributors, providing reports and data analysis.

Civil society – the name for the community of non-governmental organizations – has a particular power to bring environmental governance to the global level. Creativity, flexibility, entrepreneurship, vision and long-term thinking, and an increased ability to adapt to local conditions often allow NGOs to play a leading role in environmental monitoring. For ecosystem assessment processes, NGOs have much to offer in terms of data collecting, disseminating and analyzing information. There are other examples where NGOs serve as key information providers.

Although government officials may read review articles and research papers from NGOs, this is often not enough to effectively take civil society organizations' views into account. Additional communication mechanisms include formal advisory groups and other informal mechanisms for information exchange.

Supporting knowledge-generating institutions is essential. Universities are key generators of knowledge, yet they remain among the most underfunded

institutions in developing countries. Funding and the transfer of communication technologies will be crucial to their ability to perform these functions.

7.2. Involving public organizations in environmental governance.

The main involvement of civil society organizations in environmental governance and in particular environmental monitoring, is carried out by the EU through grants programmes.

For example, the EU LIFE programme is the main funding mechanism for environmental and climate action in the EU. The programme's budget has increased sharply from €3.4 billion during 2014-2020 to €5.4 billion for 2021-2027, reflecting the Green Deal and the EU's overall efforts to "protect the environment and climate". The LIFE programme funds projects to support cooperation between different levels of social organisation, sectors and fields of knowledge to produce replicable results. By covering 55-60% of the project budget, LIFE allows investment in the sector. The European Commission designs the programme, manages the funds, approves or rejects project proposals in accordance with the programme guidelines and audits their performance. Member States approve projects on public lands, provide co-financing and participate in projects. Member States also initiate projects themselves. Civil society and commercial organisations usually propose and manage projects and involve landowners in project activities. The projects' budget ranges from 0.5 to 15 million euros and lasts from two to seven years. Since 2005, EU funding has accounted for approximately 10% of the Estonian's national budget (and up to 20% during 2010–2013). While the LIFE programme is by no means the largest funding instrument, it focuses on environmental management. The EU is establishing National Contact Points in potential participating countries. Their main goal is to inform civil society and commercial organisations and to encourage them to apply for funding. These organisations interact with the LIFE projects through liaison officers. This is long-term and effective support for civil society organisations, for example, since 1992, a total of 39 LIFE projects have been implemented in Estonia.

7.3. Strengthening environmental governance through capacity building of non-governmental organizations.

Another project aimed at supporting NGOs in the field of environmental monitoring is the EU-NGOs project “Strengthening Environmental Governance through Capacity Building of Non-Governmental Organizations”. This is a global project funded by the European Union (EU) and implemented by the United Nations Development Department. The program is implemented and co-financed by the Small Grants Program of the Global Environment Facility (GEF) (SGP). The project aims to promote sustainable development and improve environmental governance in countries of the European region through more effective participation of civil society in environmental governance.

It provides 1:1 co-financing for project objectives. EU-NGO projects are reviewed by national coordinators in each country. These multi-stakeholder committees, composed mainly of representatives of civil society organisations, as well as representatives of government, academia, the United Nations Development Programme (UNDP) and other donors and stakeholders, are responsible for the decentralised selection and approval of grants. Grants are then awarded directly to civil society organisations and local NGOs, which take the lead in planning and implementing local projects. There is a National Coordinator in each country and the Programme often supports local grantees in project planning and implementing, assessing progress toward objectives and indicators, communicating and exchanging experiences among other grantees and stakeholders, and assessing compliance with the formal requirements of the grant award process and the partnership agreement.

Civil society has become an important member in environmental decision-making processes and a valuable partner in implementing and monitoring environmental policies at the local, national and global levels. When their capacities are properly developed, civil society organizations (CSOs) and non-governmental organizations (NGOs) can provide technical assistance to communities and support environmental protection and development programs at the local level, provide policy recommendations to local and national authorities, and facilitate communication between government and local organizations.

The EU-NGOs project focuses primarily on strengthening both the external and internal capacities of NGOs and developing professional skills in

environmental governance. It provides small grants for several NGO-led projects per participating country, approaching improved environmental governance from different perspectives. The EU-NGOs project improves the capacity of NGOs and empowers them to participate in informed and qualified manner in environmental policy-making and natural resource management. NGOs collaborate in decision-making on key issues, representing citizens and communities in discussions on the environment and sustainable development. By developing coordination and exchange among NGOs and other partners, the project aims to have a wider impact on the ability of civil society to communicate with governments on environmental governance objectives and measures.

UNDP has over two decades of experience working with local civil society on environmental management programmes through the SGP. It is therefore well placed to support CSOs and NGOs in taking coordinated actions to deepen their engagement and participation in environmental governance, creating both local and global benefits for sustainable development. In 2012, the UNDP-EU NGO Project supported 13 countries in the East and South of the European Union, with over 60 projects promoting effective civil society participation in environmental governance. The programme started its first phase in eight countries: Armenia, Belarus, Egypt, Jordan, Lebanon, the occupied Palestinian territory, Tunisia and Ukraine. During the second phase of the project in 2014, five additional countries joined the project: Algeria, Azerbaijan, Georgia, Moldova and Morocco.

EU-NGO methodology. Justification and methodology.

UNDP experience shows that NGOs have been successful in demonstration projects that enhance community capacity for biodiversity conservation, climate change mitigation and adaptation, sustainable land management, international water protection, and persistent organic pollutants reduction. However, they have been less focused on facilitating participatory policymaking and influencing decision-making processes. There tends to be a gap in capacity between field-level activities and the translation of best-practice lessons into policy and regulations.

The EU-NGO project draws on its experience and uses it to specifically target the needs of NGOs to enable them to participate more effectively in environmental management processes and environmental governance policies. The project was aligned with the European Commission's recognition of the importance of civil society action in environmental protection and resource management, as well as the European Neighbourhood Policy (ENP) National

Action Plans, which emphasise effective environmental governance and the role of NGOs. By providing targeted grants for training, capacity building and knowledge sharing, the project strengthens both the internal and external capacity of NGOs in each of the selected countries, so that they can influence policies to create and better participate in environmental governance at different levels.

The main target group for support of the EU-NGO Project are legally registered NGOs in the selected countries with an environmental mission, an environmental track record or a strong interest in environmental policy. The recommended target group is environmental NGOs with proven capacity needs.

Project objectives: A crucial initial step is to develop a partnership between the local EU and an NGO. The NGO initiator expresses an interest in capacity building in the context of a specific initiative aimed to address an environmental issue.

Project selection process.

The project selection process for the EU-NGO project follows the established standards. The project stated that proposals by legally registered national NGOs in selected countries with environmental missions and experience in environmental protection or a strong interest in environmental policy could be considered for EU-NGO grant funding. In certain cases, additional, country-specific selection criteria are discussed.

The complete grant application undergoes final approval in order to ensure consistency with national environmental requirements and development priorities, as well as alignment with the concept of environmental governance.

If approved, the proposed project receives a grant not to exceed \$50,000 for a maximum project duration of 18 months.

All EU-NGO projects are required to select at least one key environmental priority project at national level and contribute to the development of one or more of the following capacity building outcomes:

1. Engagement capacity

Increasing the capacity of stakeholders to participate in national or subnational policy analysis and dialogue processes related to environmental governance and management. In particular, promoting the formation of civil society networks, organizing multi-stakeholder roundtables that enable civil society to provide information to government officials.

2. Opportunities to generate, access and use information and knowledge.

Improving and strengthening the role of NGOs in raising awareness of environmental issues, policies, as well as disseminating environmental information and knowledge among civil society and governmental stakeholders in order to address environmental challenges and find appropriate solutions.

3. Capacity to develop strategy, policy and legislation.

Strengthening the capacity of organizations to participate in the development of policies and legal frameworks for environmental governance and management. This includes integrating environmental concerns into sectoral policies at the national level and promoting constructive dialogue between government and civil society actors, and establishing environmental policies with their participation.

4. Management and implementation capacity.

Improved organizational capacity, including project development skills, resource mobilization, business planning, and administrative capacity to participate in the implementation and management of environmental projects and programs, as well as in policy dialogue and reforms.

7.4. The role of civil society organizations in facilitating community-level monitoring.

Civil society organizations have three types of roles in the environmental monitoring process: first, as members of monitoring committees; second, as resource groups for capacity building; and third, as agencies that help carry out independent data collection.

In their first role, civil society organizations that work in close, regular contact with communities on health-related issues, especially from a human rights perspective, will be able to present community problems, experiences and suggestions for improving the functioning of the health system to the various monitoring committees. In their second role, NGOs with experience in capacity building can provide training to committee members on the community-level monitoring process, including the roles of members. All civil society organizations and health system functionaries benefit from such capacity building. In their third role, NGOs can facilitate data collection relevant to the monitoring process at all levels from the village to the national governance.

NGOs and civil society organizations could be given responsibility for overall facilitation of the initial process of committee formation and capacity building at the district level, including peripheral committees at the village level.

In the pilot phase, the training of the members of the Community Monitoring Committee at different levels is carried out by NGO facilitators. In the subsequent phases, joint teams of NGO and Department of Health facilitators may be involved. Based on the materials of the national model, training modules and orientation materials for Community Monitoring Committee members are adapted and published at the national level and used for the capacity building process.

Teams established to create an information field within the community engage in dialogue with local residents and collect and process community-based information. These teams may be sub-groups formed from the larger Monitoring Committee at certain levels, but may also include some individuals who are not members of the Monitoring Committee. The formation of such teams should be encouraged. Each team should include members of one or more facilitating NGOs, and may also include representatives of health service providers. Such teams should undergo a brief orientation exercise before starting community monitoring.

In order to conduct a community monitoring cycle, this team should select few villages for each three-month period. Village level meetings (preferably with women) should be organized in these villages. These meetings should identify the residents' experience regarding the environmental issues. The minutes of the village meetings should contain details of the villagers' experiences and perceptions.

Similarly, groups at different levels can conduct monitoring within different facilities through facility surveys and exit interviews. All this data collection can be based on Monitoring Checklists, which are prepared based on various community monitoring frameworks.

A simple questionnaire can be developed to assess civil society organizations for their capacity to act as partners in community monitoring activities and participate in monitoring committees at various levels. Such organizations can include community organizations (including self-help groups and community-based organizations) as well as non-governmental organizations operating at the relevant level that have documented activities in this area for at least three years. In addition to other questions about the organization, the

following 4 sections can be included in the questionnaire: Organizational Profile, Community Mobilization, Empowerment Activities, Legal Activities. These include: Income Generation, Village-level Women's and Men's Groups, Environmental/Natural Resource Management, Village-level Committees, Leadership Development and Training for Women, Education, Right to Information, Community Leadership Training, Livelihood Rights (e.g., rights related to forests, land, wages, displacement, etc.), Rural Organization and Mobilization on Specific Issues.

Based on their responses to the questionnaire, any organization that has at least one entry in all four sections (with a brief report on the activities carried out in this aspect) may be considered qualified. Any organization that has demonstrated experience in monitoring public services, organizing public dialogues or public hearings should be given priority for participation in Community Monitoring Committees.

Experience in monitoring government services or activities aimed at ensuring accountability.

It is worth noting here that the diversity of civil society networks and organizations involved in advocacy and monitoring should be involved at different levels, including the national level, from the very beginning of the process. The facilitation at the national level should not be entrusted entirely to a single NGO, as this may limit wider participation in the process. It should also be kept in mind that the involvement of civil society in monitoring should not be limited to parent NGOs, which are often deeply involved in implementation and which may not always be the most objective monitors of the work in which they are engaged. Especially for the community monitoring process, it is crucial that the idea is not limited to its parent NGO, but rather that organizations with experience in ensuring accountability have sufficient space and are responsible at all levels. Similarly, during the implementation phase in the districts, a variety of civil society organizations should be involved, including at the block and district levels, to ensure broad participation in the monitoring process. The process of selecting civil society organizations in order to be included in monitoring committees at all levels can be facilitated by a mentoring team at the appropriate level, under the guidance of a higher-level mentoring group. For example, a district mentoring group can suggest names of civil society organizations to be included in a district monitoring committee, taking into account the input of the state mentoring group. This should be a participatory

process involving different networks and civil society organizations and should not be limited to NGOs.

7.5. Air quality monitoring and management – public participation in decision-making.

Legal framework for public participation in environmental protection and conservation issues

According to Article 13 of the Constitution of Ukraine, the land, its subsoil, atmospheric air, water and other natural resources located within the territory of Ukraine, including the natural resources of its continental shelf, exclusive (maritime) economic zone are objects of property rights of the Ukrainian people. On behalf of the Ukrainian people, the rights of ownership are exercised by state authorities and local self-government bodies within the limits defined by this Constitution.

Furthermore, according to Article 50 of the Constitution of Ukraine, everyone has the right to an environment that is safe for life and health as well as the right to compensation for damages caused by the violation of this right. Everyone is guaranteed the right to free access to information concerning the state of the environment, the quality of food products and household items, as well as the right to disseminate it. Such information may not be classified by anyone.

According to Article 6 of the Law of Ukraine "On Environmental Protection", central and local executive bodies, as well as local self-government bodies, when developing environmental programs, involve the public in their preparation. This participatory process is facilitated through the proactive publication of draft environmental programs for public review, the solicitation of stakeholder comments and proposals regarding the projected initiatives, and the organization of public hearings to ensure transparent deliberation.

A wide list of environmental rights of citizens of Ukraine is defined in Article 9 of the Law of Ukraine "On Environmental Protection", and important in the context of this study are the right to:

1. An environment safe for life and health.
2. Participation in the discussion and submission of proposals to draft regulatory legal acts, materials on the placement, construction and reconstruction

of facilities that may negatively affect the state of the environment, submission of proposals to state authorities and local governments, legal entities participating in decision-making on these issues.

3. Participation in the development and implementation of measures aimed at environmental protection, rational and integrated use of natural resources.

4. Free access to information concerning the state of the environment (environmental information) and free receipt, use, distribution and storage of such information, except for restrictions established by law.

5. Judicial appeal of decisions, actions or inaction of state authorities, local self-government bodies, and their officials regarding the violation of the citizens' environmental rights, in accordance with the procedure prescribed by law.

Article 10 of the same Law defines the guarantees of citizens' environmental rights. It also establishes that activities that obstructs the exercise of citizens' right to a safe environment and their other environmental rights shall be terminated in accordance with the procedure established by this Law and other legislation of Ukraine.

Article 11 of the Law of Ukraine “On Environmental Protection” provides that Ukraine guarantees its citizens the realization of environmental rights granted to them by law. Local councils, state authorities in the field of environmental protection and the use of natural resources are obliged to provide comprehensive assistance to citizens in carrying out environmental protection activities, take into account their proposals for improving the state of the environment and rational use of natural resources, and involve citizens in decision-making on environmental protection and the use of natural resources. Any violated rights of citizens in the field of environmental protection must be restored, and their protection is carried out in court in accordance with the legislation of Ukraine.

According to Article 36 of the Constitution of Ukraine, citizens of Ukraine have the right to freedom of association in public organizations for the protection of their rights and freedoms and the satisfaction of political, economic, social, cultural and other interests, with the exception of restrictions established by law in the interests of national security and public order, the protection of public health or the protection of the rights and freedoms of others. No one may be forced to join any association of citizens or be restricted in their rights for belonging or non-belonging to political parties or public organizations.

From a practical point of view, an important legal form of exercising citizens' rights is public consultation. The main requirements for organizing and conducting public consultations by executive authorities on the formation and implementation of state policy are defined in the Procedure for conducting public consultations on the formation and implementation of state policy, approved by the Resolution of the Cabinet of Ministers of Ukraine No. 996 79 dated November 3, 2010. Public consultations are conducted with the aim of involving citizens in the management of public affairs, providing them with the opportunity to freely access information about the activities of executive authorities, as well as ensuring the publicity, openness and transparency of the activities of these bodies. The results of public consultations are taken into account by the executive authority when making a final decision or in its further work. Public consultations are organized and conducted by the executive authority that is the main developer of the draft legal act or prepares proposals for the implementation of state policy in the relevant sphere of state and public life.

Public associations, religious, charitable organizations, creative unions, trade unions and their associations, employers' organizations and their associations, bodies of the public self-organization, non-governmental mass media, other non-profit societies and institutions legalized in accordance with the legislation (hereinafter referred to as Civil Society Institutions) may initiate public consultations on issues not included in the indicative plan. Such initiatives may be proposed either via the Public Council or directly to the relevant executive authority. In a case, that a proposal to conduct public consultations on one issue has been received from at least three Civil Society Institutions, such consultations shall be mandatory. Public councils may also initiate public consultations not included in the indicative plan.

Public consultations are conducted in the form of public deliberations, electronic consultations (direct forms) and evaluation of public opinion (indirect form).

According to Article 16 of the Law of Ukraine “On Environmental Protection”, non-environmental organizations are endowed with a wide range of rights. Among them, within the scope of this research, are the following:

- 1) participate in the development of plans and programs related to environmental protection, as well as develop and promote their environmental programs;

- 2) to initiate national and local referenda on issues related to environmental protection, the use of natural resources, and ensuring environmental safety;
- 3) submit proposals to the relevant bodies regarding the organization of territories and objects of the nature reserve fund;
- 4) participate in activities of international non-governmental organizations focused on environmental protection issues;
- 5) participate in the preparation of draft legal acts on environmental issues;
- 6) to appeal, in accordance with the procedure established by law, decisions regarding the refusal or fail to provide environmental information upon request, or an unlawful rejection of a request and its incomplete fulfillment.

The Law of Ukraine "On Environmental Impact Assessment" establishes the legal and organizational principles of environmental impact assessment aimed at preventing environmental damage, ensuring ecological safety, environmental protection, rational use and reproduction of natural resources, in the process of decision-making regarding the conduct of economic activities that may have significant impact on the environment, taking into account state, public and private interests.

According to Article 2 of this Law, Environmental Impact Assessment is a procedure that provides public discussion, analysis by the competent authority, in accordance with Article 9 of this Law, of the information provided in the environmental impact assessment report, any additional information submitted by the economic entity, as well as information received from the public during the public discussion, during the procedure for assessing transboundary impacts, and other information. It is also stated that the public is equated with economic entities.

The Law of Ukraine "On Strategic Environmental Assessment" provides that a strategic environmental assessment is carried out on the basis of the principles of legality and objectivity, transparency, public participation, scientific validity, balance of interests, comprehensiveness, prevention of environmental harm, long-term forecasting, accuracy and completeness of information in the draft document, and international environmental cooperation.

Generalization of the experience of public participation in the work of environmental commissions and councils under executive authorities at the national and regional levels.

In accordance with the Resolution of the Cabinet of Ministers of Ukraine No. 827 83, dated August 14, 2019, the commission on state monitoring in the

field of ambient air protection and air quality management includes representatives of public associations that carry out their activities within the zone or agglomeration (upon consent). In accordance with the Order No. 261 of the Ministry of Environmental Protection and Natural Resources dated April 20, 2021, an Interdepartmental Commission on State Monitoring in the Field of Ambient Air Protection was established. The commission includes 22 people, with only 1 member representing the public (which is less than 5% of the numerical composition).

The composition of the Kyiv zone commission stands out in a certain way, since public representatives are not included in the commission. The composition of the Zaporizhzhia zone commission stands out in the opposite way, which includes the largest number of public representatives. However, additional comments are required for the personal composition of the Dnipro zone commission and the Dnipro, Mariupol and Zaporizhzhia agglomerations. The Dnipro zone commission includes the Head of the Public Environmental Council under the Regional State Administration, who actually represents the interests of 19 public organizations. The Dnipro city agglomeration commission includes a representative of the Public Environmental Council under the Dnipro City Council, representing the interests of 34 public organizations. The Zaporizhzhia agglomeration commission includes the Head of the Public Council under the Executive Committee of the Zaporizhzhia City Council, representing the interests of 37 public organizations. Despite these circumstances, collective public representatives have one vote when making decisions.

Also, public participation in the formation and implementation of state and regional policy is ensured by the work of public councils under the Ministry of Environmental Protection and Natural Resources, the State Environmental Inspectorate of Ukraine, other ministries, agencies at the national level, as well as the work of public environmental councils under state regional administrations, territorial bodies of the State Environmental Inspectorate, and executive committees of city councils.

Key players among non-governmental civil society institutions in Ukraine.

The Law of Ukraine "On Public Associations" sets out the following definition of a "public association" - as a non-governmental institution of civil society:

A public association is a voluntary union of individuals and/or legal entities under private law to exercise and protect rights and freedoms, and to satisfy public interests, in particular economic, social, cultural, environmental and other interests.

A public association may carry out activities with or without the status of a legal entity. A public association with the status of a legal entity is a non-profit organization, whose main purpose is not to make a profit. Each public association develops its own charter, which specifies the main purpose of the organization and the main areas of activity.

Therefore, it is worth noting that those non-governmental civil society organizations, which in our opinion are key players, spend a significant part of their work on solving the problems of air quality protection and management. Each of the organizations has its own approach to tackling the problems of air quality protection and occupies its own niche in this process.

The public organization "Green World - Friends of the Earth" has extensive experience in the field of monitoring and managing air quality in Ukraine. The public organization originated from the informal association "SOS", which was established in the early 1970s in Dnipro. The organization was officially registered in 1997 and primarily focused on the field of sustainable development. The members of the organization have paid special attention to working with executive authorities, local governments on environmental policy, promoting renewable energy sources and environmentally friendly technologies, and the implementation of national and international environmental legislation. Thus, the members of "Green World" initiated the establishment of a Public Environmental Council under the Dnipro Regional State Administration.

Later, Green World specialists initiated the inclusion of the goal of developing a system of automated monitoring of environmental parameters in the region into the Dnipro Regional Comprehensive Program (Strategy) on Environmental Safety and Climate Change Prevention for 2016-2025. Later, when members of the "Green World" team received deputy mandates in the Dnipro Regional Council, on their initiative, specific measures were proposed in the Program, enabling the launch of a new automated environmental monitoring system in Dnipro region. Subsequently, a budget was allocated for the creation and operation of the specialized enterprise "Center for Environmental Monitoring". The NGO specialists also participated in the development of the draft Regulation on the Environmental Monitoring System of the Dnipro region.

Now the work of "Green World" is spreading throughout the Dnipro region and throughout Ukraine.

The Ukrainian Air Quality Public Monitoring Network, EcoCity, is a non-profit project of the Ukrainian Public Air Quality Monitoring Network, implemented by the NGO "Free Arduino" together with partner civil society organizations and scientific and technical advisors. This project originated as an initiative of activists and inventors in 2018 in the city of Ivano-Frankivsk and spread to all regions of Ukraine in 4 years. Currently, EcoCity is the largest network, uniting over 600 installed public air quality monitoring stations.

The impact of the EcoCity project on the development of air quality monitoring and management focuses on three main areas:

- 1) motivation of Ukrainian youth for socially useful inventions and the study of natural and technical sciences;
- 2) informing the population about air quality in industrial agglomerations and in the most remote corners of the country;
- 3) stimulating the development of national and municipal air quality monitoring systems.

Over the past 4 years, the EcoCity team, with the support of the Czech NGO Arnika and other partners, has implemented several innovations in public air quality monitoring.

The EcoCity network is not limited to monitoring the content of particulate matter PM 2.5 and PM 10, but is actively working on the entire list of WHO priority pollutants. Currently, the EcoCity project stations are able to assess air quality for 19 pollutants, including ground-level ozone, carbon monoxide, nitrogen dioxide and volatile organic compounds. 8 different types of public monitoring stations have been developed through joint efforts, including the Sapphire32 mobile station and an indoor station with the function of a "smart home". A young Ukrainian inventor and project participant Dmytro Obukhov created a specialized public monitoring operating system, Environment OS, which will allow implementing the public alert algorithm within the SmogAlarm model.

Since spring 2021, the EcoCity network, in collaboration with the "Clean Air for Ukraine" project, has been implementing an extended responsibility program and has introduced technical maintenance for public air monitoring stations. In August 2021, together with the Environmental Monitoring Center of the DOR, comprehensive studies of the air quality and stability of monitoring

results were launched – known as so called "metrological collocation experiment", which is based on the methodology of the EPA USA.

The Ukrainian public air quality monitoring network, EcoCity, has developed active partnerships with civil society institutions and academic communities. Every month, the electronic air quality map (www.eco-city.org.ua) is used by more than 20 thousand users and local governments in Ukrainian cities.

The public organization "Save Dnipro" began its work in 2017 (the first few years as an informal initiative) and over 4 years has significantly influenced the dissemination of information about air quality in Ukraine. The "Save Dnipro" team achieved this result through the environmental bot SaveEcoBot, designed to disseminate environmental information via social networks and messengers (Telegram, Viber, Facebook Messenger), and the air quality map <https://www.saveecobot.com/maps>.

It is worth noting that many public organizations and initiatives across Ukraine are involved in the development of air quality monitoring and management (in forms of civil society participation). For a detailed understanding of the subject of this research, it is recommended to examine the experience and activities of other civil society organizations, including:

The Center for Environmental Initiatives "Ecodia" is a public organization based in Kyiv, but its sphere of influence extends beyond the Kyiv region. The main areas of work are the analysis of the possibilities for implementing European legislation and standards on environmental protection and monitoring; reviewing environmental impact assessment reports of enterprises and air emission permits; communication with executive authorities on improving the current legislation in the field of monitoring.

The public organization "Dzyga" is a public organization whose scope of activity extends to the territory of the city of Zaporizhia. The members of the organization deal with issues of environmental monitoring, development of a public system of ambient air quality monitoring, climate change, and greening. This public organization has significant experience in advocacy campaigns to restore the operation of a mobile air quality monitoring laboratory. Additionally, its members serve on the Commission on State Monitoring in the Field of Ambient Air Protection and Air Quality Management of the Zaporizhia Agglomeration.

The coalition of public organizations "Enough to poison Kryvyi Rih" is an association of 19 civil society institutions. The main work of the coalition is

aimed at participating in public deliberation regarding EIA reports, as well as public discussions before issuance of permits for the emission of pollutants.

The movements "Kharkiv without coke plant" and "Anti COKE PLANT" are an informal associations of environmental activists in the city of Kharkiv, united by joint actions against environmental pollution caused by the so-called "Kharkiv Coke Plant" and other industrial enterprises in the surrounding areas. These movements have accumulated extensive empirical experience in conducting information and advocacy campaigns against industrial pollution. Furthermore, they play a critical role in the identifying and disseminating environmental crimes in the information space in the city of Kharkiv.

7.6. Main problems of practical application of citizens' rights.

Problem 1. The Procedure approved by Resolution of the Cabinet of Ministers of Ukraine No. 827 states that commissions for state monitoring in the field of ambient air protection and air quality management are to be established in each zone and agglomeration, including representatives of public associations operating within that zone or agglomeration. However, this procedure is not clearly defined, nor are the procedures for re-election and supplementation of the commission. This is the reason for the low representation of the public and expert community in these commissions. After all, it is currently impossible to understand how a decision is made regarding the necessity of including representatives of a particular NGO or experts and scientists.

Problem 2. The "close" nature of primary data on the results of monitoring the state and quality of atmospheric air from monitoring entities. For example, as of 07/01/2021, the open data portal data.gov.ua did not contain data on the state of atmospheric air according to the territorial bodies of the Hydrometeorological Center, which are structural units of the State Emergency Service of Ukraine - the Dnipro Regional Center for Hydrometeorology and the Zaporizhia Regional Center for Hydrometeorology. It is worth noting that the Hydrometeorological Center and regional hydrometeorological centers of Kyiv, Kharkiv and Donetsk regions are not included in the list of administrators of the open data portal. It should be added that such data is partially published on the website of the Ministry of Environmental Protection and Natural Resources.

We associate this phenomenon with the fact that the Procedure (CMU Resolution No. 827) does not describe in detail the mechanism of interaction

between monitoring entities in the field of information exchange. There is no procedure for ensuring access to the results of ambient air monitoring; a scheme, format and protocols for accumulating and exchanging information; a defined hierarchy at the zone and agglomeration level. There are no requirements for creating an information-analytical system at both the national level and at the agglomeration zone level. The deadline for establishing such a system is not specified. It is not specified how to implement information interaction in its absence. There is no procedure for informing the public about the state of ambient air quality.

As an example of addressing this problem, the Communal Enterprise "Center for Environmental Monitoring" of Dnipro Regional Council developed a web widget, which is presented in graphical and text versions on the websites of the Center, the Dnipro Regional Council, and the Dnipro Regional State Administration. In addition, the widget can be placed on any website for free in accordance with the instructions developed by the Center for Environmental Monitoring. The absence of an organized source of public information—an informational vacuum—has been a key driving force behind the development of civil society air quality monitoring projects across Ukraine.

Problem 3. Limited transparency of data from enterprises, institutions, organizations, whose activities lead to deterioration of the state of ambient air. Most of such enterprises do not have automated stations for monitoring the quality of ambient air. The results of their monitoring are not posted on the open data portal, and they cannot be tracked online. Some enterprises post averaged results on their websites.

A successful case is the cooperation between the CE "Center for Environmental Monitoring" of the Dnipro Regional Council and PJSC "Kryvyi Rih Cement". Data from the enterprise's automated air quality monitoring station are transmitted to the system of the Center for Environmental Monitoring, but are not uploaded to the open data portal, as PJSC "Kryvyi Rih Cement" retains control over this information.

Problem 4. Ukraine ratified the Protocol on Pollutant Release and Transfer Registers on 03.02.2016, but in practice this register does not exist. It should be noted that currently a national online platform - "EcoSystem" is operating in test mode, which contains up-to-date information on the state of the environment – (<https://eco.mepr.gov.ua/>). The platform is filled with data from executive

authorities of various levels, local governments, enterprises, institutions, and organizations of various forms of ownership.

Generalizations and recommendations.

The Law of Ukraine "On Environmental Impact Assessment" defines the public as one or more individuals or legal entities, their associations, organizations or groups. In this context, regarding environmental protection and conservation, it is advisable to consider the possibility of participation not only of public organizations (formal civil society organizations), but also of citizens guided by their own civic position and initiative.

To enhance the individual participation of citizens in the process of monitoring and managing ambient air quality in zones and agglomerations, it is recommended to pay attention to the following tools:

- development of environmental education (organization of interesting events involving professional storytellers and influencers for accessible, interesting presentation of information);

- active dissemination of not only the activities and successes of public associations, but also personified stories of the struggle for clean air for all. Wide coverage of this information will help form a clear civic position among the population and a sense that each individual voice matters. This will help move on to the next step - involvement in the work of public organizations, local team building, etc.

- transparency and publicity of the policies of governmental bodies and local self-government, access to public information from all monitoring entities and industrial facilities, the possibility of conducting an open dialogue.

Problems.

Low level of awareness and education in this area of environmental safety.

Low level of awareness in the field of rights and opportunities for citizens.

Focus on providing basic needs due to the economic situation in the country.

Low level of trust in governmental authorities and local self-government, along with the perception that citizens' opinions are never taken into account when making decisions.

Ineffective work with regulatory and legal tools available to citizens.

Despair in the fight for clean air for everyone in Ukraine.

Indifference to the problems of a clean environment and clean air for all.

Apathy towards activities in this area, both among civil society and professional and academic communities.

Low level of education in the area of environmental safety.

An important task for the coming years is to:

- strengthen efforts in the field of environmental education;
- conduct broad information campaigns and drawing citizens' attention to environmental problems in general and air quality in particular;
- implement specialized information campaigns on the need to develop state, regional and public systems for monitoring the state and quality of ambient air.

Methods of cooperation with stakeholders.

The Environmental Monitoring Center is a municipal enterprise of the Dnipro Regional Council, and therefore its organizational activities are constantly connected with its executive apparatus and the deputy corps. Representatives of the Environmental Monitoring Center participate in meetings of the commission on ecology and energy efficiency of the Dnipro Regional Council. A report on the state of ambient air pollution in the areas of the monitoring stations is generated weekly. In addition, the Environmental Monitoring Center actively cooperates with the executive committee and relevant deputies of the Dnipro City Council. Currently, work is underway to adopt the Regulation on the environmental monitoring system in the Dnipro agglomeration.

Additional attention deserves cooperation with higher education institutions of the Dnipro region. The Environmental Monitoring Center cooperates with the Oles Honchar Dnipro National University, the National Technical University "Dnipro Polytechnic", the Dnipro State Agrarian and Economic University, the National Metallurgical Academy of Ukraine, the Ukrainian State Chemical and Technological University. This cooperation has various organizational forms: joint environmental monitoring activities, preparation of scientific publications, involvement of specialists of the Environmental Monitoring Center in the educational process, internships of scientific and pedagogical workers, admission of students for industrial and pre-graduate internships, excursions. Communication with lecturers and students of universities is an important area of work of the Environmental Monitoring Center, as a successful project that operates with modern equipment and operating systems provides opportunities to acquire new knowledge and skills in the process of gaining practical experience.

Cooperation with civil society institutions.

Specialists of the Environmental Monitoring Center communicate with representatives of civil society organizations in Ukraine and abroad. For example, in 2020, joint measurements of fine particulate matter were carried out and the operation of the Environmental Monitoring Center's equipment was compared with the public monitoring equipment developed by the participants of the Airpollution project (Kharkiv). In 2021, joint measurements of gaseous pollutant concentrations (NO_2 , NH_3 , CO , O_3) were carried out with a comparison of the operation of the certified equipment of the Environmental Monitoring Center with the MonAIR 3.0 Yourairtest equipment, developed by the Noosphere Engineering School of Oles Honchar Dnipro National University. Since July 2021, a joint collocation experiment has been implemented to analyze metrological parameters of public air quality monitoring stations from the EcoCity project team (Ivano-Frankivsk).

For the effective operation of the monitoring system, it is necessary to combine the use of equipment of different accuracy, and therefore of different cost. The idea of developing the system is based on a combination of low-cost sensors and high-precision reference equipment. After all, the relief features, the nature of urban development, the combination of high-rise buildings, medium-rise and low-rise private housing of modern cities of Ukraine determine the need to install a sufficiently large number of monitoring stations to understand the degree of gas pollution of a particular territory.

According to a number of authors, the functional nature of the city affects its spatial planning, giving it specific features. Thus, on the territory of an industrial city there is a large number of industrial facilities (up to 50% of the territory), as a rule, these are railways, freight stations, access roads, sanitary protection zones. When designing, the location of the industrial facility is taken into account, measures are provided to combat harmful emissions. Industrial facilities play a large role in architecture. These statements are true for all industrial cities of Ukraine. Therefore, the development of a public monitoring system, in our opinion, can become the basis for identifying places where it is necessary to install reference monitoring stations in order to control of ambient air quality.

General recommendations.

Summarizing all the materials presented above, we can form a list of basic recommendations for the practical implementation of monitoring and management of ambient air quality in Ukraine.

The list of recommendations will be useful for three key stakeholders interested in establishing high-quality and modern environmental monitoring systems at the national, regional and local (municipal) levels.

Recommendations for executive authorities, monitoring entities and their territorial bodies.

1. It is important to improve the regulatory framework governing air quality monitoring and management in zones and agglomerations of Ukraine as soon as possible. Additional attention should be paid to detailing all procedures and mechanisms for the practical implementation of legislation at all levels.

2. For the purpose of effective dialogue and continuous improvement, it is necessary to ensure broader involvement of the public and scientists in the Commission on State Monitoring in the Field of Ambient Air Protection and Air Quality Management in all zones and agglomerations of Ukraine. This issue is especially urgent for zones with high anthropogenic load (Dnipro, Zaporizhia, Kharkiv, Donetsk, Kyiv regions, the cities of Kyiv, Dnipro, Zaporizhia, Kryvyi Rih, Kharkiv).

3. When forming human resource policy, it is advisable to pay special attention to the competencies and professional expertise of specialists in the field of air quality monitoring, and to actively invite scientists and representatives of academic communities to work.

4. Ensure regular professional development of specialists at all levels involved in monitoring and managing ambient air quality.

5. Conduct an inventory of the material and technical base and assess the possibilities of monitoring ambient air quality by each of the monitoring entities and their territorial bodies.

6. The budget required for the development of monitoring station networks for each monitoring entity should be assessed in a transparent and objective manner. This assessment should cover the expansion, upgrading, and modernization of equipment, as well as the provision of necessary office hardware, licensed software, and related technical resources.

7. Ensure the translation and harmonization of EU methodologies and standards into the national language.

8. Pay special attention to educational and capacity building activities for civil servants and deputies of all levels involved in monitoring and managing ambient air quality.

9. Organize a broad information campaign for the population in zones and agglomerations. The main goal of this campaign is to promote the ideas of sustainable development, smart cities, as well as the need for systematic monitoring of environmental components, and for assessment of its condition and environmental safety.

10. Be open and transparent in making decisions, as well as reporting on the results of their implementation to all stakeholders.

Recommendations to local self-government authorities.

1. Review existing local-level programs and strategies for monitoring the environment and air quality, taking into account the most recent amendments to the legislation of Ukraine, in particular.

2. Improve human resource policies at the level of local self-government bodies, paying special attention to the competencies and awareness of the involved specialists in the field of environmental monitoring.

3. Ensure the improvement of capacity building in the field of air quality management for specialists of structural divisions of executive authorities, as well as members of standing commissions responsible for environmental issues.

Recommendations to the interested public and civil society institutions.

1. Initiate joint air quality monitoring activities in cooperation with government authorities and local self-government bodies.

2. Nominate candidates from the civil society for inclusion in the Commission on State Monitoring in the Field of Ambient Air Protection and Air Quality Management (for all zones and agglomerations of Ukraine).

3. Encourage citizens to actively work with civil society institutions, conduct environmental and educational activities in this direction, and involve representatives of academic communities.

4. Seek proactive forms of involving experts and scientists in preparing comments on environmental impact assessment reports, obtaining permits for emissions into the atmosphere, and other documents that directly affect the condition and quality of the community's atmospheric air.

CHAPTER 8

Air quality and other environmental objects under emergency conditions

8.1. The impact of the Russian war in Ukraine on the environment.

The globally recognized “triple threat” to human existence on the planet – increasing environmental pollution, climate change and its negative impacts, and biodiversity loss – is tragically compounded in Ukraine by the hostilities in the war with Russia; the manner of Russian attacks has a devastating impact in all three areas.

Russia's invasion of Ukraine has been a human tragedy, resulting in immeasurable loss of life and health, millions of displaced people, and a humanitarian crisis. The war has damaged and destroyed critical civilian infrastructure and other important public facilities, including enterprises and roads, deprived citizens of necessary resources such as water, electricity, and medical care.

War is not only a human tragedy. It is also always the destruction of nature – an environmental catastrophe. Russian armed aggression against Ukraine causes significant damage to the nation's economy, cultural heritage and environment. It has destroyed natural ecosystems and polluted the environment. Furthermore, numerous cases of targeted destruction of natural resources and infrastructure facilities have the features of ecocide against the Ukrainian people.

Ecocide is a form of warfare by deliberate attempts to inflict irreparable damage upon the ecosystem, flora, fauna, and natural resources of the country being attacked. The aggressor state that commits ecocide aims to destroy the potential for recovery of the country that is suffering from the aggression.

Belgium became the 14th country in the world to criminalize “ecocide” within national law in 2024. Belgian law defines ecocide as “any unlawful or reckless act committed with the knowledge that there is a significant likelihood of severe and widespread or long-term damage to the environment caused by such acts.” However, the very first country where the crime of ecocide appeared in legislation was Vietnam (1990), and the very concept of “ecocide” is associated with this country.

A group of international lawyers has drafted a law that would recognize ecocide as a war crime. The initiators submitted a corresponding application to the International Criminal Court on June 22, 2021. Eight months later, Vladimir Putin would start the biggest war in Europe since the end of World War II.

In fact, the Russian aggression against Ukraine can be considered as the first case of deliberate ecocide during war in this century.

Since the beginning of the war in Donbas in 2014, almost 40% of Ukraine's environmentally valuable territories have been occupied, most of them since February 2022. The Russian army is committing ecocide and deliberately causing damage to the environment, and this damage is often irreversible.



Fig. 12. Environmental damage from the Russian military aggression.

Environmental damage from the Russian military aggression:

- hazardous chemical emissions and pollution from damaged industrial facilities;
- impact on air quality due to the destruction of cities and settlements, as well as the burning of forests;
- economic and environmental consequences of damage to agricultural areas, forests and nature reserves;
- water pollution and destruction of water infrastructure;

- contamination of sensitive ecosystems, particularly in coastal and marine areas.

The Ministry of Economy, Environment and Agriculture of Ukraine has established the “EcoSystem” website, which collects data on environmental damage based on reports from local authorities and civilians who can report relevant cases. A number of initiatives in Ukraine and around the world track the damage caused to the environment as a result of the Russian aggression. On this official platform, in the “**EcoThreat**” section of the Ministry of Environmental Protection and Natural Resources of Ukraine, statistics on recorded cases of burning oil products, forest fires, combustion of other objects, soil contamination, land littering, violations of nature reserve objects, etc. are published in real time, with a geographical reference to the area. Damage calculations are also provided, calculated by the State Ecological Inspectorate (SEI) in accordance with approved methods. The Ministry is developing a plan for their further elimination and is working on the restoration of environmental objects after occupation.

As of today, 8,196 cases of environmental damage as a result of armed aggression by the Russian Federation have been recorded in Ukraine. One of these crimes was the explosion of the Kakhovka hydroelectric power station in the summer of 2023.

The State Environmental Inspectorate of the Carpathian District recorded environmental damage from Russian aggression in the amount of over UAH 3.5 billion at the beginning of 2025.

The impact of military operations in Ukraine on soils: artillery shelling has reduced arable land, prompting a review of how other countries with similar adverse experiences have addressed soil contamination and an overview of measures already undertaken in Ukraine.

Ukrainian land has turned into a terrifying testing ground for various types of weapons ranging from long-range howitzers and multiple launch rocket systems to phosphorus bombs and cruise missiles.

The destruction of the upper fertile layer of soil, which has been formed over centuries, occurs as a result of explosions of missiles, artillery shells of various types, high-explosive aerial bombs, drones, shells of various types of MLRS, "vacuum" bombs, etc. This is despite the fact that over the past 100 years, domestic soils have lost about 30% of humus content. The ongoing war accelerates this process, as soils lose fertility due to changes in physical, chemical and physico-chemical properties.

The explosion of any type of projectile contributes a number of toxic compounds into the soil. During the detonation of rockets and artillery shells, carbon monoxide, carbon dioxide, water vapor, nitrogen oxides and dioxide, formaldehyde, cyanide vapor, nitrogen, as well as a large amount of toxic organic compounds are formed. Research conducted by the Institute of Applied Biotechnology on militarily disturbed agroecosystems in Khmelnytskyi, Kherson, and Kharkiv regions involved a series of agrochemical, toxicological, and biological studies. The main conclusion is that the diversity of military factors causes a corresponding diversity of soil alterations. And each explosion, each disturbance of the soil is a new situation that needs to be studied separately.



Fig. 13. Field after Russian shelling.

According to local residents, “after the shelling, the land becomes dead. After the winter shelling, all the vegetables had to be thrown away in the summer. The apricots became small and shriveled.” Cultivating any crops on such soils will be impossible for an extended period. After the First World War, the arable land in Europe decreased by 22.6%.

Toxic compounds can enter the soil with precipitation. For example, sulfur is a component of a significant part of ammunition. When mixed with precipitation, it turns into dangerous sulfuric acid in the soil. In the atmosphere,

sulfur and nitrogen oxides cause acid rain, which alters soil pH and damages vegetation.

Another aspect is heavy metals. In conflict zones, heavy metals sometimes exceed background values by 30 times. In particular, in the combat zones near Sloviansk, the maximum permissible concentrations of lead are exceeded by hundreds of times, and strontium and titanium, which are uncharacteristic for soils, are also present in significant quantities. Soil scientists have noted a systematic exceedances of mercury, zinc, and cadmium by six to eight times. These metals are especially dangerous because they do not decompose in nature, can migrate in water, air, and accumulate in soil and living organisms. High levels of copper, nickel, lead, phosphorus, and barium have been recorded in areas of shelling.

Ammunition fragments are also dangerous. Artillery shells of 120 mm and 152 mm caliber produce 1600-2350 and 2700-3500 fragments weighing 1 g, respectively. Cast iron with steel impurities is the most common material for the production of ammunition casings and contains not only iron and carbon, but also sulfur, copper and other components. These substances enter the soil, migrate to groundwater and, as a result, enter the food chains, affecting both animals and humans. Consequently, soil contaminated by explosions represents a long-term threat, exerting slow toxic effects human health.

The slide shows the earth turned inside out by hundreds of thousands of artillery shell explosions, huge craters all around, and kilometers of trenches on both sides of the front line. This is a comparison of the Battle of Passchendaele (1917) and the battles near Bakhmut in Donbas region. Explosions on that section of the front line turned up about 90,000 tons of soil. A 250-kilogram air bomb, when detonated, can leave behind a crater up to 8 meters in diameter and up to 4 meters deep, and turns up about 375 m³ of soil.

Ecologists note that huge craters, digging trenches and fortifications, moving heavy military machinery — all this leads to terrible landscape alterations. As a result, there is degradation of vegetation cover, increased wind and water erosion. Similar problems were encountered in Belgium and France a hundred years ago. In Europe, there are still problems with soils after the First World War, as the natural soil recovery rate is approximately 0.06 mm /year.

Soil contamination by fuels and other petroleum products occurs as a result of the movement and damage caused by land military equipment. Experts state that in soils soaked with petroleum substances, water permeability decreases,

oxygen is displaced, biochemical and microbiological processes are disrupted. As a result, water, air regimes as well as nutrient cycling deteriorate; root nutrition of plants is disrupted, their growth and development are slowed, which leads to vegetation loss.

In places where military equipment has burned and oil spills have occurred, catastrophic alterations occur in the soil. All agrochemical indicators that are necessary for successful crop cultivation are sharply affected: the amount of nitrogen, phosphorus, potassium, especially phosphorus decreases. In addition, the amount of organic matter decreases, and, most importantly, the living microflora of the soil is destroyed. Researchers have recorded a decrease in soil biogenicity by 30-50% in zones affected by equipment fires, and an increase in the heavy metals concentrations by one or two orders of magnitude.

Destroyed military equipment is also a significant hazard. It turns into tons of scrap metal, which is the source of carcinogenic waste. Experts note that "when the war is over, disposing of such a large amount of scrap metal will become another challenge. Recycling military scrap is a more complex and labor-intensive process."

Other severe aspects of the soil problem are the burial of casualties and the contamination of lands with mine. In November, the head of the Luhansk Regional Administration, Serhiy Haiday, reported that due to the mass burials of the killed occupiers, the Luhansk region is "turning into one big graveyard." It is obvious that growing crops on such land will be strictly prohibited in the future.

According to UN forecasts, it will take, under the best circumstances, 5 to 7 years, to demine Ukrainian territories, provided that the latest satellite mine identification systems are used. For example, it took Poland about 12 years after World War II to clear its territories of mines. According to UN data, Ukraine is one of the most mined countries in the world, alongside with Afghanistan, Syria, and Bosnia.

As of December 2024, according to the Ministry of Defense of Ukraine, approximately 139,000 km² of the country's territory remains potentially contaminated with mines and explosive devices. This is about 23% of the total area of Ukraine.

A significant part of these territories is located in regions where hostilities have occurred or are ongoing, in particular:

- Donetsk region
- Luhansk region

Kharkiv region
Kherson region
Zaporizhia region
Kyiv region
Chernihiv region
Sumy region

Demining operations are ongoing, and the area of contaminated land is gradually decreasing. At the end of 2023, the figure was 173,000 km², that is, 35,000 km² of agricultural land which was returned to use during this period. However, this process requires significant resources and time. According to some estimates, complete demining may take from several decades to a century, depending on the intensity and efficiency of the work carried out.

One option for reviving damaged soils could be to establish “red zones” in areas where there was intense fighting. This initiative is being proposed by specialists from the Ukrainian Nature Conservation Group (UNCG).

UNCG experts give the example of France, where after the First World War “red zones” were created and people were relocated from there. An area of more than 1,200 km² of fertile land in the area of the Battle of Verdun (1916) was recognized by the French authorities as “completely destroyed”: a strict ban on access and agricultural activities there was introduced. Later, through clearance, the area of the critically affected zone was reduced to 100 km². Over the years, without anthropogenic impact, the territory is being restored, and the craters from the explosions become part of the landscape.

Leading specialists in the field of soil restoration including scientists of the "Institute of Soil Science and Agrochemistry named after O.N. Sokolovsky", the State Institution "Institute of Soil Protection of Ukraine", as well as domestic and foreign practitioners in the revival of degraded soils - are already looking for solutions for restoring damaged soils, trying to combine the capabilities and expertise of scientists, educators, agronomists, representatives of agribusiness and civil society organizations. This collaborative approach is necessary because the critical challenges facing Ukraine in the post-war period require coordinated, joint efforts to overcome them.

8.2. Environmental and economic damages from Russian military aggression for the world and Ukraine.

The procedure for assessing the environmental consequences of military impacts on the environment is a complex, time-consuming, and expensive process. Let us consider the eco-analytical component of this procedure. Eco-analytical analysis includes an initial description of the objects of observation; initial toxicological tests or express analysis. In the laboratory, screening studies are initially carried out to identify the component composition of unknown substances. To detect chemicals, techniques such as gas chromatography with tandem mass spectrometry (GC-MS/MS, HPLC-MS/MS), infrared spectroscopy (FTIR), IRS, nuclear magnetic resonance spectroscopy (NMR), and atomic adsorption spectroscopy (AAS), etc. are used.

After screening, targeted studies are conducted to determine the quantitative content of identified hazardous substances. In parallel, ecological and toxicological studies are carried out using bioindication and biosensor analysis methods, which makes it possible to determine the integral pollution of the ecosystem and assess the impact of the habitat on living biological organisms.

Next is data expertise, standardization of test results, preparation of protocols and expert conclusions. These conclusions are submitted to the institutions that conduct forensic examinations.

The cost of research, for instance, analyzing a single soil sample to assess environmental damage caused by the Russian Federation—averages approximately USD 1,000. This includes the determination of toxic elements, heavy metals, pesticide residues, polychlorinated biphenyls and polyaromatic hydrocarbons, and a complex of physicochemical indicators of soil quality.

Assessing and calculating of the final damage caused to the environment as a whole and to its individual components, including biodiversity, as a result of Russian aggression is a large-scale task and is fully possible only after the end of hostilities. A comprehensive assessment will require monitoring studies, including studies of the dynamics of populations of living organisms.

Unfortunately, there are few laboratories that can conduct high-quality environmental monitoring for war-related pollutants. The Ukrainian Laboratory of Quality and Safety of Agricultural Products (affiliated with the National University of Life Resources and Environmental Management of Ukraine) is accredited according to the international standard DSTU ISO/IEC 17025:2019.

This standard contains requirements for measuring laboratories, compliance with which demonstrates their technical competence and ability to obtain accurate results both at the national and international levels.

The Water Monitoring Laboratory of the Western Region (Ivano-Frankivsk) received a certificate of accreditation in accordance with the requirements of DSTU EN ISO/IEC 17025:2019 in the field of chemical and physico-chemical testing methods for surface waters, return (waste water), groundwater and soil.

And, unfortunately, research institutions in Ukraine are not currently ready to monitor priority pollutants introduced into the environment as the result of warfare, including explosives, their metabolites, and rocket fuel residues.

Overcoming the damage caused during wartime requires close coordination between various structures and, potentially, the establishment of new structures, as well as the development of new skills and capabilities.

Therefore, it is important to properly organize constant monitoring according to European standards in the area of impact, in particular, monitoring of soils, groundwater and surface waters, where the hazardous consequences of military activities will manifest themselves for many years to come. Recognition of this inevitable fact should also be taken into account in the strategic planning of the functioning and scientific research of natural science departments.

Ukraine should continue to strengthen its data collection and assessment system, as well as to improve coordination at the government level and with independent and international organizations (elements of Ukraine's environmental policy in wartime).

In particular, the SEI must be reformed according to the European model. This is noted by the European Commission in its recommendations to Ukraine, and is clearly acknowledged at the state level. This is an important component of Ukraine's accession to the EU. This reform is among the TOP-5 environmental priorities for 2024.

Currently, the State Ecological Inspectorate (SEI), which is the central body for supervision and control over compliance with environmental legislation, is rather ineffective in managing its resources and powers. However, it performed effectively at the beginning of the Russian aggression and continues to work well in terms of recording the facts and assessing the damage caused by war crimes.

Beyond direct environmental contamination, the war also affects the global climate through the emission of substantial volumes of carbon dioxide and other greenhouse gases (GHGs) into the atmosphere (Fig13).

While the world struggles to significantly reduce greenhouse gas emissions to limit the increase in the average temperature on the planet to 1.5°C, additional emissions of carbon dioxide and other GHGs due to war are further complicating global efforts to address the climate crisis.

According to the latest report by the Initiative for Greenhouse Gas Accounting of War (IGGAW), the damage caused to the global climate over the past two years is estimated at 32 billion US dollars (slide 7). The report was published on June 13, 2024 by the Ministry of Environmental Protection and Natural Resources of Ukraine in cooperation with climate protection groups.

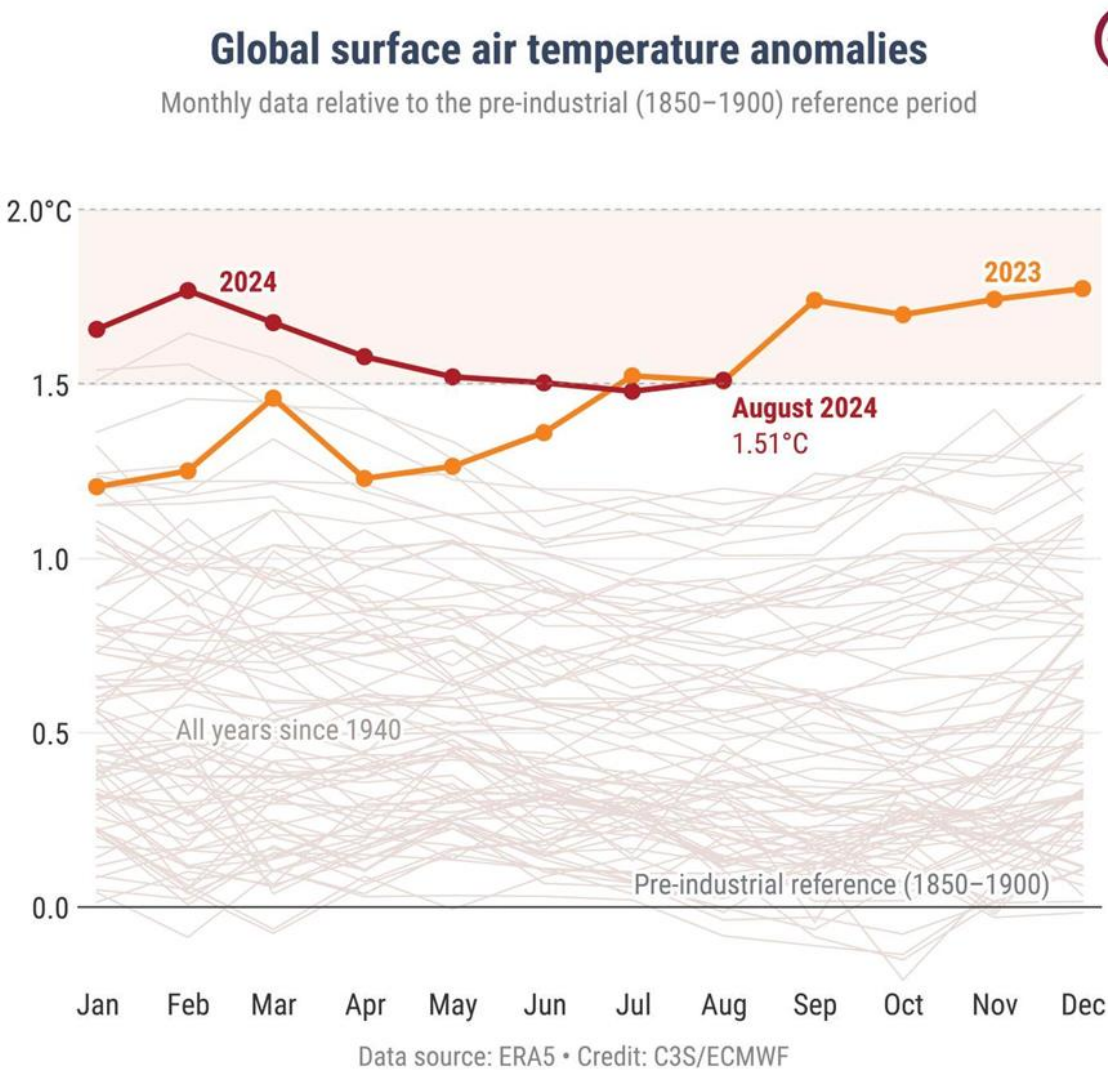


Fig.14. Global surface air temperature anomalies.

Over a 24-month period, Russia’s war against Ukraine has resulted in emissions of approximately 175 million tonnes of carbon dioxide (CO₂), often referred to as “conflict carbon.” For the purpose of calculation, all greenhouse

gases (GHGs) are converted into the so-called "CO₂ equivalent", which is why all greenhouse gases are often simply called "carbon".

As the war continues, GHG emissions continue to increase. According to this fourth interim report, GHG emissions associated with the 24 months of war have increased to 175 million tonnes of conflict-related CO₂.

175 million tonnes of CO₂ is more than the annual GHG emissions of a highly industrialized country like the Netherlands, or the emissions from placing 90 million new gasoline cars on the road, or building 260 coal-fired power plants with a capacity of 200 MW each.

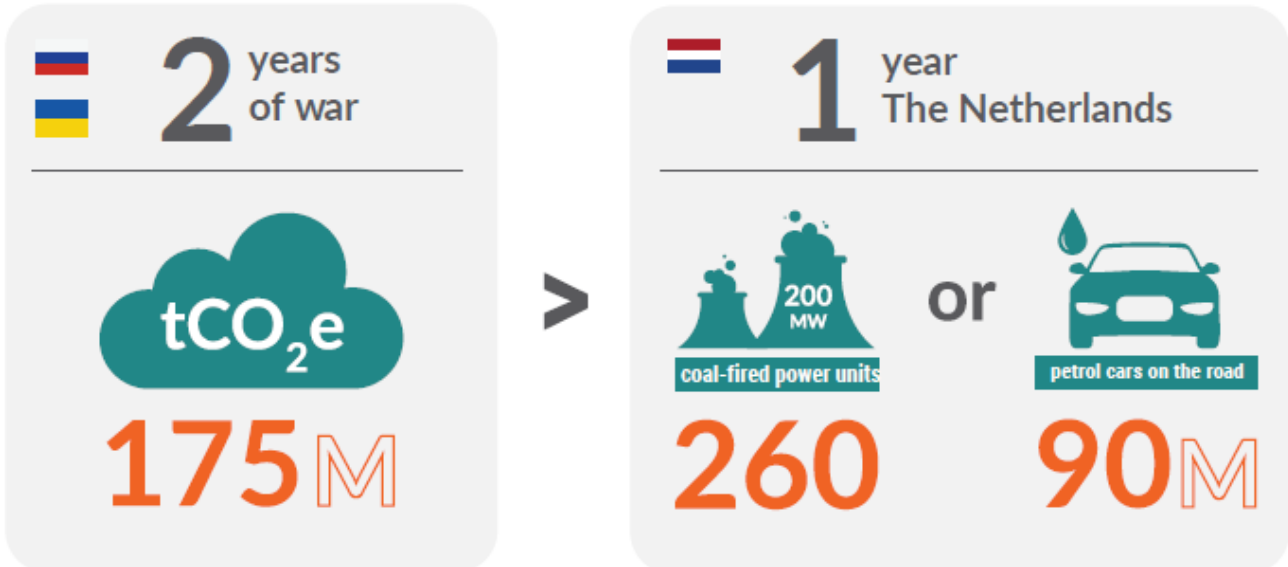


Fig.15. GHG emissions.

In the early months of the war, most emissions were caused by the extensive destruction of civilian infrastructure, which will require significant post-war reconstruction efforts. Now, after three years of hostilities, the largest share of emissions is caused by military operations, landscape fires, and damage to energy infrastructure.

The contribution of each sector in total emissions is presented in the pie chart below. In this assessment, emissions from reconstruction are roughly equivalent to emissions from the war.

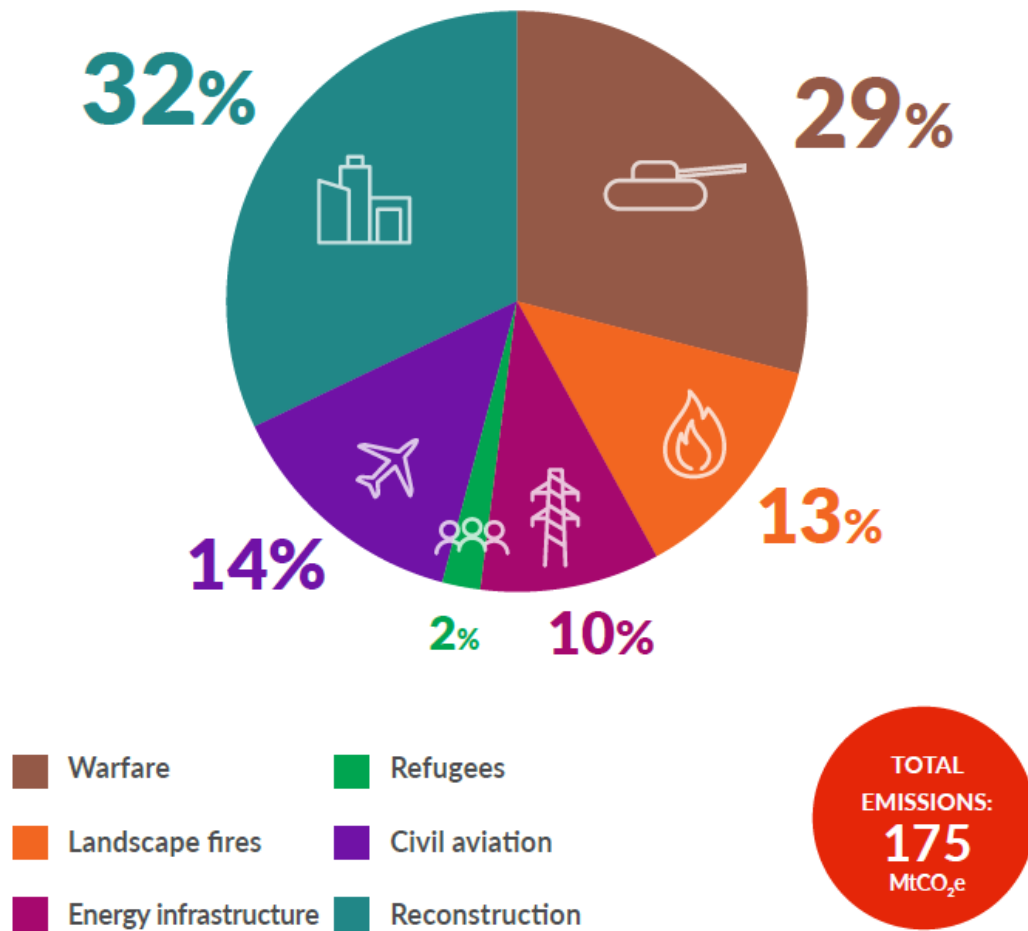


Fig.16. Distribution of total GHG emissions.

The main sources of emissions identified in the report include:

1. Military operations cause significant GHG emissions due to the extensive fuel consumption and demand for carbon-intensive materials and equipment. The largest share of these emissions, approximately 51.6 million tonnes of CO₂, comes from the operation and supply (fuel combustion) of military equipment and weapons, as well as the construction of fortifications.

2. Landscape fires: Military strikes caused large-scale forest fires, adding 22.9 million tonnes of CO₂ to total emissions; satellite imagery has provided information on 27,000 fires covering almost 1 million hectares.

3. Energy infrastructure: targeted attacks on energy facilities have significantly contributed to the release of an estimated 17.2 million tonnes of CO₂ as a result of the destruction of oil depots, oil refineries and uncontrolled greenhouse gas leaks, damage to gas pipelines, and natural gas transportation and distribution infrastructure.

4. Aviation rerouting: commercial aircraft have changed routes due to restrictions and safety concerns affecting 18 million km² of airspace over Russia and Ukraine; rerouting between Europe and Asia has resulted in additional fuel consumption, increasing emissions by an additional 24 million tonnes of CO₂.

5. Reconstruction: Post-war reconstruction of damaged and destroyed civilian infrastructure is expected to be a significant source of emissions, as rebuilding buildings and other infrastructure is highly carbon intensive due to the extensive use of large volumes of concrete and steel, potentially resulting in an increase of 56.0 million tonnes of CO₂.

6. Displacement of almost 7 million Ukrainians and Russians: total emissions related to refugees and IDPs amounting to 3.27 million tonnes of CO₂.

The Russian Federation can be held accountable for these emissions and the damage they have caused to the global climate, as without its act of aggression these GHG emissions would not have occurred.

Globally, there are growing calls to hold Russia responsible for the climate damage caused to the planet. The Russian Federation can be held accountable for these emissions and the damage they have caused to the global climate, because without its act of aggression, these GHG emissions would not have occurred.

Climate damage refers to the adverse impacts that climate change has on humanity and the environment. Such damages may result from events that occur suddenly (climate disasters such as cyclones), as well as processes that unfold gradually (such as sea level rise).



Fig.17. Climate damage.

The Initiative on Greenhouse Gas Accounting of War (IGGAW) is developing new methods to measure “conflict carbon.” Using the latest methodology, researchers have determined the cost of each tonne of carbon emitted. In a recent study published in the journal “Nature”, the preferred average social cost per tonne of CO₂ emitted is \$185. Using this “social cost” to quantify the damage from each tonne of greenhouse gas emissions, the total climate damage caused by the Russian Federation during the 24 months of war is estimated at over \$32 billion.

The report emphasizes the need to hold the Russian Federation accountable for these environmental and climate damages, and calls for international cooperation to address these consequences, which is crucial for achieving global emission reduction goals established under the Paris Agreement.

The Ukrainian government welcomed the report, saying it would become an important component of the reparations claims against Russia.

IGGAW’s estimate of emissions from Russia’s war in Ukraine relies heavily on satellite data, government information, open-source scientific research and intelligence, expert interviews, and industry reports, among other sources. Data on carbon emissions during the conflict are often incomplete. Obstacles to estimating “conflict carbon” include incomplete data availability, wartime secrecy, and physical hazards to experts.

In 2022, a UN General Assembly resolution called on Russia to compensate Ukraine for the war, and the Council of Europe established a register of damages. The climate emissions report should become part of this register.

Most of the emissions originated within Ukraine, while approximately one-third were released elsewhere, indicating that the impact of the war on greenhouse gas emissions is not confined to Ukrainian territory. Presenting the report, IGGAW’s lead expert and author Leonard de Clerk emphasized that Russia was harming both Ukraine and the global climate, noting that significant amounts of “conflict carbon” would have effects around the world.

Let us also consider the geographical distribution of emissions. Some of the emissions presented in this report have occurred or will occur within Ukraine, on territories controlled by the Ukrainian government or in occupied areas, while other emissions occurred or will occur elsewhere.

From a climate damage perspective, the geographic location of emissions is irrelevant: every tonne of GHG emitted anywhere in the world contributes

equally to climate change. However, to understand the global impact of war on emissions around the world, the geographic distribution of war-related emissions is presented below.

The majority of these emissions (64%) occurred or will occur in Ukraine, both in the territories controlled by the Ukrainian government and in the occupied territories. However, a significant portion (36%) of the emissions occurred or will occur in the rest of the world (Fig.18.).

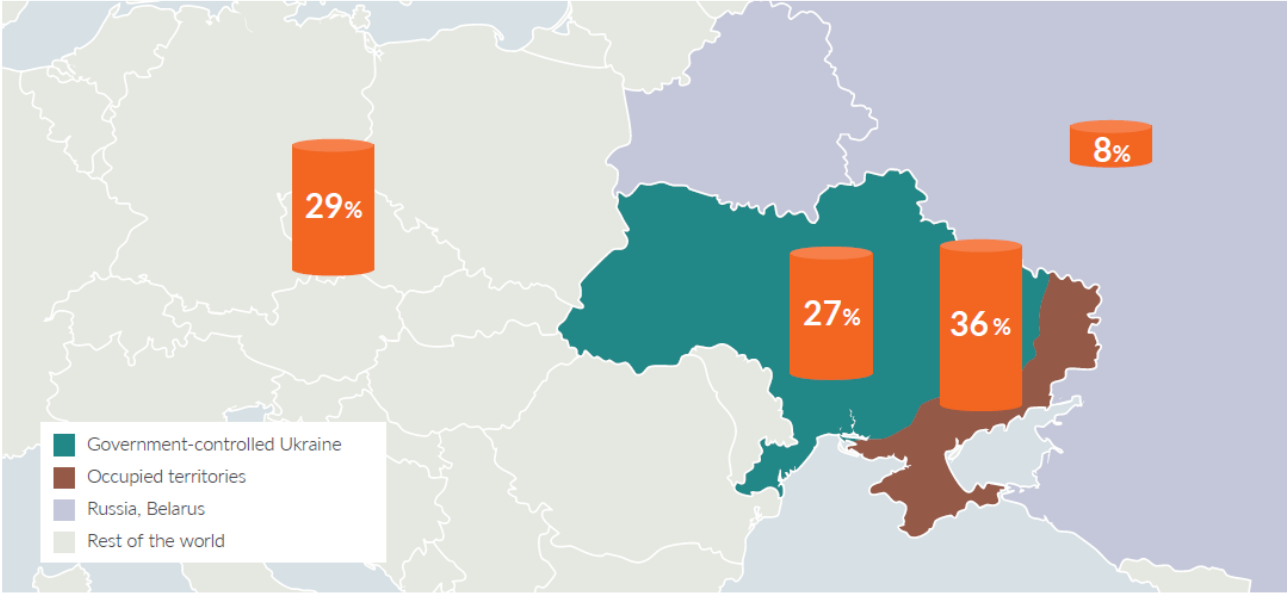


Fig.18. Geographical distribution of war emissions

During the allocation of emissions, experts made several assumptions. Let us consider the assumptions regarding one of the largest sources of GHG emissions from the Russian war – military emissions. 80% of Russian fossil fuel emissions occurred in the occupied territories of Ukraine, while 20% – in Russia. Emissions from the long-distance movement of military equipment took place in the rest of the world. Regarding ammunition – 40% of emissions occurred in Ukraine and 60% abroad due to significant dependence on military aid, while for Russia the distribution was 90% within Russia and 10% abroad (taking into account aid from North Korea and Iran).

Indirectly, the full-scale invasion has increased global insecurity and led to an increase in military expenditures, particularly on the European continent. Since the military activities are responsible for 5.5% of global emissions, an increase in military spending will inevitably lead to higher military-related emissions worldwide.

Some emissions have occurred within 24 months of war, while others will occur in the future. This is mainly due to emissions from post-war reconstruction, but it is also relevant for forests that die after major wildfires and are either decomposed over time or cut down for fuel. In both cases, biomass is eventually released into the atmosphere as CO₂ (Fig.19).

The Russian Federation should be forced to pay this climate debt owed to Ukraine and the countries of the Global South that will suffer the most from climate damage.

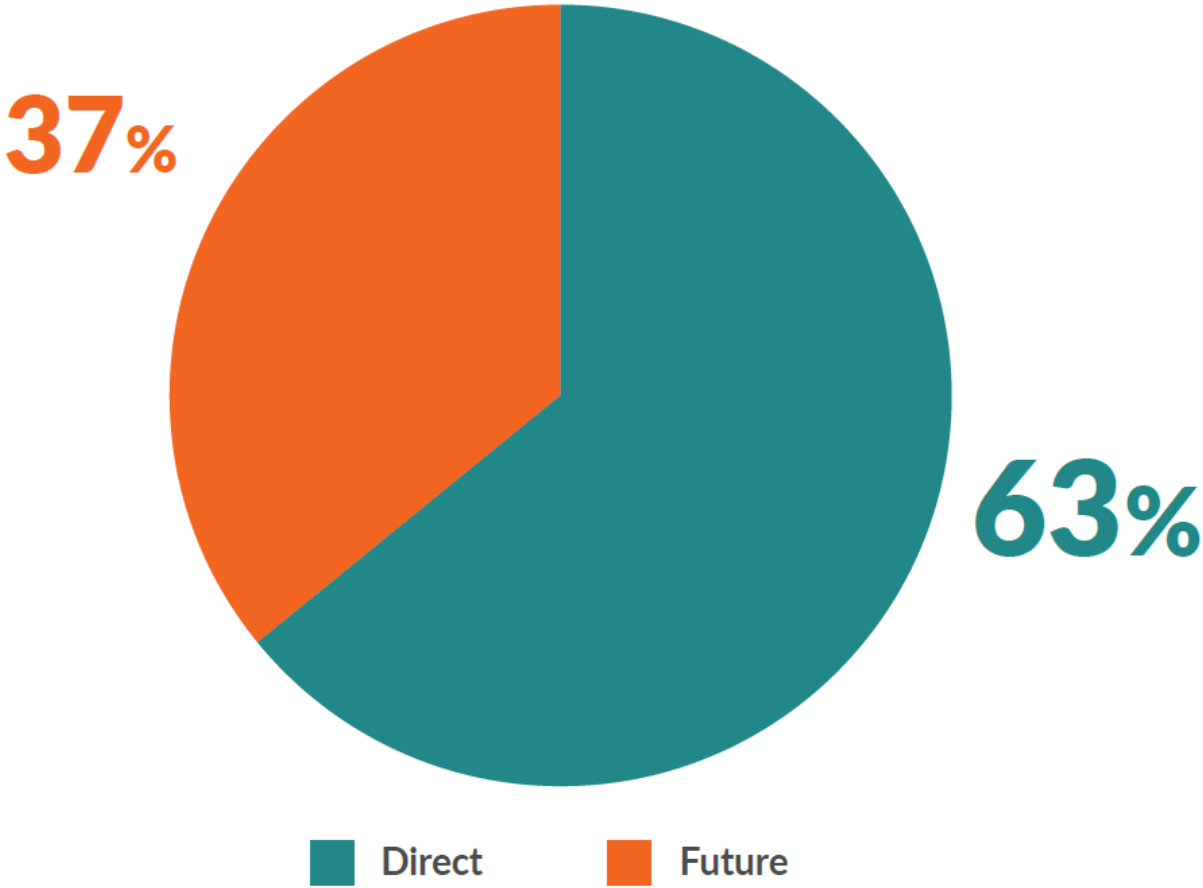


Figure 19. Distribution of emissions which occurred during 24 months of war and future emisisions/

This information is being taken seriously by the whole world. Reports on the climate impact of Russian aggression are being presented at the most important environmental events on the planet. The first report, was presented at the UN Climate Change Conference in Sharm el-Sheikh (Egypt) on November 9, 2022, covering the initial seven months of the war. The second, covering the first twelve months of the war, was presented at the UNFCCC (United Nations Framework

Convention on Climate Change) Climate Conference in Bonn, Germany, on June 7, 2023.

Accounting of the environmental consequences of the war in Ukraine should serve as a warning for the future and contribute to the development of a new global security framework for all living systems.

Global militarization will only continue to intensify. This will impose additional environmental burdens on the entire planet and reduce the prioritization of environmental objectives for a significant number of countries - a serious challenge for all of humanity in the context of existing climate and a number of other global threats to the biosphere.

Thus, Russia's invasion of Ukraine clearly demonstrated the unjustifiable costs of war in the modern world and the significant risks of large-scale anthropogenic disasters for the environment and millions of people.

Taking into account the environmental consequences of the war in Ukraine should serve as a warning for the future and contribute to the development of a new global security framework for all living systems.



REFERENCES

1. European Environment Agency. *Air Quality Status Report 2025*. HTML: TH-01-25-006-EN-Q. ISBN: 978-92-9480-710-6. ISSN: 1977-8449. <https://doi.org/10.2800/9895153>
2. European Environment Agency. *Air Pollution in Europe – 2025 Reporting Status under the National Emission Reduction Commitments Directive*. HTML: TH-01-25-017-EN-Q. ISBN: 978-92-9480-722-9. ISSN: 2467-3196. <https://doi.org/10.2800/2805780>
3. World Health Organization. *Ambient Air Pollution Data*. Available at: <https://www.who.int/data/gho/data/themes/air-pollution/ambient-air-pollution>
4. European Environment Agency. *Harm to Human Health from Air Pollution in Europe: Burden of Disease Status, 2025*. EEA Briefing 16/2025. HTML: TH-01-25-033-EN-Q. ISBN: 978-92-9480-739-7. ISSN: 2467-3196. <https://doi.org/10.2800/8961999>
5. European Environment Agency. *Harm to Human Health from Air Pollution – Burden of Disease Status 2025*. Available at: <https://www.eea.europa.eu/en/analysis/publications/harm-to-human-health-from-air-pollution-burden-of-disease-status-2025>
6. Web Report No. 22/2024. Title: *Impact of Air Pollution on Ecosystems in Europe*. EN HTML: TH-01-24-022-EN-Q. ISBN: 978-92-9480-699-4. ISSN: 2467-3196. <https://doi.org/10.2800/9670592>
7. Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.
8. Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC.
9. Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control); European Environment Agency.
10. Directive (EU) 2016/2284 of the European Parliament and of the Council of

14 December 2016 on the reduction of emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC.

11. Environmental Monitoring. Analytical report on the state and prospects for the development of the state environmental monitoring system. Ukraine, Kyiv, 2023. 119 p.

Available at: https://mepr.gov.ua/wp-content/uploads/2023/02/Monitoring-Green-Paper_15_02_2022.pdf

12. Dirty Skies Above Our Heads: Legislation in the Field of Ambient Air Protection in Ukraine and the EU. Comparative analysis of legislation, policy, and practice. Kyiv (Ukraine) / Prague (Czech Republic), 2020. 42 p.

Available at: <https://ecoaction.org.ua/wp-content/uploads/2020/12/dirty-skies-above-ua.pdf>

13. Angurets, O., Khazan, P., & Kolesnykova, K. Air Quality Management: From Concept to Implementation. Research report, edited by M. Soroka. Prague–Kyiv: Arnika, 2021. 52 p. ISBN 978-80-87651-99-5.

Available at:

https://cleanair.org.ua/wp-content/uploads/2021/11/cleanair.org.ua_i-ukrajina-fin-web-hires.pdf

14. Action Plan for Reducing Industrial Air Pollution in Cities of Ukraine. Review of policy options and recommendations, edited by Šárka Havránková. Kyiv–Prague, 2020. 31 p. ISBN 978-80-87651-75-9.

Available at: https://cleanair.org.ua/publication/chyste_povitrya_dlya_ukrayiny/

15. Air Pollution in Ukraine: A View from Space. Study based on the analysis of Copernicus Sentinel-5P satellite imagery and quality-controlled air pollution data from the Copernicus Atmosphere Monitoring Service, edited by Jan Labocha. Prague–Kyiv, 2020. 38 p. ISBN 978-80-87651-72-8.

Available at:

https://cleanair.org.ua/wp-content/uploads/2020/11/cleanair.org.ua_ukraine-space-ua-final-web.pdf

16. European Pollutant Release and Transfer Register (E-PRTR). Available at: <https://prtr.eea.europa.eu>

17. European Commission. Commission Report to the Council and the European Parliament on the Implementation of Directive 2008/1/EC concerning Integrated

- Pollution Prevention and Control and Directive 1999/13/EC on the Limitation of Emissions of Volatile Organic Compounds due to the Use of Organic Solvents in Certain Activities and Installations. October 2015, p. 4.
18. European Commission. Commission Report to the Council and the European Parliament on the Implementation of Directive 2008/1/EC on Integrated Pollution Prevention and Control and Directive 1999/13/EC on the Limitation of Emissions of Volatile Organic Compounds and Their Compounds from the Use of Organic Solvents in Certain Activities and Installations. October 2015, p. 5.
19. Act No. 76/2002 Coll. on Integrated Pollution Prevention and Control, on the Integrated Pollution Register, and amending certain acts.
20. Ministry of Industry and Trade. Scope of Activities of the Ministry. 2014. Available at: <http://www.mpo.cz/dokument1926.html>
21. Ministry of the Environment. History and Scope of Activities of the Ministry. 2015. Available at: <http://www.mzp.cz/cz/ministerstvo>
22. Ministry of the Environment. Integrated Pollution Prevention and Control. No date. Available at: <http://www.mzp.cz/ippc>
23. Ministry of Agriculture. About the Ministry of Agriculture. 2015. Available at: <http://eagri.cz/public/web/en/mze/ministry/>
24. Czech Environmental Inspectorate. Overview of the Activities of the Czech Environmental Inspectorate and Its Competences in Selected Environmental Areas. 2015. Available at: <http://www.cizp.cz/O-nas/Pusobnosti>
25. CENIA (Czech Environmental Information Agency). Department of Integrated Prevention. 2012. Available at: <http://www.cenia.cz/www/oddeleni-integrované-prevence>
26. Ministry of Industry and Trade. Public Administration Authorities. 2009. Available at: <http://www.ippc.cz/obsah/kontakty-a-odkazy/organy-statni-spravy/#praha>
27. Krupa, Antonín. Information on Inspection Activities of the Czech Environmental Inspectorate. November 2015.

- Available at: <http://www.ippc.cz/dokumenty/DF0640/prezentace/data-z-kontrolni-cinnosti-cizp>
28. Annual Report of the Czech Environmental Inspectorate for 2017. 2017. Available at: <http://www.cizp.cz/file/mj8/vyrocnizprava-CIZP-2017.pdf>
29. Ministry of the Environment. IPPC Database. Available at: www.mzp.cz/ippc
30. European Environment Agency. The European Air Quality Index. “About the European Air Quality Index.” Available at: <https://airindex.eea.europa.eu/Map/AQI/Viewer/#>
31. Services to Develop an EU Air Quality Index (EU AQI). Final Report, Issue 1.1. Report for the European Commission, DG ENV, ENV.C.3/FRA/2013/0013. 16 December 2016. Ricardo Energy & Environment.
32. CAQI Air Quality Index: Comparing Urban Air Quality across Borders. European Union, European Regional Development Fund, Regional Initiative Project Cite Air II, INTERREG IVC Programme, 2012. 38 p.
33. Hygienic Regulations: Maximum Permissible Concentrations of Chemical and Biological Substances in Ambient Air of Populated Areas. Order of the Ministry of Health of Ukraine No. 52 of 14 January 2020. Available at: <https://zakon.rada.gov.ua/laws/show/z0156-20>
34. Hygienic Regulations for Chemical Substances in the Air of the Working Zone. Order of the Ministry of Health of Ukraine No. 1596 of 14 July 2020. Available at: <https://zakon.rada.gov.ua/laws/show/z0741-20>
35. Hygienic Regulations on Indicatively Safe Levels of Exposure to Chemical and Biological Substances in Ambient Air of Populated Areas. Order of the Ministry of Health of Ukraine No. 52 of 14 January 2020. Available at: <https://zakon.rada.gov.ua/laws/show/z0157-20>
36. State Sanitary Norms, Rules and Hygienic Standards “Radiation Safety Standards of Ukraine” (NRBU-97). Resolution of the Chief State Sanitary Physician of Ukraine, First Deputy Minister of Health of Ukraine, No. 62 of 1 December 1997. Available at: <https://zakon.rada.gov.ua/rada/show/v0062282-97>
37. International Commission on Radiological Protection. The 2007 Recommendations of the International Commission on Radiological

- Protection. Annals of the ICRP, 2007, Vol. 37, Issues 2–4. ISBN 978-0-7020-3048-
38. European Environment Agency. The European Air Quality Index. “About the European Air Quality Index.”
Available at: <https://airindex.eea.europa.eu/Map/AQI/Viewer/#>
39. Integrated Pollution Register. Available at: www.irz.cz
40. Angurets, O., Khazan, P., Kolesnykova, K., Kushch, M., Chernoxova, M., & Havranek, M. Environmental Impacts of Russia’s War Against Ukraine. Publication date: 20 March 2023. 84 p. ISBN 978-80-88508-07-6. Available at: <https://cleanair.org.ua/wp-content/uploads/2023/03/cleanair.org.ua-war-damages-ua-version-04-low-res.pdf>
41. Pankiv, Z. P. Land Resources. Textbook. Publishing Center of Ivan Franko National University of Lviv, 2008. 272 p.
42. Tomiltseva, A. I., Yatsyk, A. V., & Mokin, V. B. Environmental Foundations of Water Resources Management. Textbook. Kyiv: Institute of Environmental Management and Sustainable Nature Use, 2017. 200 p.
43. Stankevych, S. V., & Holovan, L. V. Technoecology. Textbook. Kharkiv National Agrarian University named after V. V. Dokuchaiev. Kharkiv: Ivanchenko I. S. Publishing House, 2020. 338 p. Available at: http://pdf.lib.vntu.edu.ua/books/2021/Stankevich_2020_338.pdf
44. Depleted Uranium, Pyridostigmine Bromide, Sarin, and Vaccines. Washington, DC: National Academy Press, 2000.
45. Loboichenko, V. M., & Plisko, A. V. Assessment of Environmental Consequences of Explosions of Cartridges and Grenades at Ammunition Depots. Collection of Scientific Works of Cadets, 2017, Issue 15, pp. 112–120.
46. Small Arms Training Manual. Main Directorate of Combat Training of the Ground Forces of the Armed Forces of Ukraine. Scientific editor N. O. Stetsenko. Kyiv, 2005. 45 p.
47. Ivanov, E. V., & Vasyukov, A. E. On the Composition and Quantity of Gases Generated during Explosions of Ammunition at Storage Facilities. Report 1: Small Arms Ammunition. Problems of Emergency Situations. Collection of Scientific Papers of the National University of Civil Protection of Ukraine. Kharkiv, Issue 21, 2015, pp. 30–37.

48. Korniiichuk, S. P., Turinskyi, O. V., Pievtsov, H. V., et al. Modern Weapons and Military Equipment of the Armed Forces of the Russian Federation. Reference guide for participants of the Joint Forces Operation, edited by S. P. Korniiichuk. Kharkiv: DISA PLUS, 2020. 1220 p.
49. Marenets, M. A., Buller, M. F., Shcherban, V. V., Banishevskii, V. V., & Belova, L. A. Ballistic Solid Rocket Propellant: Comparative Assessment of Combustion and Detonation Products. Bulletin of KDPU, Issue 2/2006 (37), Part 2, pp. 72–75.
50. Trofymenko, M. Yu., Chesnokov, M. M., & Drahan, H. S. Structure of the Flame Jet during Combustion of a Solid Fuel Mixture under Elevated Pressure. Bulletin of Odesa State University, 2001, Vol. 6, Issue 3. Physical and Mathematical Sciences, pp. 159–162.
51. Van Wazer, J. R. Phosphorus and Its Compounds. Vol. 1. New York: Interscience Publishers, 1958.
52. Toxicological Profile for White Phosphorus. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, 1997.
53. Kozii, O. I., Petruk, M. P., Vytrykush, N. M., & Vakhula, O. M. The Dioxin Issue of Waste Incineration. Bulletin of the National University “Lviv Polytechnic”, No. 868, 2017, pp. 291–296.
54. Bezak-Mazur, E., & Szendryk, T. Transboundary Problems of Environmental Toxicology. Donetsk: State Enterprise “Information and Analytical Center ‘Donbassinformat’”, 2008. 300 p.
55. Bova, A. A., et al. Military Toxicology and Toxicology of Extreme Situations: Practical Manual. Minsk: Belarusian State Medical University, 2010.
56. Ministry of Environmental Protection and Natural Resources of Ukraine. Official news item.
Available at: <https://mepr.gov.ua/news/39871.html>
57. Ivaniuta, S. P., & Yakushenko, L. M. Analytical Report: The European Green Deal and Climate Policy of Ukraine.
Available at: <https://doi.org/10.53679/NISS-analytrep.2022.12>
58. State Environmental Inspectorate of Ukraine. Official webpage. Available at: <https://www.dei.gov.ua/posts/2226>

59. Cabinet of Ministers of Ukraine. Resolution No. 303 of 13 March 2022. Available at: <https://zakon.rada.gov.ua/laws/show/303-2022-%D0%BF#Text>
60. Kovalchuk, V. A. Wastewater Treatment. Rivne: Rivne Printing House JSC, 2002. 622 p.
61. Rabcheniuk, O. O., Khomenchuk, V. O., & Kurant, V. Z. Iron in Aquatic Ecosystems: Forms, Biological Significance, and Toxicity to Fish. Scientific Notes of Ternopil National Pedagogical University. Biology Series, 2016, No. 3–4 (67), pp. 107–119.
62. Ukrainian Nature Conservation Group. What Should Be the Fate of Ukrainian Territories Damaged by Explosions? Available at: <https://uncg.org.ua/>
63. Herasymenko, O. I., Herasymenko, K. O., & Antonov, A. H. Forensic Medicine. Kyiv: KNT, 2016. 3rd edition. 630 p.
64. Explosive Ordnance Guide for Ukraine. Geneva International Centre for Humanitarian Demining (GICHD), 2022. 220 p. Available at: https://www.gichd.org/fileadmin/AMAT/_uploads/GICHD_Ukraine_Guide_2022_Second_Edition_in_Ukrainian.pdf
65. Protsko, Ya. I. Impact of Oil and Petroleum Products on Soil Cover. Bulletin of Poltava State Agrarian Academy, 2010, No. 2, pp. 189–191.
66. Pozniak, S. P., & Teleguz, O. H. Anthropogenic Soils. Textbook. Lviv: Ivan Franko National University of Lviv, 2021. 200 p.
67. Safranov, T. A. Environmental Foundations of Nature Use. Odessa: ODEKU, 2002. 226 p.
68. State Environmental Inspectorate of Ukraine. Official webpage. Available at: <https://www.dei.gov.ua/posts/2226>
69. Cabinet of Ministers of Ukraine. Resolution No. 484 of 3 July 1995. Available at: <https://zakon.rada.gov.ua/laws/show/484-95-%D0%BF#Text>
70. Cabinet of Ministers of Ukraine. Resolution No. 631 of 26 April 2003. Available at: <https://zakon.rada.gov.ua/laws/show/631-2003-%D0%BF#Text>
71. Ministry of Environmental Protection and Natural Resources of Ukraine. Order No. 16 of 16 January 2021. Available at: <https://zakon.rada.gov.ua/laws/show/z0406-21#Text>

72. Cabinet of Ministers of Ukraine. Resolution No. 1209 of 21 November 2011. Available at: <https://zakon.rada.gov.ua/laws/show/1209-2011-%D0%BF#Text>
73. Cabinet of Ministers of Ukraine. Resolution No. 665 of 23 July 2008. Available at: <https://zakon.rada.gov.ua/laws/show/665-2008-%D0%BF#Text>
74. Cabinet of Ministers of Ukraine. Resolution No. 575 of 10 May 2022. Available at: <https://zakon.rada.gov.ua/laws/show/575-2022-%D0%BF#Text>
75. Additional Protocol to the Geneva Conventions of 8 June 1977. Available at: https://zakon.rada.gov.ua/laws/show/995_199#Text
76. United Nations Compensation Commission (UNCC). Official webpage. Available at: <https://uncc.ch/>
77. United Nations Compensation Commission – Prospects for Funding Environmental Restoration in Ukraine after the War with the Russian Federation. Review of UNCC Activities. Ecology. Law. Human. Available at: <http://epl.org.ua/wp-content/uploads/2022/05/Kompensatsijna-komisiya-OON.pdf>
78. United Nations Compensation Commission (UNCC). Claims Overview. Available at: <https://uncc.ch/claims>
79. Ministry of Ecology and Natural Resources of Ukraine. Order No. 303 of 29 August 2011. Available at: <https://zakon.rada.gov.ua/laws/show/z1097-11#Text>
80. Ministry of Environmental Protection of Ukraine. Order No. 389 of 20 July 2009. Available at: <https://zakon.rada.gov.ua/laws/show/z0767-09#Text>
81. Gemmill, B., et al. “The Role of NGOs and Civil Society in Global Environmental Governance.” 2002, pp. 77–100.
82. Rosenschöld, R., Munck, J., & Vihma, P. “Achieving Social-Ecological Fit in Projectified Environmental Governance: Exploring Vertical and Horizontal Dimensions.” *Environmental Science & Policy*, 136 (2022), pp. 127–135.
83. Tschentscher, T. *Promoting Sustainable Development through More Effective Civil Society Participation in Environmental Governance*. New York: United Nations Development Programme, 2016.
84. National Museum, India. Official webpage.

Available at: <https://nhm.gov.in/index1.php?lang=1&level=2&sublinkid=172&lid=246>

85. EO Handbook. Sustainable Development Goals, Part 1.4.

Available at: http://eohandbook.com/sdg/part1_4.html

86. Group on Earth Observations (GEO). Official webpage.

Available at: <https://earthobservations.org/index.php>

87. EO Handbook Database.

Available at: <http://database.eohandbook.com/>

88. EO for SDG. Available at: <https://eo4sdg.org/>

89. Committee on Earth Observation Satellites (CEOS). Official webpage.

Available at: <https://ceos.org/>

90. GEO. Earth Observations for the 2030 Agenda.

Available at: https://earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf

91. United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). Working Group 6.

Available at: <https://ggim.un.org/UNGGIM-wg6>

92. EO Handbook. Sustainable Development Goals.

Available at: <http://www.eohandbook.com/sdg/>