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Air Pollution from the Destruction of Military Equipment: the Desk-based project

student-driven citizen science project

Objective

This project aims to assess the extent of damage caused to the airspace of Ukraine as a result of the destruction of military equipment of the Russian occupiers. The group will monitor the destruction of the number of units of military equipment by type. The data obtained will be used to calculate the emissions of certain pollutants into the atmospheric air and the amount of damage caused. The results obtained are the basis for collecting a contribution from Russia for the facts of ecocide caused to the environment.

Relevance of the problem: As a result of the armed aggression of the Russian Federation and hostilities in various regions of Ukraine, the quality of atmospheric air, a valuable natural resource, is significantly deteriorating. Air quality control and assessment of the damage caused is one of the priority tasks of environmental protection and documentation of the consequences of the war.

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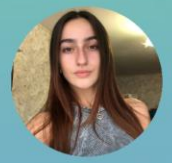

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Regulatory framework

The key document for all calculations is the “Methodology for Calculating Fugitive Emissions of Pollutants into the Atmospheric Air as a Result of Emergency Situations and/or Martial Law and Determining the Amount of Damage” approved by the Order of the Ministry of Environmental Protection and Natural Resources of Ukraine No. 175 dated 13.04.2022 (Methodology No. 175). This act establishes an official approach to determining emissions and calculating the economic equivalent of damage.

Collecting baseline data on destroyed equipment

We collected and systematized data on destroyed military equipment, including:


Tanks (various modifications)


Combat armored vehicles (IFVs, APCs)


Artillery systems


Multiple launch rocket systems (MLRS)


Airplanes


Helicopters


Military-purpose vehicles


Fuel tankers


Speedboats


Landing ships


Unmanned aerial vehicles (UAVs)


Air defense systems


Cruise missiles


Specialty Vehicles

We mainly relied on the official reports from the General Staff of the Armed Forces of Ukraine and the Ministry of Defense of Ukraine for our information. We kept our data up-to-date regularly because the number of destroyed vehicles was always on the rise.

We did our calculations every Saturday—specifically on 03/22/2025, 03/29/2025, 04/05/2025, 04/12/2025, 04/19/2025, 04/26/2025, 05/03/2025, 05/10/2025, 05/17/2025, and 05/24/2025. But we started from 07/12/2023, which helped us keep track of the current situation and understand how environmental damage was changing over time.

Date	Tanks	IFVs	Artillery systems	MLRS	Air defense systems	Airplanes	Helicopters	Military-purpose vehicles	Fuel tankers	Speedboats	Large landing ships	UAVs	Cruise missiles
7/12/2023	4090	7990	4402	674	415	315	310	6978	77	18	2	3726	1271
3/22/2025	10403	21609	24944	1327	1111	370	331	41045	280	25	3	30338	3121
3/29/2025	10478	21796	25451	1345	1122	370	335	42118	280	25	3	31234	3121
4/5/2025	10541	21952	25730	1350	1124	370	335	42673	281	25	3	31778	3123
4/12/2025	10591	22055	26092	1362	1127	370	335	43526	281	25	3	32278	3145
4/19/2025	10676	22266	26600	1368	1139	370	335	44881	281	25	3	33176	3148
4/26/2025	10711	22320	26965	1372	1145	370	335	45770	281	25	3	33897	3196
5/3/2025	10745	22369	27234	1375	1153	370	335	46722	281	25	3	34665	3197
5/10/2025	10790	22440	27637	1380	1158	372	335	47549	281	25	3	35482	3197
5/17/2025	10831	22553	27942	1386	1167	372	336	48528	281	25	3	36278	3197
5/24/2025	10852	22622	28201	1395	1169	372	336	49358	281	25	3	37177	3197

Determination of pollutant emissions

For each type of destroyed military equipment, specific pollutant emission rates were determined, including:

- Nitrogen oxides (NOx)
- Ammonia (NH3)
- Sulfur dioxide (SOx)
- Carbon dioxide (CO2)
- Carbon monoxide (CO)
- Non-methane volatile organic compounds (NMVOCs)
- Particulate matter (PM10 + PM2.5)
- Heavy metals: lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), selenium (Se), zinc (Zn)
- Benzo(a)pyrene

Emissions are expressed in tons of pollutant per unit of destroyed equipment. These figures are averaged and take into account the typical composition of materials, fuel and ammunition. Each of these substances has a specific negative impact on human health and the environment.

Date	CO2	CO	PM10 + PM2,5 (Soot)	NMVOC	NOX	Zn	Ni	Cd	SOx	Pb	Hg	As	NH3	Cu	Cr	Se	Benzo(a)pyrene
7/12/2023	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/22/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3/29/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/5/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/12/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/19/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4/26/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/3/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/10/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/17/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5/24/2025	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Calculation of pollutant emissions

The total amount of each individual pollutant entering the atmospheric air (denoted as Мівкид) is calculated in stages:

1. Calculation of emissions from one type of equipment:

- The amount of emission of the i-th substance from the destruction of all units of one specific type of military equipment is determined.
- This is done by multiplying the total number of destroyed units of this type of equipment by the corresponding specific emission of this substance for this type of equipment.

Formula:
Мівкид (type of equipment) = Number of units of this type of equipment × Specific emission of i-substance for this type of equipment (t/unit)

2. Calculation of total emissions for all types of equipment:

Formula:
Emission (total) = ∑ (for all types of equipment) Emission (type of equipment)

To obtain the total emission volume of the i-th pollutant for all types of destroyed equipment, the emissions of this substance from each type of equipment are summed up.

Calculation of the amount of damage for each pollutant

The amount of damage for each pollutant (Psh) is calculated using the formula:

$$Psh = Мівикид \times Sp \times Kneb \times Kv \times Kmp \times Kpp$$

Where:
Мівикид - mass of fugitive emission of a specific pollutant (in tons).
Sp - the tax rate for this pollutant (in UAH/t).
Kneb - the hazard class coefficient for this substance.
Kv – environmental impact factor (event duration).
Kmp – event scale factor.
Kpp – coefficient of the nature of the origin of the event (martial law).

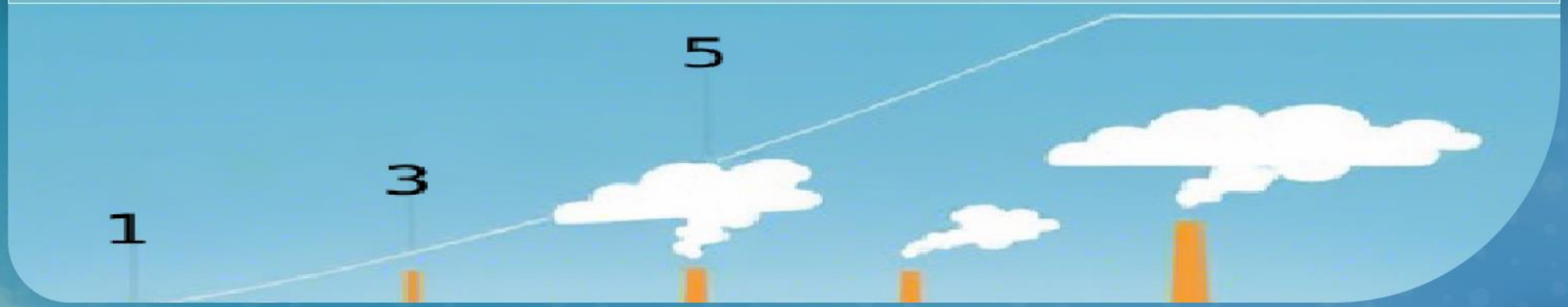
This calculation is performed separately for each of the identified pollutants (NOx, CO, SOx, heavy metals, etc.), which allows for a detailed picture of the damage in terms of individual pollutants.

Determination of environmental tax rates

For the economic assessment of damage, tax rates for emissions into the atmospheric air by stationary sources of pollution of certain pollutants, established by Article 243 of the Tax Code of Ukraine, were used.

Determining the hazard class coefficient

For each substance, a corresponding hazard class coefficient (Kneb) was determined, which was taken from Appendix 3 to Methodology No. 175. This coefficient reflects the degree of toxicity and harmful effects of the substance on living organisms and the environment.
The higher the hazard class (and, accordingly, the greater the Kneb value), the more serious the consequences of the substance entering the atmosphere. For example, for substances of the 1st hazard class, such as mercury, cadmium, benzo(a)pyrene, this coefficient is the highest, which significantly increases the estimated amount of damage.



Determining the environmental impact factor

According to Methodology No. 175, when calculating damage, the environmental impact coefficient (Effect) is taken into account, which depends on the duration of the event. The values of this coefficient are determined in accordance with Appendix 4 to Methodology No. 175, which provides for a gradation of the coefficient depending on the duration of burning or emission:

- Up to 12 hours
- From 12 to 24 hours
- More than 24 hours
- Separate value for cases where the exact duration of the event cannot be determined

In conditions of active hostilities and the lack of the possibility of detailed documentation of each individual event, to standardize calculations and avoid subjective assessments, the value of the coefficient Kv=3, provided by the Methodology for cases where the duration of events is not determined, was adopted. This provided a single approach to all calculation cases in the absence of more detailed information.

Determining the event scale factor (Kmp)

The event scale factor (Kmp) is an important component of the damage calculation formula. Its values are given in Appendix 5 to Methodology No. 175 and are set depending on the mass of the burnt substance or the area of the fire.

However, since the calculation of the emission volumes was based on the number of units of destroyed equipment, the exact application of this factor was complicated. Therefore, Kmp was applied conditionally, based on general expert assessments of the scale of destruction. To ensure a conservative and unified approach in the absence of detailed data, the minimum Kmp coefficient of 1.2, provided for cases "in case of non-determination or up to 50 t/Ha", could be applied. This compromise solution allowed taking into account the scale factor at least at the minimum level specified by the Methodology.

Determining the coefficient of the nature of the origin of the event

The coefficient depending on the nature of the origin of the event (Kpp) is determined in accordance with Appendix 6 to Methodology No. 175. This appendix establishes different Kpp values for emergency situations of varying severity and for martial law conditions.

Since all analyzed events of destruction of military equipment and related emissions of pollutants occurred as a result of hostilities during martial law in Ukraine, for all calculations the maximum value of this coefficient, provided for martial law, was assumed, namely Kpp=10. Such a value significantly increases the estimated amount of damage, reflecting the particular severity and social danger of the environmental consequences caused by the war.

Calculation of the total amount of damage

To obtain an aggregate estimate of the economic damage caused to atmospheric air, the total amount of damage (Psh(total)) is calculated as the arithmetic sum of the amounts of damage for each individual pollutant:

$$Rsh(total) = \sum Rsh(for\ each\ substance)$$

This approach allows for a comprehensive financial assessment of the total negative impact on atmospheric air from all emissions considered. This is an important indicator for further analysis, the formation of claims for compensation for damages and the planning of environmental restoration measures. The total figure reflects the cumulative effect of pollution by various toxic components.

Cruise missile data processing

Special attention was paid to the calculation of emissions from the destruction of cruise missiles, since there are no direct specific emission indicators for this type of weapon in Methodology No. 175. This is due to the difficulty of determining the exact composition of the materials of the case, explosive part and rocket fuel, which may contain highly toxic components, such as heptyl or its derivatives, as well as strong oxidizers that form specific products during combustion, including dioxins.

Adapted Chinese methodology

Due to the lack of approved national standards, the methodological principle used in Chinese calculations was adapted. This principle is based on a proportional recalculation of emissions from the tank to the missile based on the ratio of their masses. It was assumed that the average mass of a cruise missile is approximately 1-2 tons, while the mass of a tank is about 40-60 tons. Thus, the mass of the missile is approximately 25-40 times less than the mass of the tank. The specific emissions of pollutants for the cruise missile were taken as the specific emissions for the tank, reduced proportionally, for example, by a factor of 25.

Problems of special equipment data analysis

In the process of work, the question arose of the correct classification and calculation of emissions from the destruction of "special equipment". This category of military equipment is broad and includes various special-purpose vehicles, such as electronic warfare (EW) equipment, engineering equipment, command and staff vehicles, ambulances, etc.
The problem was that for many types of such special equipment there are no approved specific emissions of pollutants in Methodology No. 175 or other available official sources. The possibility of conditionally equating some types of special equipment to the category of "automobile equipment", for which specific emissions exist, was discussed. However, this approach was recognized as potentially incorrect due to significant differences in the design, materials and possible specific equipment of special equipment.

Guided by the principle of caution and the need to ensure maximum accuracy of calculations, it was decided not to temporarily include "special equipment" in detailed calculations until more accurate data is obtained or appropriate methodological clarifications are developed. This limitation was necessarily noted in the conclusions and reports to emphasize that the real damage could be even higher.

Special equipment data analysis

According to available data, as of May 24, 2025, the total losses of special equipment of the Russian Federation reached 3,895 units. These figures, although not always detailed in open sources, indicate the scale of the problem. In particular, 37,177 units of unmanned aerial vehicles were destroyed, and 49,639 units of tactical trucks. Each such loss is not just scrap metal, but a potential source of pollution.

Combat support equipment includes engineering vehicles, evacuation, medical, logistics equipment and nuclear and chemical weapons. They contain lubricants, hydraulic fluids, anti-corrosion coatings (including hexavalent chromium) and disinfectants, which, when released into nature, pollute soil and water, harm living organisms and disrupt ecosystems.

Each unit of destroyed equipment leaves its mark in the form of pollutants. An estimate of the average amount of such substances per unit of equipment, based on known characteristics, allows us to understand the scale of the problem. For example, one unit of equipment can contain from 50 to 100 liters of hydraulic fluid, up to 5 kg of lithium batteries, as well as about 0.5–1 kg of lead and 0.1–0.2 kg of cadmium and mercury in electronics.

Patrol ship data analysis

A similar methodological difficulty arose when attempting to estimate emissions from the destruction of patrol ships. The existing tables of specific emissions include the categories "light speedboats" and "large landing ships", for which the corresponding coefficients are established. However, patrol ships, in terms of their characteristics, size, displacement, type of power plants and equipment, may differ significantly from both small boats and large landing ships, and therefore it was decided not to carry out calculations for patrol ships until more accurate data or specialized coefficients for this class of naval equipment become available.

Presentation of results

The results of all calculations performed, concerning the volumes of emissions of individual pollutants and the estimated amounts of damage in monetary terms, were systematized and presented in the form of detailed tables. The following tables were formed for each specific reporting date:

- Types of destroyed military equipment and their quantity.
- List of main pollutants.
- Calculated volume of emissions of each substance (in tons).
- Applied coefficients (Kneb, Kv, Kmp, Kpp) and tax rate (Sp).
- Calculated amount of damage from the emission of each substance (in hryvnias).
- Final total amount of damage on the relevant date.

This form of presenting the results ensured transparency of the calculations, the possibility of their verification and detailed analysis of the structure of the damage caused.

Visualization of results

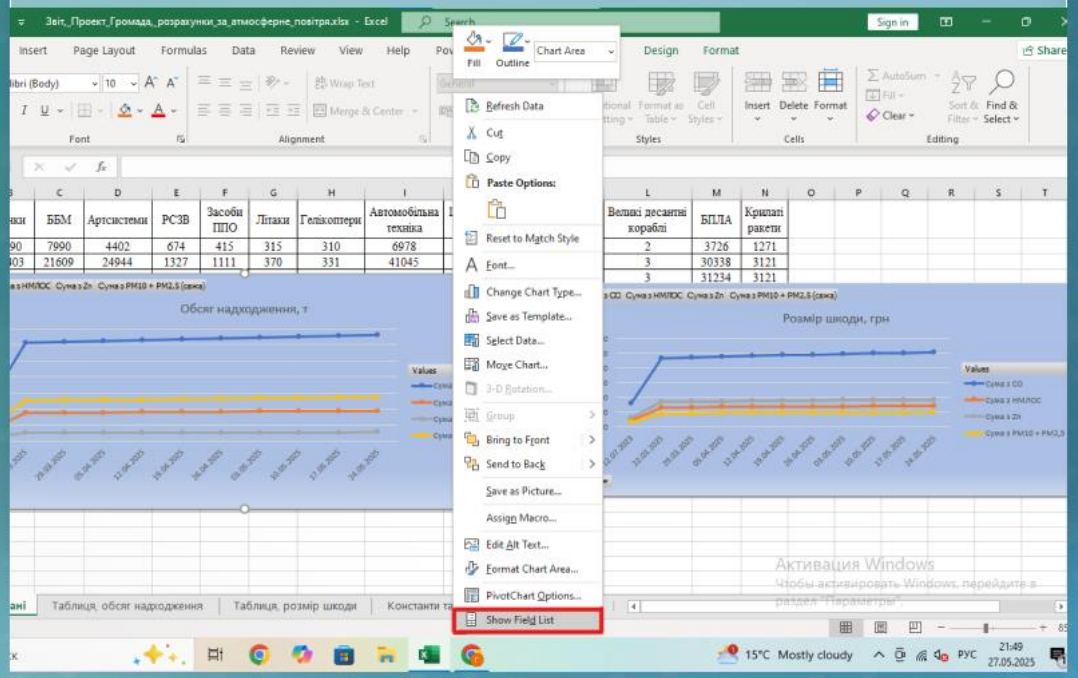
To increase the clarity and facilitate the perception of the obtained data, especially when analyzing the dynamics of changes, visualization tools were actively used - in particular, the construction of graphs. Thus, a pivot chart was developed.

This type of graph allows you to filter and select individual types of pollutants, thereby enabling both a comparison of their volume of receipt and the amount of damage, and a study of the dynamics indicated. Both of the specified tables are localized in the “Data” sheet.

Excel

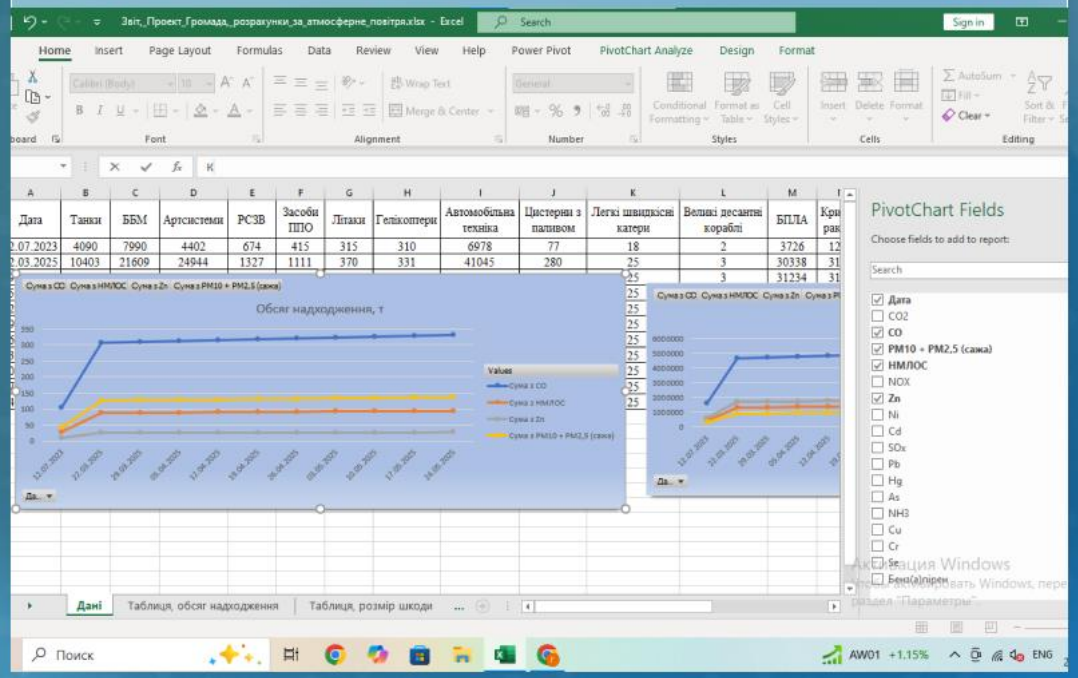
Instructions for graphs (step 1)

Right-click on the graph and select “Show Field List”



Instructions for graphs (step 2)

Select the types of pollutants
that are of interest for further analysis



Problems of qualifying ecocide

The problem of qualifying ecocide in this case is related to several fundamental and complementary problems:

1. Imperfection of Article 441 of the Criminal Code of Ukraine. The use of evaluative concepts, such as "ecological catastrophe" or "atmosphere poisoning", complicates the legal interpretation and proof of the elements of the crime (research by R. V. Veresha et al., p. 155)

2. The subjective side of ecocide assumes the presence of direct intent, which is traditional for the science of criminal law (research by R. V. Veresha et al., p. 155, Scientific and Practical Comentary to the Criminal Code of Ukraine, edited by V. Ya. Tatsiya et al. (here-in-after referred to as the Comentary), p. 993). Part 2 of Article 24 of the Criminal Code of Ukraine gives next definition of direct intent: "Direct intent is if a person was aware of the socially dangerous nature of his act (action or inaction), foresaw its socially dangerous consequences and desired their occurrence". In the context of the Project, this looks illogical: as if the enemy is deliberately destroying its own equipment in order to harm the environment. For such a qualification to make sense, one would have to take into account only strikes by drones and missiles, excluding other types of equipment.

3. Some scientific sources (Comentary, pp. 993-994, article by Rybachek V. K., pp. 511-512) note that the actions provided for in Article 441 of the Criminal Code of Ukraine have the potential to cause an ecological disaster. However, the concept itself is evaluative and does not have a clear legislative definition. Doctrinal criteria (large area of damage, significant limitation of vital activity, duration or irreversibility of changes, extinction of species, etc.) are difficult to apply to the scattered consequences of UAV and missile attacks throughout the territory of Ukraine. This complicates the proof of an ecological disaster, which makes the qualification of such actions as ecocide unlikely and legally weak. Summing up the above, given the imperfection of legislative techniques, the qualification of the act (in the context of the Project) as ecocide is extremely problematic.

Results

The results of the comprehensive calculations were systematized and presented in the form of detailed tables and visual graphs. These materials comprehensively reflect the scale of the environmental consequences of the destruction of military equipment for the atmospheric air of Ukraine and include:

Data on the number of destroyed equipment

Detailed accounting of destroyed military equipment units by main types (tanks, armored personnel carriers, artillery systems, MLRS, aircraft, helicopters, automotive equipment, air defense systems, UAVs, ships/boats, fuel tanks) as of each reporting date.

Volumes of pollutants entering

Quantitative assessment of the mass of key pollutants (NOx, CO, CO2, SOx, NMVOC, PM10+PM2.5 particulate matter, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, benzo(a)pyrene) released into the atmosphere as a result of combustion and destruction of equipment. Data are presented in tons and calculated for each reporting date.

Amount of damage in monetary equivalent

The estimated cost of damage to atmospheric air is expressed in hryvnias. The assessment was carried out separately for each pollutant, and the total amount of damage was also calculated for each reporting date.

Dynamics of damage growth

Thanks to regular data updates and calculations for different dates, a clear dynamics of the growth of pollutant emissions and the cumulative amount of damage over time was demonstrated. Graphic materials clearly illustrate these trends.

Conclusion

The detailed and multi-stage calculations made it possible to quantitatively assess the significant scale of damage caused to the atmospheric air of Ukraine as a result of the destruction of military equipment during a full-scale war. The applied step-by-step approach, based on the officially approved "Methodology for calculating fugitive emissions..." (Order of the Ministry of Environment No. 175) and the use of up-to-date data from official sources, ensured the necessary level of validity and reproducibility of the results obtained.

These data are extremely important for documenting environmental crimes, forming an evidentiary base for future international trials and obtaining reparations. At the same time, the limitations of existing methodological approaches identified in the course of the work, in particular regarding the assessment of emissions from some modern types of weapons (cruise missiles, certain types of special equipment) and specific toxic compounds (e.g., dioxins), clearly indicate the urgent need for further scientific development, improvement, and adaptation of national methodologies for assessing environmental damage to the realities and challenges of war. This will require the involvement of a wide range of experts, additional research, and possibly the development of new regulatory instruments.

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Google Sheets

Report,_Project_Gromada,_payments_for_atmospheric_air.
URL:
https://docs.google.com/spreadsheets/d/1xmpjpf7TzQi8wnv07SUqDbntIU9U7khUHCP8csU1PfA/edit?gid=936739864#gid=936739864

Community_Report_Confirmation_of_some_statistical_data_for_the_project
URL: https://docs.google.com/spreadsheets/d/1SPjzatT72tyV-QjYGN7qTO343kXu_oYin0el5QKhz5g/edit?usp=sharing