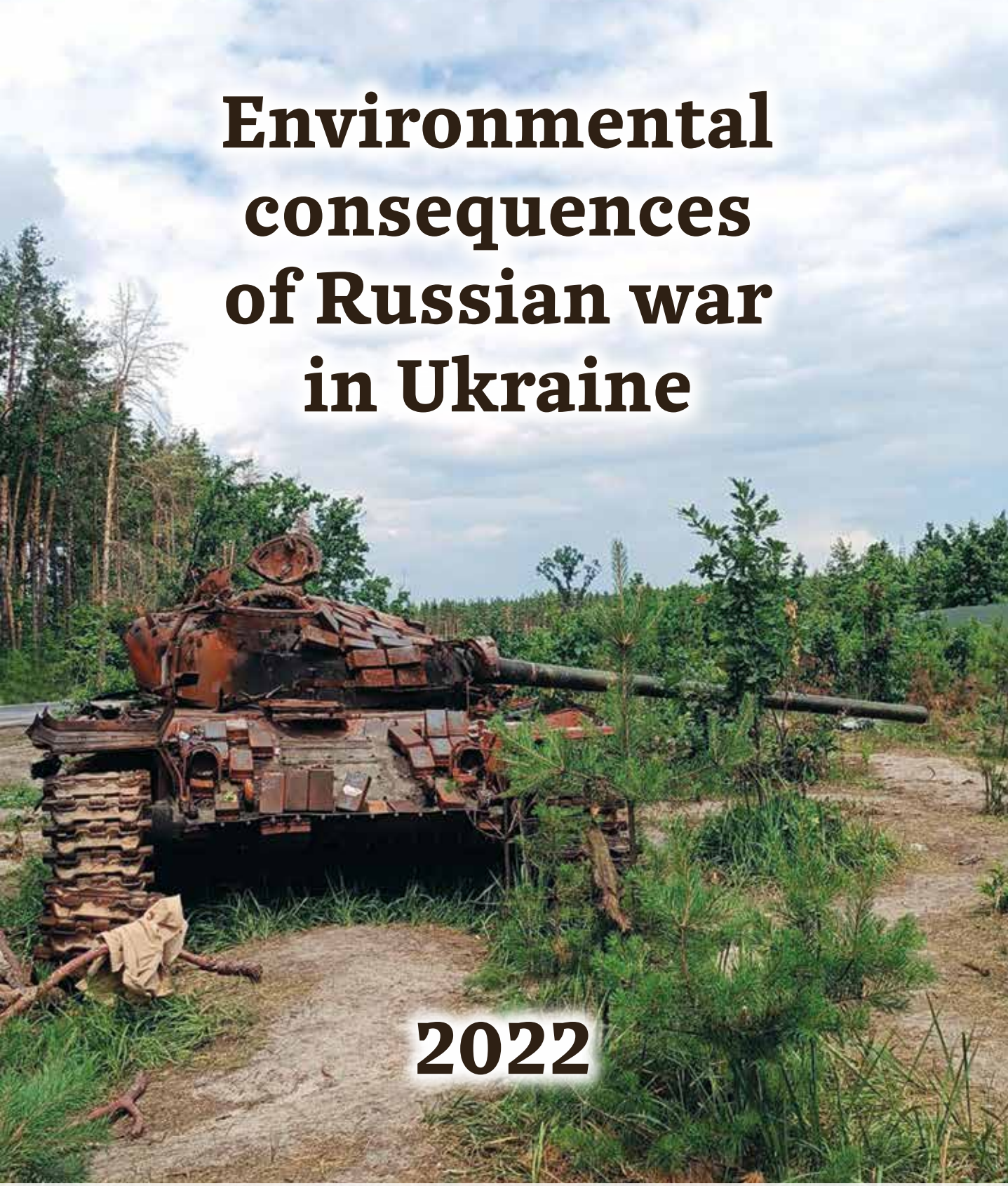
Environmental consequences of Russian war in Ukraine



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This report is the results of the research into impacts of Russia's military aggression on the environment of Ukraine. It highlights and analyses the damage that Russian occupiers have caused to the environment during 9 months since the wide invasion of the war, which started in 2014. Historical examples of how environment has been affected by the wars and damage compensation mechanisms are outlined and reviewed in the report.

UKRAINE, DAMAGE TO THE ENVIRONMENT, ENVIRONMENTAL CONSEQUENCES OF WAR.

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Content

Introduction

In 2014, the Russian Federation launched a brutal, bloody and destructive war against the sovereign state of Ukraine. The stated goal of this war, (as articulated by the Russian Federation), is to either assume total control over our state or to ensure its complete destruction. Both objectives are contrary to the right of the Ukrainian nation to self-determination and both are in direct conflict with the UN Charter of which the Russian Federation is a signatory. On 24 February, 2022, a new stage of the war began in the form of a full-scale offensive by the aggressor on all the borders of Ukraine. The tragic circumstances not only changed human destinies immediately, but also created new threats to Ukraine's natural environment. So the impact of Russia's crimes against the environment need to be examined, studied, condemned and indemnified for the future.

This work summarises and analyses the damage caused by the Russian occupiers to the environment of Ukraine during the first nine months of the war, between February and November 2022. It gives an assessment of the special features of the country's economy and its energy industry and heavy industry that have created the prerequisites for the most significant environmental risks, not only for Ukraine but also for the entire continent. The subject of the analysis is all the territories that have been damaged, but the Zaporizhzhia, Dnipropetrovsk, and Kharkiv regions are the focal points of the report. The data necessary for the research was collected on the territories of these regions, including the testimonies of those who witnessed the events.

According to the results of the research, we will try to answer the following questions:

1) How does military equipment and activity endanger the environment (ammunition, grenades, rockets, etc.)? (Section 1)

2) How do military actions influence the environment of Ukraine in terms of the specific features of each of the following components? (Section 2):
   - air pollution and climate change;
   - oceans, seas, rivers, and lakes;
   - soils and the impact on agriculture;
   - ecosystems and biodiversity;
   - human settlements and industrial complexes.

3) Has the environment been damaged as a result of the war? What international mechanisms are available to provide reparations for such damage as compensation? (Section 3)

4) What measures is the government taking to register and itemize the damage inflicted by the actions of the Russian Federation? (Section 4)

5) What conclusions can be drawn and what forecasts can be made about the negative impact of the war on the environment in the medium and long term? What are the most important issues to be discussed after the end of the war to mitigate the environmental impact? How is the postwar renewal of cities and the economy to be aligned with ecological standards and the principles of sustainable development? (Section 6)

We believe that this report will be of interest not only to those in different fields of expertise, such as environmental protection and sustainable development but also to the representatives of governments.

We would also like to mention that at the moment part of our team is fighting on the front line for the independence of Ukraine. Since we are fully convinced of our victory, we took the decision to conduct this research during this hard, bloody war. Unlike our enemy, we consider the most valuable thing in the world to be not only human life but also the life of every single species that inhabits our territories. It is important for us to understand how we are going to live after our victory and in what state our natural environment, with its rivers, meadows, woods, and heaths, will be found, and how these can be returned to their natural state.

Our team sincerely wishes everybody a clear sky without shelling and the fastest possible liberation of Ukraine from the Russian invaders.

I. The main sources of environmental pollution during military activities

Russia started the active phase of its invasion of Ukraine on 24 February, 2022, bringing about thousands of broken lives, massive disruption of the infrastructure of the cities and villages of Ukraine, and severe damage to its economy. Among the other often underestimated consequences of the war, we want to draw attention to the long-term effects of the hostilities on the environment and the extensive disruption of ecosystems.

Russia's invasion of Ukraine took place along the entire length of the shared border and partly from the territory of Belarus. Virtually all the climate zones of Ukraine have been affected by the military activities and, as a result, hundreds of hectares of various and rare biogeocenoses have been destroyed. Clearly, the real scale of the damage caused to the ecosystem can be assessed only after the complete end of the occupation of our territories.

The territories of Zhytomyr, Kyiv, Chernihiv, Sumy, Kharkiv, Luhansk, Donetsk, Zaporizhzhia, Kherson, and Mykolaiv oblasts have undergone active hostilities.

The assessment of the damage caused to the ecosystem of Ukraine is strongly connected to the special features of every single region exposed to the combat activities. Here, we need to mention that before the war broke out, some of the ecological problems of those regions had not been tackled properly. It is a well-known fact that regions with developed industry impose an extremely heavy load on the environment for a long time, making it extremely vulnerable. For instance, if areas massively ploughed for crops have suffered from irrational management for years, the hostilities on their territory will become a trigger for making them completely unsuitable for agricultural use. If a chemical industry plant has been poisoning certain cities or districts for dozens of years because of the outdated treatment plants, the shelling of such a plant will lead to a man-made disaster that will instantly destroy biogeocenoses that have already been heavily affected. Such a situation can be easily compared to an organism that is exhausted after a long time fighting an illness and, finally, is subjected to a mass infection with a new virus instead of the proper treatment.

One of the most severe long-term consequences for ecosystems is considered to be the chemical contamination of the places where a lot of ammunition was used. Man-made disasters caused by the bombing and shelling of the enterprises and critical infrastructure facilities of our country also damage the environment significantly. In addition to that, Russia's use of long-range mis-

siles also creates man-made disasters throughout the whole territory of Ukraine, in particular the industrially developed regions with concentrations of energy, mining, processing, chemical, and other industrial facilities become the most vulnerable targets.

Photo of damaged military vehicle

Ukraine is a very large agrarian country where the most part of its economy is comprised of production and export of agricultural products. Ukraine ranks among the countries with large areas of arable land. Agricultural land occupy 70.5% of the country's total area, 57% of which is tillable land (up to 86% in some regions)[1]. The combat activities that have taken place in Ukraine have significantly damaged our fields for ploughing and other mechanised farming activity as well as brought about long-term chemical and biological contamination of the fertile soils. Thousands of fired shells, detonated and burned military equipment, abandoned in the fields and plantations, will remain as a massive and unlimited source of contamination of our soils and groundwater with iron, aluminium, copper and other heavy metals and their compounds for hundreds of years.

Ukraine is considered to be one of the countries with a deficit of water resources (surface and underground water suitable for use in the national economy of Ukraine). It is among the European countries[2] with the biggest water shortage. The situation is aggravated when drowned military equipment and explosions from ammunition emit a set of harmful substances that leak into groundwater and then enter surface waters having a huge negative impact on the water resources.

[1] Паньків З.П. Земельні ресурси: Навчальний посібник.[Land resources: Tutorial]. – Видавничий центр ЛНУ імені Івана Франка, 2008. – 272 с.

[2] А.І. Томільцева, А.В. Яцик, В.Б. Мокін. Екологічні основи управління водними ресурсами: навч. посіб. [Ecological foundations of water resources management: tutorial]. – К.: Інститут екологічного управління та збалансованого природокористування, 2017. – 200 с.

Consequences for land resources: destruction and pollution

Thus, the process of recording and documenting the damage and its long-term impact on the environment of Ukraine becomes the crucial issue in assessing the amount of reparations which will be demanded from Russia following the end of hostilities.

It is important to define a range of the main sources of contamination that have a long-term impact on the environment before focusing on the analysis of the impact of military activities on each element of the ecosystem such as air, water resources and soils.

First of all is the ammunition that has been massively expended on the battlefield.

1.1 Chemical composition and features of the use of some types of ammunition

In modern armour-piercing subcaliber projectiles, the armour-piercing part (core) is mostly made of depleted uranium. The use of this metal is related to its physical properties – the ability to self-ignite and burn as a result of a collision with armour and its penetration. At the same time, small fragments of the uranium core of the projectile spread and cause the burning of combustible materials or the detonation of ammunition inside the target. Almost 70% of the entire mass of depleted uranium contained in the projectile burns out turning into an aerosol of radiotoxic uranium oxides (U_3O_8, UO_2) with particles from 0.5 to 5 microns during the explosion. A significant amount of such dispersion

of aerosols remains in the air for a long time, then settles gradually on the surface and migrates into the soil and groundwater later[3].

Unfortunately, the use of depleted uranium ammunition has not been thoroughly studied yet in terms of its long-term impact on human health. In fact, depleted uranium creates the ultimate danger when it enters the body in the form of the dust particles. Such particles of insoluble uranium can remain in the lung tissues and especially in the lymph nodes for up to several years. Uranium that enters the gastrointestinal tract is poorly absorbed into the bloodstream[4]. Since depleted uranium is known to be mainly an alpha emitter (alpha particles are easily intercepted by minor barriers, even a sheet of plain paper), its deposition in body tissues, where there is no protection from alpha radiation can cause the most harm and danger. The fact that uranium is a heavy metal should not be ignored either as its accumulation in the body can impair the functions of the kidneys, liver and other organs[5].

The toxic content of the percussion and blasting capsules, devices designed for igniting a powder charge in a firearm, or for detonating charges of explosive substances (for example, a grenade fuse) has a significant impact on the environment. Such capsules contain propelling explosives that are used, most often, as initiators of the detonation of brisant explosives (substances capable of crushing and destroying objects in the explosion zone) or for igniting gunpowder and other combustible substances. The ability to detonate from a simple initial impulse (impact, friction, pressure, spark) is a typical feature of propelling explosives. For example, the fuse of a grenade after detonation makes a small explosion that “activates” the explosives, contained in a significant amount in its case. The capsule of the cartridge explodes after being hit, igniting the gunpowder, which in its turn, releases the bullet.

As a rule, the content of the capsules is a shock-ignition mixture of substances. Most often, the components of shock-ignition mixture are known to be mercury fulminate $Hg(ONC)_2$, antimony Sb_2S_3 (trisulphide antimony), Bertolet salt $KClO_3$ (potassium chlorate). Mixture for the rifle cartridges contains the components in the following proportions: mercury fulminate : antimony : Bertolet salt = 6.7 : 27.8 : 55.5% by mass; for revolver and pistol cartridges, respectively,

[3] Станкевич С.В. Техноекологія: навч. посібн. [Technoecology: tutorial] / С.В. Станкевич, Л.В. Головань; Харків. нац. аграр. ун-т ім. В. В. Докучаєва. – Харків: Видавництво Іванченка І. С., 2020. – 338 с. Режим доступу: http://pdf.lib.vntu.edu.ua/books/2021/Stankevich_2020_338.pdf

[4] Carolyn E. Fulco, Catharyn T. Liverman, Harold C. Sox, Editors, Committee on Health Effects Associated with Exposures During the Gulf War, Division of Health Promotion and Disease Prevention / Gulf War and Health: Volume 1. Depleted Uranium, Pyridostigmine Bromide, Sarin, and Vaccines // NATIONAL ACADEMY PRESS Washington, D.C. 2000 – 432 p

[5] See 3

25.0 : 37.5 : 37.5% by mass[6].

In fuses for grenades, the blasting capsule with an aluminium body contains a shock mixture, lead acid ($Pb(N_3)_2$) – 0.2 g and TNRS (lead trinitroresorcinate $CH(NO)OPb$ – 0.1 g; a blasting capsule with a copper body contains a shock mixture that comprises mercury fulminate – 0.5 g (0.41 g of mercury). An acid blasting capsule is used in the UZRG type fuse (unified hand grenade fuse). Taking into account molecular weight of the substances, it is possible to calculate that one blasting capsule of the UZRG type fuse contains approximately 200 mg of lead[7].

The use of a significant amount of additional stabilising and initiating substances, including tin and its compounds, bismuth and its compounds (bismuth oxide, bismuth carbonate, bismuth nitrate, etc.), strontium nitrate ($Sr(NO_3)_2$), magnesium powder, and many others[8] in ammunition should also be taken into account.

It is important to mention that understanding of the content of the ammunition helps to predict the amount of polluting emissions that forms as a result of their use. The biggest pollution, in particular by heavy metals, is predicted to be in places where ammunition warehouses are destroyed.

1.2 Missile weapons and their use

The missiles of different types are reported to be among the weapons, actively used by Russia all over Ukrainian territory. These are, for instance, the missiles, launched by multiple rocket launch system (MLRS), and large long-range cruise missiles (Kh-22, Kh-101, Kh-555, Kalibr, Iskander, etc.).

Such types of missiles are dangerous not only because of their explosive-equipped combat but also because of the use of toxic fuel. Missiles of such type have solid or liquid fuel engines. Solid-fuel missiles can be stored for quite

[6] Лобойченко В.М., Пліско А.В. Оцінка екологічних наслідків від вибухів патронів та гранат на складах боєприпасів [Assessment of environmental consequences of ammunition and grenade explosions at ammunition depots] // Збірник наукових робіт курсантів. – 2017. – Випуск 15. – с. 112-120

[7] Настанова зі стрілецької справи. Головне управління бойової підготовки Сухопутних військ Збройних Сил України [Instruction on shooting. Main Department of Combat Training of the Land Forces of the Armed Forces of Ukraine]. Науковий редактор Н.О. Стеценко // Київ 2005. – 45 с.

[8] Иванов Е.В. К вопросу о составе и количестве газов при взрыве боеприпасов на складах. Сообщение 1. Патроны для стрелкового оружия [Regarding the composition and quantity of gases during the explosion of ammunition in warehouses. Message 1. Cartridges for small arms] / Е.В. Иванов, А.Е. Васюков // Проблеми надзвичайних ситуацій. Збірник наукових праць НУЦЗ України. –2015. – Вип. 21. – С. 30-37

a long time, and are launched without problems, but their engines have lower performance than liquid-fueled ones. Therefore, solid missiles are used at limited distances.

The anti-aircraft missiles used by Russia in the S300 complexes are two-stage solid-fuel missiles with the gas-dynamic control bodies of the first stage. The difference in the design of the missiles of various modifications is mainly related to an increase in the fuel supply in the first stage, which raises the range or speed of their flight. Such anti-aircraft missiles are equipped with high-explosive fragmentation warheads that weigh about 150 kg. Within the main part of the missile there are blocks of onboard equipment that control the guidance and operation of the missile. These missiles are primarily designed for air defence, but Russia modifies them and uses them as "surface-to-surface" missiles to attack the front-line cities.

Photo of missile remnants

"Air-to-ground" missiles, for example, Kh-101, are cruise missiles that are launched from tactical bombers and have a turbojet engine on liquid rocket fuel that provides the ability to fly at an altitude of up to 10 km and at a distance of up to 5500 km. The weight of such a missile together with a full fuel tank is approximately 3500 kg, its length is 7.45 m. The missile is equipped with a warhead with propelling mass of up to 400 kg[9].

The missiles launched at Ukrainian territory contain hundreds and thousands of kilograms of chemical substances, which after their complete burn or, when their remnants fall into the nature, pollute the environment endangering all species with their toxicity. That is why it is not recommended to approach the remnants of the rockets. One of the factors that also causes danger is considered to be the leftovers of rocket fuel from the downed missiles that remain

[9] Сучасне озброєння і військова техніка Збройних сил Російської Федерації. Довідник учасника ООС [Modern weapons and military equipment of the Armed Forces of the Russian Federation. Handbook of the JFO participant] / С.П. Корнійчук, О.В. Турінський, Г.В. Пєвцов, та ін.; за заг. ред. С.П. Корнійчука // Х.: ДІСА ПЛЮС, 2020. –1220 с.

at the impact site of the rocket. Even simple inhalation of the liquid rocket fuel vapours can be fatal. It is necessary to mention that solid fuel is less toxic to the environment due to its aggregate state but it is difficult to stop its burning, and the products of combustion of such fuel are dangerous.

Combustion or disposal of solid ballistite-type missile fuels used in multiple launch rocket systems (MLRS) (Uragan, Grad, etc.) is accompanied by the formation of a number of toxic components: CO, HCH, NO, NO_2, etc. The products of combustion or explosion of solid rocket fuel contain lead in the form of its oxide PbO and aerosols. In general, burning or disposal of solid rocket fuel leads to the formation of : CO up to 416.2 g/kg, C up to 86.4 g/kg, Pb up to 6.7 g/kg, PbO up to 1.8 g/kg, NO up to 161.6 g/kg, NO_2 up to 2.9 g/kg, CH_4 up to 55.0 mg/kg, NH_3 up to 0.3 g/kg, HNO_2 up to 0.4 g/kg, HCN up to 5.2 g/kg. A mixture of the products of detonation of initiating explosives (which are used to detonate the main explosive substance in the missile) and the explosive substance of the warhead of the missile itself are added to this mixture. The products of the combustion of electronics, the missiles are equipped with, are also toxic[10].

Fuel based on ammonium perchlorate (NH_4ClO_4) is used in the more complex high-precision anti-aircraft missiles and during the process of combustion, ammonium perchlorate decomposes according to the formula: $2NH_4ClO_4 \rightarrow Cl_2+O_2+4H_2O+2NO$. But in the torch of the flame, the formed substances continue to interact with each other. H_2O, N_2O_2, Cl_2, HCl, NO_2, N_2O_3 are known to be the final products of ammonium perchlorate decomposition. Moreover, the mixture contains the products of rubber combustion, metal oxides and products of rocket electronics combustion[11].

[10] Маренец М.А., Буллер М.Ф., Щербань В.В., Банишевский В.В., Белова Л.А. Баллиститное твердое ракетное топливо: сравнительная оценка продуктов горения и детонации [Ballistic Solid Rocket Fuel: Comparative Evaluation of Combustion and Detonation Products] // Вісник КДПУ. Випуск 2/2006 (37). Частина 2 – с. 72-75

[11] М Ю. Трофименко, М.М. Чесноков, Г.С. Драган. Структура факела при горінні твердої суміші паливної системи при підвищеному тиску [The structure of the torch during the burning of a solid mixture of the fuel system at increased pressure] // Вісник Одеськ. держ. ун-ту. – 2001. – Т.6, вип. 3. Фіз-мат. науки. – с. 159-162.

1.3 Ammunition with white phosphorus

It is important to point out that Russian military constantly uses ammunition with white phosphorus. In military terms, white phosphorus is used in mortar and artillery shells, aerial bombs and grenades. The intense emission of smoke during the burning of phosphorus serves as an effective masking, therefore white phosphorus is widely used in smoke grenades. The main function of the process of intense burning of white phosphorus in the air is burning out designated targets and manpower.

As a result of the burning of white phosphorus, white smoke, which consists mainly of trioxide (P_4O_6) and pentaoxide (P_4O_{10}) of phosphorus, forms in the air. These phosphorus oxides are extremely hygroscopic and absorb quickly even little amounts of moisture, forming a number of phosphorus-containing acids, such as orthophosphoric (H_3PO_4), pyrophosphoric ($H_4P_2O_7$), orthophosphoric (H_3PO_3), hypophosphoric (H_3PO_2), polyphosphoric acids of the general formula $H_n+2P_nO_{3n}+1$ (where n = 2 – 8) and a number of other linear and cyclic polyphosphates P_6-P_{16}. Importantly, this composition of white phosphorus smoke changes over time. Phosphine (PH_3) can be formed during the burning of white phosphorus if the amount of oxygen is insufficient[12].

Due to its gaseous state, low solubility in water and weak reactivity, phosphine that forms as a result of the burning of white phosphorus can remain in the air for a much longer period of time than the other reaction products. Phosphine can also form when white phosphorus gets into the water with oxygen deficiency. Under such conditions, phosphine formed in the water quickly leaves the water and enters the air. It takes phosphine about one day to decay into safe substances in the air.

Elemental phosphorus can be found in the air for a short period of time (from several minutes to several days) as it oxidises to oxides and then to acids rapidly. But if the process of burning is intense, aerosol particles of phosphorus can be wrapped by oxides preserving elemental white phosphorus. Phosphorus, which penetrates into the soil or water environment, acts in a similar way. Wrapped in oxides, white phosphorus can stay there for up to several years if the soils or water environment lack oxygen. The use of white phosphorus ammunition leaves approximately 10% of phosphorus which does not burn completely in the soil or water.

As a matter of fact, a significant amount of aerosols from the burning of phosphorus overcomes the buffering capacity of the soil (the property of the soil to maintain a constant reaction of the soil solution) badly disrupting its pH

[12] John R. Van Wazer. Phosphorus and Its Compounds. Vol.1. Interscience Publishers, 1958. – 2046 pp

Photo of a destroyed shopping mall in the town of Bucha

level. The interaction of metals with phosphoric condensates can lead to their leaching and further migration.

If plants are exposed to the harmful effects of white phosphorus, it can lead to various negative effects, depending on the plant species, smoke concentration, duration of exposure, relative humidity, and wind speed. These effects can be the following: leaf tip burn, leaf curl, leaf drop, flower drop, chlorosis, necrotic spots, wilting, desiccation, and complete dieback[13].

1.4 Indirect consequences of the use of ammunition

This is not only the "cocktail" of chemical compounds contained in ammunition that does harm to the nature and environment but also the consequences of their use: destruction and burning of buildings, enterprises, and critical infrastructure facilities. Analysis of the man-made disasters that have taken

[13] A Toxicological Profile for White Phosphorus / Agency for Toxic Substances and Disease Registry Division of Toxicology/Toxicology Information Branch 1600 Clifton Road NE, E-29 Atlanta, Georgia 30333 // 1997. – 248 p.

place on the territory of Ukraine as a result of shelling almost every day since the beginning of the Russian invasion shows, that the main targets for the Russian Federation to strike are oil depots, power plants, communication infrastructure and large industrial facilities that support the economy and defence capability of our country. Fires and explosions in such locations are always a distinct environmental disaster.

For example, burning of electrical equipment at enterprises pollutes the environment with polychlorinated biphenyls (PCBs) and dioxins. Dioxins are the results of thermal exposure to polychlorinated biphenyls (at temperatures below 1000 ºC).

Polychlorinated dibenzofurans (PCDFs), commonly known as "dioxins" and polychlorinated biphenyls (PCBs), are a group of toxic and persistent chemicals that negatively affect human health including skin immunotoxicity, impact on the reproductive system, teratogenicity, adverse effects on the nervous system, and carcinogenicity[14].

Dioxins, like polychlorinated biphenyls, are very well adsorbed on any materials: their adsorption capacity is enormous. These poisonous substances are considered to be better adsorbed by suspended impurities when the air temperature is low, so their content in the air significantly reduces. When in water, dioxins and PCBs, due to their hydrophobic properties, are adsorbed by solid particles and sediment in the silt of reservoirs. These substances are easily transported through food chains (for example, algae – plankton – fish – humans or soil – plants – animals – humans). It is notable, that the half-life of dioxin in the soil is 8–10 years, for polychlorinated biphenyls it is 5 years, and the period of partial elimination of these substances from the human body is 3–8 years[15] [16].

Furthermore, mass emissions of chemicals from damaged chemical plants and storage tanks contribute a lot to the pollution of ecosystems.

For example, in April 2022, when Russian troops twice shelled the city of Rubizhne, Luhansk oblast, it led to massive emissions of nitric acid into the atmosphere. When exposed to the air, concentrated nitric acid is known to evaporate intensely and form nitrogen dioxide. This compound dissolves well in water with the following formation of nitric acid. It also causes acid precipi-

[14] О.І. Козій, М.П. Петрук, Н.М. Витрикуш, О.М. Вахула. Діоксинова проблема сміттєспалювання [The dioxin problem of waste incineration] // Вісник Національного університету «Львівська політехніка». – № 868. – 2017. – С.291–296

[15] See 14

[16] Е. Безак-Мазур. Транскордонні проблеми токсикології довкілля [Transboundary problems of environmental toxicology] / Е. Безак-Мазур, Т. Шендрік. – Донецьк: ГП «Информ.-аналитический центр «Донбассинформ» 2008, – 300 с.

tation and strongly affects living organisms. When a person inhales nitric acid vapours, he feels a sharp pain in the throat, chest and stomach. Dry cough, nausea with a discharge of mucus and blood appear soon. Mucous membranes get immediately affected, throat and lungs swell, with the later lethal outcome[17]. Due to good solubility in water, nitric acid vapours quickly get into soils and groundwater, dramatically increasing their acidity. This leads to the mass death of biocenoses of the particular polluted areas.

Another example is the "Tolyatti-Odesa" ammonia pipeline in Bakhmut district, Donetsk oblast, which was severely shelled in May 2022. Depressurization of the pipeline led to an ammonia leak. Ammonia is known to cause damage to the environment. For example, ammonia oxidation adds to the formation of greenhouse gases and the leaching of nutrients from ecosystems. Other than that, high concentrations of ammonia in the aquatic environment can cause problems not only with the development of fish but also their deaths. The negative impact of this component on the environment is related to its alkaline nature: ammonia molecules react with acidic compounds such as sulfur dioxide (SO_2) and form atmospheric aerosols that degrade air quality. Being in contact with ammonia more than allowed, a person can experience serious problems with health: ammonia begins to interact with moisture on the skin, eyes, mouth, mucous surfaces and forms a caustic substance that leads to necrosis of tissues. Symptoms such as irritation or burns of the skin, eyes and throat, and lung problems that can cause respiratory failure are considered to be serious risks for people exposed to ammonia emissions[18].

So, each fired projectile carries a range of significant impacts on the safety of the environment and can cause a major ecological disaster if big industrial facilities are damaged. Section II will provide a detailed analysis of the impact of combat activities on the separate components of Ukraine's environment.

[17] Военная токсикология и токсикология экстремальных ситуаций. Практикум: учеб. Пособие [Military toxicology and toxicology of extreme situations. Workshop: tutorial] / А.А. Бова и др; под ред. А.А. Бова. – Минск: БГМУ, 2010. – 264 с.

[18] See 17

II. The impact of military activities on the separate environmental components of the Ukraine

2.1 The influence of military activities on the air

Military activities that have been causing fires on the industrial and infrastructural objects, the residential sector and natural ecosystems, emissions of volatile compounds as a result of damage to industrial objects, have emitted large quantities of greenhouse gases and other pollutants into the air. According to preliminary estimates of the Ministry of Environmental Protection and Natural Resources of Ukraine[19], due to the increased consumption of fuel and lubricants by military equipment, almost 4 million tons of carbon dioxide have been emitted into the atmosphere over the first 150 days of the full-scale invasion. That gives grounds to state that combat activities affect at least the local climate but currently it is difficult to predict the scale of these changes.

Ukraine supports the European Union's goals which underpin the climate change policy, and therefore ratified the Paris Climate Agreement in 2016. The goal of Ukraine's climate policy is to reduce greenhouse gas emissions by 65% by 2030 and achieve climate neutrality no later than 2060[20].

The state of the air in the technogenically loaded regions is a crucial issue, which has been regularly updated at the regional and national levels. The publication "Atmospheric air quality management: from concept to implementation" (2021)[21] provides general information on the amount and structure of emissions thrown out into the air.

[19] https://mepr.gov.ua/news/39871.html

[20] Іванюта С.П., Якушенко Л.М. Аналітична доповідь: Європейський зелений курс і кліматична політика України [Analytical report: European Green Course and climate policy of Ukraine]. Режим доступу: https://doi.org/10.53679/NISS-analytrep.2022.12

[21] Ангурець О., Хазан П., Колесникова К. Управління якістю атмосферного повітря: від концепції до впровадження [Air Quality Management: From Concept to Implementation]. Arnika, 2021. Режим доступу: https://cleanair.org.ua/publication/upravlinnya-yakistyu-atmosfernoho-povitrya/

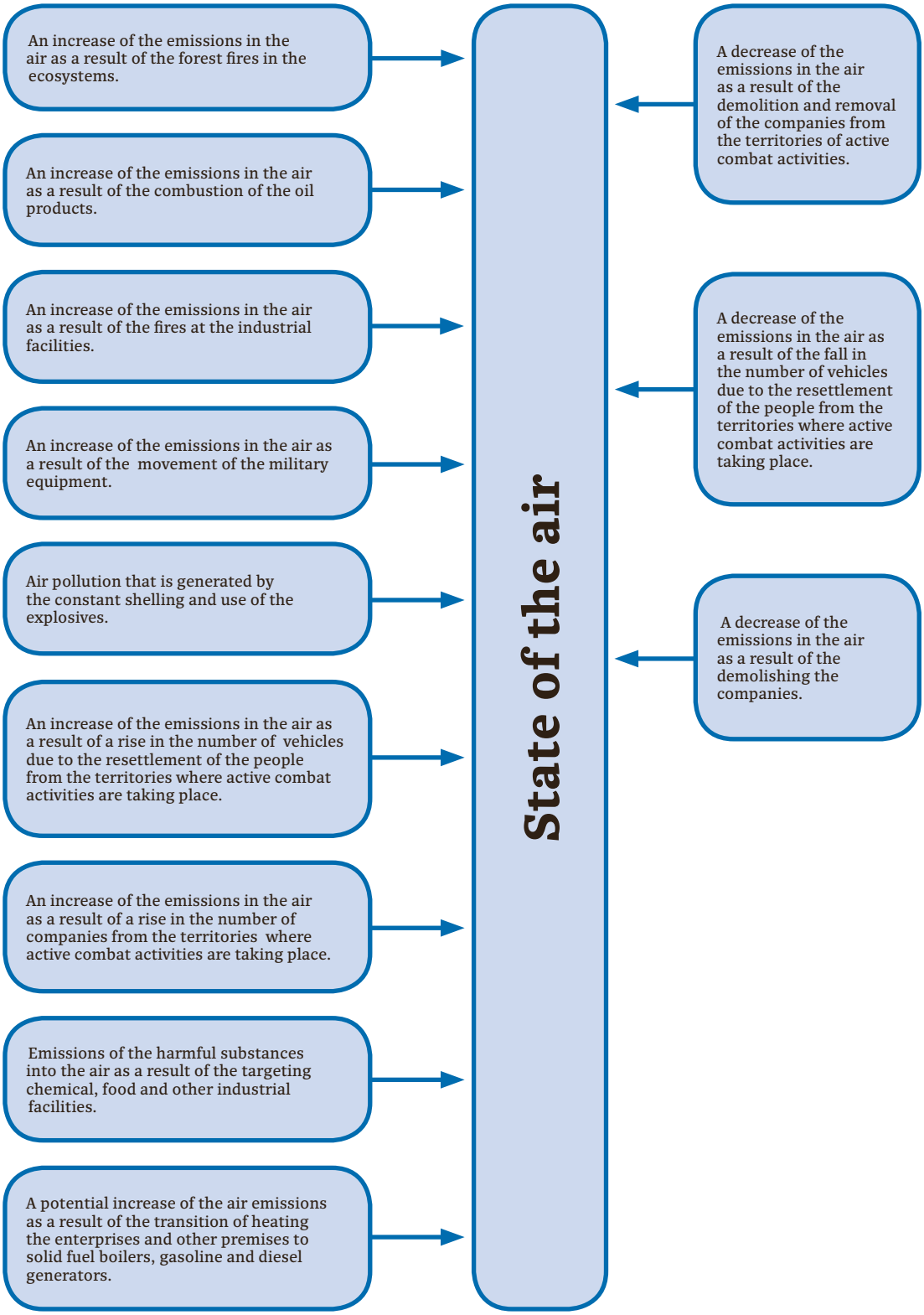

Figure 2.1 – Factors that affect the state of the air

According to the official data of the Armed Forces of Ukraine published by the Ministry of Environmental Protection and Natural Resources of Ukraine, as of 12 October 2022, the emissions of pollutants into the air were recorded as follows:

- combustion of petroleum products – 499 473 tons of combustion products;
- forest fires – 43 486 822 tons;
- fire of other objects – 5 847 897 tons.

According to the data of the State Environmental Inspectorate of Ukraine given in its digests[22] (the digests referred to are from February to July 2022), the following facts that had had an impact on the state of the air were registered:

- hitting industrial objects, infrastructure objects – more than 129 facts;
- hitting military infrastructure objects – more than 20 facts;
- targeting oil depots, oil refineries, deposits, gas stations – more than 42 facts;
- targeting gas pipelines – more than 15 facts;
- fires in the forest areas of the forestry, in natural ecosystems, agricultural lands – more than 29 facts.

The industrial targets exposed to shelling are known to be the following: thermal power plants, production, and storage facilities of the enterprises of various industries and various production scales, etc. Some facts are related to the damaged tanks, where dangerous volatile substances had been stored. Targets included but were not limited to: in April 2022, a tank with nitric acid was hit in Rubizhnye, Luhansk oblast (see Section 1.4 for more details); in May, the territory of Severodonetsk Azot PJSC, which produced fertilizers and nitrogen compounds in the Luhansk oblast was subjected to regular shelling; in June 2022, at least two workshops of the same enterprise were damaged as a result of shelling, one of them – an ammonia production workshop.

Fires in production and warehouses occur regularly because of enemy shelling, which leads to the emission of a large amount of combustible products into the atmosphere. The danger of such fires aligns with the fact that products and materials of various origins are often stored in warehouses creating favourable conditions for forming a chemical "cocktail", that affects the environment on a scale that is difficult to estimate.

[22] https://www.dei.gov.ua/posts/2226

As a result of the shelling of energy infrastructural facilities, aside from emissions into the atmosphere associated with direct damage to such enterprises, the emergency and scheduled power outages for businesses and citizens have occurred. Currently, generators of various capacities, which operate based on gasoline or diesel fuel, are widely used to ensure production processes, the operation of shops, the post office, etc. The use of wood and pellets in solid fuel boilers, known as sources of combustion products in the air, has increased to heat homes in the private sector.

Since the beginning of the full-scale invasion the State Environmental Inspectorate have not conducted either scheduled or unscheduled inspections in accordance with the Resolution of the Cabinet of Ministers of Ukraine N303 dated March 13, 2022[23], that is related to the fulfilment of the requirements of environmental legislation by business entities, the fact which may negatively affect the integrity of conducting business activities.

As for the fires in natural ecosystems that are caused by shelling, they can also have a long-term effect because they cannot be extinguished for a long period of time and combat activities often expose the firefighters to extra risk.

Although it is currently difficult to estimate the actual volumes and the structure of emissions into the air as the result of military actions, it is possible to state that Russian aggression directly and indirectly negatively affects the state of the atmosphere.

Under such conditions, the work of automated air monitoring systems at various levels, including state, municipal and public networks should be specially focused on. Data from these systems should be applied for documenting environmental crimes caused by Russia's aggression.

Taking into account the significant risk of man-made accidents caused by the war and the probability of using chemical weapons by the aggressor, it is also necessary to expand the list of substances that are measured and provide devices for measuring gamma radiation.

2.2 The impact of military activities on the state of water resources of Ukraine

Water resources belong to the national treasures of every country and are a natural basis for their development. They supply all spheres of life and human economic activity, define the opportunities for the development of industry

[23] Resolution of the Cabinet of Ministers of Ukraine N303 as of 13.03.2022. Access at: https://zakon.rada.gov.ua/laws/show/303-2022-%D0%BF#Text

and agriculture, help to place settlements, and support recreational and health facilities.

Bodies of surface fresh water in Ukraine cover the area of 21.1 thousand km^2 or, 4% of the country's territory (603.7 thousand km^2). These are rivers, lakes, reservoirs, ponds, canals, etc.

Considering the different types of natural and climatic conditions of the regions of Ukraine, the problem of water supply is usually solved through territorial and seasonal redistribution of water resources. Large state trunk canals of complex purpose play a significant role in providing low-water regions with water resources, which supply about 3 billion m^3 of water every year.

1103 reservoirs with a total volume of more than 55 billion m^3, about 49 000 ponds and 7 large canals with a total length of 1021 km and 10 large-diameter water pipelines, which supply water to low-water regions of the country have been built in Ukraine[24].

Conducting military activities on a large territory of Ukraine means that its water resources, especially in its southern regions with the low water supply, and in its eastern regions with a big load of industry on water resources, will be subjected to significant damage.

There are three key factors, that can be referred to as the consequences of combat activities that can cause ecological disaster in the sphere of water resources of Ukraine:

1) disruption of the sewage treatment plants that purify city wastewater;
2) disruption of the process of water supply to population and enterprises in large cities;
3) direct mechanical and chemical pollution of reservoirs and groundwater as a result of combat activities

Let us have a look into them in more detail.

2.2.1 Disruption of the sewage treatment plants that purify city wastewater

The term "city wastewater" is referred to as a mixture of different categories of wastewater (domestic, industrial, air), which is sent to city sewage treatment plants for treatment.

Household wastewater is generated from using tap water in everyday life. It is discharged from sanitary equipment of residential buildings, bathing and

[24] See 2

laundry facilities, public catering enterprises, institutions (schools, hospitals, etc.). It contains both secretions of people and household waste such as food leftovers, sand, soap and detergents, cloth, paper, etc. Household wastewater can be considered as a diluted mixture of urine and feces, kitchen (wastewater from cooking and washing dishes), bathroom and laundry wastewater (wastewater from hygienic procedures and laundry).

Household sewage always contains many microorganisms that live in the stomach and on the skin of a human body, that are washed off from the clothes, vegetables, fruits, meat, etc. However, some pathogenic microorganisms can be recognized among them. A special feature of household wastewater is the relative constancy of its composition, the feature that is like both, human physiology and its economic activity.

Industrial wastewater differs greatly both in quantity and composition. This, in turn, depends on the type of production and technological processes as well as type of the raw materials used. Industrial wastewater can be classified into three categories:

1) Industrial wastewater that contains organic substances and has no toxic substances (for example, wastewater from food processing plants) in its composition. Such wastewater can be discharged into the city sewerage;
2) Industrial wastewater that contains organic substances together with toxic impurities that prevent the biochemical oxidation of these organic substances (for example, tannery wastewater). Such wastewater is subjected to the local treatment to remove toxic impurities before its discharge into the city sewerage;
3) Industrial wastewater that does not contain any organic substances. Wastewater of such category is not allowed into the city sewerage.

Atmospheric wastewater is generated on the territory of a sewer facility during rain, snowmelt, and street washing. In modern cities, in addition to the sand and garbage washed from paving stones, atmospheric wastewater also contains organic substances. Therefore, considering its composition, it can often be referred to as mildly polluted domestic wastewater[25].

In fact, urban wastewater treatment is a multi-stage process that requires special facilities, the availability of cleaning chemicals, and compliance with the technological process. Let us imagine what happens when treatment facilities are damaged or, there is a lack of chemicals for water purification or, sediments are handled improperly. A toxic mixture that comprises chemicals,

[25] Ковальчук В.А. Очистка стічних вод [Sewage treatment]. – Рівне: ВАТ «Рівненська друкарня», – 2002. – 622 с.

biological waste, helminth eggs and many bacteria gets into water bodies potentially causing an uncontrollable ecological disaster.

Before a full-scale part of the war broke out in Ukraine, Ukraine had had a problem with handling water resources, the treatment plants not working the way they should, the equipment outdated requiring proper service. From February till September 2022, Russian occupying forces disrupted the operation of sewage treatment plants in Ukraine many times. Several important objects of the water treatment facilities of the Vasylivsk Water Supply and Drainage Service Plant, located in the village of Verkhnya Krynytsia, Zaporizhzhia region have been destroyed by shelling of Russian troops in March 2022. The administrative building and the power line were also damaged. The building of sewage pumping station N1, which supplies wastewater from the city of Vasylivka to the sewage treatment facilities, has also been destroyed. The efficiency of these treatment facilities equals 10 thousand m^3/day. As of October 2022, the work of the treatment facilities had not been resumed, which means that up to 10 thousand m^3/day of untreated city wastewater were discharged into the Dnipro River for more than 200 days. It is really difficult to estimate the volume of wastewater that has been generated at these treatment plants after the occupation since a lot of people have left but also many Russian military settled there.

Since the beginning of March 2022, the treatment facilities of the Municipal Enterprise "Mariupol Production Department of Water Supply and Sewerage" in the city of Mariupol has ceased to function correctly because of lack of electricity supply and active combat activities. As a result, untreated return (waste) water has been discharged into the Sea of Azov.

On 9 March 2022, the sewage treatment facilities were shelled in the city of Mykolaiv. As a result, the unit's electrical system was damaged and the mechanical wastewater treatment system was partially broken down. Reserve sand traps, that are parts of the technological scheme of mechanical purification of wastewater from small debris and sand were destroyed. The concrete slabs of the corridor-type aeration tanks and the aeration system of the aeration tanks, where the biological treatment of wastewater takes place, were also damaged. As a result, the sewage treatment plants that served a large number of the population were unable to function for a long time.

On 19 April 2022, the sewage treatment facilities in the village of Novotroitske, Volnovasky district, Donetsk oblast were reported to be damaged. The level of the damage and the consequences are still unknown.

These are the examples that have been documented but the general state of things is much worse. The wholeness of the sewage systems is constantly being disrupted as well as the pipes are being depressurized in the areas

of shelling in the front-line territory of the Donetsk, Luhansk, Zaporizhzhya, Mykolaiv, and Kherson oblasts. It is impossible to estimate the current level of leakage of sewage water into the soil and groundwater over the whole territory of Ukraine and will not be possible to estimate until the conclusion of the war. Moreover, as electricity supply is constantly being interrupted by shelling, it leads to preventing the pumps that drive water through the treatment facilities from operating correctly and interrupts the oxygen saturation of the water, needed for purification in aeration tanks (stage of biological water purification).

Apart from the mechanical disruption of the treatment facilities, there is a problem with their optimal functioning capacity. As a rule, chlorine and perchloric lime are used at some stages of water purification but most often, the reagent methods with the set of traditional coagulants $Al_2(SO_4)_3$, $FeCl_3$, $Fe_2(SO_4)_3$, $FeSO_4$, CaO[26] are used for physical and chemical treatment of wastewater. Unfortunately, the supply of the necessary chemicals was put on hold after the occupation of part of Ukrainian territory, so it is impossible to assess the quality of service the treatment facilities on the temporarily occupied territories provide.

Another big problem connected to the disruption of the work of treatment plants is the fact that those who provided professional maintenance of the treatment plants on the occupied territories have left. Both, the occupation, and loss of specialists critically exacerbates the problem of handling water resources.

2.2.2 Disruption of water supply to the population and enterprises in large cities

The vulnerability of large cities could clearly be observed when the aggressors were destroying Mariupol. After Russian troops surrounded the city, they deliberately destroyed the water supply and sewerage infrastructure of the city. Inhabitants were surviving on supplies of bottled water and in addition also were also collecting rainwater as best they could. As the sewage system was out of operation, all sewage and waste products were simply spreading over the streets and in the underground shelters. Due to constant shelling, the city wells and boreholes were quickly contaminated or were simply out of reach to people. According to the eyewitnesses who managed to flee from the city, people who were shot by Russians or killed during the shelling were those, who were out of shelters on their way for food and water.

[26] See 25

On April 12, 2022 another large city was exposed to the difficulties with water supply. Russian military damaged the Dnipro-Mykolaiv aqueduct, which supplied water to the city of Mykolaiv. Fortunately, by that time, the city had not been occupied and starting from April 16, and step by step, the Ukrainian authorities provided the supply of technical water for the needs of the population. They also allocated funding from the budget to drilling artesian wells so that the city could have water. Even though the problem of water supply has been solved, this is one more fact that speaks to a real vulnerability of large cities when it comes to ensuring their livelihoods in emergency situations. Furthermore, mass discharges of untreated sewage into reservoirs significantly worsens the quality of water collected at water intake stations. This is the reason why the normal level of water purification provided to the population cannot be sufficient. Clearly, the occupying forces and the occupying authority show no signs of improving the situation with the purification of water.

In general, the situation with water supply of the eastern oblasts of Ukraine remains very difficult. On April 24, 2022 the water main of the "Siversky Donets – Donbas" canal was damaged. As of October 2022, due to the constant combat activities it is still impossible to renew its wholeness. Consequently, a lot of settlements in the Donetsk and Luhansk regions have become dependent on the underground sources – wells and boreholes and the technical water delivered by the occupiers.

2.2.3 Pollution of the surface and underground waters because of military activities

Military activities are known to cause mechanical and chemical pollution of reservoirs and groundwater. Massive flooding of military equipment and ammunition in reservoirs, leaks of oil products and other chemical compounds as a result of destruction of large industrial facilities and biological pollution due to a large concentration of human and animal corpses, can be regarded as the most serious sources of pollution.

In early May 2022, near the village of Bilogorivka in the Luhansk oblast, Russian troops tried to cross the Siverskyi Donets River to surround Ukrainian troops defending the city of Severodonetsk. The Armed Forces of Ukraine successfully broke the crossing pontoon and a huge amount of burned and submerged Russian equipment together with approximately 400 bodies of Russian soldiers were drowned in the river or remained on its banks. And this is not the only unsuccessful attempt of Russian troops to cross the Siverskyi Donets River. Clearly, such actions add much to complex pollution of the water body with iron compounds and other heavy metals, fuel from submerged

equipment, compounds formed because of the decomposition of bodies, etc. Besides, lots of the military equipment were deliberately submerged by the Russian occupiers in the Siverskyi Donets and Oskil rivers during liberation of the territory of the Kharkiv region by the Armed Forces of Ukraine in September 2022. They did it to prevent the Ukrainian troops taking possession of their weapons and armoury. In fact they destroyed everything which they could not take during their escape.

All types of the drowned military equipment create significant pollution of water bodies by ions of metal. As tons of steel corrode, the water bodies become oversaturated with metal ions poisoning aquatic ecosystems. Metals, especially in their ionic form, quickly bind to the border epithelial structures of hydrobionts, become bioavailable and easily get through cell membranes, disrupting their functioning. Bioaccumulation of ferrum can be a subject to a potential hazard, even if concentration of the metal in water increases slightly. This is the result of the biological function of ferrum in the organism of hydrobionts that occurs under low concentrations, and its excessive accumulation can lead to chronic or acute poisoning[27].

Moreover, every unit of the submerged military equipment emits tens and hundreds of liters of petroleum products used for its operation: diesel fuel, gasoline, oil, lubricant, etc. In fact, oil and oil products is regarded to be a mixture of extremely toxic hydrocarbons, which can be in different migratory forms. For example, when in water, oil products can undergo a range of processes, such as: assimilation by aquatic organisms, sedimentation, emulsification, formation of oil aggregates, oxidation, dissolution, and evaporation.

As a rule, when surface water bodies are polluted, oil products spread over the surface of the water forming a film, which gradually gets rid of light fractions because of the process of evaporation (25% of the stain evaporates within a few days). As for low-molecular components, they get out of the stain as a result of dissolution. It should be mentioned, that oil pollution is known to concentrate other pollutants, such as heavy metals and pesticides and when the oil film spreads over a large area it creates conditions for various chemical reactions.

[27] Рабченюк О.О., Хоменчук В.О., Курант В.З. Ферум у водних екосистемах: форми знаходження, біологічне значення та токсичність для риб [Ferrum in aquatic ecosystems: forms of occurrence, biological significance and toxicity to fish]. Наук. зап. Терноп. нац. пед. ун-ту. Сер. Біологія. 2016. № 3–4 (67). с. 107–119.

Overall effect of oil products on the living organisms can be classified into 5 categories:

1. Direct poisoning with fatal outcome;
2. Serious disorders of physiological activity;
3. Effect of direct covering of a living organism with oil products;
4. Painful changes caused by the penetration of hydrocarbons in the body;
5. Changes in the biological structure of the habitat[28].

2.3 Impact of military activities on the land resources of Ukraine

Agricultural lands are the most valuable resource of the country that meet the basic needs of the society[29]. They occupy the largest part of the Ukrainian lands – approximately 70% of all available land resources (40378.2 thousand hectares).

The function of living space is considered to be one of the main biogeocenotic functions[30].

As of October 2022, the combat activities have been continued in Ukraine along approximately 1300 km of the front line covering a large percentage of agricultural lands: fields, protective forest strips, pastures, farm territories.

According to the information fixed on the maps[31], in October 2022 the areas of the front stabilised on the territories ploughed as agricultural lands, on the protective forest strips and near the small settlements. Every day massive artillery shelling is being conducted, heavy air bombs are being dropped, rockets with large explosive charges are being fired along the entire front line. Moreover, phosphorus bombs, constantly used by Russian troops, are burning down all living things across the large areas.

According to the Ministry of Defense of Ukraine, on the most active days

[28] Бондарук А.В., Бойченко С.В., Черняк Л.М., Радомська М.М. Проблема очищення природних водойм, забруднених стічними водами об'єктів сфери нафтопродуктозабезпечення [The problem of cleaning natural reservoirs contaminated with wastewater from petroleum product supply facilities] // Наукоємні технології № 4 (28), 2015. – с.353-357

[29] Паньків З.П. Земельні ресурси. Практикум: навчальний посібник.[Land resources: Tutorial] / Паньків З.П., Наконечний Ю.І. – Львів: ЛНУ імені Івана Франка, 2020. – 196 с.

[30] Паньків З.П. Земельні ресурси: Навчальний посібник [Land resources: Tutorial] – Видавничий центр ЛНУ імені Івана Франка, 2008. – 272 с.

[31] Map of the combat activities on the territory of Ukraine. Access at: https://deepstatemap.live/

Front sector in Kharkiv oblast as of 13.10.2022

Front sector in Zaporizhzhia oblast as of 13.10.2022

Front sector in Kherson oblast as of 13.10.2022

Russia have fired 40–60 thousand shells of various types at the positions of the Ukrainian troops[32] and about 5 thousand shells of various types have been released in response. These indicators are dynamic by nature and change every day, depending on where the front line is, an increase of the weapons supplied to Ukrainian militaries by their partners and other factors. This data outlines the consequences for the land resources in the zone of active combat activities. One of them is a bad mechanical disruption of the ground surface as the result of explosions, moving equipment and construction trenches.

When the shells fired at military positions explode, craters up to 0.5-5 meters deep (depending on the weapon) form destroying vegetation and soil cover. The soil profile and the hydrological regime of the soil are disrupted too. At the same time, a new, not typical for this area soil profile forms. The construction of military engineering structures, i.e. systems of trenches for infantry, trenching the tanks and artillery and armored combat vehicles have similar influence. All this can be referred to as a significant disruption of soil cover[33].

Each ammunition explosion is a complex mixture of chemicals that settle in the soil layer suppressing the growth of vegetation for years or decades,

[32] Information posted on official Telegram channel of Commander in Chief of the Armed forces of Ukraine. Access at: Telegram: Contact @CinCAFU

[33] Українська природоохоронна група: Якою має бути доля пошкоджених вибухами українських територій? [Ukrainian nature protection group: What should be the fate of Ukrainian territories damaged by explosions?]. Режим доступу: https://uncg.org.ua/

Photo of positions of Ukrainian troops near the city of Bakhmut of Donetsk oblast, November 2022

reducing the population of soil animals and bacteria destroying local biogeocenosis. As plants easily accumulate heavy metals that poison the soil after ammunition explosions, it is not recommended to consume agricultural products grown in the fields that have been touched upon by combat activities.

Shelling also often causes fires, when dry grass or trees subjected to explosions catch fire and as a result, fertile soil layer becomes damaged and plants, their root systems, and the reducers – bacteria and micromycetes destroyed. At the same time, the content of mineral substances in soil increases supporting the further development of the exogenous succession of plant cover.

As it has already been mentioned, on the most active days, about 50,000 different shells are fired at the military positions on Ukrainian lands. For example, the weight of a steel shell of a tank high-explosive projectile, which breaks into fragments is 15.7 kg. The weight of a shell of a 122 mm artillery projectile is 21.76 kg, of a 155 mm projectile – 36.45 kg[34]. However, it is difficult to predict exactly the number of the shells fired each day. For example, 50 000 of 122 mm shells correspond to 1 080 000 kg of steel torn into fragments that litter Ukrainian soil. Millions of kilograms of metal – remnants of ammuni-

[34] Посібник для України «Вибухові боєприпаси» [Guide for Ukraine «Explosive munitions»], GICHD, 2022. – 220 с. Режим доступу: https://www.gichd.org/fileadmin/AMAT/_uploads/GICHD_Ukraine_Guide_2022_Second_Edition_in_Ukrainian.pdf

tion and destroyed and abandoned equipment, oversaturate our soils with iron compounds that inhibits the growth of plants and the vital activity of soil organisms for a long time.

Another factor that affects soil fertility is its compaction by heavy equipment, explosions, using fertile layer of the compacted soil while constructing the trenches. Such compaction of soils is always followed by the processes of silting and waterlogging and, as a result, the loss of their fertility.

Human casualties are always the result of active combat activities. If to consider the problem from a biological point of view, mass burials or simply abandoned human bodies are always abundance of organic material, which releases a number of poisonous substances during its decomposition. The process of decomposition of dead bodies can also cause an outbreak of diseases, the causative agents of which were kept in the bodies during life. Furthermore, animals die en masse as a result of combat activities. As for the farm animals, they are reported to die during the shelling of farms at a large-scale, hundreds and sometimes thousands of animals at the same time.

The process of body decomposition is a complex microbiological process where the organics, mainly proteins, break down under the impact of the microorganisms. The organics decay forms amino acids, organic acids, hydrogen sulfide, methane, ammonia, carbon dioxide, mercaptans and lots of poisonous substances. Gaseous decomposition products transfer into the air, soil absorbs soluble products and the protein mass completely disappears over time. But the process of the complete body decomposition can take years, all depending on the conditions[35]. Toxic products will be kept in the soil, absorbing into the groundwater or released into the air. Such massive organic pollution has similar impact of hindering the development of biogeocenoses as chemical pollution or mechanical damage of the soil profile do.

Furthermore, mass accumulation of organic and inorganic waste is reported to take place at the territories seized by military. For instance, a certain position can be held for months, and dozens of soldiers living there leave a significant amount of waste. First of all, these are vital products. Constant shelling restricts movement in the positions, so a place for a toilet and other waste is equipped depending on the type of the place in the nearest forest strip/tree belt/lowland. Months pass and the areas equipped for waste on those territories become quite polluted.

Severe missile and artillery damage to the rear support of Ukrainian troops has been done since the beginning of the Russia's attempts to invade the entire territory of Ukraine in 2022. The fuel and energy complex, namely oil storage

[35] Герасименко О. І., Герасименко К. О., Антонов А. Г. Судова медицина [Forensic Medicine]. Київ КНТ – 2016. Видання третє. 630 с.

facilities and oil refineries were severely struck – dozens or even hundreds of damages to the oil storage facilities with massive fires and oil leaks into the environment were registered as of October 2022.

Oil is a liquid natural solution that consists of a wide variety of the hydrocarbons of different structure and high-molecular tar-asphaltenic substances. A certain number of salts and trace elements such as C – 83-87%, H – 12-14%, N, S, O – 1-2%, less often – 3-6% (due to S) dissolve in it. Besides, numerous microelements constitute the tenths and hundredths of a percent of oil[36].

As for geochemical properties of oil, they are considered as separate features of its components: methane hydrocarbons (including solid paraffins), cyclic hydrocarbons, resins, asphaltenes, and sulfur compounds.

Solid paraffin is quite difficult to destroy and oxidizes while exposed to the air. It can easily block all the pores of soil cover for a long time, clogging up its free moisture exchange and breathing processes. This definitely leads to complete degradation of the biocenosis.

The most toxic components of oil are aromatic hydrocarbons. Its concentration of only 1% of soil moisture can easily kill all plant forms

Resin-alphathene components are very harmful to the soil ecosystems not because of their chemical toxicity, but because of a significant change in the water-physical properties of soils. If oil leaks from above, its tar-asphaltenic components absorb mainly in the upper, humus horizon, sometimes solidly cementing it. At the same time, the pore space of soil decreases. In this case the pore space of soil shrinks.

Resin-asphaltene components are hydrophobic. When wrapping the roots of plants, they hinder access of moisture to the roots and plants die.

Under the negative impact of oil pollution, a new ecological environment emerges, where all links of natural biocenoses change or completely transform. A common feature of all oil-contaminated soils is a change in number and limitation of species diversity of soil meso- and microfauna and microflora[37].

One of the important factors for preserving the integrity and productivity of Ukraine's land resources is maintaining their optimal water regime. In the arid steppe zone of Ukraine ploughed agricultural lands are irrigated to maintain high productivity. As of October 2022, it is difficult to assess the state of irrigation systems on the areas under occupation. But it is already obvious that the irrigation systems along the conflict lines will be destroyed causing disrup-

[36] Процько Я.І. Вплив нафти та нафтопродуктів на ґрунтовий покрив [Impact of oil and oil products on soil cover]. Вісник Полтавської державної аграрної академії: № 2, 2010. – с. 189-191

[37] See 36

tion to the hydration regime of the lands.

Another aspect of the hydrological regime of soil disruption is flooding large areas caused by dams destruction. At the beginning of Russian invasion in February 2022, Ukrainian soldiers blew up bridges, crossings and dams to stop the advance of Russian troops. From September to November, during the retreat from the Donetsk and Kherson regions, Russian troops blew up the hydraulic structures.

The situation in Donbas (Donetsk and Luhansk oblasts), where there are many coal mines, still remains difficult. As of October 2022, there are no reliable statistics about functioning mines that are controlled by Ukraine, but lots of them are known to be flooded due to the active combat activities and lack of possibility to pump out mine water.

Flooding of mines results in the situation when highly mineralized mine waters with an excessive content of chloride, sulfate and manganese pollute the wells and open reservoirs in the surrounding area. Thousands of hectares of land become completely uninhabitable. Water available in such regions becomes poisonous to plants, farm animals and people. As for the populated areas, they become flooded too. The high level of groundwater, regularly replenished by mine waters, is also fed by acidic waters that flow from the mine dumps during the rain[38].

For example, in the town of Vuhledar, Donetsk oblast a M.S. Surgai mine has been flooded due to the enemy shelling. Coking coal was mined there. Since 24 February 2022, the “Southern Donbas mine No.1”, located nearby, was also flooded, as well as eight coal mines in Luhansk Oblast.

2.4. The impact of military activities on the natural ecosystems of Ukraine

The Ukrainian natural ecosystems have been directly and indirectly affected by military activities. Given the impact’s specifics, both ecosystems and their certain components (soil, aquatic area, trees stand, etc.) have been damaged in various situations.

Ecosystems consist of two interconnected subsystems – an aggregate of organisms (biocenosis) and an abiogenic environment (biotope)[39].

A complete destruction of an ecosystem is a destruction of all its com-

[38] Позняк С.П., Телегуз О.Г. Антропогенні грунти [Anthropogenic soils] / Навчальний посібник / – Львів: ЛНУ імені Івана Франка, 2021. – 200 с.

[39] Сафранов Т.А. Екологічні основи природокористування [Ecological basics of natural resource management]. – Одеса: ОДЕКУ, 2002. – 226 с.

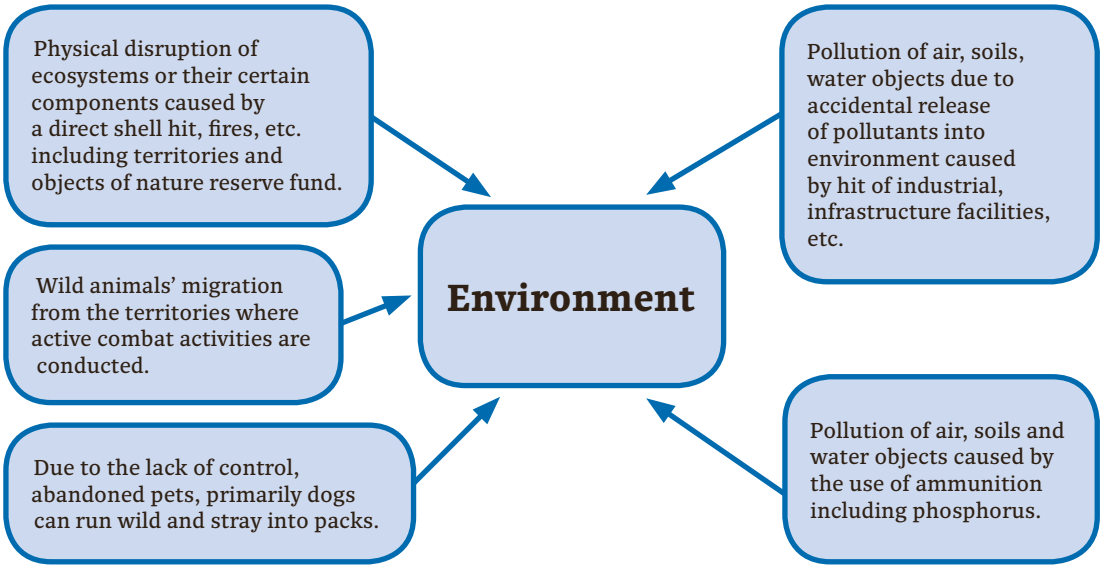

Figure 2.2 Factors influencing the state of natural ecosystems

ponents: the death of plants, animals, and microorganisms, the disruption of the fertile soil layer, and sometimes the transformation of the microrelief. Destruction of the ecosystem's certain components is also a serious impact, which most likely will cause degradation or complete transformation of the ecosystem.

A direct shell hit on the territory of natural ecosystems causes a physical disruption of ecosystems or their certain components, resulting in the death of vegetation, animal life, and their habitats in the affected area. It also causes changes in area micro-relief, pollutants penetration, temperature effect due to fires, etc.

It is in natural ecosystems where the most of biodiversity is concentrated, including species with conservation status. Plants and animals (invertebrates and vertebrates) living in urban ecosystems are also affected, including inhabitants of parks, squares, and green areas that do not have conservation status, and territories of nature reserve fund within settlements.

As for origin type, the impact caused to the natural ecosystems and biodiversity by military aggression could be as follows:

- mechanical (debris, solid particles);
- chemical;
- physical (noise, vibrations, etc.).

Based on the official data provided by the digests[40] of the State Ecological

[40] https://www.dei.gov.ua/posts/2226

Examples of the consequences of combat activities

Inspectorate of Ukraine (dated from February to July 2022) the following facts of impact on the natural ecosystem have been registered: more than 39 cases of vegetation loss caused by shelling and fires in forests that are parts by forestries, steppe, and reed biogeocenoses, including more than 9 facts of damages to territories and objects of the nature reserve fund. Based on the data provided by the Ministry of Environmental Protection and Natural Resources of Ukraine[41], 2.9 million hectares of forests have been affected by the war, 812 territories and objects of protected territories (20% or 0.9 million hectares) are under threat and/or suffer from combat activities as of August 2022.

Land resources, being the habitat of soil organisms, suffer from mechanical and chemical pollution. Every single shelling causes waste of land resources with buildings and equipment debris, components or parts of goods and their packaging, spillage of liquid components, including toxic ones in addition to the impact of the shell itself.

Water resources are affected too, resulting in hydrobionts' loss. Thus, ac-

[41] https://mepr.gov.ua/news/39684.html

cording to the data provided by Igor Rusev in his post[42] on the page of the "Tuzly Estuaries" National Natural Park dated October 19, 2022, since the beginning of the war, about 50 thousand cetaceans have already died.

In addition, the environment suffers from the impact of physical factors – noise, vibration, infrasound, ultrasound, electromagnetic radiation, etc.

Currently, several methodologies calculating losses and damage to the environment are in force in Ukraine[43]. A complete list of methodologies is given in section IV.

The negative impact on land resources, as geobionts' habitat, is estimated according to the methodologies for determining the value of the damage caused by contamination and littering[44] land resources, land deterioration, as well as violation of the land use regime, norms, and regulations[45].

The impact on water resources, being hydrobionts' habitat, is estimated according to the methodology for calculating the amount of compensation for damages caused to the state as a result of violations of the legislation on the protection and rational use of water resources[46]. It is also based on the methodology for determining damage from oil pollution[47], and the procedure for calculating the amount of compensation and paying damages caused by pollution from vessels, ships, and other watercraft of territorial and internal sea waters of Ukraine[48]. Charges for calculating the amount of compensation for damage caused by illegal extraction (harvesting) or destruction of valuable species of aquatic biological resources[49] have also been set.

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42 https://www.facebook.com/permalink.php?story_fbid=pfbid02UF7YbGNUxosybdWEbFJ1VayFGarE6Aaqfmt9iiHA14tHbFSTo5zYcpJGvu8Tou5Dl&id=432082570182393

43 https://www.dei.gov.ua/posts/2225

44 Order N171 of the Ministry of Environmental Protection and Nuclear Safety of Ukraine as of 27.10.1997. Access at: https://zakon.rada.gov.ua/laws/show/z0285-98#Text

45 Resolution N963 of the Cabinet of Ministers of Ukraine as of 25.07.2997. Access at: https://zakon.rada.gov.ua/laws/show/963-2007-%D0%BF#Text

46 Resolution N484 of the Cabinet of Ministers of Ukraine as of 03.07.1995. Access at: https://zakon.rada.gov.ua/laws/show/484-95-%D0%BF#Text

47 Resolution N631 of the Cabinet of Ministers of Ukraine as of 26.04.2003. Access at: https://zakon.rada.gov.ua/laws/show/631-2003-%D0%BF#Text

48 Order N16 of the Ministry of Environmental Protection and Natural Resources of Ukraine as of 16.01.2021. Access at: https://zakon.rada.gov.ua/laws/show/z0406-21#Text

49 Order N1209 of the Ministry of Environmental Protection and Natural Resources of Ukraine as of 21.11.2011. Access at: https://zakon.rada.gov.ua/laws/show/1209-2011-%D0%BF#Text

As for species of flora, charges for calculating damage caused to the forest[50] have been approved. It should be noted that charges for calculating damage caused to steppe, reed, and other biogeocenoses have not been approved yet. Note that given the active shelling of the energy system of Ukraine, the number of illegal forest felling seems to be increasing.

As for the territories and objects of the nature reserve fund the charges for calculating damage caused by violation of the legislation on the nature reserve fund[51] have been approved. They include damage caused by:

- illegal felling or damage to trees;
- destruction or damage to lawns and flower gardens;
- illegal collection or destruction of wild herbaceous plants, forest floor, medicinal plants, wild fruit, nuts, mushrooms, berries, secondary forest materials;
- illegal extraction or destruction of species of animal life, damage or destruction of their homes and structures, places of stay and reproduction;
- damage to karst speleological, geological and hydrological objects;
- transport travel, flyby and landing of aircraft;
- arbitrary use of land, removal of soil cover, pollution and littering of their territories;
- destruction or damage to drainage ditches, drainage and anti-erosion systems, roads, and other objects.

As for the species of animal life today there are neither methods nor charges for calculating the amount of damage caused to the animal world in the territories that do not have nature protection status, due to military aggression. The negative impact of combat activities on the breeding period of wild animals and the spawning of fish should also be mentioned.

Special attention should be paid to zoological parks that are the objects of the nature reserve fund, in particular, Mykolaiv, Kharkiv, Kyiv ones; "Feldman Ecopark" regional landscape park in Kharkiv[52] [53]; "Aquarium" scientific and educational complex of O. Honchar Dnipro National University, equestrian clubs, and other eco-educational objects – all of them have been affected. Some of them have been exposed to direct effects through shelling and damage to the territory and infrastructure, others have been affected indirectly through pow-

[50] Resolution N665 of the Cabinet of Ministers of Ukraine as of 23.07.2008 Access at: https://zakon.rada.gov.ua/laws/show/665-2008-%D0%BF#Text

[51] Resolution N575 of the Cabinet of Ministers of Ukraine as of 10.05.2022 Access at: https://zakon.rada.gov.ua/laws/show/575-2022-%D0%BF#Text

[52] https://thegard.city/articles/207897/yak-poterpae-vid-vijni-ukrainska-flora-ta-fauna

[53] https://ukrainer.net/poriatunok-tvaryn/

er outages, lack of food for animals, and the inability to maintain the proper temperature regime[54].

Natural ecosystems, including the territories and objects of the nature reserve fund, have been under intense man-made influence even before the full-scale invasion (for the natural territories of Donetsk and Luhansk oblasts before 2014). Not only territories where active combat activities have been waged, but also territories that have been exposed to regular missile attacks or other impacts. It will be possible to estimate and calculate the final damage caused to the environment in general and its certain components such as biodiversity, as a result of Russian aggression to a full extent only after the end of combat activities. A comprehensive assessment will require doing monitoring research, including those of the dynamics of populations of living organisms.

2.5 The impact of military activities on human settlements and industrial complexes of Ukraine

The natural and constructed components of settlements (Fig. 2.3) have been destroyed and damaged as a result of combat activities.

The physical destruction and/or damage of settlements green areas and their certain components, have a few impacts. On the one hand, these are habitats of living organisms (biodiversity), and on the other hand, these are "the green shield" of settlements, since green plantations are a buffer against pollutants contained in the air (including solid particles) for the population and have a phytoncide effect.

Moreover, flora and fauna suffer from the other types of impacts: mechanical and chemical pollution, as well as noise, vibrations, etc.

Damage to constructed components, i.e. buildings, infrastructure, and industrial facilities, causes a threat because their collapsing additionally to debris to the environment (mechanical pollution) can be also accompanied by exposure to toxic compounds.

Thus, for example, sewage discharges, gas emissions, and fires may occur due to damage to residential buildings and communications. Another danger, both for the population and for the environment, is a long-term disruption of water supply and drainage systems.

[54] https://www.facebook.com/aquarium.dp.ua/posts/pfbid02tyooNBbxdrmQZ4N2vSPKZCKwkoXL8f7XbrCntU517JLVLG7MZtTWgCuHG8Br6gfrl

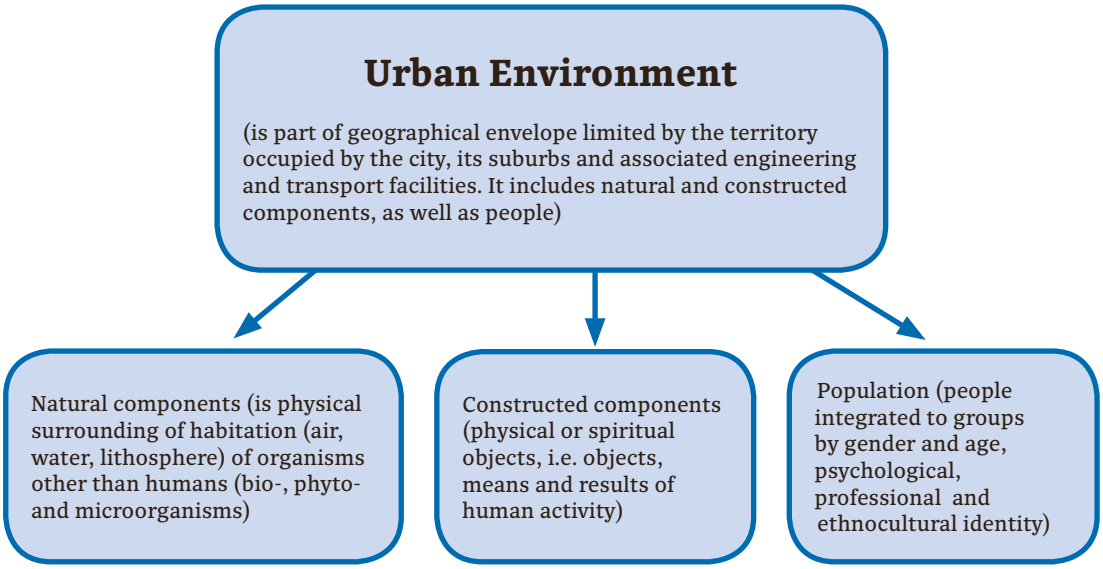

Figure 2.3 – Components of the urban environment (based on data[55]).

Table 2.1 provides information on the volume of damage and disruption of residential and non-residential real estate objects, and other infrastructure resulting from a full-scale invasion. It is based on the data given in the report[56] as of 1 September 2022, published within the "Russia will pay"[57] project. It has been implemented by the KSE Institute together with the Office of the President of Ukraine, the Ministry of Economy, the Ministry for Reintegration of the Temporary Occupied Territories, the Ministry of Infrastructure of Ukraine, and the Ministry of Development of Communities and Territories of Ukraine[58].

Damage to agricultural enterprises involved in farming animals also poses a high risk to the environment. A number of facts have been registered on direct shell hits and fires caused by shelling, and failure / disruption of farming (for example, damage to communications, the inability of feeding, and maintaining a sanitary regime), which resulted in the death of domestic animals. It caused pollution of land resources and the air. One of the great examples is a poultry farm in the village of Chornobayivka in Kherson oblast, where the

[55] Василенко І.А., Півоваров О.А., Трус І.М., Іванченко А.В. Урбоекологія [Urboecology] / І.А. Василенко, О.А. Півоваров, І.М. Трус, А.В. Іванченко – Дніпро: Акцент ПП, 2017. – 309 с.

[56] https://kse.ua/ua/Russia-will-pay/

[57] https://damaged.in.ua/

[58] See 56.

destruction of the local power plant caused by shelling, led to shutdown of the automated bird feeding system. About 4 million chickens died[59]. The investigation is known to be conducted under Article 441 of the Criminal Code of Ukraine (ecocide)[60].

The impact of combat activities on the population as a component of urban environment requires special attention. According to the estimates of international organizations, a real number of Ukrainians who have moved to safer territories of Ukraine may reach 8 million people[61].

According to the data published by the Ministry of Reintegration of the Temporarily Occupied Territories of Ukraine 1.7 million people have chosen Western Ukraine as a place of their temporary residence. They have chosen in particular Lviv, Ivano-Frankivsk, Chernivtsi, Zakarpattia, Ternopil, Khmelnytskyi, Rivne, and Volyn oblasts. The Northern region, i.e. Kyiv, Zhytomyr, Chernihiv, and Sumy oblasts, hosted 1.6 million internally displaced people (IDPs), the Central region, including Vinnytsia, Cherkasy, Kirovohrad, Poltava oblasts hosted 1 million IDPs, and the Southern region, Odesa, Mykolaiv in particular – 0.7 million IDPs.

Internal migration leads to the depopulation of certain areas and excessive population concentration of others. Due to the displacement of such a large number of people, additional burden incurs on the cities that host them. It includes an increase of water supply and pressure on drainage systems, increasing volume of household waste, etc.

For example, the population of the city of Dnipro was 968 502 inhabitants [62] as of 1 January 2022, and almost 180.5 thousand internally displaced persons live in the city of Dnipro as of November 2022. This is 18% increase compared to the beginning of the year. Assuming that the number of internally displaced persons not registered, but living in the city, is more or less the same as the number of residents who relocated from the city, the load on the life support systems has increased by approximately the same 18%.

Attacks targeting the Ukrainian energy system have not only polluted environment with debris and combustion products caused by fires but also with combustion products generated by the use of solid fuel boilers and fuel generators by businesses and the population.

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[59] https://agropolit.com/news/23611-u-chornobayivtsi-na-ptahofabritsi-zaginulo-4-mln-kurey

[60] https://focus.ua/uk/voennye-novosti/540428-est-ugroza-bakterialnoho-zarazheniya-v-chernobaevke-iz-za-vs-rf-proizoshel-massovy-mor-ptic-foto

[61] https://www.rada.gov.ua/news/news_kom/229321.html

[62] https://index.minfin.com.ua/ua/reference/people/town/dnepr/

Examples of housing stock objects' destruction

It should be noted that the complete or partial destruction of settlements caused by combat activities certainly gives impetus for the development of modern principles of urban planning.

Moreover, decentralisation is becoming increasingly important in terms of autonomy of the communities. It can actually provide the communities with energy, central water supply, and drainage systems independence. The energy autonomy of private households (including private residential buildings) when using the sources of renewable energy (for example, solar power plants, heat pumps, etc.) is of great importance too.

Table 2.1 – Volumes of damage and destruction of objects of residential and non-residential real estate and other infrastructure due to a full-scale invasion as of 1 September 2022 (based on the Report[63])

Destruction of Housing stock	The total area of damaged or destroyed objects is 74.1 million m^2, which is 7.3% of the total area of the housing stock of Ukraine. According to the preliminary estimates: • 18.6 thousand residential buildings (with a total area of 16.3 million m^2) have been partially damaged (with a degree of destruction less than 10%). • 45.1 thousand residential buildings (with a total area of 27 million m^2) have been moderately damaged (with a degree of destruction of more than 10% and less than 40%). • 72.1 thousand residential buildings (with a total area of 30.8 million m^2) have been completely destroyed (with a degree of destruction of more than 40%).
Destruction of administrative buildings	Based on preliminary data, 616 administrative buildings have been destroyed as a result of combat activities, including • 595 – buildings of state and local government bodies; • 21 – centres for administrative services provision.
Destruction of health care facilities	Since the beginning of the war, at least 978 health care facilities have been damaged or destroyed. By type mostly the following health care facilities have been destroyed or damaged as a result of the war: • outpatient clinics – 356; • hospitals – 289; • at least 24 private medical facilities
Destruction of educational institutions and objects of scientific infrastructure	Due to combat activities, at least 810 objects of educational infrastructure have been destroyed and 1639 have been damaged. The largest number among the damaged and/or destroyed educational institutions belongs to schools (1270) and kindergartens (786). Based on preliminary estimates, 117 objects of movable and immovable property of 34 institutes and other institutions of the National Academy of Sciences of Ukraine have been destroyed, damaged, and removed for the needs of the Armed Forces of Ukraine. The preliminary total estimate of losses, only for scientific institutions of the National Academy of Sciences, amounts to $7.8 million.
Social protection objects destruction	Due to the large-scale fights in various oblasts of Ukraine, social objects have been also destroyed and damaged, including social protection establishments, geriatric institutions, sanatoriums, children's camps and orphanages, boarding schools, and institutions working with homeless people. The largest share in the total number and value of damages belongs to social centres, sanatoriums, and boarding schools.

[63] See 56

Destruction of cultural objects, religious buildings, tourism, and sports objects	Since the beginning of the war, there have been damaged or destroyed at least: • 775 cultural objects (including 335 houses of culture/palaces of culture, 33 museums); • 80 religious buildings, including 77 temples/churches; • 149 tourist infrastructure objects; • 153 sports objects, including 59 sports schools.
Destruction of industrial facilities	At least 412 industrial facilities have been damaged or destroyed. The real number seems to be higher, as information on all enterprises is not available, especially on those located in the temporarily occupied territories.
Destruction in the retail trade sphere	Due to military activities, significant damage has been caused to 2910 retail outlets with a total area of 1.6 million m^2. The following facilities and objects have been included in this category: warehouses (excluding wholesale warehouses), pharmacies, shops, and gas stations.
Destruction of agro-industrial complex facilities and damage to land resources	The total capacity of destroyed granaries reaches 6.5 million tons of output produced, and the capacity of damaged granaries exceeds 2.9 million tons of simultaneous storage capacity.
Transport infrastructure objects destruction	At least 110 terminals and railway stations, as well as 19 airports and civilian airfields, have been damaged.
Road facilities destruction	Due to military activities 25.0 thousand km of roads, as well as 315 bridges and bridge crossings of state, local or communal significance, have been destroyed.
Destruction of the objects of Railway infrastructure	At least 500 km of railway track have been damaged. The number of damaged terminals and railway stations is 111, including 40 being destructed or damaged on territories controlled by Ukraine and the rest located in uncontrolled territories.
Destruction of the objects of Aviation industry	19 airfields have been damaged, including 12 civil and 7 dual-purpose airfields (excluding military ones).
Destruction of the objects of Port industry	Since the beginning of the war, port assets have been destroyed or damaged in at least four ports.
Destruction caused to postal operators	Since the beginning of the war property of several hundred post offices, dozens of terminals/depots and vehicles have been destroyed or damaged (according to Ukrposhta and Nova poshta's data).

Destruction of communal transport infrastructure and private vehicles	According to the estimates, the direct losses caused to communal enterprises and private carriers, in particular regarding the destroyed transport, amount to $0.657 billion, including destroyed trolleybuses, trams, and buses. Direct losses caused to private transport amount to approximately $1.7 billion or 188 thousand cars. Additionaly, 623 fire trucks with a cost of $30 million have been lost, excluding other specialised equipment.
Digital infrastructure	There are 3534 stations of mobile connection out of operation, which is almost 11% of the total number.
Energy	More than 10 combine heat and power plants (CNP) are considered completely destroyed or damaged. 18% of solar generation is located in the occupied territories in Kherson oblast and 6% has been damaged or destroyed. Some solar power stations are located on the occupied territories of Zaporizhzhia oblast. About 80% of wind generation is located in the occupied territories and part of it has been damaged by shelling; 3.5% of bioenergy facilities are under occupation and at least 4 plants have been destroyed.
Utility sector	Based on preliminary estimates, during the period of the full-scale invasion, on the territories where combat activities are conducted: • 4 CNP have been completely destroyed in the following cities and towns: Okhtyrka in Sumy oblast, Kremenchuk in Poltava Oblast, Severodonetsk in Luhansk Oblast and in Chernihiv. Another 8 have been damaged in the following cities and towns: Zelenodolsk in Dnipropetrovsk Oblast, Avdiyivka and Mykolaivka in Donetsk oblast, Eskhar urban-type settlement in Kharkiv oblast, Sumy, Mykolaiv and Kharkiv (2 CNPs); • 322 boiler houses have been partially damaged or completely destroyed, most of them are located in Kharkiv, Kyiv, Chernihiv, Donetsk, and Mykolaiv oblast. 99 centralised heating units have been partially damaged or completely destroyed, more than 222 linear km of heat network have been completely destroyed; • more than 827 linear km of water supply networks have been destroyed, and 13 water treatment plants have been partially damaged or completely destroyed. Additionally, 71 water pumping stations have been destroyed/ damaged; • 5 water testing laboratories in the region have been destroyed or damaged; • more than 244 linear km of sewage networks have been destroyed and 64 sewage pumping stations have been partially damaged or completely destroyed. 23 sewage treatment facilities are also considered destroyed or damaged. • 16 landfills for the disposal of household waste have been destroyed. 3 garbage sorting lines and 3 biogas plants have been completely destroyed as well. The transport for waste removal has been destroyed, including 180 garbage trucks.

Examples of industrial facilities' destruction

Examples of vehicles' destruction

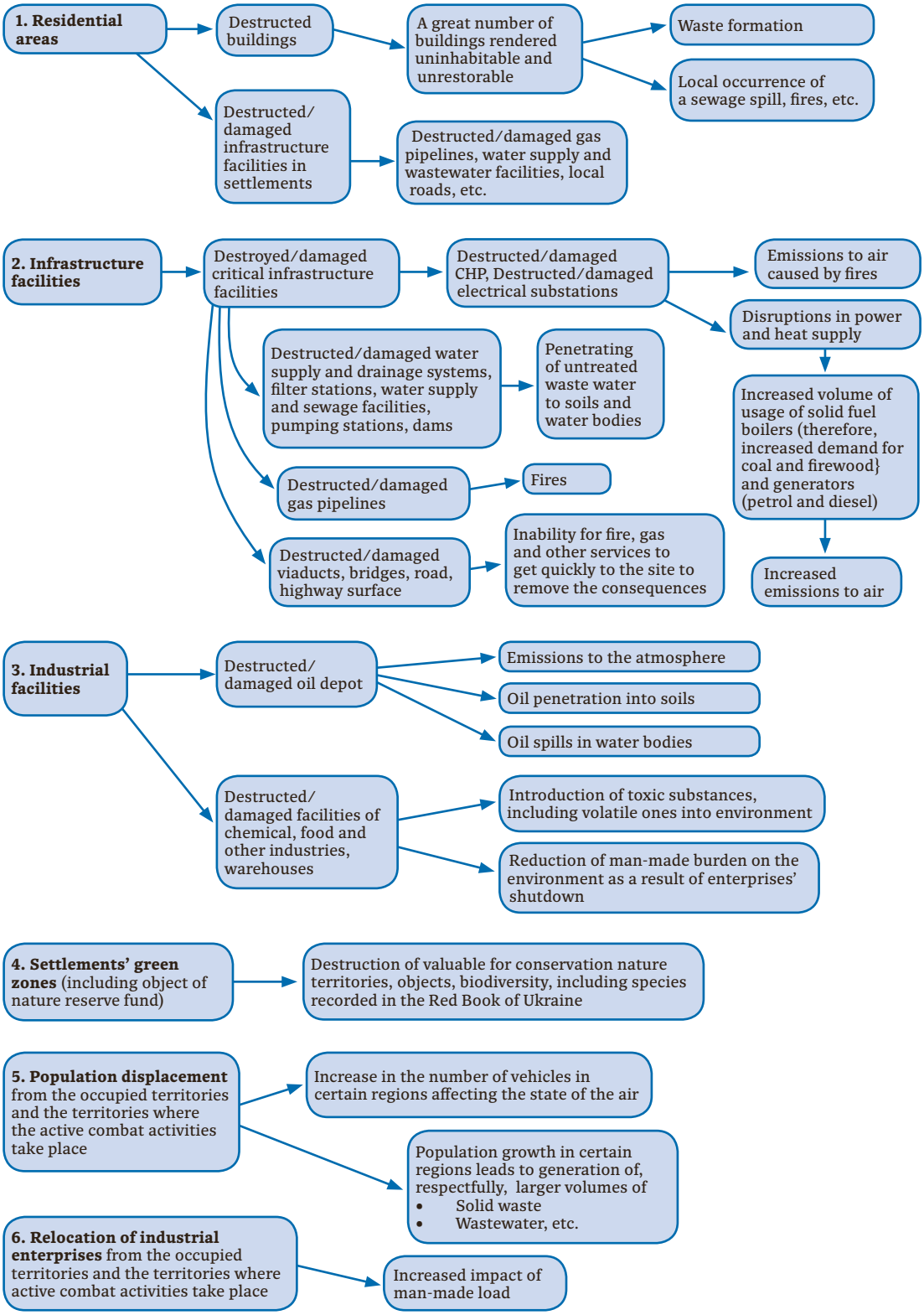

Figure 2.4 – Chart of the environmental impact of combat activities

III. Environmental damage in the history of wars and the mechanisms of international reparations

Any armed conflict, any war, is not just about the physical destruction of enemies on the battlefield here and now. There are always a number of severe long-term consequences for the area where weapons are used. As a rule, negative long-term impact starts at the preparatory stage of war. The production of weapons and military equipment is by no means far from being environmentally friendly. Explosives, rocket fuel and fuel for military equipment are a concentration of dangerous chemicals that can potentially harm all the living if they penetrate the environment. Penetration of the environment occurs: firstly, at the production stage; secondly at the stage of military training, and then finally, as a result of combat activities.

Even in the most ancient times, people saw and understood/realised the devastating consequences of warfare. The cities that had been under protracted siege were uninhabitable for a long time due to the ecological disaster that took place there. Moreover, the advancing troops destroyed food and wood sources around the city, which caused resource and food starvation there after its liberation or lifting of the siege.

From the beginning of historical times, people started to describe and establish certain rules of war. In Deuteronomy[64] the Bible mentions certain ecological aspects of warfare, in particular, it is forbidden to cut down trees, especially fruit trees, around a city that is under siege for a long time.

Nowadays, there are international legal norms for warfare means and rules, which should be strictly observed by the parties of the conflict. Article 55 of Section III of the Protocol Additional to the Geneva Conventions (Protocol I)[65], dated June 8, 1977, determines the need to protect the environment from damage during combat activities: “Care shall be taken in warfare to protect the natural environment against widespread, long-term and severe damage. This protection includes a prohibition of the use of methods or means of warfare which are intended or may be expected to cause such damage to the natural environment and thereby prejudice the health or survival of the population. Attacks against the natural environment by way of reprisals are prohibited”.

[64] Deuteronomy. Chapter 20. Access at: https://www.bible.com/uk/bible/186/DEU.20.UBIO

[65] Protocol Additional to the Geneva Conventions of 12 August 1949, dated 8 June 1977. Access at: https://zakon.rada.gov.ua/laws/show/995_199#Text

One of the most famous wars in human history where the environment became a military target was the Second Indochina War of 1961–1975. At that time, the US Army conducted a long-term Operation Ranch Hand lasting from 1962 until 1971 aiming at destroying vegetation in South Vietnam and Laos[66].

The damage to the environment occurred was caused by using phytotoxicants – chemicals that deliberately destroyed the local jungle. Toxins were sprayed from planes, helicopters, and by ground teams. The main objective of the military operation was to reveal the base camps and facilities, movement routes, and arms supply channels of the resistance forces, which were successfully defended by deep camouflage in the jungle. The Operation's tasks also included the undermining of the enemy's food base by destroying rice plantations and long-term chemosterilization of soils, the devastation of pastures, and poisoning of water bodies.

Certainly, the use of phytotoxins was not the only method of warfare. Mass bombardment of the territory and various chemical substances with an irritating effect were also used. During the Second Indochina War, according to official data, approximately 30% of the territory of South Vietnam was affected. Spraying mangrove forests and plantations was carried out less often. This was due to their greater vulnerability to chemicals. According to various estimates, about 80% of the mangrove forests in the coastal zone were affected, and almost completely died. Tropical forests, playing a key role in climate formation and regulating the ecosystems of the entire region, were regularly sprayed. This led to the death of more than 60% of the trees. A totally "burnt" territory is estimated at about 1.6 million hectares[67].

Parallel intensive jungle bombing caused another negative consequence. Blast craters in the extensive devastated area got filled with water and created spacious wetlands. Those reservoirs became breeding sites for malaria mosquitoes and, as a result, centres of tropical malaria[68].

The above-mentioned facts prove the significant damage caused to the environment during the Second Indochina War. Since then, environmental protection during armed conflicts has become a topical issue for global discussions.

Kuwait's claims against Iraq arising out of the Persian Gulf War (1990–1991) appeared as the first official case of the international community addressing the claims for compensation for environmental damage in the post-war peri-

[66] М. Требін. Війни в історії людства та їхні наслідки: уроки для України [Wars in the history of mankind and their consequences: lessons for Ukraine] \\ Вісник Львівського університету. Серія філос.-політолог. студії. 2015. Випуск 6

[67] Arthur H. Westing. Ecological Consequences of the Second Indochina War. Publisher: Taylor & FrancisISBN 91-22000-62-3. 1976 – 119 pp.

[68] See 66

od. Iraq's aggression was accompanied by significant damage to the environment of Kuwait and the surrounding area. During the occupation of Kuwait, about 10.8 million barrels of oil were deliberately spilled in the Persian Gulf by the Iraqi military. As a result, 600 km of the Saudi Arabian coastline was polluted. About 1 billion barrels of oil spilled due to the Iraqi military blowing up about 600 oil wells, resulting in the contamination of groundwater and desert ecosystems. Another damage to Kuwait's desert ecosystems was caused by the construction of military structures, fortifications, trenches, bunkers, etc. Several million mines and unexploded ammunition were scattered across the territory of Kuwait, including beaches, coastlines, and the desert[69].

Thus, during a month, the Iraqi invaders destroyed dozens of oil and oil product storage facilities, as well as oil refineries. They also hit gas pipelines, acid tanks, and fertilizer warehouses, causing extensive emissions of dangerous pollutants into the air, soil, groundwater and water bodies. The similarity of the damage caused by the actions of the Russian occupiers in Ukraine in 2022 with Kuwait's experience provides insight into possible ways to estimate the damage and calculate compensation for it.

In 1991, the United Nations Compensation Commission (UNCC)[70] was established as a subsidiary organ of the United Nations Security Council, under Security Council Resolution N687 (1991) to process claims and pay compensation for loss and damage suffered as a result of Iraq's unlawful invasion and occupation of Kuwait in 1990–1991. This body recorded, estimated, and awarded compensation to clean and repair the damaged soil, water, coastal ecosystems, and covered other damages.

The commission received a percentage of the proceeds generated by the export sales of Iraqi oil and petroleum products. This percentage was originally set at 30% by the Security Council under resolution N705 (1991) and adopted by Security Council resolution N986 (1995), as well as in a number of subsequent resolutions. The funds level was set at 25% in December 2000 by Security Council resolution N1330 (2000). The revenues generated by the export sales of Iraqi oil, petroleum products, and natural gas, contributed to the Compensation Commission, were adjusted to 5% under paragraph 21 of Security Council resolution N1483 (2003), adopted on 22 May 2003. In 2018, the percentage to the fund was reduced to 0.5%, in 2019 it was 1.5%, and 3% in 2020[71].

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[69] The Environmental Consequences of War: Legal, Economic and Scientific Perspectives/ ed. Austin J.E., Bruch C.E./ Cambridge University Press. 2000.

[70] The United Nations Compensation Commission (UNCC). Access at: https://uncc.ch/

[71] Компенсаційна комісія ООН – перспектива фінансування відновлення довкілля в Україні після війни із рф Огляд діяльності Компенсаційної комісії ООН// Екологія. Право. Людина [The United Nations Compensation Commission – the perspective of

In fact, the commission was involved in collecting proceeds generated by the export sales of Iraqi oil and paying compensation for claims submitted to the commission. At its first meeting in August 1991, the UN Compensation Commission (UNCC) identified six categories of claims listed below[72]:

1) Claims submitted by individuals who had to depart from Kuwait due to Iraq's military invasion;
2) Claims submitted by individuals or their family members who suffered serious personal injury and/or death as a result of the aggression;
3) Claims from individuals for commercial losses and damages to private property up to US $100,000 each.
4) Claims from individuals for commercial losses and damages to private property above US $100,000 each.
5) Claims of corporations and other private legal entities (including the oil sector) to compensate for their losses.
6) Claims filed by Governments and international organizations for losses incurred in evacuating citizens; providing relief to citizens; and damage to the government property and environment.

The Compensation Commission's mandate included processing claims for direct damage to the environment and depletion of natural resources, including losses or costs for[73]:

- abatement and prevention of environmental damage, including expenses directly relating to fighting oil fires and purification of coastal and international waters from oil;
- reasonable measures already taken to clean and restore the environment or future measures which can be documented as reasonable measures necessary to clean and restore the environment;
- reasonable monitoring and assessment of environmental damage for the purposes of evaluating and abating the harm and restoring the environment;
- reasonable monitoring of public health and performing medical screenings for the purposes of investigation and combating increased health risks as a result of the environmental damage;
- depletion of or damage to natural resources.

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financing for environmental renewal in Ukraine after the war with Russian Federation. Review of the UNCC's activities // Ecology. Law. Person]. Режим доступу: http://epl.org.ua/wp-content/uploads/2022/05/Kompensatsijna-komisiya-OON.pdf

[72] The United Nations Compensation Commission (UNCC). Claims review. Access at: https://uncc.ch/claims

[73] See 71

Ultimately, the UN Compensation Commission paid out US $52.4 billion of compensation to more than 1.5 million successful claimants. With the final payment made in January 2022, the damage caused by Iraq's invasion is considered to be completely compensated.

It is crucial for Ukraine to note that the Compensation Commission in its reports indicated the importance of documenting the baseline condition of the environment and natural resources prior to the invasion of Iraq. But if there is no data that the damage has been completely caused by the occupation and the factors of impact are not related to military actions, or related partially, the losses cannot be compensated. That is why it is important for Ukraine to develop and improve the environmental monitoring system even before the end of the war. A monitoring network of air quality[74], the state of the surface and underground waters, and analyses of the state of soils are crucial in this respect. An active and extensive network of environmental monitoring is, in fact, a contribution to the guarantee of billions of dollars of reparations for environmental damage, which as of October 2022, is already catastrophic.

At the national level, Ukraine should be actively involved in collecting evidence of damage caused by Russian troops, gathering and storing data on the state of the environment, and health of population, conducting environmental impact analyses and assessing the damage caused. On a daily basis, (since the full-scale invasion), Russia shells the territory of Ukraine, destroying oil depots, chemical industry enterprises, power lines, dams, and other critical infrastructure. Likewise, every day Ukraine spends significant funds on eliminating the consequences of these shells and restoring critical infrastructure. These costs should be compensated by Russia.

The UN Compensation Commission also compensates the costs of other Governments that helped in the restoration and damage reduction in the conflict zone. That opens the door to partnership on this issue with other Governments.

[74] See 21

IV. Legal ways of determining and calculating the damage caused to natural resources and the environment as a consequence of the armed aggression by the Russian Federation

Since the very beginning of the large-scale invasion, Ukraine began to record the damage caused by the aggressor.

In order to create a unified system of control over threats resulting from the armed aggression of the Russian Federation against Ukraine, according to the Law of Ukraine "On the Legal Regime of Martial Law", Decree of the President of Ukraine N64/2022 as of February 24, 2022 "On the Imposition of Martial Law in Ukraine", Law of Ukraine "On Environmental Protection", Regulations on the State Environmental Inspectorate of Ukraine, approved by the Resolution of the Cabinet of Ministers of Ukraine N275 as of 19.04.2017, based on the order of the State Environmental Inspectorate of Ukraine N73 as of 01.02.2022, an Operational Headquarters (hereinafter referred to as the Headquarters) has been established[75].

The tasks of the Headquarters include: recording, calculation, and systematisation of the data on damages caused to the natural environment as a result of emergencies or dangerous events (incidents) caused by the military activities of the aggressor state, in particular:

- explosions, bombardment of fuel and lubricant warehouses, oil storage facilities, enterprises that may use hazardous and/or chemicals in production;
- damage, destruction or shutdown of sewage treatment facilities before discharge into water bodies – water utilities, industrial facilities;
- destruction of the dams of filtration fields and leakage of waste on the terrain; destruction of treatment or hydraulic structures;
- ignition (burning, decay) of waste disposal sites – landfills;

[75] https://www.dei.gov.ua/posts/2243

Figure 4.1 – Composition of the Operational Headquarters (https://shtab.gov.ua/#information)

- damage to soil, burning, deforestation – especially in the territories of the nature reserve fund[76].

The Procedure for determining damage and losses caused to Ukraine as a result of the armed aggression of the Russian Federation[77] approved by Resolution of the Cabinet of Ministers N326 as of 20.03.2022 indicates the areas of determining damage and losses (Table 4.1).

[76] https://shtab.gov.ua/#information

[77] Resolution of the Cabinet of Minister of Ukraine N326 as of 20.03.2022. Access at: https://zakon.rada.gov.ua/laws/show/326-2022-%D0%BF#Text

Table 4.1. – Areas and methodologies of determining damage and losses

LAND RESOURCES

Deals with damage to and destruction of fertile topsoil and damage caused by land contamination and littering.

Main assessment indicators

- Costs for recultivation of lands that were damaged as a result of military operations, constructions, fences, boundary signs, boundary openings, means for the arrangement of the state border
- Losses incurred by owners (land users) of land plots of agricultural purposes;
- Expenditures for restoration of land melioration systems.
- Damage to soils and land plots due to soil contamination with substances negatively affecting their fertility and other useful properties;
- Damage to soils and land plots caused by littering of land plots by external objects, material, wastes and/or other substances.

Methodologies[78]

- Is carried out according to the Methodology[79] approved by the Order of the Ministry of Agrarian Policy and agreed by Ministry of Reintegration of Temporarily Occupied Territories
- According to the Methodology[80] [81] Approved by the Order of the Ministry of Environmental Protection upon the recommendation of the State Environmental Inspectorate agreed with the Ministry of Reintegration

State authorities responsible for determining damage and losses

- Oblast authorities, Kyiv City State Administration (for the martial law period – military administrations)
- State Environmental Inspectorate

SUBSOIL

Deals with losses caused by unauthorized soil use.

Main assessment indicators

- Volume of unauthorized, in particular illegal subsoil use
- Losses caused by unauthorized subsoil use

[78] See 43

[79] Order N167 of the Ministry of Environmental Protection as of 04.04.2022. Access at: https://zakon.rada.gov.ua/laws/show/z0406-22#Text

[80] See 44

[81] See 45

Methodologies

According to the Methodology[82] approved by the order of the Ministry of Environmental Protection and Natural Resources of Ukraine upon the recommendation of the Ukrainian Geological Survey agreed with the Ministry of Reintegration

State authorities responsible for determining damage and losses

Ukrainian Geological Survey

WATER RESOURCES

Deals with water resources contamination, littering, depletion and other actions that can worsen water supply, could be harmful to human health, cause a decrease in fish stocks and other objects of aquatic product, deterioration of the wild animals' living conditions, a decrease of soil fertility and other adverse phenomena due to changes in the physical and chemical properties of water, a decrease of their capacity for natural purification, a violation of the hydrological and hydrogeological regime of waters

Main assessment indicators

- Losses caused by unauthorized, in particular illegal water resources use
- Losses caused to the environment within territorial sea, exclusive (sea) economic zone and internal sea waters of Ukraine in the Black and Azov seas

Methodologies

According to the Methodologies [83] [84] [85] [86] [87] [88] [89] approved by the orders of the Ministry of Environmental Protection and Natural Resources of Ukraine upon the recommendation of the State Environmental Inspectorate agreed with the Ministry of Reintegration

State authorities responsible for determining damage and losses

State Environmental Inspectorate

[82] Order N 303 of the Ministry of Environmental Protection and Natural Resources of Ukraine as of 29.08.2011. Access at: https://zakon.rada.gov.ua/laws/show/z1097-11#Text

[83] Order N389 of the Ministry of Environmental Protection and Natural Resources of Ukraine as of 20.072009. Access at https://zakon.rada.gov.ua/laws/show/z0767-09#Text

[84] See 48

[85] See 47

[86] See 46

[87] See 49

[88] Order N252 of the Ministry of Environmental Protection and Natural Resources of Ukraine as of 21.07.2022. Access at https://zakon.rada.gov.ua/laws/show/z0900-22#Text

[89] Order N309 of the Ministry of Environmental Protection and Natural Resources of Ukraine as of 19.08.2022. Access at https://zakon.rada.gov.ua/laws/show/z1253-22#Text

AIR

Area includes damage caused by pollutants' emissions into the air.

Main assessment indicators

- Volume of accidental emissions

Methodologies

According to the Methodology[90] [91] approved by the orders of the Ministry of Environmental Protection and Natural Resources of Ukraine upon the recommendation of the State Environmental Inspectorate agreed with the Ministry of Reintegration

State authorities responsible for determining damage and losses

State Environmental Inspectorate

FOREST FUND

Area includes losses and damage caused to forests and forest land plots and related costs.

Main assessment indicators

- Losses of forestry production due to restrictions on land users' rights
- Losses of forest users caused by temporary occupation of land plots, restrictions on their use and unearned income due to temporary land plots' non-use

Methodologies

According to the Methodology[92] approved by the order of the Ministry of Environmental Protection and Natural Resources of Ukraine upon the recommendation of the State Forest Resources Agency of Ukraine agreed with the Ministry of Reintegration

State authorities responsible for determining damage and losses

State Forest Resources Agency of Ukraine

NATURE RESERVE FUND

Deals with losses caused to the territories and objects of the nature reserve fund and related costs.

Main assessment indicators

- Losses caused to nature territories and objects due to their damage or destruction

[90] Order of the Ministry of Energy and Environmental Protection of Ukraine. Access at: https://zakon.rada.gov.ua/laws/show/z0414-20#Text

[91] Order N175 of the Ministry of Environmental Protection and Natural Resources of Ukraine as of 13.04.2022. Access at: https://zakon.rada.gov.ua/laws/show/z0433-22#Text

[92] See 50

Methodologies

According to the Methodologies[93] [94] approved by the order of the Ministry of Environmental Protection and Natural Resources of Ukraine upon the recommendation of the State Environmental Inspectorate agreed with the Ministry of Reintegration

State authorities responsible for determining damage and losses

State Environmental Inspectorate

To meet the requirements of the Procedure, three orders of the Ministry of Environmental Protection and Natural Resources of Ukraine have been registered and entered into force in the Ministry of Justice of Ukraine, in particular:

1. The order N167 "On approval of the Methodology for determining the amount of damage caused to land and soil as a result of emergency situations and/or armed aggression and combat activities during martial law" dated 04.04.2022 has been registered on 11.04.2022 under N406/37742;
2. The order N175 "On approval of the Methodology for calculating unorganized emissions of polluting substances or mixtures of such substances into the air as a result of emergency situations and/or during martial law and determining the amount of caused damage" dated 13.04.2022 has been registered on 16.04.2022 under N433/37769.
3. The order N252 "On the approval of the Methodology for determining losses caused by water pollution and/or clogging and arbitrary use of water resources" dated 21.07.2022 has been registered on 09.08.2022 under N 900/38236.

The methodology for determining damage caused to the natural environment within the territorial sea, exclusive maritime (economic) zone, and internal sea waters of Ukraine in the Azov and Black seas has been approved by the order N309 of the Ministry of Environmental Protection and Natural Resources of Ukraine dated 19.08.2022 and registered in the Ministry of Justice of Ukraine on 17.10.2022 under No. 1253 /38589.

The methodology for determining the damage and losses caused to the territories and objects of the nature reserve fund as a result of the Russian Federation's armed aggression has been approved by order N424 of the Ministry of Environmental Protection and Natural Resources of Ukraine dated 13.10.2022 and registered in the Ministry of Justice of Ukraine on 16.11.2022 under N1416/38752.

[93] Resolution N541 of the Cabinet of Ministers of Ukraine as of 24.07.2013. Access at: https://zakon.rada.gov.ua/laws/show/541-2013-%D0%BF#Text

[94] Order N424 of the Ministry of Environmental Protection and Natural Resources of Ukraine as of 13.10.2022. Access at: https://zakon.rada.gov.ua/laws/show/z1416-22#Text

According to the order N78/1 of the State Environmental Inspectorate of Ukraine as of 15.04.2022, a Working Group has been created at the Operational Headquarters for the development of methodological documents and the procedure for determining damage and calculating losses caused to natural resources and the environment as a result of the Russian Federation's armed aggression[95]. It includes the following subgroups:

- international legislation and practice;
- recording facts, formation of an evidence base;
- air;
- soils, land, waste;
- waters of the seas;
- surface water;
- subsoil, including underground water;
- forest resources;
- nature reserve fund, biological resources;
- radiation.

The Working Group includes more than 60 experts drawn from different areas. The air subgroup is represented by specialists from the "Clean Air for Ukraine" programme.

Information on the results of the activities of the Headquarters operating within the State Environmental Inspectorate of Ukraine is provided by a monthly digest[96] on the official website.

There is also an official website of Headquarters[97] where information on its composition, activities, etc. is provided. The site provides a clear procedure on how to convey information if a person has witnessed an eco crime. It can be done through a phone hotline (Telegram, WhatsApp, Viber), Telegram chatbot, e-mail, or completing an online form. It also specifies what information is needed (indication of the geolocation or exact address of the emergency situation, its brief description (burning, polluting, etc.), indication of the owner or entity (who is the victim, if available)).

The law enforcement agencies involve territorial and interregional territorial bodies of the State Environmental Inspectorate to record information on the damage caused to the environment as a result of Russia's military aggression on the territory of Ukraine, conduct a criminal investigation and carry out the environmental sampling with subsequent relevant instrumental and laboratory measurements.

95 https://www.dei.gov.ua/posts/2222

96 https://www.dei.gov.ua/posts/2226

97 https://shtab.gov.ua/

Based on paragraph 4, subsection 8 of the Regulation on the State Environmental Inspectorate of Ukraine[98] (hereinafter SEI), SEI calculates the amount of damage, costs and losses caused to the environment and natural resources of the state within its competence, as a result of accidents, emergency situations, military aggression, military, terrorist or other criminal acts, including those that have occurred since the beginning of the martial law's legal regime. It is worth noting that the above-mentioned paragraph 4 has been amended according to the Resolution N1111 of the Cabinet of Ministers of Ukraine as of 30.09.2022[99].

Based on paragraph 24, Article 23 of the Law of Ukraine "On the National Police"[100], the national police contribute within their powers to the establishment and implementation of the legal regime measures of martial law or state of emergency, emergency environmental situation if any such measures are declared for the whole territory of Ukraine or in any specific area. Paragraph 41 of the same Article stipulates that the National Police conduct technical and forensic crime scene inspections, including those related to fires, as well as to special explosion works in case of explosions, receiving information on the detection of suspicious explosive objects and threat of explosion.

For most of the incidents that occurred as a result of Russia's armed aggression on the territory of Ukraine, criminal proceedings have been started and pre-trial investigations are being carried out by the Prosecutor's office. Based on Articles 71 and 93 of the Criminal Procedure Code of Ukraine, specialists of territorial and interregional territorial bodies of the SEI are involved in determining the circumstances and the nature of the consequences of the relevant dangerous events.

Costs are mostly calculated for polluting the air by unorganised emissions of pollutants or their mixture during the burning of petroleum products and for the damage caused to the soil by Russia's invasion of the territory of Ukraine[101]. As for the end of October, the territorial and interregional territorial authorities of the SEI assessed losses in the total amount of UAH 1 336 644 459.60 based on the Methodologies in force, including

[98] Resolution N275 of the Cabinet of Ministers of Ukraine as of 19.04.1017. Access at: https://zakon.rada.gov.ua/laws/show/275-2017-%D0%BF?find=1&text=%D0%B2%D0%BE%D1%94%D0%BD#w1_1

[99] Resolution N1111 of the Cabinet of Ministers of Ukraine as of 30.09.2022 Access at: https://zakon.rada.gov.ua/laws/show/580-19#Text

[100] Law of Ukraine N580-VIII as of 02.07.2015. Access at: https://zakon.rada.gov.ua/laws/show/580-19#Text

[101] Letter of SEI N3982/8/12-22 as of 02.08.2022 in response to information request.

- for littering land resources – in the amount of UAH 410 426 731.38;
- for contamination of soils with substances negatively affecting their fertility and other useful properties – in the amount of UAH 2 303 631.36;
- for water pollution and clogging – in the amount of UAH 139 968.65;
- for emissions of pollutants into the air – UAH 923 774 128.20.

EcoZagroza[102] [Ecothreat], being an official resource of the Ministry of Environmental Protection and Natural Resources of Ukraine publishes not only damage estimations calculated by the State Environmental Inspectorate based on the approved methodologies but it also provides statistics of the recorded cases of fuel fires, forest fires, ignition of other objects, soil pollution, land pollution with waste, nature reserve fund objects damage, oil products and poisonous substances spillage in water, etc.

Using this resource, witnesses can report the fact of a crime by filling in the form, choosing the impacted category (air, waste, soil, water, forest, and nature reserve fund) and adding a description and photo-video materials.

The website of the Ministry of Environmental Protection and Natural Resources of Ukraine[103] provides information on environmental monitoring in the area of combat activities, in particular: information on the environment in Donetsk, Luhansk, Zaporizhzhia, Dnipropetrovsk, and Kharkiv oblasts in the second quarter of 2022 based on observational data of hydrometeorological organisations[104]. The above-mentioned information contains data on the levels of radiation, air quality, lakes, and array of surface water.

Every week, the ministry compiles a digest[105] of the key consequences of the Russian aggression on the Ukrainian environment, which provides important statistics in the form of infographics. For example, it provides data on the percentage of the Emerald network territories affected by the full-scale Russian invasion of Ukraine, types of mostly affected ecosystems, and so on.

The information posted on the official pages of the SEI[106] and the Ministry of Environmental Protection and Natural Resources of Ukraine[107] in Facebook social network, Telegram-channel, promptly covering the recent news, sup-

[102] https://ecozagroza.gov.ua/

[103] https://mepr.gov.ua/

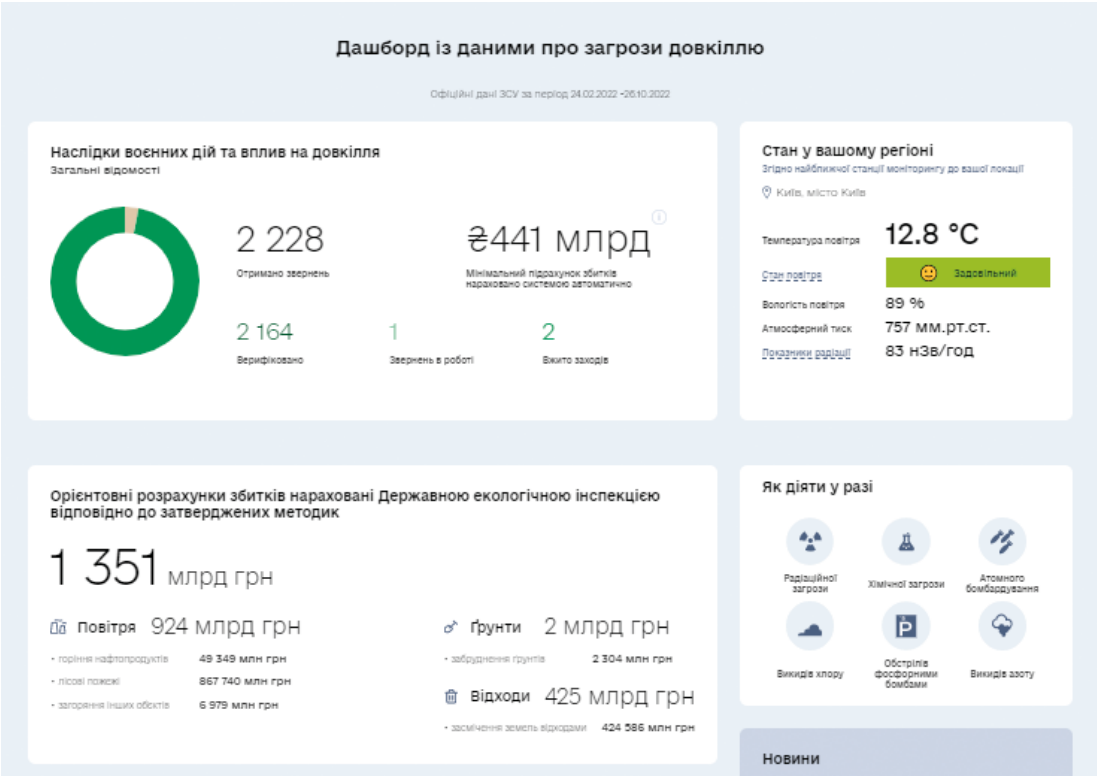
[104] https://mepr.gov.ua/timeline/Ekologichniy-monitoring-v-zoni-ATO.html

[105] https://mepr.gov.ua/search/?s=%D0%B4%D0%B0%D0%B9%D0%B4%D0%B6%D0%B5%D1%81%D1%82

[106] https://www.facebook.com/deiukr

[107] https://www.facebook.com/EnvironmentalofUkraine/

ports the activity of Ukrainian citizens, as well as citizens of other countries in this information field.



EcoZagroza site page: dashboard with data on environmental threats

Examples of infographics on Emerald network

Examples of infographics from the page of the Ministry of Environmental Protection and Natural Resources of Ukraine posted on Facebook social network (https://www.facebook.com/EnvironmentalofUkraine/)

V. War against Ukraine – war against the environment: view of war from the Czech perspective

"There is no such thing as an ecological war"

This chapter presents an additional analysis given by Mr. Myroslav Havranek, an environmental protection expert and Director of the Czech Environmental Information Agency. The research was conducted in parallel with the main research of the team and is an important additional analysis of specific aspects of the war that are important for assessing comprehensively its consequences.

The war started by Russia in 2014, flared up with a new intensity by invasions and massive shelling in February 2022 has been destroying Ukrainian lives, homes, and infrastructure, but also irrevocably affecting the environment.

The goal of this text is not an inventory list of damages caused by the Russian war, but a presentation of important categories of environmental impacts resulting from this war and an operative estimate of their extent about publicly available information. It has to be taken into account that, unfortunately, the "fog of war" still hangs over Ukraine and data cannot at this time be verified independently. Russia releases data and statements that are at best half-truths, but mostly pure fabrications, to keep the Russian population in the dark about what is really happening in Ukraine. Ukraine, although it tries to monitor and quantify the damage caused by the war, is still a party to the conflict, whose main goal is to survive and liberate its occupied territory and therefore, all activities are focused on achieving this goal and little time can be allocated to other tasks which are not focusing on repelling the invader from Ukrainian territory.

Physical damages

Physical damage to the environment is a type of harm that is often underestimated in ordinary environmental impact assessments. The reason is that in the event of an accident or a leakage, the physical damage to the environment is marginal compared to the harm caused by contamination of the site. We are usually concerned only if an infrastructure or specially protected species and habitat are affected. This conflict is exceptional by its scope. This can be

demonstrated for example by the amount of artillery ammunition used. Both, the Russian doctrine and the Ukrainian doctrine, put great importance on field artillery – both conventional and missile.

Each artillery shell fired is an energy flow in the environment, which aims to release energy in the form of an explosion, and this energy subsequently causes (destructive) work in the environment, such as scattering metal fragments, creating an explosion crater, destroying the enemy forces etc. One 155 mm artillery shell will produce an energy flow, depending on the size of the detonator and the explosive charge, in the order of tens of MJ (the author's conservative estimate is 84 MJ). The consumption of this ammunition is a subject for debate, however, estimates published by Western agencies are around 9,000-60,000 artillery and tank shells per day on the Russian side, and according to estimates, for example here[108, 109] Russia has consumed two thirds of its artillery and tank ammunition reserves since the beginning of its invasion of Ukraine.

That is something in the magnitude of 10 million artillery and tank shells out of an estimated stockpile of 17 million. Ukrainian consumption is less commented on by the Western services but estimates range from 4 to 7 thousand shells a day, that is something around two million shells since the beginning of the war. This means that just the consumption of artillery ammunition causes an energy flow the size of a Hiroshima-type nuclear bomb every 14 days of fighting. In other words, the physical destruction of the environment after more than 300 days of fighting could be compared to the effect of 20 Hiroshima-type nuclear bombs.

Obviously, this is a conservative estimate, since we are only talking about field artillery shells, so the actual energy flow will be much higher. Admittedly, the comparison with a nuclear bomb falters on both legs, because fortunately we are not talking about contamination with radioactive substances and this enormous energy flow is dispersed in space and time more than it would be in case of a nuclear bomb, but for an idea of the destructive potential of this energy flow, this comparison is sufficient.

[108] https://news.err.ee/1608800317/edf-intelligence-chief-russia-has-used-up-two-thirds-of-its-ammunition

[109] https://www.defensenews.com/smr/reagan-defense-forum/2022/12/04/russia-burning-through-ammunition-in-ukraine-at-extraordinary-rate/

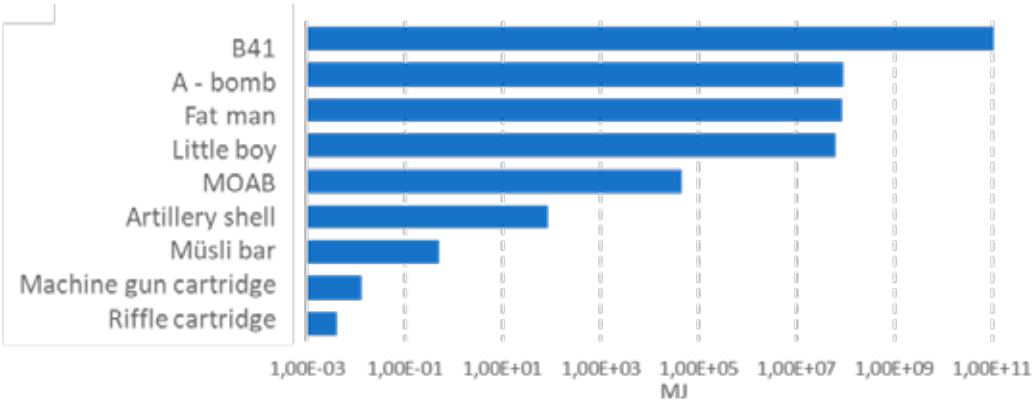


Figure 5.1 – Illustrative energy content of selected carriers (source: Wiki, author's calculations)

Demolition debris

The destruction described in the previous chapter affects the landscape (e.g., destruction of forests, fields covered with craters...) but also through the damage to built-up areas and infrastructure. In addition to the suffering of the population, these destructions produce waste. Ukraine's waste management was not in particularly good condition before the war, but even the most developed countries in the world could not handle the production of demolition waste in such volumes without difficulties. For example, during the tornado in 2021 in the Czech Republic which destroyed four villages in a narrow strip, over two hundred thousand tons of demolition debris and other waste was generated. The destruction of infrastructure in Ukraine is enormous. Conservative estimates based on the collected records[110] reached values of over CZK 3,375 billion (USD 135.9 billion) at the end of November 2022.

The volume of waste generated in this way is not known, but in general the demolition of lower buildings generates around 1-2 tons per m^2 of built-up area[111], in the case of panel houses, the selective demolition, carried out as part of the CEVOOH[112] project, generated for a five-story panel building almost 1,400 tons of debris, of which 11 tons was hazardous waste.

[110] See 56

[111] Salah M. El-Haggar, Chapter 8 – Sustainability of Construction and Demolition Waste Management, Sustainable Industrial Design and Waste Management, Academic Press, 2007, Pages 261-292, ISBN 9780123736239, https://doi.org/10.1016/B978-012373623-9/50010-1.

[112] https://cevooh.cz/#vystupy

If we were to take these reference values and apply them to the numbers in Table 1, we get an estimate of over 60 million tons of demolition waste generated from apartment and residential buildings between February and November 2022. As we are working with very imprecise input data, this is a conservative – lower estimate of this value.

Table 5.1. – Destruction of infrastructure in Ukraine (KSE, Russia will pay project, 11/2022)

Type	Numbers
Family houses	126 700
Apartment buildings and hostels	17 100
Agricultural machinery	84 200
Cars	194 800
Schools	2 918
Medical facilities	1 131
Sports and cultural facilities	1 171

Infrastructure renewal

Destroyed infrastructure does not only burden the environment with debris. The infrastructure fulfilled a certain function, and after or even during the war, it will need to be replaced. This replacement will certainly be made in part by recycling of the demolition waste generated by the war, but a lot of the material will have to be produced again. The manufacturing process for most construction materials is anything but environmentally friendly. The two main building components that Ukraine will need for the recovery are iron/steel and concrete. Both materials are energy-intensive to produce and thus have a large carbon footprint.

Again, we do not have complete input data on what the restoration of Ukraine will include, but even with simplified estimates based on the area of destroyed buildings (approx. 0.3 t CO_2 eq./m^2) and the length of destroyed roads (approx. 65 t CO_2 eq./km of road) we get to emissions in the order of 600 million tons of CO_2 eq. This estimate is based on information available at the end of November and does not consider, the fact that the systematic de-

struction of Ukraine's critical infrastructure and terrorist attacks against the civilian objects began in November. This estimate also does not include the increased consumption of fuels for the movement of material, the extraction of primary raw materials and other factors that will play a significant role in the total sum. Just for comparison, the annual total emission of greenhouse gases in the Czech Republic is approx. 130 million tons of CO_2 eq.

Fuel consumption

Again, we are calculating data which is usually unavailable even during the peacetime. The military's fuel consumption is generally considered to be classified and confidential information. The war against Ukraine is very fuel intensive. The bloggers informing on the war estimated that around 15 million litres of fuel per day is used up for the occupying forces and their air support.

Obviously, this number is again very imprecise, and the consumption will vary depending on the phase of combat operations. But even based on this indicative number, we can estimate that Russia generated from the beginning of the war to the end of 2022 only from the fuel consumption over 12 million tons of CO_2 eq. In the case of Ukraine, we should be more cautious, although the Ukrainian army needs fuel, it is very often at the expense of reduced availability and decreased fuel consumption by the Ukrainian population. This estimate does not consider other emissions from combustion, for example from destroyed fuel depots.

Forest fires

Considering the impact of war on the climate, the fires of vegetation, especially forest, are the perhaps the most significant. According to Copernicus[113] sources, a dramatic increase in number of forest fires has been recorded in Ukraine during the year 2022 compared to the year 2021. For the year 2022, the European Forest Fire Information System (EFFIS) estimates the total burned area at 456,513 ha in areas larger than 30 ha[114], while the Ukrainian side reports over 6.5 million ha of forest damaged by forest fires.

Forest fires increased 77 times compared 2021[115]. Forest fires, in addition to

[113] https://effis.jrc.ec.europa.eu/

[114] The system is not able to capture smaller burnt areas and in the case of Ukraine its results are supplementary to local statistics.

[115] See 104

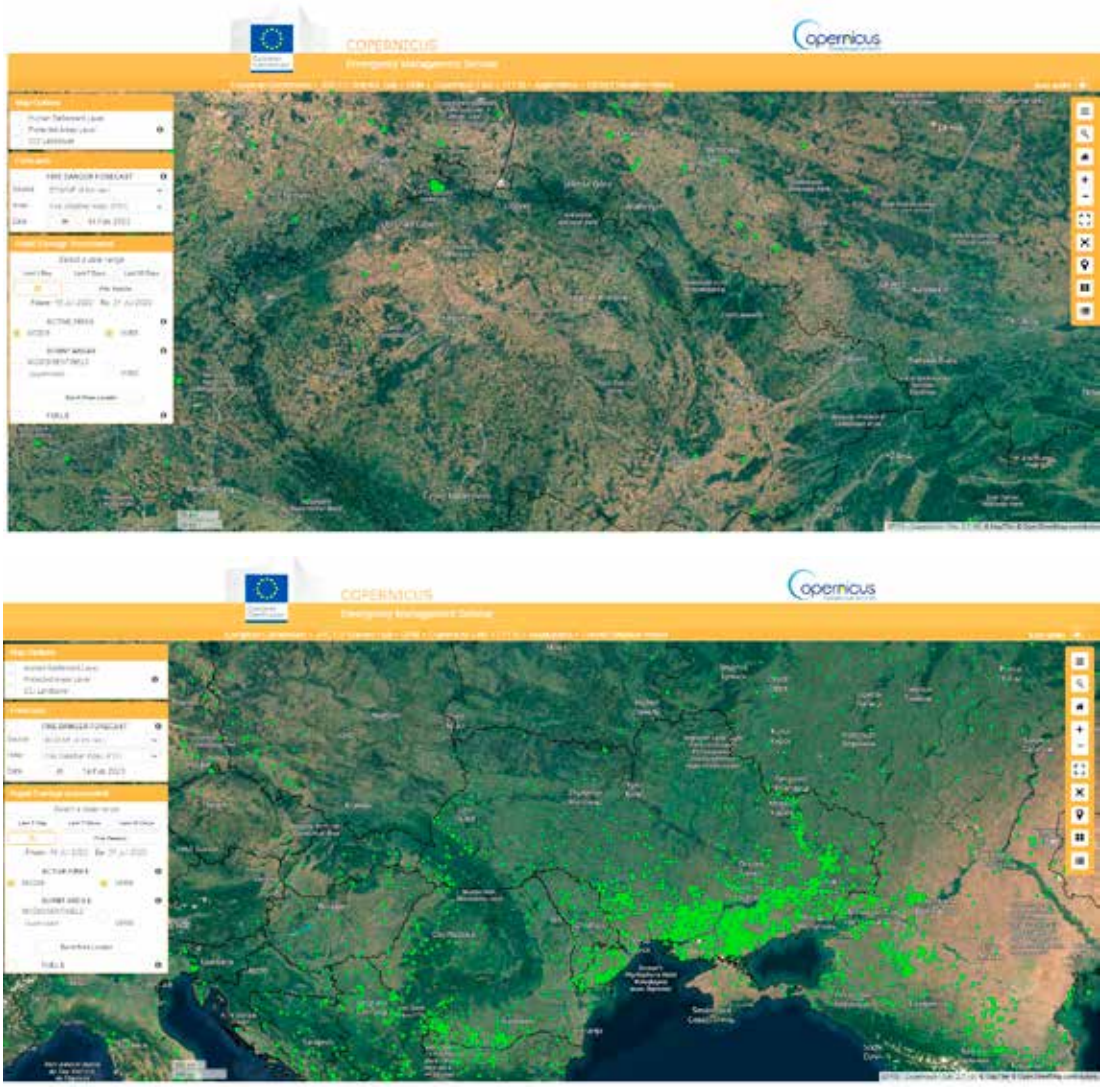


Figure 5.2 – Example of forest fires for July and August 2022, CR and UA (Source: EFFIS, 2023)

the loss of the ecosystems, also activate a large amount of carbon stored there. Figure 2 shows a comparison of last summer's months, when the Czech Republic was dominated by a fire in the České Švýcarsko National Park, and how the situation with the fires in eastern Ukraine looked at that time. Over 70% of all fires in Ukraine in 2022 were related to war activities.

Calculating the total emissions from burned forests is also problematic although there are some estimates of how much carbon a hectare of middle belt forest contains (approx. 37 tons C/ha potential emissions of 135 t/CO_2eq.).

However, the emission depends to which extent is the forest ecosystem destroyed by fire and how much of the accumulated carbon is actually released.

The EFFIS makes an estimation of the released emissions from the recorded fires at 29 million t CO_2 eq. but considering that the system registers less forest fires than the Ukrainian statistics, it is expected that the value will be significantly higher. If we use the values estimated by EFFIS as the basis of the emission factor (i.e. emission flow of 63.5 t CO_2eq./ha) and the area damaged by forest fires from Ukrainian statistics for calculating the total emission from forest fires in Ukraine the final volume could be much higher (over 2 billion t CO_2 eq.).

VI. Conclusions and forecasts regarding the negative impact of war on the environment

The consequences of the impact of combat activities on the environment, can be classified as follows:

1. Direct mass exposure to toxic chemicals released to the environment by use of military equipment, ammunition components, explosives, and rockets fuel;
2. Environmental devastation caused by physical impact of fires, explosions, soil damage, etc.;
3. Destruction of the environment by man-made disasters caused by the shelling of industrial enterprises (mass emissions of ammonia, chlorine, nitric acid, etc.).

Every fired projectile is a mixture of hazardous substances. Depleted uranium and its oxides, mercury compounds, lead compounds, strontium, aluminium, volatile products of organic combustion (nitrogen and sulfur compounds), and many other substances, have a composition that is difficult to identify – all these chemical components will poison biogeocenoses for many years, make significant territories unsuitable for crops and poison many water bodies. A large amount of flooded and buried military equipment and ammunition, which will decompose for hundreds of years and poison ecosystems with metals, oil products, etc. will cause the same impact.

The energy released from rockets and ammunition explosions will have the following consequences:

- leaks of ammonia, chlorine, oil and oil products, acids, and other highly toxic substance that occur due to the destruction of industrial storage tanks for hazardous substances;
- mass emissions of pollutant into the air, surface and underground water, soil caused by the destruction of sewage treatment facilities at industrial enterprises;
- large-scale fires with emissions of dangerous combustion products caused by the burning of oil products and power grid equipment;
- disruption of the hydrological regime of the territories caused by the destruction of hydro-technical structures;

- mechanical destruction of ecosystems caused by the massive shelling of military positions that forms burned-out soil compacted craters. Such territories require hundreds of years to restore their fertility and biodiversity.

Any war causes the mass death of people and animals. Due to active combat activities, a significant number of the deceased are left unburied for a long time or buried at small depths. A similar situation is observed in the front-line settlements that have been completely destroyed by Russian troops, for example, in the city of Mariupol. People are often buried in the streets, and animals die and remain unburied at the destroyed farms. All this complicates the epidemiological situation in large areas and provokes the spread of viruses and bacterial diseases. Contamination of soil, surface, and underground water with organic substances in the places of decomposition of human and animal bodies is also reported to take place.

All these consequences require a detailed survey to be carried out in the de-occupied territories and in the places of combat activities. As of October 2022, active combat activities in Ukraine have been conducted on the territory of about 1300 km of the front line, significantly covering agricultural lands: fields, protective forest belts, pastures, and farm territories. That is why food security becomes an important issue in the future. Significant territories will lose their fertility, and agricultural crops will be accumulating heavy metals and other dangerous substances brought by combat activities into the soil and groundwater. Livestock fodder bases will also be poisoned. Surface water, which is also used to provide the population with drinking water, will require deep chemical treatment. Following the end of combat activities, each separate plot of land will require the development of a plan for its recultivation, and each individual body of water, where a lot of equipment and bodies have been flooded, will have to be cleaned to acceptable sanitary standards. Large man-made disasters resulted in leaks of oil, ammonia, and chlorine, and significant environmental pollution with polychlorinated biphenyls (PCBs) and dioxins due to the burning of electrical equipment will require the development of a set of actions for cleaning and restoring the affected areas. Shallow mass burials of people and animals will need to be exhumed, disinfected, and reburied according to sanitary standards. To summarise, there is a need to provide a comprehensive assessment of the environmental state after the end of the war and develop a general plan for the restoration of the natural state of damaged territories as well as special projects for the decontamination of the polluted territories.

The study examines the impact of the Russian war in Ukraine with a focus on the environment but in connection with other areas of human life. There-

fore, its last part is devoted to questions that have not been answered today. These are important questions for Ukraine of the future. We should start looking for the answers to these questions together now.

The authors of the study are consistent supporters of the Concept of sustainable development and "a green economy" and have repeatedly investigated and raised the issue of Ukraine's transition to this development model[116]. Let's explore/look into the most important areas necessary for the country's sustainable transition.

Economy

Modern economic model of Ukraine still has a lot to do with the Soviet occupation. It refers primarily to the energy, mining, processing, and chemical industries. These sectors are characterised by high energy and material intensity, high waste and a significant impact on the environment and human health[117]. The war has already caused enormous destruction of the facilities of these industries. At this point, it is impossible to forecast the final consequences. One of the crucial issues for the future of Ukraine is its economic specialisation and development priorities. Very soon the country will need economic restoration and restart. The easiest way to do it is to rebuild all the destroyed facilities without changing their structure, and leaving the main economic sectors unchanged. However, the precondition for the mid- and long-term success of the country is possessing its place in the modern world economic model, in compliance with the industry 5.0 and the post-industrial economy. Ukraine has sufficient natural potential and reserves of many mineral resources to form the various branches of the economy and the full cycle of production of various products.

Energy

Energy is regarded to be one of the driving forces of economic development. Russia's large reserves of fossil fuels, such as natural gas and oil, have enabled

[116] П.В. Хазан, О.В. Ангурець, О.М. Скакальский. Впровадження "зеленої економіки" в Дніпропетровській області. Рекомендації для влади. [Implementation of "green economy" in Dnipropetrovsk oblast. Recommendation for authorities]. Дніпро. 2017 р.

[117] О.В. Ангурець, П.В. Хазан Впровадження корпоративної соціальної відповідальності на підприємствах гірничовидобувної промисловості умова сталого функціонування території. [The introduction of corporate social responsibility at mining enterprises is a condition for the sustainable functioning of the territory]. Дніпро 2013р.

this country to get significant financial revenues in recent decades. Thus, the dictatorship of Putin's regime has managed to not only allocate large funds for military needs but financed the corruption in political and business circles abroad, in particular in Ukraine. Based on this, we can talk about the contribution of fossil fuels not only to climate change and environmental pollution but also to the global political crisis. It should also be taken into account that Putin's regime is not the only dictatorship existing due to natural reserves of energy resources. This should be a warning for the future.

The war in Ukraine has demonstrated the importance of country energy supply in modern armed conflicts. Right now, the Russians are actively destroying Ukraine's energy infrastructure, trying to leave the country without light and heat in winter. To some extent these intentions have succeeded, demonstrating the vulnerability of the existing energy system while facing the challenges of modern warfare. The use of renewable energy sources should counter this threat. Starting from the autonomous use of solar and wind energy to meet the needs of individual households, communities, and small settlements, combined with maximum energy efficiency approaches for buildings. The principles of such a model for Dnipropetrovsk oblast are provided in the Strategy for Energy Saving, Energy Efficiency and Development of Renewable Energy Sources of the Dnipropetrovsk Oblast for 2018–2035[118]. It is a distributed energy supply to communities provided by practically infinite resources of renewable energy sources that would prevent large areas from blackouts caused by shelling.

Obviously, large industrial energy-intensive facilities could not be completely provided by energy in this way, but the population and small businesses could become largely energy independent.

At the same time, the war has returned coal energy as a part of the Ukraine energy strategy agenda enhancing the importance of nuclear energy. After victory, an extensive professional discussion with involvement of the society should be initiated to tackle the following issue: what kind of energy should be developed in Ukraine and how to combine environmental security with energy security to ensure its maximum sustainability under conditions of potential hostile actions aimed at destroying the infrastructure of electricity generation and transmission.

[118] Strategy for Energy Saving, Energy Efficiency and Development of Renewable Energy Sources of the Dnipropetrovsk Oblast for 2018-2035. Access at: https://oblrada.dp.gov.ua/rishennia/sklikannia-7/xi-sesiya/%E2%84%96-275-11vi%D1%96-01-12-2017/

Urban Development

The current population of Ukraine is predominantly urban. Approximately 69% of the population live in cities and towns[119].

One of the features of this war is a massive destruction of urban, energy and industrial infrastructures (which is usually a part of urban agglomerations) by troops of the Russian federation. The ecological consequences of such actions have been discussed above. It is obvious that a significant number of Ukrainian cities will require partial, and in some cases, almost complete reconstruction. Most Ukrainian cities and their infrastructure were built after the end of the Second World War from the second half of the 40s until the 60s of the 20th century. This building-up was based on the economic and political paradigm of the USSR, orientated to a cold war and confrontation with the West, including nuclear war. An essential part of the economy and construction focused on the development of the military-industrial complex and its support. All this determined the logic of cities and key infrastructure construction in Ukraine. A good example is the agglomeration of the city of Dnipro, where the Pivdennyi Machine-Building Plant became the pinnacle of the industrial complex, being the main producer of Soviet rockets built on an extensive base of energy, mining, and chemical industries.

Post-war Ukraine will face an important question: what principles of modern urbanism will be laid down when planning the reconstruction of cities and how to combine them with the need to ensure safety for residents? Currently, we cannot predict the type of relationship between Ukraine and Russia or the state entities that will emerge on its territory after the end of the war. However, we can predict that the threat to Ukraine security from the east will exist for a long time. This threat will affect most areas of our lives, including the cities' reconstruction and development. We have already heard about the obligatory availability of bomb shelters in new buildings[120] and the construction of sites protecting against rocket attacks and bombings in places where people gather (public transport stops, etc.).

Environmental monitoring can take on the additional function of determining dangerous substances in air, water, soil, and radiation caused by combat activities and become a component of civil defence.

The location of industrial facilities having a production cycle that includes hazardous substances or leads to the formation of hazardous waste, within the city limits or near them, creates not only a man-made but also a military

[119] https://www.worldometers.info/world-population/population-by-country/

[120] Law of Ukraine N 2486-IX as of 29.07.2022. Access at: https://zakon.rada.gov.ua/laws/show/2486-IX#Text

threat. This threat should be considered while constructing new facilities and restoring the damaged and destroyed ones.

The new existence conditions of Ukraine require that all strategic documents, including general plans for city development, be created and adjusted taking into account potential military activities and the necessity to create maximum security for citizens.

It is worth noting that the war consequences will affect not only Ukraine. It is obvious that the biggest war in Europe since the Second World War has already become the cause of global militarization. Further, these trends will only intensify. This means an additional environmental burden on the entire planet and a weakening of priorities of environmental goals for a significant number of countries – a serious challenge for all humanity under the conditions of the existing climate and some other global problems for the biosphere.

Summarising, we would like to note that Russia's invasion of Ukraine vividly showed the unjustified price of war in the modern world and the significant risks of large-scale man-made disasters for the environment and millions of people.

The example of the war's environmental consequences in Ukraine should be a warning for the future and help to develop a new system of global security, which should cover not only humanity but the biosphere as well.

Authors profiles

Olexiy Angurets is Head of NGO "Green World, Friends of the Earth", an author and a founder of the environmental monitoring system in Dnipropetrovsk oblast, Member of the Dnipropetrovsk Regional Council of the VII convocation (2017 – 2020), Deputy Chair of the Regional council of the executive apparatus – Head of the Department for Ecology, Energy Efficiency and Green Economy of the Dnipropetrovsk Regional Council (2019 – 2021). One of the authors of Dnipropetrovsk Oblast Comprehensive Program for Environmental Safety and Climate Change Prevention, the Strategy for Energy Saving, Energy Efficiency and Development of Renewable Energy Sources of Dnipropetrovsk Oblast.

A member of the executive committee of Friends of the Earth Europe (2015-2016). Coordinator and consultant of more than 15 national and international environmental programs. An author and co-author of more than 50 scientific and popular publications in the field of ecology, sustainable development, green economy, and biological safety. Awarded a commemorative medal "For a significant contribution to the development of the Dnipropetrovsk region".

Pavlo Khazan, PhD, is an officer of the Armed Forces of Ukraine, and a veteran of the Russian war in Ukraine since 2014. In 1996, he graduated from the Dnipro National University in physics and electrical engineering. From 1996 to 2015, he was engaged in the research in the field of mathematical modelling, environmental protection and energy at the Institute of Ecology of the National Academy of Sciences of Ukraine. He is a fellow of the "Wider Europe" program of the John Smith Trust in the UK (2008), he is an author and founder of the environmental monitoring system. Pavlo is an expert in energy, ecology and green economy projects, cooperated with the British Council, Deutsche Gesellschaft für Internationale Zusammenarbeit and UNDP, a member of the

Executive Committee of Friends of the Earth Europe, a Ukrainian representative in the European Green Party, worked on the preparation of the program documents in the European Parliament in cooperation with The Greens/EFA faction. A member of the environmental movement since 1991, he managed public programs and campaigns, including against shale gas in Ukraine in cooperation with Milieudefensie. He is an author of a number of articles in the field of ecology and electrical engineering in the civil and military spheres, 34 scientific works and more than 100 other publications in the field of sustainable development, environmental engineering, renewable energy, economics and statistics, co-author of 4 regional strategies and programs, in particular, Dnipropetrovsk Oblast Comprehensive Program for Environmental Safety and Climate Change Prevention, the Strategy for Energy Saving, Energy Efficiency and Development of Renewable Energy Sources of Dnipropetrovsk Oblast.

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Maksym Kushch, graduated with MSc in Biology from Oles Honchar Dnipro National University in 2015, a member of the public organization "Green World – Friends of the Earth", a serviceman in the Armed Forces of Ukraine (since 2019).

Marcela Černochová, MBE, is a coordinator of the Czech-Ukrainian long-term campaign Clean Air For Ukraine, implemented by the Czech NGO Arnika. She has more than 20 years' experience in the non-profit sector. She worked as a director of an organisation devoted to wildlife conservation, the Czech Otter Foundation and Třeboň Wildlife Rescue Centre, being still involved as Member of the Executive Board. She worked at the Ministry for Regional Development for five years focusing on the implementation of regionally targeted development programmes and coordinating the Smart Administration projects and strategic management within the framework of the Ministry. For almost nine years she managed the British Chamber of Commerce in the Czech Republic, which was awarded the Best British Chamber of Commerce in Europe in 2017. In 2022, she was acknowledge for her services and was appointed as Member of the Most Excellent Order of the British Empire (MBE). She participated at a number of international missions, including one-year humanitarian mission to Haiti (2012); managed several international research and conservation project.

Miroslav Havránek, Director of the Czech Environmental Information Agency. He graduated from Charles University in the subject Environmental protection. He worked as a researcher and project team leader at the Center for Environmental Issues of Charles University. Here he specialized in the assessment of interactions between human society and the environment, with reference to climate change, waste and energy. In recent years, he has developed the methods and use of strategic planning and foresight in the field of the environment. Regularly publishes in media and scientific journals and presents at international conferences. Since 2018, he has been managing the Czech Environmental Information Agency.