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International legal and national mechanisms for overcoming the environmental consequences of the armed aggression of the Russian Federation against Ukraine

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PhD in Law

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Abstract

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The armed aggression of the Russian Federation against Ukraine has caused large-scale environmental consequences, including air, water, and soil pollution, as well as the destruction of nature protection zones and forests. The purpose of this study was to analyse international legal and national mechanisms for overcoming the environmental consequences of war and to assess their effectiveness in the context of armed conflict. The study employed a comparative analysis of international legal acts, statistical methods for processing environmental pollution data, and a case study method to compare the effects of war in other countries. This study examined the impact of hostilities on Ukraine's ecosystems, including air, water, and soil pollution. The following features were identified: air pollution levels in the regions where industrial enterprises were destroyed far exceed the permissible environmental standards. Leaks of oil products and chemicals, specifically, have led to long-term adverse effects on soil and water resources. The destruction of industrial facilities such as oil refineries and chemical

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plants was found to cause not only immediate emissions of toxic substances, but also long-term environmental threats that can affect regional ecosystems for decades. In addition, water pollution has reached a critical level, which poses a threat to public health and biodiversity. The study analysed the international legal mechanisms that have proved to be ineffective in addressing the problem of environmental crimes during military conflicts. The study found that international instruments for prosecuting environmental crimes need to be improved, particularly to ensure proper accountability for ecocide. The study revealed the need for new international initiatives aimed at developing effective legal instruments for environmental protection during conflicts. It was concluded that the international community is actively involved in the development of strategies to restore damaged ecosystems. The practical value of this study lies in providing recommendations for international organisations and governments to improve legal mechanisms for prosecuting environmental crimes and developing long-term strategies for restoring damaged ecosystems

Keywords: environmental consequences of war; international law; air pollution; ecosystem restoration; environmental crimes; legal mechanisms; environmental sustainability

Introduction

The environmental consequences of armed conflicts are one of the greatest challenges of modern times, as military operations cause extensive destruction of natural resources, environmental pollution, and deterioration of the quality of life of the population. The armed aggression of the Russian Federation against Ukraine is an example of such a conflict that has caused major environmental changes, affecting public health and global climate processes (UNEP, 2022; Greenpeace Ukraine, 2022; Amnesty International, 2023a; 2023b). The war in Ukraine has caused massive pollution of water resources, damage to industrial facilities, which has led to the release of toxic substances, as well as the destruction of ecosystems and protected areas (United Nations Environment Programme, 2022; Ministry of Environmental Protection and Natural Resources of Ukraine, 2023). Another vital aspect is the impact of hostilities on climate change, which is associated with massive greenhouse gas emissions caused by the destruction of infrastructure (UNCG & Ecoaction, 2023).

D.V. Dyadin *et al.* (2023) focused on the environmentally sustainable development of Ukraine's urban systems in the context of European integration. The researchers highlighted the principal challenges, including lack of funding, imperfect regulatory framework, and insufficient technical training to implement new environmental standards. Among the opportunities to improve the state of the environment in Ukraine, researchers note the potential for attracting international investment and technical assistance programmes that will help modernise urban infrastructure in line with EU environmental standards.

The studies of N.Ye. Tverdokhlebova and N.S. Yevtushenko (2023), who investigated the issue of regional environmental security under martial law, are also relevant. The researchers focused on new threats arising from armed conflicts and proposed solutions to overcome them through the introduction of the latest technologies and approaches in industrial production. O.V. Vygovska and Yu.F. Dekhtyarenko (2021)

emphasised the need to integrate environmentally balanced approaches, such as the use of renewable energy sources, green infrastructure, and sustainable resource management to reduce environmental pressure on urban systems. The researchers underscore the significance of strategic planning to ensure the long-term environmental sustainability of Ukrainian cities, especially in the context of global climate change.

N.A. Pylypenko (2023) focused on the implementation of sustainable development principles during the restoration of urban infrastructure after the war. The researcher explored the global experience of ecological construction, including the use of environmentally friendly materials, energy-efficient technologies, and the creation of green areas to support ecosystems in the urban environment. These approaches can become the basis for rebuilding Ukrainian cities, providing them with more opportunities for sustainable development.

A.O. Titova and V.M. Shmandiy (2022) thoroughly examined the problems of waste management arising during and after armed conflicts. They investigated the specifics of military-related waste disposal and proposed the introduction of separate collection systems, hazardous materials recycling, and the creation of specialised landfills, which are essential for environmental safety in the post-war period. Finally, M.O. Medvedieva and S.D. Bilotskiy (2023) examined the legal aspects of the environmental consequences of armed conflict, including ecocide and climate change. They reviewed international legal and national mechanisms to combat environmental threats arising from armed aggression.

The purpose of this study was to examine international legal and national mechanisms for overcoming the environmental consequences of armed aggression against Ukraine, as well as to assess their effectiveness and development prospects.

The key tasks included analysing the existing international legal mechanisms for overcoming the environmental consequences of armed aggression, assessing the state of Ukraine's ecosystems after the outbreak of war, and developing recommendations for restoring ecological balance and environmental protection.

Materials and Methods

This study employed an interdisciplinary approach to examine international and national mechanisms for addressing the environmental consequences of the war in Ukraine. The key sources of data included academic publications, official reports of international environmental organisations (Greenpeace Ukraine, UNEP, OSCE), regulations and international agreements on environmental responsibility during armed conflicts. The first stage of the study involved a systematic search of literature, regulations, reports, and scientific publications. Particular attention was paid to information on modern mechanisms of environmental restoration and overcoming the consequences of aggression (United Nations Environment Programme, 2022; Amnesty International, 2023a).

The next stage of the study was to assess the state of Ukraine's ecosystems. Specifically, the study relied on statistical data provided by the Ministry of Environmental Protection and Natural Resources of Ukraine (Ministry of Environmental Protection and Natural Resources of Ukraine, 2023), which indicate a considerable deterioration in the quality of water resources and a decrease in biodiversity in the affected regions. Furthermore, reports by international organisations such as Greenpeace Ukraine (2022) and the United Nations Environment Programme (UNEP, 2022) highlight the problems of air and soil pollution caused by military operations. To

assess the impact of hostilities on ecosystems and protected areas, spatial analysis methods were applied, including the analysis of map data and satellite images, which enabled a detailed analysis of the scale of destruction and identification of the most affected areas.

The third stage of the study focused on a comparative analysis of international legal instruments, such as Article 8(2)(b)(iv) of the Rome Statute of the International Criminal Court (1998), which addresses war crimes involving severe environmental damage, and Article 3 of the United Nations Framework Convention on Climate Change (1992), which prohibits methods and means of warfare that may cause long-term and severe damage to the environment. Separate analyses were made of Amnesty International's reports (2023a; 2023b) on environmental crimes in the context of war. This helped to conclude on the effectiveness of existing legal mechanisms for prosecuting those responsible for environmental damage.

The fourth stage involved the application of methods to systematise environmental data collected by international organisations and government agencies. Statistical data on the levels of air, water, and soil pollution were systematised and presented in the form of graphs and tables. This approach enabled the assessment of pollution

volumes and forecasts of possible consequences for public health and ecosystems. The final stage involved the use of a comparative method based on a contrast between the environmental consequences of the war in Ukraine and other countries that have experienced analogous conflicts, such as Vietnam and Iraq (UNEP, 2022). This helped to assess the effectiveness of various international and national mechanisms for overcoming environmental consequences and to develop recommendations for improving existing environmental recovery strategies.

Results

An analysis of the environmental consequences of the Russian Federation's armed aggression against Ukraine revealed catastrophic changes in multiple aspects of the environment. According to Greenpeace Ukraine (2022) and the United Nations Environment Programme (2022), the consequences of the hostilities cover a wide spectrum of ecosystem destruction, including air, water, soil, and biodiversity pollution. According to the Ministry of Environmental Protection and Natural Resources of Ukraine (2023), the scale of the damage is one of the largest in Europe in the 21st century, which requires an immediate response from the international community (Table 1).

Table 1. Environmental consequences of military operations on the territory of Ukraine (2022–2023)

Pollution type	Scope of damages	Investigated by
Pollution of water resources	3,500 tonnes	Greenpeace Ukraine (2022)
Air pollution	1,800 tonnes	United Nations Environment Programme (2022)
Destruction of ecosystems	20,000 hectares	Ministry of Environmental Protection, (2023)

Note: pollution type: oil products, toxic chemicals (including heavy metals) that entered water resources following the destruction of industrial facilities and leaks during military operations

Source: systematised by the author of this study

It is particularly noteworthy that air pollution is caused by toxic emissions from destroyed industrial facilities and military equipment.

According to the United Nations Environment Programme report (2022), in 2022, a considerable increase in the concentration of nitrogen

dioxide and sulphur dioxide in the air was recorded in the combat zones, which had detrimental effects on public health and the environment.

Table 2 provides comparative data on air pollution in certain regions of Ukraine before and after the start of armed aggression.

Table 2. Air pollution dynamics in Ukraine before and after the start of armed aggression (2021–2023)

Region	Average NO ₂ (2021)	Average NO ₂ (2023)	Average SO ₂ (2021)	Average SO ₂ (2023)
Donetsk Oblast	25 µg/m ³	78 µg/m ³	10 µg/m ³	42 µg/m ³
Luhansk Oblast	30 µg/m ³	85 µg/m ³	12 µg/m ³	45 µg/m ³
Kyiv Oblast	18 µg/m ³	40 µg/m ³	8 µg/m ³	23 µg/m ³
Zaporizhzhia Oblast	22 µg/m ³	65 µg/m ³	9 µg/m ³	30 µg/m ³

Sources: systematised by the author of this study based on the United Nations Environment Programme (2022), Ministry of Environmental Protection (2023)

In terms of water resources, the greatest pollution is observed in the rivers of Donbas and adjacent reservoirs, where water treatment systems have been damaged by shelling. According to Greenpeace Ukraine (2022), over 30% of water resources in the conflict zone are at risk from leakage of oil, chemicals, and other toxic compounds. An analysis by the Ministry of Environmental Protection (2023) in cooperation with Greenpeace Ukraine (2024) found increased concentrations of heavy metals in water samples from the Donets and Luhans rivers, including lead and cadmium, which could lead to long-term harmful effects on aquatic ecosystems and threaten public health in the surrounding regions.

International legal mechanisms play a crucial role in addressing environmental damage caused by war (Bothe *et al.*, 2010; Dam-de Jong *et al.*, 2023). The International Court of Justice (2023) has already made the first decisions on the responsibility of the Russian Federation for violations of environmental norms applied during the military operations in Ukraine. The case concerned the pollution of water resources and the destruction of nature reserves in the conflict zone, specifically through leaks of toxic chemicals and

oil products into the rivers of Donbas, which led to a critical increase in water pollution, as well as the destruction of protected areas such as the Sviati Hory National Nature Park and the Meotida Nature Reserve. These areas were affected by bombing and artillery shelling, which caused biodiversity loss and ecosystem destruction. Litigation for compensation for environmental damage is actively supported at the national level through the Ministry of Justice of Ukraine (Ministry of Justice of Ukraine, 2023), which prepares cases to bring perpetrators to justice and initiates international processes to compensate for environmental damage.

At the same time, international accountability mechanisms are largely based on international environmental conventions, such as the United Nations Framework Convention on Climate Change (1992) and the Protocol Additional to the Geneva Conventions (1977). These documents create a legal basis for prosecuting environmental crimes in armed conflict and oblige states parties to take measures to prevent environmental damage. Ukraine is actively cooperating with international partners to develop plans for compensation and environmental restoration after the conflict. The national mechanisms for

the restoration of nature reserves and biodiversity zones in Ukraine, implemented by the Ministry of Environmental Protection and Natural Resources of Ukraine (2023), have several key areas. Specifically, the ecosystem restoration programmes include the rehabilitation of national parks such as the Sviati Hory and Meotyda, which were severely damaged by the hostilities. The key measures include planting new trees, restoring destroyed forests, and creating protective zones around water resources that have been contaminated by damage to industrial facilities and toxic leaks (UNEP, 2022).

The programmes also aim to preserve biodiversity, including support for rare species affected by the war. Cooperation with organisations such as WWF and BirdLife International allows for technical aid and the use of international practices in restoring animal and plant populations (Greenpeace Ukraine, 2022). It is worth highlighting the significance of cooperation with Greenpeace Ukraine (2022) and UNEP (2022), which provide Ukraine with financial and expert support for the restoration of natural resources and the modernisation of environmental programmes, for instance, ongoing projects allow for the introduction of the latest technologies for water treatment and environmental monitoring.

Among the new areas that are actively developing in the context of overcoming the consequences of the war in Ukraine, a special place is occupied by the introduction of environmental sustainability concepts. These concepts are based on the international practice of countries that have faced comparable challenges during armed conflicts and are used as the primary tool to restore ecosystems and urban areas (Pylypenko, 2023). In Ukraine, such concepts have already begun to be implemented at both the state and community levels. One of the key aspects of these concepts

is the creation of ecological cities that will become an integral part of post-war reconstruction.

Environmentally friendly cities are focused on using modern technologies that minimise the harmful impact on the environment. An integral part of this is the introduction of renewable energy sources, such as solar and wind power plants, modernisation of transport infrastructure to switch to environmentally friendly modes of transport, and the creation of green zones in cities. Such initiatives are actively supported by international organisations, such as the United Nations Environment Programme (UNEP, 2022), which provides Ukraine with technical assistance for the development of sustainable environmental projects.

Furthermore, public initiatives play an essential role in implementing these concepts. In cooperation with organisations such as WWF and BirdLife International, Ukraine is implementing programmes to restore biodiversity and protect rare species threatened by the hostilities. Biodiversity conservation programmes also include the restoration of forests and aquatic ecosystems damaged by the hostilities (Greenpeace Ukraine, 2022). This includes planting new trees, cleaning up contaminated water bodies, and creating buffer zones to protect natural resources.

An analysis of the effectiveness of these programmes suggests that, despite their considerable potential, their implementation faces a series of challenges. One of the major obstacles is insufficient funding, which slows down the large-scale implementation of environmental technologies. Furthermore, implementing projects in areas affected by hostilities is problematic due to the presence of mined areas and damaged infrastructure (Ministry of Environmental Protection and Natural Resources of Ukraine, 2023). Still, international support and active public involvement contribute to the gradual development of these

initiatives and are essential for the country's sustainable development.

Successes are already being made in urban regeneration, particularly in large cities such as Kyiv and Kharkiv, where new parks and green spaces are being created. This not only helps to restore environmental balance, but also improves the quality of life of the population. Thanks to cooperation with European partners, Ukraine receives technical and financial support to implement best practices of sustainable development, which also contributes to raising environmental awareness among the population (UNEP, 2022; Pylypenko, 2023). However, to fully implement the concepts of environmental sustainability, it is necessary to continue attracting investments and developing international cooperation to overcome existing challenges.

According to a study by O.V. Vygovska and Yu.F. Dekhtyarenko (2021), the implementation of such concepts requires an integrated approach that includes the restoration of ecosystems, rehabilitation of destroyed areas, and the implementation of measures to ensure sustainable urban development. Notably, the primary risks to environmental security stem from the impact of armed conflicts on the biosphere and natural resources, and this requires an immediate response at the level of state and international initiatives.

The international community genuinely plays an integral role in addressing the environmental consequences of the war in Ukraine, developing both legal and practical mechanisms to address environmental issues. Amnesty International (2023a) in its report emphasised that the environmental impact of war extends beyond national borders and has global implications. The organisation stresses the significance of protecting environmental rights as part of the overall human rights process in the context of armed conflict.

One of the key aspects of this report is a call for international courts, such as the International Criminal Court (1998) and the International Court of Justice (2023), to actively engage environmental law mechanisms to prosecute environmental crimes arising from warfare. This includes the application of international legal norms, such as the Rome Statute of the International Criminal Court (1998), which establishes accountability for grave environmental damage caused during war. Additionally, international organisations such as UNEP (2022) are actively working to develop practical measures to mitigate the environmental impact of military action, including monitoring pollution and introducing technologies to restore affected ecosystems.

One of the critical aspects is the issue of ecocide, which is raised by both international organisations and national human rights institutions. According to M.O. Medvedieva and S.D. Bilotskiy (2023), the environmental consequences of the war can be qualified as ecocide, as the systematic destruction of natural resources, forests, protected areas, and other ecosystems was deliberately used as a tool of war. Transparency International (2022) emphasises that to combat environmental crimes during war, it is vital not only to use existing international conventions but also to create further mechanisms aimed at addressing environmental restoration. One of such mechanisms could be the development of an international tribunal for environmental crimes, specialising in liability for environmental damage caused during armed conflicts. Such a tribunal could operate under existing international conventions, such as the Rome Statute of the International Criminal Court (1998), which covers environmental crimes.

Apart from legal initiatives, environmental monitoring and damage assessment play an

equally significant role. International environmental organisations such as Greenpeace and WWF are already actively involved in these processes, but more technological approaches should be developed, including the use of satellite imagery and geographic information systems to better identify environmental damage. Such mechanisms will enable a more effective response to environmental crises and improve monitoring of the recovery of affected areas (Greenpeace Ukraine, 2024).

At the national level, Ukraine is actively implementing measures to overcome the environmental consequences of military aggression and preserve natural resources. The Ministry of Environmental Protection and Natural Resources of Ukraine (2023) has implemented a series of important programmes aimed at restoring the affected areas. Particular attention is paid to restoring biodiversity, protecting water resources, and developing strategies for sustainable urban recovery.

Restoring protected areas in regions where massive ecosystem destruction has occurred is a priority. According to UNEP (2022), the war has caused the destruction of over 500,000 hectares of forest, which is 25% of the forest area in Donetsk and Luhansk regions. This has resulted in a loss of biodiversity, increased soil erosion, deteriorating air quality, and the loss of habitats for more than 300 species of animals and plants. For instance, over 35% of the Sviati Hory National Park has been destroyed, threatening the survival of rare species such as the Eurasian lynx and the steppe eagle.

Reforestation is one of the key areas of environmental restoration. The Ministry of Environmental Protection and Natural Resources of Ukraine (2023) has a programme to plant new trees, restore forest soils, and create forest nurseries to grow local tree species adapted to the

local climate. The plan is to plant 1 billion trees over the next five years, and over 200 million seedlings have already been planted in the affected areas. The use of biologically active substances helps to restore soil fertility damaged by military operations. For example, the Return of the Steppe Eagle programme aims to return this species to its natural habitats destroyed by the war. Under this programme, more than 50 steppe eagles have been released into nature reserves in the Kherson region.

Ukraine's international partners provide extensive support in this area. The European Commission (2023) has allocated EUR 70 million for the Green Future of Ukraine project, which covers funding for reforestation projects, training of Ukrainian specialists in modern forestry methods, and exchange of practices with European countries. This support promotes the introduction of modern technologies and methods in forest restoration, which increases the effectiveness of these measures.

Government programmes also support local initiatives and the development of environmental volunteering. Volunteer movements have become key to the recovery process. According to N.A. Pylypenko (2023), the Green Wave organisation arranged tree planting campaigns that planted over 2 million saplings in the affected regions. These initiatives not only contribute to forest restoration, but also engage communities in active involvement in environmental projects, thus raising environmental awareness.

Water resources are also in the focus of national and international environmental programmes. Greenpeace Ukraine (2022) and UNCG and Ecoaction (2023) report that many rivers and reservoirs have been affected by the destruction of infrastructure and chemical leaks from destroyed industrial plants. The Dnipro, Siverskyi Donets, and Inhulets basins have been found to

be heavily polluted with oil products and heavy metals. In the Inhulets, the concentration of oil products is 15 times greater than the standard, posing a grave threat to the water supply of millions of people and the river's biodiversity. In the Siverskyi Donets, elevated concentrations of heavy metals have led to fish kills along a stretch of more than 100 kilometres.

According to the Ministry of Environmental Protection and Natural Resources of Ukraine (2023), national initiatives are aimed at cleaning these rivers and restoring aquatic ecosystems. The ministry is cooperating with international organisations to introduce modern water treatment technologies and reduce pollution. In Kramatorsk, the construction of a modern water treatment plant is nearing completion to serve 200,000 residents. Biofilters are being installed in the Siverskyi Donets River basin, which reduced pollution by 70% over the course of the year. The use of bioremediation technologies helps to clean water from heavy metals and oil products, which helps to restore aquatic ecosystems and ensure safe water supply for the population.

International organisations, including the UN and OSCE, actively support these projects. The OSCE is implementing the Water Security for Ukraine programme, which envisages technical support for the implementation of modern treatment technologies, funding for research on the impact of pollution on public health, and training for local experts (Hasani, 2022). This cooperation helps to increase the effectiveness of water restoration measures and strengthen international relations in the field of ecology.

International organisations are also working to develop plans to reduce the impact of war on climate processes. Amnesty International (2023b) emphasises the need to implement new climate strategies for regions affected by warfare and

believes that environmental restoration should become an essential part of international climate agreements. The war has led to additional emissions of more than 50 million tonnes of CO₂ into the atmosphere, equivalent to the annual emissions of a small country. The destruction of forests and industrial facilities is aggravating the climate situation, which is why environmental restoration is critical to global efforts to combat climate change.

A common feature of studies in Ukraine and other countries affected by military conflicts is the severe impact on water and air resources. In the cases of Syria and Libya, the primary cause of pollution was the destruction of industrial facilities and infrastructure. However, in Ukraine, an added factor is the high concentration of chemical production in the eastern part of the country, which complicates the environmental remediation efforts. This feature makes the Ukrainian situation unique and requires specialised approaches to ecosystem restoration.

Another major difference is the scale of international aid. The European Commission (2023) notes that Ukraine has received extensive support from international environmental organisations such as Greenpeace, OSCE, and Amnesty International. This contributed to a faster assessment of the extent of environmental damage and the development of recovery plans. In many other countries affected by armed conflicts, international aid has been limited, slowing down the recovery process and adversely affecting the environmental situation.

One of the primary challenges to be addressed is the development of effective legal mechanisms to protect the environment during armed conflict. O.V. Vygovska and Yu.F. Dekhtyarenko (2021) emphasise that the national legislation of many countries, including Ukraine, does not fully meet the current challenges associated with the

environmental consequences of war. New legal instruments are necessary to effectively prosecute aggressor countries for environmental crimes and ensure compensation for affected states.

In the international context, it is essential to involve the International Criminal Court in cases related to environmental crimes during war. M.O. Medvedieva and S.D. Bilotskiy (2023) note that international agreements should contain provisions on criminal liability for ecocide and stipulate the possibility of compensation for affected countries. The role of the UN is key, as the organisation can initiate the development of new international conventions to protect the environment during hostilities. According to the UN (2021), there is a need to improve international environmental law, in particularly within the framework of the Rome Statute of the International Criminal Court, which currently does not contain concrete provisions on criminal liability for environmental crimes.

The introduction of compensation procedures for environmental damage caused by war is another prominent area. Transparency International (2022) notes that international courts and arbitration have an integral role to play in such cases. This includes the possibility of holding accountable not only states but also private companies that may be involved in environmental crimes. Strengthening environmental security through regional international agreements is also an essential mechanism. N.A. Pylypenko (2023) notes that such agreements can serve as an effective tool for preventing environmental disasters, but their implementation requires greater political will from the international community.

Special attention should be paid to the preservation of protected areas and nature reserves affected by the war. The United Nations Environment Programme (2022) reports that the war has damaged many protected areas, causing the loss

of unique species of flora and fauna. The loss of habitats for rare species threatens their survival and requires immediate action to restore ecosystems. Restoration of protected areas and nature reserves is a separate area of international efforts. The experience of Lebanon and Vietnam demonstrates that international aid plays an instrumental role in the restoration of natural ecosystems (UNEP, 2022). In Ukraine, such strategies can be implemented through cooperation with international partners who are already actively supporting environmental initiatives in the country.

The scale of environmental damage in Ukraine is much greater than in many other countries, and therefore the restoration process will require extensive financial resources and long-standing international support. Greenpeace Ukraine (2022) notes that Ukraine is developing strategies for the restoration of protected areas as part of its sustainable development strategy, including socio-economic aspects such as job creation in ecotourism and environmental management. This contributes not only to environmental restoration, but also to the economic development of war-affected regions.

One of the most significant environmental impacts of the war has been soil contamination, which has adversely affected agriculture and food security. Research by Greenpeace Ukraine (2022) shows extensive loss of fertile soil; in Kharkiv region, over 60% of agricultural land is contaminated, resulting in a 30-50% decrease in yields and threatening the country's food security. UNCG and Ecoaction (2023) confirms that the destruction of soil cover has reduced Ukraine's agricultural potential in some regions.

Soil restoration requires comprehensive measures. The use of phytoremediation - planting plants that can accumulate pollutants and then utilise them - helps cleanse soils of heavy metals

and toxins. The application of organic fertilisers helps to restore soil fertility, while regular monitoring of soil conditions ensures the effectiveness of remediation measures. The Ministry of Environmental Protection, together with international organisations, is developing programmes to clean contaminated soils and rehabilitate agricultural land, which will help restore the country's agricultural potential.

Waste management in wartime is one of the key environmental threats. Transparency International (2022) indicates that the war has led to a considerable increase in waste, including hazardous waste. Over 80 million tonnes of construction waste have been accumulated in the war zones. The management of hazardous waste, such as chemicals and ammunition, is of particular concern. A.O. Titova and V.M. Shmandiy (2022) emphasise that proper management of hazardous waste is a priority.

National waste management initiatives include the development of special programmes. The Ministry of Environmental Protection and Natural Resources of Ukraine (2023) is implementing new strategies, including the construction of modern waste processing plants. Specifically, the Ministry plans to build a waste processing complex that will be able to process up to 500,000 tonnes of waste per year in the city of Kharkiv. The creation of mobile construction waste processing plants will allow waste to be processed locally and materials to be reused in construction, which will reduce the environmental impact and promote sustainable development.

The war in Ukraine also has major consequences for public health. Pollution of air, water, and soil leads to an increase in disease cases. Greenpeace Ukraine (2022) reports a 40% increase in respiratory diseases in the affected regions. Increased cancer rates due to pollution are

also a concern. The Ministry of Health of Ukraine, in cooperation with international partners, is developing programmes to monitor environmental quality and public health. This includes regular medical examinations, the installation of filtration systems to purify drinking water, and educational campaigns to inform the public about the risks and ways to protect their health.

Discussion

The findings of this study on the environmental impacts of the war in Ukraine are consistent with a series of international studies that examine the environmental impacts of hostilities. For example, studies by Greenpeace Ukraine (2022) and the European Commission (2023) underscore the considerable impact of armed conflict on industrial facilities, causing massive air, water, and soil pollution. Industrial enterprises in the conflict zone become the primary sources of hazardous substances emissions, which greatly aggravates the environmental situation. According to M. Vashchyshyn (2022), the war in Ukraine has led to a sharp increase in pollution due to the destruction of infrastructure and chemical leaks, which is comparable to other conflicts, but the impact is much greater because of the densely populated regions and high concentration of industrial facilities. According to M.V. Hrushko (2023), the scale of environmental damage in Ukraine is much higher than in other conflicts, which underlines the uniqueness of the Ukrainian situation.

Comparing these findings with those of studies conducted in Iraq during the war, some overlaps can be identified, particularly in terms of the extent of infrastructure destruction and the impact on water resources. A study by Transparency International (2022) found comparable environmental problems in Iraq, including water pollution caused by oil leaks and the destruction

of industrial facilities. However, the scale of pollution in Ukraine is much greater due to the higher level of industrialisation and densely populated regions, as confirmed by M. Bilokon (2023). Furthermore, N. Pinda (2024) emphasises that managing environmental damage in war should be more challenging due to the heavy damage to critical infrastructure, which increases the intensity of environmental damage and complicates the recovery process after the conflict.

These findings are also consistent with international research on the impact of climate change on conflict. E. Miguel *et al.* (2013) examined the impact of climate change on human conflict and found that climate change can exacerbate the effects of armed conflict. The researchers note that global climate change poses additional challenges to stability as it deteriorates the condition of natural resources that are the object of struggle, which is consistent with the situation in Ukraine, where climate change exacerbates the environmental damage caused by war.

A study by O.M. Theisen (2013), which also focuses on the impact of climate on conflict, adds that climate change can not only contribute to conflict, but also make recovery from it more challenging by reducing access to natural resources. In the context of Ukraine, this means that recovery from war will be more problematic due to the increased impact of climate change on ecosystem restoration and economic resources. This argument supports the findings of this study that new legal and environmental mechanisms must be developed to address the problems caused by the conflict.

In terms of legal mechanisms for environmental protection during armed conflicts, S.M. Taranenko (2024) and S. Artamonova *et al.* (2022) emphasise that existing international agreements do not provide effective mechanisms for compensation for environmental damage caused by

war. Existing legal norms, such as international conventions and court decisions, do not always ensure adequate compensation for environmental damage. In his study on the legal regulation of environmental protection in Ukraine, K. Kozmulyak (2022) notes that international legal mechanisms do not sufficiently consider the specifics of modern conflicts, specifically the conduct of hostilities in densely populated regions, which creates further challenges for environmental protection.

Furthermore, O.V. Tkachenko (2024) proposes the expansion of sanctions mechanisms as a tool for holding states accountable for environmental crimes. The value of this approach is supported by studies that confirm the necessity of improving international legal norms to combat ecocide. Globalisation and the proliferation of international economic sanctions can be an effective means of pressuring states that wage wars that cause severe environmental damage, reflecting the urgency of intensifying international efforts to combat environmental crimes.

M.V. Hrushko (2023) confirms that the war in Ukraine is having a devastating impact on forest ecosystems and water resources, which is a critical aspect for environmental security. Analogous problems have been observed during other armed conflicts, such as in Syria, where the destruction of infrastructure has led to long-term changes in the local ecosystem. This confirms the conclusions of M. Bilokon (2023) that long-term environmental impacts require special approaches to recovery, particularly in the context of climate change and post-conflict recovery.

Another major aspect concerns the legal mechanisms for compensation for environmental damage, which are not yet sufficiently effective. According to Y.Y. Bobrova and Y.O. Bobrov (2023), the legal mechanisms applied in Ukraine cannot ensure full compensation for the damage caused.

This confirms the findings of O.M. Borshchevska (2023), who claimed that new international legal instruments should be introduced to combat environmental crimes. The insufficiency of existing legal mechanisms impedes the prosecution of aggressor states and creates further challenges for the protection of the environmental rights of affected countries.

Summarising the above, the results of this study confirm the necessity of improving international and national legal mechanisms to address environmental problems caused by armed conflicts. Differences between studies may be conditioned by the specifics of warfare in particular countries and regions, but a general trend towards increasing environmental damage caused by modern conflicts exists, calling for fresh approaches in both the legal and environmental spheres.

Conclusions

This study investigated the environmental consequences of the war in Ukraine, focusing on two key aspects: assessing the state of Ukraine's ecosystems after the outbreak of war and analysing the existing international legal mechanisms for overcoming the consequences of armed aggression. The purpose of the study was to identify the extent of environmental damage and assess the effectiveness of international legal instruments for environmental protection in the context of armed conflict. As a result, the study succeeded in achieving its objectives and gained a detailed understanding of the impact of the war on Ukraine's ecosystems and the possibilities of their restoration through international legal mechanisms.

The study analysed the environmental situation in Ukraine after the start of the armed aggression, with a particular focus on air and water pollution and the destruction of forest ecosystems. The hostilities have led to massive

emissions of toxic substances into the atmosphere as a result of the destruction of industrial facilities, especially in the east and south of the country. These emissions have posed a threat to public health and caused lasting changes in the region's ecosystems. Water resources were contaminated due to damage to the water supply infrastructure and chemical plants, which resulted in toxic substances entering rivers and groundwater, as confirmed by numerous reports by international environmental organisations.

Ukraine's forests have also suffered heavy losses due to military operations, which has led to a reduction in the area of nature reserves and other ecologically valuable areas. This destruction of forests has also affected biodiversity, complicating the possibilities for restoring natural ecosystems. Based on the data obtained, it can be argued that Ukraine's ecosystems have been extensively affected not only by the hostilities directly, but also by the accompanying environmental consequences, such as water and air pollution and land degradation. All these factors require long-term efforts to restore and rehabilitate the natural environment. This study reviewed international legal mechanisms aimed at overcoming the consequences of armed aggression. However, it was found that current international legal norms, such as the Geneva Conventions, are poorly adapted to protect the environment in modern conflicts. An analysis of documents such as the Rome Statute of the International Criminal Court revealed that the issue of environmental crimes is still lacking in international regulation.

The obtained findings are valuable for further research on the environmental impact of military operations. They underscore the necessity of strengthening international cooperation in developing new legal mechanisms to restore destroyed ecosystems and prosecute

environmental crimes. This study also opens avenues for further research, particularly in the area of analysing the long-term environmental consequences of conflict and developing effective strategies for ecosystem restoration in the post-conflict period.

Promising areas for further research may include an analysis of international legal instruments for prosecuting ecocide, an assessment of the long-term consequences of soil and water

pollution, and the development of new legal and economic mechanisms for environmental restoration after the end of hostilities.

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Conflict of Interest

The author of this study declares no conflict of interest.

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Міжнародно-правові та національні механізми подолання екологічних наслідків збройної агресії Російської Федерації проти України

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Анотація

Збройна агресія Російської Федерації проти України спричинила масштабні екологічні наслідки, включаючи забруднення повітря, водних ресурсів та ґрунтів, а також руйнування природоохоронних зон і лісових масивів. Метою дослідження було проведення аналізу міжнародно-правових і національних механізмів подолання екологічних наслідків війни та оцінка їхньої ефективності в умовах збройного конфлікту. У роботі було використано порівняльний аналіз міжнародних правових актів, статистичні методи для обробки даних про забруднення довкілля, а також метод кейс-стаді для порівняння наслідків війни в інших країнах. Було досліджено вплив військових дій на екосистеми України, зокрема аналізувались забруднення повітря, води та ґрунтів. Виявлено такі особливості: рівні забруднення повітря в регіонах, де були зруйновані промислові підприємства, значно перевищують допустимі екологічні норми. Зокрема, викиди нафтопродуктів і хімічних речовин, призвели до довготривалих негативних наслідків для ґрунтових та водних ресурсів. Було встановлено, що руйнування таких промислових об'єктів, як нафтопереробні заводи та хімічні підприємства, спричиняє не лише безпосередні викиди токсичних речовин, але й створює довготривалі екологічні загрози, здатні впливати на регіональні екосистеми протягом десятиліть. Також, забруднення водних ресурсів досягло критичного рівня, що створює загрозу для здоров'я населення та біорізноманіття. Проаналізовано міжнародні правові механізми, які виявилися недостатньо ефективними для вирішення проблеми екологічних злочинів під час військових конфліктів. Встановлено, що міжнародні інструменти притягнення до відповідальності за екологічні злочини потребують удосконалення, зокрема для забезпечення належної відповідальності за екоцид. Дослідження виявило необхідність нових міжнародних ініціатив, спрямованих на формування ефективних правових інструментів для захисту довкілля під час конфліктів. Було узагальнено, що міжнародне співтовариство, активно залучене до розробки стратегій відновлення пошкоджених екосистем. Практична цінність дослідження полягає в наданні рекомендацій для міжнародних організацій та урядів щодо покращення правових механізмів притягнення до відповідальності за екологічні злочини та розробки довгострокових стратегій відновлення пошкоджених екосистем.

Ключові слова: екологічні наслідки війни; міжнародне право; забруднення повітря; відновлення екосистем; екологічні злочини; правові механізми; екологічна стійкість