ENVIRONMENTAL CONSEQUENCES OF THE DESTRUCTION OF CRITICAL INFRASTRUCTURE IN UKRAINE: ANALYSIS OF EVENTS FOR 2024-2025

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Abstract. The article analyzes the main risks associated with critical infrastructure and high-risk facilities in wartime. Particular attention is paid to the consequences of attacks on energy, industrial, and water infrastructure.

Keywords: critical infrastructure, hazards, war.

Анотація. У статті проаналізовано основні ризики, пов'язані з критичною інфраструктурою та об'єктами підвищеної небезпеки в умовах війни. Особлива увага в роботі приділяється наслідкам атак на енергетичну, промислову та водну інфраструктуру.

Ключові слова: критична інфраструктура, небезпеки, війна.

Introduction. In 2024–2025, Ukraine again faced large-scale challenges in the field of critical infrastructure security. As a result of military operations, damage to energy, industrial, and water supply facilities, the risks of environmental disasters of a regional and even interstate scale increased. These events demonstrated that critical infrastructure not only ensures the vital activity of society, but can also become a source of environmental danger when it fails or is destroyed [1].

Analysis of the state of the issue. The most acute consequences were the attacks on energy facilities, gas storage facilities, water treatment plants and industrial enterprises in the central and eastern regions of Ukraine [2]. Thus, in January-November 2024, large-scale destruction of energy facilities in the Kyiv, Kharkiv and Dnipropetrovsk regions caused long-term power outages, and massive attacks on thermal power plants and substations led to large-scale fires, fuel and oil leaks, carbon monoxide and fine dust emissions into the atmosphere. According to DTEK, in February 2024 alone, more than 50% of generating capacity was damaged, which complicated the operation of water treatment and sewage systems in the eastern regions, and fires at substations led to oil and fuel leaks that contaminated soil and surface water.

The purpose of the study – analysis of the main hazards associated with critical infrastructure and high-risk facilities in wartime.

Methods, materials, and research results. Leaks from water treatment facilities in Zaporizhzhia, Mykolaiv and Kharkiv regions (2024–2025) due to partial destruction of pumping stations and treatment facilities after shelling led to the discharge of untreated wastewater into the Dnipro and Seversky Donets. This caused local outbreaks of bacterial contamination of water bodies.

In the summer and autumn of 2024, damage was recorded at an oil refinery in Kremenchuk. As a result of a strike on fuel tanks, more than 15 thousand tons of toxic combustion products were released into the air. Air pollution was recorded in Poltava and Cherkasy regions, as well as a leak into the tributaries of the Dnieper (oil products were discharged into the Psel River).

Attacks on gas infrastructure in January 2025 in Kharkiv and Poltava regions led to damage to main gas pipelines, followed by methane ignition and air pollution from incomplete combustion products. CO_2 emissions reached over 120 thousand tons. Gas pipelines and storage facilities in eastern and southern Ukraine (in particular in the Donetsk and Melitopol regions) were also damaged, causing local explosions and a threat of air pollution from methane and combustion products.

Damage to the treatment facilities in the front-line city of Nikopol in May 2025 after a missile strike led to the leakage of sewage from the city sewer into a local reservoir, where a mass death of fish was recorded.

Pollution after the explosion of ammonia fertilizer warehouses in the Kharkiv region in July 2025 caused nitrates in the soil to exceed 8 times the norm, and in water – 5 times the norm. There was local poisoning and death of fish and aquatic organisms.

Damage to water treatment systems was recorded in a number of settlements in Zaporizhzhia and Mykolaiv regions, which caused temporary ingress of untreated wastewater into the Dnieper and Southern Bug River.

During 2024-2025, there will be repeated outages of external power supply to Zaporizhzhia NPP, creating risks for the reactor cooling systems and spent fuel pools. The IAEA has repeatedly recorded an increase in the concentration of cesium in soil samples near the plant.

In addition, the russians blew up an ammonia pipeline near the village of Rusyn Yar, carrying out another targeted terrorist attack. As a result, a poisonous cloud was released into the air, which is dangerous for people and animals, as it can cause burns to the respiratory tract and eyes.

The destruction of critical infrastructure creates a chain reaction: the energy crisis entails technological shutdowns that increase the risk of accidental emissions into the environment, which causes the following main environmental consequences [3]:

– air pollution due to increased concentrations of carbon monoxide, sulfur compounds and particulate matter due to fires;

– ingress of fuels and lubricants, chemical reagents, heavy metals into soil and water;

– disruption of the water balance, reduction in the quality of drinking water, degradation of small river ecosystems;

– creation of biological risks due to the destruction of treatment facilities and waste storage facilities, which leads to an increase in the risks of the spread of bacteria and toxic substances.

In view of this, the environmental safety of critical infrastructure requires a new approach. The primary task is to modernize facilities using sustainable materials, backup power systems, and emergency leak containment systems. It is necessary to

develop regional action plans in case of man-made accidents and ensure constant monitoring of the condition of facilities using unmanned surveillance systems and satellite data. Increasing the readiness of emergency services, creating mobile environmental laboratories, and involving public structures in environmental monitoring are also important parts of this strategy.

The events of 2024–2025 have demonstrated that the issues of environmental safety of critical infrastructure are inseparable from national security. Energy, industrial and water facilities that ensure the life of the state can, in case of damage, become a source of environmental disaster. Therefore, the restoration and development of infrastructure should be carried out taking into account the environmental standards of the European Union and the principles of sustainable development, which combine economic efficiency, public safety and environmental protection.

Conclusions. Analysis of the events of 2024–2025 shows that Ukraine's critical infrastructure remains one of the most vulnerable areas in the national security system. Its damage or destruction not only disrupts energy and industrial stability, but also poses a serious threat to the environment. The environmental consequences of such incidents are manifested in air, soil and water pollution, degradation of natural ecosystems, increased risks to public health and loss of biodiversity.

Military actions have demonstrated that infrastructure facilities can become targets, and therefore should be considered not only as elements of economic stability, but also as potential sources of environmental danger. Modern challenges require a transition from a reactive approach to systemic environmental security, which involves risk prevention, environmental monitoring and technical protection of critical infrastructure facilities.

To reduce environmental impacts, it is necessary to implement modern monitoring technologies, create regional programs for environmental safety, improve the qualifications of emergency and rescue service personnel, and involve the public in environmental monitoring.

The restoration of damaged facilities should be carried out taking into account the environmental standards of the European Union, the principles of sustainable development, and the requirements of energy sustainability. Preservation of ecological balance in conditions of military influence is possible only if environmental criteria are integrated into the state security and reconstruction policy. And the ecological safety of critical infrastructure is not only a technical or environmental task, but a strategic direction for the protection of the state, which determines the quality of life of the population, the stability of the economy, and the long-term sustainability of Ukraine.

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