

DOI 10.36074/logos-01.08.2025.018

THE APPLICATION OF ADVANCED TECHNOLOGIES FOR ENVIRONMENTAL PROTECTION

Elnur Mammadov¹

1. Professor*National Defence University, Baku, Azerbaijan***ORCID ID: 0009-0006-4121-2618**

Introduction

The environmental impact of military operations has become an increasingly significant issue in modern warfare. Historically, military activities have been associated with extensive ecological damage, including the pollution of air, water, and soil, the destruction of natural habitats, and the depletion of critical resources. As global awareness of environmental sustainability grows, the need for the armed forces to adopt more eco-friendly and sustainable practices has never been more pressing. The concept of military ecology has emerged as a crucial aspect of modern defense strategies, aiming to mitigate the environmental footprint of military actions while maintaining operational effectiveness.

The traditional approach to military operations often prioritized immediate tactical advantages over long-term environmental concerns. However, recent advancements in military technology and global environmental policies have shifted the focus towards integrating sustainability into defense planning. New technologies, particularly in the areas of energy efficiency, waste management, and environmental monitoring, are playing a pivotal role in this transition. These innovations not only enhance the environmental protection measures within the military but also contribute to broader sustainability goals, ensuring that military operations do not compromise the health and stability of ecosystems.

The objective of this paper is to explore the future of military ecology, with a specific focus on the application of cutting-edge technologies for environmental protection. By examining the role of emerging technologies in monitoring environmental conditions, reducing ecological footprints, and improving the sustainability of military operations, this paper seeks to highlight the potential for creating a more environmentally responsible military. As global defense strategies evolve, the integration of these technologies will be essential in shaping the future

섹션 12.

ECOLOGY AND ENVIRONMENTAL PROTECTION TECHNOLOGIES

of military ecology, promoting both national security and environmental well-being.

Main part

The integration of advanced technologies into military operations is crucial for minimizing environmental damage caused by defense activities. As military operations have traditionally led to significant ecological consequences, ranging from pollution of natural resources to habitat destruction, the need for more sustainable military practices has become imperative. The advent of modern technologies offers the potential to mitigate these impacts, improve environmental monitoring, and enhance the sustainability of military operations. This section explores key technological advancements that are contributing to environmental protection within the military, including environmental monitoring systems, sustainable military equipment, and waste management technologies.

One of the primary ways in which military operations can be made more sustainable is through the implementation of sophisticated environmental monitoring and detection systems. These technologies enable military forces to assess and respond to environmental risks in real-time, ensuring prompt action in mitigating potential harm to ecosystems.

Environmental sensors - Advanced environmental sensors, including those mounted on unmanned aerial vehicles (UAVs) and other military platforms, provide continuous data on a wide range of environmental variables. These sensors are capable of detecting chemical, biological, radiological, and nuclear (CBRN) agents, as well as pollutants in the air, water, and soil. Their ability to monitor environmental conditions in real time allows military units to swiftly identify contamination, minimizing the extent of environmental damage and ensuring the safety of military personnel.

Satellite and drone surveillance - Satellites and drones are integral components of modern military environmental monitoring. They provide a comprehensive view of large geographical areas, which is essential for assessing environmental changes such as deforestation, soil degradation, and water contamination. Drones, in particular, allow for the collection of high-resolution data from remote or hazardous locations, facilitating immediate response to emerging environmental threats.

The development of more sustainable military equipment plays a pivotal role in reducing the environmental footprint of defense operations. These innovations focus on minimizing energy consumption, reducing emissions, and using environmentally friendly materials in military hardware.

Energy-efficient military vehicles - Military vehicles have traditionally relied on fossil fuels, contributing to high levels of emissions and pollution. However, recent

advancements have led to the development of hybrid and fully electric military vehicles. These vehicles are designed to reduce fuel consumption and decrease carbon emissions, offering a more sustainable alternative to traditional military transportation.

Renewable energy solutions - Military bases and operations, particularly in remote or forward-deployed areas, are increasingly adopting renewable energy sources, such as solar, wind, and biofuels. The use of solar panels and wind turbines for electricity generation significantly reduces reliance on non-renewable energy sources, such as diesel generators. Moreover, the adoption of biofuels in aircraft, ground vehicles, and naval vessels helps decrease carbon emissions while providing a more sustainable fuel alternative.

Biodegradable and eco-friendly materials - The development and use of biodegradable materials in military operations help mitigate environmental pollution caused by long-lasting plastic waste. Military manufacturers are increasingly using eco-friendly materials for packaging, protective coatings, and other equipment, ensuring that waste generated during operations decomposes quickly and does not pose a long-term environmental threat.

Waste Management Technologies

Effective waste management in military operations is essential for minimizing the ecological impact of military activities. Waste disposal challenges are particularly pronounced in conflict zones, where waste management infrastructure is often inadequate. The military is addressing these challenges by developing advanced technologies for waste management, including chemical neutralization and mobile recycling units.

Chemical and hazardous waste disposal - The disposal of hazardous materials, such as chemicals and radioactive substances, remains a critical issue in military operations. To address this, military forces have developed advanced incineration and neutralization systems capable of safely processing hazardous waste. These technologies reduce the risk of contamination in the surrounding environment and ensure that toxic substances do not pose a long-term threat to ecosystems.

Mobile waste recycling units - The development of mobile waste recycling units allows for waste management in remote or forward-deployed military bases. These units are capable of converting waste into useful resources, such as compost or biofuels, helping to minimize waste disposal needs while contributing to the sustainability of operations. Recycling efforts reduce the need for landfill disposal and promote the conservation of valuable materials.

Water purification and treatment systems - Military operations in conflict zones often involve water scarcity and contamination. Advanced water purification systems, such as reverse osmosis and UV filtration, provide clean drinking water for

섹션 12.

ECOLOGY AND ENVIRONMENTAL PROTECTION TECHNOLOGIES

military personnel while preventing environmental degradation caused by wastewater and contamination. These systems ensure that water resources are used efficiently, mitigating the environmental impact of military operations on local water supplies.

The integration of advanced technologies into military operations has a significant role to play in reducing the environmental impact of military activities. Through the deployment of environmental monitoring systems, the use of sustainable military equipment, and the development of effective waste management technologies, the military is working toward reducing its ecological footprint. As these technologies continue to evolve, they will further enhance the sustainability of military operations, ensuring that environmental considerations are integrated into defense strategies. Continued investment in research and development will be essential for addressing future environmental challenges and promoting the long-term sustainability of military operations.

The military sector is increasingly adopting cutting-edge technological solutions to mitigate environmental impacts associated with defense activities. These innovations are transforming how armed forces approach ecological security, encompassing the prevention, detection, and remediation of environmental contamination caused by military operations. With modern warfare pushing the boundaries of resource consumption, energy demands, and waste generation, military technology must evolve to include sustainable practices. This section delves into the key technological innovations driving the future of military ecology, including advanced environmental monitoring systems, sustainable operational technologies, and waste management solutions.

Modern military operations benefit from sophisticated monitoring systems that enable real-time data collection and environmental risk management.

Sensor Networks and UAVs - Advanced sensors, often integrated into military vehicles or drones, detect pollutants and hazardous substances, enabling timely responses to contamination. Drones and satellites further enhance environmental surveillance by providing high-resolution data over large areas.

AI for Data Analysis - AI-powered systems analyze environmental data to identify patterns, predict risks, and inform decisions, improving environmental management and mitigating potential damage.

To reduce its ecological footprint, the military is integrating sustainable technologies into its equipment and operations.

The development of hybrid and electric military vehicles helps reduce fuel consumption and emissions, contributing to cleaner operations.

Solar, wind, and biofuels are increasingly used to power military bases and vehicles, minimizing reliance on fossil fuels.

Biodegradable and recyclable materials are being used for packaging, components, and construction, reducing long-term environmental waste.

Efficient waste management is crucial for reducing environmental harm in military operations.

These units process waste into compost, biofuels, and recyclable materials, minimizing waste disposal needs.

Advanced technologies neutralize hazardous chemicals and radioactive materials, reducing environmental contamination.

Mobile water purification systems provide clean drinking water and prevent contamination, preserving local water resources.

Technological innovations in environmental protection are revolutionizing military operations, allowing for more sustainable practices. By utilizing advanced monitoring systems, eco-friendly equipment, and effective waste management technologies, the military is reducing its environmental impact while maintaining operational effectiveness. Continued investment in these technologies will be vital for ensuring sustainable military practices in the future.

The integration of Artificial Intelligence (AI) and robotics into military operations is transforming how environmental risks are managed. These technologies enhance the efficiency and precision of environmental protection efforts by automating processes, improving data analysis, and optimizing resource use. In the context of military ecology, AI and robotics play a crucial role in environmental monitoring, decontamination, and waste management, providing unprecedented capabilities for mitigating the ecological impact of defense activities.

AI is increasingly being applied to assess and predict environmental risks in real-time, allowing for proactive management of ecological hazards.

Predictive analytics - AI-powered algorithms analyze large volumes of environmental data collected by sensors, drones, and satellites to forecast environmental risks. By identifying potential issues such as contamination or resource depletion, these systems enable military planners to take preventive actions before a situation worsens.

Optimization of resources - AI also helps optimize resource allocation in military operations. For example, machine learning models can predict the most efficient use of energy and materials, reducing waste and ensuring that military forces operate in an environmentally responsible manner.

Robotic systems are becoming increasingly important in the decontamination and cleanup of hazardous environments. These autonomous systems are capable of performing tasks that would be dangerous or inefficient for human personnel, improving safety and operational effectiveness.

섹션 12.

ECOLOGY AND ENVIRONMENTAL PROTECTION TECHNOLOGIES

Autonomous decontamination robots - Robots equipped with specialized tools and sensors are deployed to neutralize chemical, biological, and radiological contaminants in hazardous zones. These robots can work in high-risk areas, such as nuclear disaster sites, without putting human lives at risk.

Waste disposal robots - Robotics is also being utilized to handle and process waste in military operations. Automated systems are capable of collecting, sorting, and neutralizing waste materials, ensuring that hazardous substances are safely managed while reducing the environmental impact of waste disposal.

The development of integrated smart systems in military bases and operational areas is helping reduce resource consumption and environmental harm.

Energy management systems - AI-driven energy management systems are being employed to optimize the energy use of military facilities. These systems monitor energy consumption in real-time, adjust settings based on demand, and help reduce overall energy waste, contributing to a more sustainable operation.

Smart waste management - Robotic waste collection and sorting systems, combined with AI for waste tracking, enhance the efficiency of waste disposal processes. These systems ensure that materials are recycled or disposed of in an eco-friendly manner, minimizing the long-term environmental footprint of military operations.

AI and robotics are revolutionizing the way the military approaches environmental protection. By automating environmental monitoring, optimizing resources, and improving the efficiency of decontamination and waste management, these technologies offer significant advantages in mitigating the ecological impact of military activities. As AI and robotics continue to evolve, their role in ensuring sustainable military operations will only become more critical, paving the way for a greener, more efficient defense strategy

Conclusion

The future of military ecology is intrinsically tied to the continuous evolution and integration of advanced technologies aimed at reducing the environmental impact of defense operations. The advancements in environmental monitoring, sustainable military equipment, waste management systems, and the application of Artificial Intelligence and robotics are significantly enhancing the military's ability to minimize ecological damage while maintaining operational readiness. These innovations not only contribute to the preservation of natural resources but also align with broader global sustainability goals, ensuring that military activities are conducted in an environmentally responsible manner.

As the military sector embraces these technologies, it is crucial to recognize the challenges associated with their implementation, including resource allocation,

technical adaptation, and the need for ongoing research and development. However, the continued integration of these technologies offers promising prospects for a future where military operations are conducted with greater ecological awareness and minimal environmental disruption.

Looking forward, the collaboration between defense sectors, environmental experts, and technological innovators will be essential in achieving sustainable military practices. The focus on environmental protection within military strategies will not only enhance national security but also contribute to global ecological stability. As such, the future of military ecology depends on the continued development and application of these transformative technologies, ensuring that defense priorities and environmental stewardship are harmonized for the benefit of both current and future generations.

REFERENCES:

- [1] Axundov, R. Q. (2022). Radiasiya və kimyəvi təhdidlərdən mühafizənin vəziyyəti və inkişaf perspektivləri. Bakı: Milli təhlükəsizlik və hərbi elmlər, (3), 8.
- [2] Axundov, R. Q. (2023). Azərbaycan Ordusunda radiasiya, kimyəvə bioloji mühafizənin inkişaf problemləri və onların həlli yolları. Hərb sənətinin aktual problemləri” beynəlxalq elmi-praktik konfransın materialları,–Bakı: MMU, 137-138.
- [3] Axundov, R. Q. (2023). Azərbaycan Ordusunda radiasiya, kimyəvi və bioloji kəşfiyatının əsasları. Bakı: Hərbi bilik, (4), 16-20.
- [4] Axundov, R. Q. (2023). Dərinin fərdi qoruyucu vasitələrinin tətbiqi və inkişaf perspektivləri. Bakı: Milli təhlükəsizlik və hərbi elmlər, (4), 9.
- [5] Axundov, R. Q. (2023). Radiasiya, kimyəvi və bioloji mühafizə sisteminin texniki təminatının analizi. Ümummillə lider Heydər Əliyevin anadan olmasının, 100, 470-472.
- [6] Axundov, R. Q. (2023). Radiasiya, kimyəvi və bioloji mühafizə sisteminin təkmilləşdirilmə istiqamətləri. Müdafiə sənayesi üzrə ixtisaslı kadr hazırlığı: radioelektron, aerokosmik sistemlər və robotlar” mövzusunda II Respublika elmi-texniki konfransın materialları,–Bakı: AzTU, 89-92.
- [7] Axundov, R. Q., Abiyev, Q. A., & Nabizadə, Z. Radiasiyanın aktiv kömürlərin mexaniki möhkəmliyinə təsiri. Tibb elmləri doktoru Əzəm Təyyar oğlu Ağayevin anadan olmasının, 75, 14-17.
- [8] Axundov, R., & Abdullayev, R. S. (2023). Karbon əsaslı adsorbentlərin sintezi və tətbiqi. Bakı: Milli təhlükəsizlik və hərbi elmlər, (1), 9.
- [9] Akhundov R.G., Hashimov E.G. (2025) Radiation and chemical protection as a strategic priority of environmental security in the military sphere. Здобутки та досягнення прикладних та фундаментальних наук XXI століття, р.202-211. DOI: <https://doi.org/10.62731/mcnd-16.05.2025.005>
- [10] Akhundov R.G., Hashimov E.G. (2025) The impact of new technologies on enhancing the efficiency of armed forces. Проблеми та перспективи реалізації та впровадження міждисциплінарних наукових досягнень, р.186-195. DOI: <https://doi.org/10.62731/mcnd-13.06.2025.004>
- [11] Akhundov, R. (2017). Radiation-thermal activation of coal for water purification. In Ecological and environmental chemistry (pp. 141-141).



섹션 12.

ECOLOGY AND ENVIRONMENTAL PROTECTION TECHNOLOGIES

- [12] Akhundov, R. (2023). Application of means of remote radiation reconnaissance. In Modern trends in the development of information and communication technologies and management tools. Abstracts of the Thirteenth International Scientific and Technical Conference. – Kharkiv, Ukraine (Vol. 2, pp. 8-9).
- [13] Akhundov, R. (2024). Environmental Warfare – Modern Global Challenge. In Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference (No. 7, pp. 332-335).
- [14] Akhundov, R. (2024). The Environmental Consequences of Military Activity. In 20 години България в НАТО и НАТО в България (pp. 410-422). Военна академия „Г. С Раковски“.
- [15] Akhundov, R. G. (2023). Methods of conducting chemical exploration. Abstracts of reports of the eleventh international scientific and technical conference “Problems of informatization”. – Kharkiv, Ukraine (Vol 2, pp.104-105).
- [16] Akhundov, R. G., & Eldarov, E. A. (2024). Special operations forces in modern conflicts. Вестник науки и образования, (6[149]), 16–20.
- [17] Akhundov, R. G., & Ibadov, P. (2023). Problematic issues and prospects for the development of airborne radiation, chemical and biological reconnaissance systems. Baku: National security and military sciences, -2023.-1 (9). – p, 38-46.
- [18] Akhundov, R. G., & Mustafayev, I. I. (2020). Radiation-initiated processes of activation of charcoal. Journal of Radiation Researches, 7(1), 27-34.
- [19] Akhundov, R., & Hashimov, E. (2025). Military activity and the environment: The need for a systemic approach to radiological and chemical safety. In Zdobutky ta dosyagnennya prykladnykh ta fundamental'nykh nauk XXI stolittya: Zbirnyk naukovykh prats z materialamy IX Mizhnarodnoyi naukovoyi konferentsiyi (pp. 187-196). UKRLOGOS Group. <https://doi.org/10.62731/mcnd-16.05.2025.004>
- [20] Akhundov, R., & Hashimov, E. (2025). The environmental impact of war: Effects, challenges, and solutions. In Theory of modernization in the context of modern world science: Proceedings of the 5th International Scientific Conference (pp. 103-110). UKRLOGOS Group. <https://doi.org/10.62731/mcnd-27.06.2025.002>
- [21] Akhundov, R., & Islamov, I. (2025). Implementation of new technologies for cleaning and neutralizing radiological and chemical contaminants in military environments. Матеріали конференцій МЦНД, (30.05. 2025; Київ, Україна), 321-329. <https://doi.org/10.62731/mcnd-30.05.2025.006>
- [22] Akhundov, R., & Islamov, I. (2025). Innovative technologies for radiation and chemical protection in the armed forces. In Ricerche scientifiche e metodi della loro realizzazione: Esperienza mondiale e realtà domestiche: Collection of scientific papers with proceedings of the VII International Scientific and Practical Conference (pp. 247-254). UKRLOGOS Group. <https://doi.org/10.36074/logos-06.06.2025.050>
- [23] Hashimov, E. G., & Bayramov, A. A. (2017). Application of GIS and seismic location method for detection of invisible military objects. Monograph //- Baku: Military Publishing House, 2017, 246 p.
- [24] Hashimov, E. G., Bayramov, A. A., & Khalilov, B. M. (2015). Operative detection of ground enemy objects. Baku: Herbi Bilik, (1), 33-47.
- [25] Hashimov, E.G., Bayramov, A.A. (2015). Detection unobserved moving armored vehicles by seismic method. *National Security and Military Sciences*, 7(1), 128-132.
- [26] Islamov, I., Akhundov, R., Dimitrov, D., & Panevski, V. (2025). Modeling of a Circular Disk Monopole Antenna Fed from a Microwave Broadband Coplanar Waveguide. *Advanced Physical Research*, 7(2), 184-195. <https://doi.org/10.62476/apr.72184>.
- [27] Jabrayilov, A. R., Hashimov, E. G., & Akhundov, R. G. (2025). The role of environmental monitoring in ensuring the safety of military units. In *Current directions of development*

of information and communication technologies and control tools: Proceedings of the 15th International Scientific and Technical Conference (Vol. 1, pp. 128-129). Baku; Kharkiv; Žilina.

- [28] Mammadov, E. V., Islamov, I. C., (2025). Development of effective personal protective equipment against radiation and chemical hazards. Current directions of development of information and communication technologies and control tools (Vol. 4, pp. 84–85). Baku–Kharkiv–Žilina: Impress. <https://www.kpi.kharkov.ua/eng/>
- [29] Mammadov, E. V., Islamov, I. C., (2025). Development of multilayered protection systems against chemical, radiological, and biological hazards for military personnel. Current directions of development of information and communication technologies and control tools (Vol. 1, pp. 112–113). Baku–Kharkiv–Žilina: Impress. <https://www.kpi.kharkov.ua/eng/>
- [30] Mammadov, E. V., Islamov, I. C., (2025). Eco-innovations and sustainable development in the military sector in the face of contemporary challenges. Current directions of development of information and communication technologies and control tools (Vol. 1, pp. 126–127). Baku–Kharkiv–Žilina: Impress. <https://www.kpi.kharkov.ua/eng/>
- [31] Mammadov, E. V., Islamov, I. C., (2025). Innovative technologies for radiological and chemical safety in military units. Current directions of development of information and communication technologies and control tools (Vol. 1, pp. 118–119). Baku–Kharkiv–Žilina: Impress. <https://www.kpi.kharkov.ua/eng/>
- [32] Mammadov, E. V., Islamov, I. C., (2025). The impact of military activities on the environment: Pathways for minimizing consequences. Current directions of development of information and communication technologies and control tools (Vol. 1, pp. 122–123). Baku–Kharkiv–Žilina: Impress. <https://www.kpi.kharkov.ua/eng/>
- [33] Piriyeu, H.K. (2023) The Second Karabakh War: military-political and military-technical aspects. *Scientific Works*. 1(21), 7-16.
- [34] Talibov, A. M., Hashimov, E. G., & Akhundov, R. G. (2025). Modeling and forecasting radiological and chemical threats in the military sphere. In *Current directions of development of information and communication technologies and control tools: Proceedings of the 15th International Scientific and Technical Conference* (Vol. 1, pp. 120-121). Baku; Kharkiv; Žilina.
- [35] Talibov, A. M., Hashimov, E. G., & Akhundov, R. G. (2025). The use of unmanned aerial vehicles for monitoring chemical and radiation contamination. In *Current directions of development of information and communication technologies and control tools: Proceedings of the 15th International Scientific and Technical Conference* (Vol. 4, pp. 88-89). Baku; Kharkiv; Žilina.
- [36] Talibov, A.M. et al. (2024) Environmental safety of nanomaterials application // *Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference*. Vol. 3, p.55-56.
- [37] Ахундов, Р. Г. (2024). Влияние военной деятельности на окружающую среду. Санкт-Петербург, 29(1), 51.