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BIOLOGICAL, CHEMICAL, AND ENVIRONMENTAL THREATS DURING WAR

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FORENSIC GENOMICS IN THE INVESTIGATION OF BIOINCIDENTS: CURRENT CAPABILITIES AND LIMITATIONS

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In the 21st century, risks associated with the use of biological weapons and the deliberate dissemination of pathogens have taken on new significance due to advances in biotechnology and the increasing accessibility of genetic engineering tools. Globalization, armed conflicts, terrorist threats, and pandemics create conditions for the occurrence of bioincidents—both deliberate and accidental. In this context, forensic genomics plays a crucial role—a field that combines molecular biology, genomics, and forensic science to detect, identify, and attribute biological agents involved in criminal or emergency events.

Forensic genomic approaches enable not only the taxonomic identification of a pathogen but also strain-level typing, detection of genetic modifications, reconstruction of evolutionary relationships and geographic origin, and assessment of treatment resistance mechanisms. Thus, forensic genomics provides critical evidentiary support in the investigation of bioincidents by offering detailed, objective, and reproducible information.

Key tools of forensic genomics include next-generation sequencing (NGS), real-time PCR (RT-qPCR), metagenomic analysis, bioinformatics, as well as classical typing methods (e.g., STR profiling, SNP analysis). NGS technologies allow for whole-genome profiling of samples using minimal amounts of biological material. These techniques have enabled full genomic analysis without the need to culture microorganisms, which is especially important when dealing with highly pathogenic or non-viable agents in laboratory conditions.

The metagenomic approach, which does not require prior knowledge of the suspected pathogen, allows for its detection amidst diverse microbial communities—within soil, air, water, tissue remains, or environmental swabs. This makes metagenomics indispensable for analyzing anonymous or complex biothreats. Bioinformatic platforms—such as Kraken, MetaPhlAn, Geneious, Nextstrain, and others—play a central role in interpreting sequence data. They facilitate pathogen identification, classification based on reference databases, mutation analysis (related to virulence or antibiotic resistance), and assessment of possible laboratory origin (e.g., presence of CRISPR edits or vector elements).

A historical example of successful forensic genomics application was the 2001 Bacillus anthracis incident in the U.S., where whole-genome sequencing of the samples revealed that the spores originated from a specific laboratory culture, forming the basis for subsequent criminal prosecution. This case established a precedent for the use of genomic methods as legal evidence in bioterrorism-related trials.

In the following years, the investigation of bioincidents became increasingly complex due to the globalization of infections, limited access to data, and the rapid spread of genetically modified pathogens. Nevertheless, forensic genomics enables rapid threat response: identifying infection sources, tracing their geographic origin, assessing potential transmission routes, and conducting epidemiological contact tracing. During the COVID-19 pandemic, large-scale genomic surveillance systems such as GISAID were implemented, enabling global phylogenetic monitoring of SARS-CoV-2 evolution. This experience affirmed the importance of mass sequencing for early detection of emerging variants and effective outbreak control.

In certain cases, forensic genomic data have underpinned international sanctions and diplomatic pressure, particularly in situations involving laboratory leaks or concealed bioincidents.

Despite its high potential, the application of forensic genomics faces several limitations:

Lack of standardized international protocols for sample collection, processing, and analysis complicates inter-laboratory cooperation. Genomic data are often inadmissible in court due to concerns over procedural validity.

Limited access to global reference databases for pathogens, especially dual-use agents. Some countries refrain from publishing full pathogen genomes out of fear they could be exploited for reverse bioengineering or development of resistant strains.

Bioethics and biosafety concerns remain critical. Using genomic data for criminal investigations requires adherence to confidentiality, informed consent (when human subjects are involved), and strict control over sensitive information.

Resource constraints in low- and middle-income countries hinder implementation due to the high cost of equipment, lack of trained personnel, and underdeveloped infrastructure, creating global disparities in bioincident response capacity.

The future of forensic genomics lies in equipment miniaturization, automation, and artificial intelligence. Portable sequencing platforms already enable field analysis without the need for transport to centralized labs—critical in war zones, emergencies, or biological accidents. Next-generation bioinformatics platforms are expected to provide real-time interpretation using large reference databases and machine learning models. Such developments could shift the paradigm from reactive analysis to proactive forecasting of biological threats.

At the international policy level, discussions are underway about creating a global registry of laboratory pathogens with controlled access and establishing universal response protocols for bioincidents with mandatory sequence-based analytics. This would enhance transparency, consistency, and timeliness in investigations.

Forensic genomics is a powerful, modern tool in the fight against biological threats. It enables the detection, identification, and attribution of biological agents with high precision and reliability. Its advantages include the ability to work with trace samples, identify pathogens without cultivation, analyze mixed specimens, and trace infection sources. However, the field faces numerous challenges—from ethical and legal to technical and financial. Overcoming these barriers will require close international cooperation, method standardization, open information sharing, and responsible use of genomic data. In the long term, forensic genomics is poised to become a cornerstone of global biosecurity, capable of responding rapidly and effectively to any form of bioterrorism or accidental pathogen release.

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ASSESSMENT OF KNOWLEDGE, ATTITUDES, AND PREPAREDNESS OF NURSING AND EMERGENCY MEDICAL SERVICES STUDENTS TO COUNTERACT BIOLOGICAL THREATS

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In recent years, the threat of bioterrorism, long marginalized in public discourse, has significantly increased. The world is currently facing various biological threats, including emerging infectious diseases, bioterrorist attacks, and the potential use of biological weapons [1, 2, 3]. Unlike other types of weapons, biological agents are difficult to detect or diagnose in their early stages, and their use often results in the rapid and widespread transmission of diseases, numerous casualties, and social destabilization [4, 5].

The emergence of new, highly contagious biological agents poses a serious challenge to the healthcare system. It requires substantial changes in medical care organization, infrastructure planning (including the design of healthcare facilities), ensuring adequate resources, ongoing sanitary-epidemiological surveillance, and effective communication. Timely and appropriate medical assistance is of key importance in this context.

In our opinion, one of the most critical factors determining the healthcare system's capacity to respond to biological threats is the level of preparedness and training of medical personnel. The first line of contact with patients includes emergency medical responders and mid-level healthcare staff – they are the first to identify threats and initiate countermeasures. Therefore, assessing their ability to respond to biological incidents is essential [6].

Nurses constitute the largest professional group in the healthcare system. They play a key role in emergency preparedness, management, response, and patient care. In the event of a bioterrorist attack, nurses must possess appropriate knowledge, attitudes, and competencies to quickly assess the situation, isolate potential cases, and prevent further spread of infection [7, 8, 9, 11].

The significance of mid-level medical personnel in combating biological threats lies in the diversity of their roles. Nurses are responsible for direct patient care, including monitoring vital signs, symptom control, medication administration, and ensuring patient comfort and safety. They also implement infection control procedures, educate patients and their families, coordinate care among different professionals, participate in preventive campaigns, and monitor emerging infectious disease cases.

Given the above, this study aimed to assess the level of knowledge, attitudes, and preparedness of nursing and emergency medical services students at the Cavalry Captain Witold Pilecki State University of Małopolska in Oswiecim to respond to biological threats.

The methodological basis of our study was the "Knowledge–Attitude–Practice" (KAP) model [11]. We analysed the knowledge, attitudes, and practical skills of students necessary for an effective response in biosafety-related situations. The study was conducted between 2023 and 2025 among students who completed courses such as microbiology and parasitology, tropical diseases, infectious diseases, hospital infections, epidemiology, and public health. The curricula included content on hazardous biological agents, anti-epidemic measures, and population protection.

Classes included lectures, practical exercises, problem-based learning, situational simulations, and remote education. The program also prepared students to care for patients with infectious diseases caused by bioterrorism agents, including: bioterrorism characteristics, response systems, procedures in suspected infection cases, clinical symptoms, diagnostics, isolation principles, and initial and preventive treatment.

The assessment was based on a 5-point scale test. Questions covered symptom recognition, identification of bioterrorism agents, response algorithms to epidemiological threats, sequence of preventive and intervention actions, and proper handling, transport, and disposal of biological materials, as well as personal protection during rescue operations. A higher score indicated a better level of knowledge and competence. The average score obtained by nursing students was 4.4±0,31, and by emergency medical services students was 4.2±0,4. Students' willingness to participate in rescue operations during a bioterrorist attack was rated high; all respondents expressed readiness for active involvement.

Competence levels assessed after completing the training cycle also showed high results, despite a limited number of practical hours devoted to the subject. Nursing students scored an average of 4.0±0,34, and emergency medical students scored 4.3±0,41.

To achieve an even more objective assessment of training effectiveness, we recommend implementing simulation-based training methods, such as virtual educational modules for learning to care for patients with infectious diseases caused by bioterrorism agents.

Our study highlights the need to modify and enhance educational programs by emphasizing the availability, repeatability, and effectiveness of training, especially in the context of increasing biological threats.

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ASSESSMENT OF WORKERS' HEALTH RISKS FROM AIR POLLUTION BY CHEMICAL SUBSTANCES

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Today, Ukraine is experiencing one of the most difficult pages of its history - a full-scale invasion of the Russian Federation. This war affected all spheres of life in our country. The aggressor caused and continues to cause irreparable damage to the environment, destroying entire ecosystems. Of course, the regions on the contact line are most affected. However, the entire territory of Ukraine is subjected to brutal attacks by the enemy, therefore, in war conditions, the risk of toxic substances entering the air of working areas increases significantly due to: destruction of industrial enterprises (especially chemical, oil refining, metallurgical industries); use of ammunition containing or causing the release of toxic substances; fires causing the release of combustion products; use of chemical weapons (real or potential risk) (Table 1).

Table 1

Causal and consequential effects of exposure to workplace air pollution on workers' health

Occasion	Potential pollutants	Вплив на здоров'я працюючих
Destruction of warehouses/industrial enterprises	Ammonia, chlorine, phenol, benzene, formaldehyde	Acute and chronic poisoning, carcinogenicity
Burning materials	Dioxins, polyaromatic hydrocarbons, carbon monoxide	General toxic, mutagenic effect

Occasion	Potential pollutants	Вплив на здоров'я працюючих
Explosives	NOx, CO, Pb, sulfur compounds	CNS and respiratory system disorders
Mobile generators and military equipment	CO, NOx, SO2, PM2.5/PM10 particles	Hypoxia, chronic diseases of the respiratory system
Use of weapons	White phosphorus, perchlorate, heavy metals	Respiratory tract and skin damage, general toxic effects

Assessing the risks to workers' health from air pollution of the work area by chemicals in wartime is an essential procedure that takes into account both traditional sources of pollution (production processes) and new threats caused by military actions (explosions, fires, destruction of infrastructure, etc.). This allows identifying potential hazards, assessing the degree of risk, and developing measures aimed at minimizing or eliminating the harmful effects of chemicals.

Identification of risk factors, proving their role in the health of workers, as well as quantitative characterization of the dependence of harmful effects on the levels of exposure to specific factors allows us to assess the real threats to the health of workers exposed to hazardous factors and to justify the implementation of appropriate preventive measures.

It is very difficult to establish the carcinogenic load for individual factors of the production environment, since their influence on the body of workers, especially in carcinogenic industries, is limited, and the result of the action may manifest itself in the distant term of life. In order to characterize the impact of specific harmful factors on humans, methodological approaches have been developed to establish correlations between the carcinogenic load and occupational and occupationally related morbidity of workers.

When conducting a risk assessment procedure, attention should be paid to its phased nature. The first stage is the identification of hazardous chemicals, which allows you to identify substances used or formed in the production process, analyze safety data sheets and determine their physicochemical properties, toxicity and hazard class.

The next step involves assessing the dose-effect relationship, which allows investigating the relationship between the dose or concentration of a chemical and the frequency of adverse effects in workers exposed to the substance. It is also necessary to establish the lowest dose that causes adverse effects and to determine the patterns of effect growth with increasing dose.

Establishing the risk caused by air pollution in the work area allows not only to predict the probability and medical and social significance of possible health disorders under different scenarios of its impact, but also to justify the phasing and prioritization of measures to manage risk factors at both the individual and population levels (working contingents).

In parallel, the results obtained can be the basis for establishing and justifying economic losses to society as a result of the deterioration of the occupational health of working contingents or calculating the cost of implementing preventive measures and optimizing working conditions.

Therefore, the introduction and successful implementation of the stages of the risk assessment methodology allows solving both traditional and new tasks of preventive medicine, taking into account a complex of socio-economic and environmental problems.

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PHARMACEUTICAL WASTE MANAGEMENT IN THE CONTEXT OF THE EUROPEAN GREEN DEAL

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The European Green Deal 2020 is a flagship initiative of the European Union aimed at achieving climate neutrality by 2050, covering a wide range of sectors and areas of activity [1]. One of these important areas is pharmaceutical waste (PhW) management, which is addressed in the European Parliament Resolutions of 17 September 2020 and 24 November 2021 on a strategic approach to pharmaceuticals in the environment. These resolutions state that the Pharmaceutical Strategy should contribute to achieving the objectives of the European Green Deal by covering the full life cycle of a medicinal product. It is emphasized that the management of PhW should be carried out in accordance with the goals and objectives of the circular economy [2, 3].

PhW is generated at all stages of the life cycle of a medicinal product, namely: pharmaceutical development, technology transfer, industrial production, circulation (including purchase, sale, and prescription-dispensing of a medicinal product), the process of satisfying needs (consumption), cessation of production and medical use of a medicinal product, and the disposal and neutralization of PhW. Simultaneously, the disposal and neutralization of PhW at the various stages of a medicinal product's life cycle exhibit a sequential-parallel nature [4]. Given the multifaceted nature and complexity of PhW, it is important for each country to develop a national concept for PhW management based on the European

Green Deal [5], taking into account an integrated approach and cooperation between various stakeholders: state and local authorities, pharmaceutical manufacturers, medical and pharmacy facilities, waste collection and disposal organizations, scientists, and the public.

Future-oriented PhW management must be environmentally sound and cost-effective. In our opinion, special attention should be paid to formulations with a relatively high content of active pharmaceutical ingredients, especially tablets (obtained by direct compression) or powders. Such drugs include, for example, acetylsalicylic acid, acetaminophen, acetylcysteine, ibuprofen, norsulfazole, sulfonamide, and furacilin. Instead of disposal, expired medications of this type can often be utilized to recover active pharmaceutical ingredients. This approach presents an economically more attractive alternative to the de novo synthesis of these ingredients, as demonstrated by studies involving acetaminophen, tetracycline, and ibuprofen [6].

Furthermore, another promising avenue within the circular economy, offering potential for semi-industrial application, is the production of reagents for organic synthesis directly from the APIs present in these non-medically useful drugs. In our previous research, we proposed a simple procedure for the chemical disposal of various unusable drugs containing paracetamol in different dosage forms (Tylenol extra strength, McNeill Consumer; Paracetamol, Stirolbiopharm, Ukraine; Rapidol, Balkanpharma-Dupnitza AD, Bulgaria; Efferalgan, Bristol-Myers Squibb, France; Daleron C, KRKA, Slovenia) [7]. It has been clearly shown that these formulations are rich sources of various frequently used reagents for organic synthesis and industrial production. We found that by acid hydrolysis of the above drugs, one can obtain 4-aminophenol hydrochloride with 16-87% yields, depending on the starting dosage form. Moreover, it has been shown that the chemical transformation of paracetamol (capsules and tablets) in the reaction with benzyl chloride in an alkaline medium provides the formation of **N**-[4-(benzyloxy)phenyl]acetamide as an interesting reagent for organic synthesis. The purity (over 95%) of the obtained products was confirmed by LC-MS [8]. The aforementioned reagents are crucial in the synthesis of drug intermediates with industrially attractive yields. An important area of research-grade chemical recycling is the synthesis and creation of libraries of biologically active compounds based on the particular drug structure. This approach has been shown to be successful for the design of new molecules, depending on the pharmacological potential of the synthetic precursor as a starting material. The aim could be to potentiate the potency, reduce toxicity, or even create a new biological profile for the obtained derivatives. For example, we have shown that the use of ibuprofen or diclofenac sodium as starting compounds allows us to obtain a series of 1,3,4-oxadiazole-2-thiols, 1,2,4-triazole-3-thiols, 2-thioxo- and 2-imino-4-thiazolidinones, thiazolidine-triazole hybrid molecules, and 3**H**-thiazoles with structural fragments of these nonsteroidal anti-inflammatory drugs. These classes of compounds demonstrated, in a series of biological experiments, not only the expected anti-inflammatory effect but also significant anti-trypanosomal and antitumor activity [9, 10].

By developing the aforementioned approaches, scientists can address several issues in modern pharmaceutical science: the innovative and recycling-oriented utilization of PhW, support for local production of medications from the obtained materials, and advancement of research starting with chemically known scaffolds. This situation has unexpectedly emerged from an excessive supply of large amounts of pharmaceuticals when the latter cannot be objectively used for their primary goal – to treat or prevent diseases as ready-to-use formulations.

In conclusion, the management of PhW from the perspective of the European Green Deal is not only an environmental necessity but also a strategic opportunity for a more sustainable, safe, and responsible healthcare system. The transition to a circular economy and the reduction of environmental pollution are key principles that should underpin the management of PhW at all stages of a medicine's life cycle.

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THE QUALITY OF NUTRITION AMONG STUDENTS OF HIGHER EDUCATION IN CONTEMPORARY REALITIES

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Introduction: The quality of nutrition is one of the key factors determining the health, physical and intellectual development, and academic success of higher education students. Student years are a period of significant changes in young people's lives, associated with adapting to new learning conditions, living arrangements, and independent living. In contemporary realities, particularly amidst the full-scale war in Ukraine, the issue of rational nutrition becomes especially relevant, as stress, limited resources, and changes in the usual rhythm of life can negatively impact students' eating habits [3, 5]. Insufficient or unbalanced diets can lead to nutrient deficiencies, the development of chronic diseases, and decreased performance [1, 3]. The purpose of this article is to analyze the state of nutrition quality among higher education students in current conditions and to identify the main problems affecting the formation of healthy eating habits.

Peculiarities of Student Nutrition. Research shows that student nutrition is often characterized by irregularity, a prevalence of fast food, insufficient consumption of fruits, vegetables, and whole grains, and excessive intake of sweets and sugary drinks [3]. These negative trends are driven by several factors, including:

- Economic constraints: Students' budgets are often limited, forcing them to choose cheaper but less nutritious products [5].
- Lack of time: A demanding academic schedule leaves little time for preparing healthy meals, encouraging recourse to quick, ready-to-eat foods [7].
- Stress and psychological pressure: Studying, examination periods, and adapting to new environments cause stress, which can

affect eating behavior, leading to emotional overeating or, conversely, loss of appetite [4].

– Lack of cooking skills: Many students begin living independently for the first time, lacking sufficient experience and knowledge about rational nutrition and preparing healthy meals [3].

– Influence of social environment: Peer eating habits can also influence food choices and eating styles [2].

Impact of Martial Law on Student Nutrition Quality. The impact of martial law on the quality of student nutrition in Ukraine holds a special place in the analysis. Studies confirm that the war significantly changes young people's eating habits [3, 6, 7]. Instability, psychological tension, and forced displacement can lead to:

– Changes in diet: Food availability may be limited, forcing students to consume less diverse and nutritious food [5].

– Increased consumption of "comfort" food: In stressful conditions, there's an increased craving for foods high in sugar and fats, which temporarily improve mood but are not beneficial for health [3].

– Irregular meal patterns: Changes in daily routines, due to air raid alerts and other circumstances, can lead to skipped meals or chaotic eating [7].

– Worsening psycho-emotional state: Stress, anxiety, and uncertainty negatively affect appetite and nutrient absorption, which can exacerbate overall health [3].

Despite these challenges, it's important to note that some medical students, for example, show a certain awareness of the importance of a healthy lifestyle, even though their actual nutrition may not align with their knowledge [2, 4]. This indicates a gap between theoretical knowledge and practical skills in the field of rational nutrition.

Hygienic Assessment of Nutrition and Ways to Improve It. A hygienic assessment of students' actual nutrition reveals significant deviations from rational nutrition standards [5, 6]. This underscores the need to develop and implement programs aimed at improving the eating habits of higher education students. Possible directions include:

– Educational programs: Including disciplines on rational nutrition, clinical nutriciology, and food hygiene in curricula [1, 3]. This will help students develop a conscious attitude towards their health and nutrition.

– Information and educational work: Conducting lectures, seminars, and training sessions aimed at raising awareness about the principles of healthy eating, preparing nutritious meals, and the benefits of a rational diet [7].

– Creating a favorable food environment: Ensuring the availability of healthy food in student canteens and buffets, expanding the range of healthy products, and setting moderate prices.

– Psychological support: Providing assistance to students in overcoming stress that may affect their eating habits through psychological counseling and support groups.

– Forming a culture of healthy lifestyle: Promoting physical activity, abstaining from harmful habits, and creating conditions for healthy recreation.

Conclusion: The quality of nutrition among students of higher education in contemporary realities, especially under martial law, is problematic and requires a systematic approach. Unhealthy eating leads to negative health consequences, reduced performance, and lower academic success. Addressing this issue requires comprehensive measures, including educational programs, information and educational work, creating a favorable food environment, and psychological support. Only through the joint efforts of educational institutions, medical professionals, and students can healthy eating habits be formed, serving as a guarantee of strong health and a successful future.

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THE ROLE OF NON-FORMAL EDUCATION IN PROTECTING PUBLIC HEALTH IN THE POST-WAR PERIOD

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The military aggression in Ukraine has caused significant environmental challenges, particularly the unintentional release of persistent organic pollutants (POPs) into the environment [1]. These compounds are considered a global ecological and public health problem due to their bioaccumulative nature and potential to enter the human body, especially children, through food chains [2, 3]. Despite the severe risks, public awareness of POP-related threats in Ukraine remains critically low [4]. A gap exists at the state level between the need for ecological safety and the capacity of formal education to deliver practical knowledge and adaptive skills.

This research highlights the preventive role of public awareness as a key factor in ensuring ecological safety during wartime and post-war recovery. The authors propose that non-formal education serves as an effective tool for communication and public protection, particularly through youth initiatives. Experiences from the International Carpathian School [5, 6] underscore the potential of non-formal education in preparing the population, especially students, for environmental challenges. The interdisciplinary approach through Sustainable Development Goals

(SDGs 3, 4, 6, 11, 15, 17) enables the integration of educational, scientific, and civic efforts into national recovery processes.

The objective of the study is to emphasize the importance of raising public awareness about the health hazards posed by POPs, which have increased due to prolonged combat operations, fires, and damaged industrial infrastructure. The hypothesis is that improved awareness can effectively mitigate the impact of POPs on the most vulnerable groups - pregnant women, mothers, and children under three. Education for sustainable development, particularly in initiatives like the Carpathian School, launched in 2018 in Kosiv, Ivano-Frankivsk region, offers promising pathways. This school introduces participants to the best EU technologies for the decontamination of territories affected by toxic chemicals [5].

The research focuses on the influence of public awareness on sanitary safety in environments contaminated by POPs. The study employs an analytical approach, utilizing secondary sources such as scientific literature, WHO reports, and UNEP assessments. It examines past military operations in Vietnam, the Middle East, and the Balkans—highlighting civilian exposure to chemicals like Agent Orange, PCBs and dioxins—using qualitative content analysis via MAXQDA Analytics Pro 2022.

The war in Ukraine has inflicted lasting damage on soil and geological systems, affecting agriculture and ecosystem stability. Among the most concerning long-term environmental consequences is land degradation caused by POP contamination [7]. Polychlorinated biphenyls used in energy technologies and dioxins from fires and explosions can remain in ecosystems for decades. These substances cause a range of toxic effects, including chloracne, reproductive and developmental issues, immunotoxicity, and cancer. The primary exposure pathway is through food, with higher levels near conflict-damaged areas, landfills, and forests.

Historical data from conflicts in Kosovo, Serbia, and the Middle East reveal increased cancer rates and reduced life expectancy due to environmental pollution [8-12]. Protecting the environment during armed conflicts is increasingly recognized as a component of humanitarian law. However, the implementation of guidelines for industrial and energy site decontamination remains limited.

Current life safety education in Ukrainian schools is insufficient. The removal of safety subjects from the national curriculum by the Ministry of Education and Science reflects a systemic issue [13]. Public awareness is alarmingly low—only 4% of the population is informed about POP risks [2]. The Carpathian School addresses this gap by offering international volunteer educational programs focused on youth and civic engagement. It fosters cross-border cooperation, particularly with Baltic and Visegrad countries, showcasing solutions like phytoremediation and biofiltration to clean polluted soil and air.

Modern educational technologies are crucial for knowledge transfer, skill development, and professional training to enhance public safety and youth resilience in post-war environments. The study's results can inform public health communication strategies and workforce development, especially in medicine and emergency response [14-16].

Educational interventions should be integrated into the national bio-ecological safety system. This requires incorporating chemical, environmental, and biological safety, disaster medicine, and related disciplines into both formal and non-formal education.

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BIOLOGICAL FACTORS OF THREATS TO HUMAN HEALTH AND LIFE DURING WAR

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Today, among the large number of threats to the life and health of citizens that occur during the full-scale war in Ukraine, biological dangers deserve great attention. Thus, among terrorist acts that are committed in the form of sabotage, assassinations and assassinations, hijacking, attacks on computer networks, a significant part falls on bioterrorism, which, through the use of biological weapons, as well as the manufacture and distribution of dangerous food products, threatens the spread of mass infectious diseases among people, animals and plants and poses a danger to the health and life of the population.

As is known, a wide range of pathogens and their toxins can be used for the purpose of bioterrorism as a military threat. However, the most contagious pathogens are most often used: smallpox viruses, Marburg hemorrhagic fever, Ebola, plague, anthrax, tularemia, botulism toxin. Less contagious pathogens can be used with a lower degree of probability: brucellosis, Venezuelan equine encephalitis, foot-and-mouth disease, melioidosis, typhus, yellow fever, cholera, tetanus and diphtheria toxins. In addition, there are pathogens whose use is problematic: rabies, influenza, parenteral hepatitis, HIV, syphilis, gonorrhea and staphylococcal infections [1]. Accordingly, the problems of countering bioterrorism are constantly in the field of view of the National Security and

Defense Council of Ukraine, the Ministry of Health and the State Emergency Service of Ukraine.

In modern conditions of war, a system of knowledge about the striking properties of biological weapons and the protection of troops against them is important. Thus, the military team with its inherent features of staffing, life and living conditions and activities of personnel during the period of hostilities often undergoes rapid changes in the conditions of deployment of troops, forced stay in areas unfavorable for epidemic diseases, and great physical exertion. In view of this, disruptions in nutrition, certain deficiencies of a sanitary and epidemiological nature, etc., are possible, which, in turn, contributes to the emergence of infectious diseases.

At the same time, properly organized anti-epidemic measures in the Armed Forces of Ukraine are of paramount importance. They are aimed at preventing and eliminating infectious diseases in the troops. This is achieved by carrying out a complex of works by the medical service to neutralize sources of infection, disrupt the mechanism of transmission of the infectious agent, and create an unfavorable environment for the body to infectious diseases.

Another factor that poses a threat to the health and life of the population is the pollution of air, soil and water bodies in the places of hostilities in the territories of their residence. Thus, a significant excess of microbiological indicators has been recorded. Accordingly, such water cannot be used for consumption, recreation or processing of food products, and sown areas for growing crops. In addition, when ecological systems are disrupted, natural foci of particularly dangerous infections (tularemia , plague, anthrax, etc.) are activated, as well as their spread. In fact, today the occupiers in Ukraine have created an ecocide regarding the environment. And a number of criminal proceedings have already been opened on this occasion.

It should be noted that in Ukraine, currently, there are over three thousand microbiological laboratories operating, in which work is constantly carried out with biological agents of pathogenicity groups II-IV. In order to strengthen the anti-epidemic regime and increase the safety of these institutions, a number of organizational and practical measures have been taken in recent years. Orders of the Ministry of Health of Ukraine on improving the safety of institutions and strengthening the anti-epidemic regime of work in microbiological laboratories have been approved. An inspection of microbiological departments (laboratories) of state institutions, institutions and organizations responsible for the biosecurity of the state has been carried out. It was established that the material and technical support of these institutions and institutions is insufficient. Based on its conclusions, measures have been proposed to improve the biological safety of institutions and the procedure for maintaining culture collections.

The issues of biosafety and biosecurity when working with pathogenic microorganisms are constantly discussed at international and national meetings. The creation and provision of guaranteed safe working conditions in microbiological laboratories and, primarily, in units working with especially dangerous infections is a task of national importance.

Thus, today it is extremely important to be ready at any time to perform diagnostics in order to prevent the importation, primarily, of quarantine and dangerous infectious diseases of bacterial and viral etiology, which creates a methodological basis for readiness for rapid diagnosis of pathogens used with bioterrorist intentions.

Important To preserve the life and health, as well as the working capacity of the affected population, timely organization and implementation of sanitary-hygienic and anti-epidemic measures is important, which should be carried out in conjunction with medical and evacuation measures.

A systematic assessment of the biological or bacteriological situation should be carried out on the basis of the results of biological reconnaissance. To this end, it is necessary to carry out non-specific and specific indication of biological agents, which involves a number of stages and is carried out by chemical troops and the medical service.

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RUSSIA – A BIOLOGICAL THREAT TO THE GLOBAL COMMUNITY

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A feature of terrorism in the 21st century is that, for the first time, a state like Russia has become a terrorist. To wage military aggression against Ukraine, it employs an entire arsenal of tools, including those characteristic of terrorism in all its forms. One such real threat of a terrorist nature is the potential for the aggressor to execute a bioterrorist attack against our state. As is typical of an aggressor, Russia has repeatedly spread disinformation to persuade the world community of the alleged presence of biological weapons in Ukraine and the ongoing related scientific research in this area with the involvement of foreign countries (about the so-called biolaboratories), in order to accuse our state of violating the requirements of the Biological Weapons Convention [1].

It is important to note that biological weapons have neither been developed nor stored, nor are they currently being developed on the territory of Ukraine. In fact, the Russian Federation itself poses a potential source of biological threats to the national security not only of Ukraine but also of the entire world. Following the collapse of the USSR in the 1990s, the first president of the Russian Federation disclosed certain aspects of the biological weapons development programme within the Union. The world became aware that the USSR was effectively developing biological weapons. Thus, from 1973 until at least 1991, a covert comprehensive programme known as “Biopreparat” operated within the Union under the guise of civilian activities. The institution bearing the same name (in secret correspondence - A/S A-1063) was a scientific and production association, whose tasks included not only the standard production of medicines and vaccines but also the covert development of biological weapons.

The divisions of “Biopreparat” in the late 70s and early 80s of the 20th century were engaged in the production of new types of biological weapons and also conducted active research and development on around 50 pathogenic agents, including pathogens of such dangerous diseases as anthrax, Ebola, Marburg, Lassa fevers, smallpox, typhus, plague, etc.

As the former first deputy head of the Biopreparat programme, Kanatzhan Alibekov, stated after the collapse of the USSR while in exile in the United States: “There are only two mechanisms for preventing a biological attack: an effective intelligence service and an effective system of biological security and biological protection of the country. An effective intelligence service capable of preventing an attack, an effective system of biological security and biological protection - to minimise its negative effect if the attack does occur” [2]. According to the “legend” to cover up illegal activities, the Biopreparat system was allegedly aimed at mass production of drugs needed by ordinary citizens - vitamins, medicines, antibiotics and vaccines. Its true purpose was only discovered in the 1990s when it became clear that Biopreparat had practically no peaceful activities, as it consisted of specialised institutes and factories for the creation of means intended for biological warfare.

To develop biological weapons, there must be appropriate scientific, laboratory, technological, and production conditions that necessitate laboratory protection at the BSL-3+ level or, preferably, at the BSL-4 level, which Ukraine has never possessed and still lacks. Currently, there are only about 20 laboratories worldwide with the highest level of protection. These are extremely costly projects. Therefore, Russia merely fabricates its falsehoods about bioweapons as a means to justify its invasion of Ukraine to the global community. After the collapse of the Soviet Union, the lion's share of the scientific and production potential for the development and manufacture of biological weapons, as well as the accumulated stockpiles, remained within the territory of the Russian Federation. Additionally, stocks of biological weapons materials from other republics were also transferred to Russia. The most substantial biological facilities that Russia inherited from the USSR, which can be utilised for the development and production of biological weapons, are as follows.

Scientific and production institutions where scientific research can be conducted on the development of combat strains of pathogenic microorganisms and their delivery means include: Obolensk (Moscow region) - Institute of Applied Microbiology; Koltsovo (Novosibirsk region) - Virological Institute (currently "Vector"); St. Petersburg - Institute of Especially Pure Biological Preparations; Lyubuchany (Moscow region) - Immunological Institute; Moscow - Institute of Biological Instrumentation, which during the USSR was focused on developing equipment for biological weapons production plants; Yekaterinburg (Chkalovsky district, 19th military town) - a secret microbiological centre of the Ministry of Defence of Russia, one of the centres for the creation of offensive biological weapons during the USSR, which also includes the Sverdlovsk Institute of Military Equipment Problems; Moscow - Moscow Institute of Safety Engineering; Kirov – Kirov Institute of Microbiology; Berdsk – Berdsk Technical Institute of Active Biological Substances, and several other open medical and biological research institutes and centres.

Production facilities: Penza - Penza Biosynthesis Plant; Berdsk - Berdsk Research and Production Base, as well as seven more reserve facilities that will be brought into operation for the production of bioweapons in the event of a war. Three biological weapons testing ranges from the Soviet Union remain in operation in Russia: Reutov (Moscow District), Shikhany (Volga District), and Stryzhi (Kirov District).

Since Putin assumed power in Russia, this area has intensified its activities. In November 2013, the leadership of the Russian Federation developed and approved a significant programme "Fundamentals of State Policy in the Field of Ensuring Chemical and Biological Security of the Russian Federation for the Period

Until 2025 and Beyond." Its implementation is supported by a number of scientific publications, including those of dissident scientist Lev Fedorov, who notes that based on the achievements of the former Soviet Union, "…using genetic engineering methods, modern Russian creators of biological weapons have created the most effective combat strains (and at the same time vaccines) of the most dangerous pathogenic bacteria resistant to modern antibiotics – plague, anthrax, tularemia, and gangrene with a mortality rate of about 100%" [3].

In 2021, the Russian Armed Forces, as part of this programme, received new radio-biochemical reconnaissance systems RKB-8 and RKB-9. These systems are based on the armoured vehicle "Tiger" and the automobile chassis "Typhoon". Sampling occurs in automatic mode without the crew entering the zone of potential contamination. The aforementioned RKB-8 and RKB-9 are equipped with unmanned aerial vehicles for aerial remote radio-biochemical reconnaissance. The effectiveness of RKB-8 and RKB-9 is twice that of the previous systems in service with the Russian army. Thus, a terrorist country that claims that all its neighbours wish to attack it and is developing bioweapons at the behest of the West is merely attempting to divert attention from itself, while simultaneously posing a genuine biological threat not only to Ukraine but also to the entire global community.

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SECTION 2 CHEMICAL, RADIATION, AND ENVIRONMENTAL SAFETY DURING WAR AND TECHNOGENIC STRESS

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PROBLEMS AND PROSPECTS OF HOUSEHOLD WASTE DISPOSAL IN THE LVIV REGION

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At the present stage of our planet's existence, the natural environment and anthropogenic activity are inseparable, so the problem of harmonizing their relations has acquired global significance. The ecological situation, especially now, in war conditions, remains difficult. Combat operations and the use of various types of weapons have an extremely negative impact on ecosystems and the psychosomatic health of people. For example, soil degradation occurs due to compaction, salinization, flooding, littering, pollution, etc. Air and water resources are being polluted and protective forest strips along highways and railways are being destroyed. The enemy is destroying our forests, using wood to construct fortifications, laying infrastructure, heating, and cooking [1].

The problem of littering territories with household waste is also growing, especially in the western regions of Ukraine, which is associated with a high concentration of the population due to a large number of internally displaced persons. In addition, in the territories liberated from occupation, a lot of construction waste has accumulated, resulting from the destruction of residential buildings and infrastructure, and damaged civilian cars and military equipment remain.

The morphological composition of household waste determines the percentage ratio of various components in the total waste mass. According to the World Bank, the world's average morphological composition of household waste is as follows: organic waste: 44-50% – food scraps, garden waste, spoiled products. This waste is bioconvertible and can be used to produce compost or biogas; plastic: 12-20% – plastic bottles, packaging, containers. Plastic is one of the most problematic types of waste due to its long decomposition period – from 100 to 1000 years; paper and cardboard: 10-12% – newspapers, magazines, and packaging boxes. Paper is a valuable raw material for recycling; glass: 5-10% – bottles, cans. Glass. Glass can be recycled an infinite number of times without losing quality; metal: 3-5% – tin cans, aluminum packaging. Metals are easily recyclable, and their reuse significantly reduces the need for new resource extraction; other waste, 10-15%, includes textiles, electronics, construction, and medical waste [3,4].

The chemical composition of household waste depends on its morphology. The main chemical elements that make up household waste are: Carbon (40-50%) – the main component of organic waste, plastics and paper; Oxygen (30-40%) – is part of biomass and cellulose; Hydrogen (5-7%) – is found in food waste, plastics; Nitrogen (1-3%) – mainly in organic waste and Sulfur, phosphorus, metals – in small quantities. In addition, household waste may contain heavy metals (mercury, lead, cadmium), which are dangerous for the environment and, in particular, for human health.

According to statistics, the accumulation of household waste in Ukraine before the Russian military aggression was critical (in 2021, more than 90% of household waste was taken to landfills, only 7% was recycled, and 1.7% was incinerated), and now it can be considered catastrophic. According to statistics, global waste disposal indicators have constantly decreased over the past ten years. Only 6.9% of materials after recycling are used as secondary raw materials, and the rest of the household waste is subject to unauthorized, natural disposal.

Resolving the critical situation with the formation, accumulation, collection, and safe disposal of household waste, characterized by the further development of environmental threats, necessitated the adoption of the Law of Ukraine "On Waste Management". "It provides for the "following changes in waste management: a new effective permitting system; decentralization of waste management; multi-level planning; infrastructure development; European principles – waste management hierarchy, extended producer responsibility, «polluter pays» [2].

Currently, landfilling is the most common method of waste disposal in the world, especially in developing countries. This method consists of placing waste in specially designated areas with a protection system against soil and groundwater contamination. However, landfilling has significant disadvantages: during the anaerobic decomposition of organic waste, methane is released, one of the most potent greenhouse gases; the formation of leachate that can penetrate groundwater; landfills require constant monitoring and reclamation.

A more effective and safe waste disposal system is one of separate collection. Sorting household waste makes it possible to use it as secondary raw materials. The organic component of waste can be composted. Composting is carried out at specialized enterprises and can also be carried out locally or directly on household plots.

Lviv has a city program for composting organics, which involves the installation of special containers for 240 liters. This is for collecting and transporting food waste by separate trucks to composting sites. This program is financed from the city budget, namely the LME «Zelene Misto», Lviv [5]. The compost obtained during the fermentation process is used to landscape the city.

However, due to the ingress of plastic, glass, textiles, and other foreign objects into the container with food waste, the compost is contaminated with these components. It cannot be a fertilizer, but only an organic mixture of technical quality [6], which can be used to reclaim household waste landfills. These lands have changed the relief structure, land reclamation, during construction, and other works.

We investigated the morphological composition of compost (organic mixture of technical quality) in the 1-10 mm fraction (Composting Station of the LME «Zelene Misto»): polymer content – 340 mg/kg; glass – 1788 mg/kg; metals – 572 mg/kg; textiles – 93 mg/kg.

Therefore, introducing modern technologies, developing processing infrastructure, and raising environmental awareness among citizens will contribute to solving the problem of the safe disposal of household waste.

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LEGAL GUARANTEES OF ENVIRONMENTAL RIGHTS OF CITIZENS OF UKRAINE IN THE CONDITIONS OF MARTIAL LAW

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Russia's full-scale invasion of Ukraine has resulted in a violation of the basic environmental rights of millions of citizens. It has become an environmental catastrophe that is causing irreparable damage to the environment.

Environmental rights of citizens are a set of legal opportunities and means enshrined in law and guaranteed by law. They allow satisfying the needs and interests of citizens in the field of environmental protection, use of natural resources and environmental safety [1, c. 39].

Guarantees of environmental rights are enshrined in the Constitution. According to Article 50 of the Constitution of Ukraine, everyone has the right to a safe environment for life and health and to compensation for damage caused by a violation of this right. Everyone is guaranteed the right of free access to information on the state of the environment, the quality of food and household items, as well as the right to disseminate it. Such information cannot be classified by anyone. The list of environmental rights of Ukrainian citizens is provided for in Article 9 of the Law of Ukraine “On Environmental Protection”, but it is not exhaustive and may be defined by other laws of Ukraine.

Under martial law, which was imposed by Presidential Decree No. 64/2022 of February 24, 2022, one of the most important environmental rights is being violated - the right of citizens to an environment that is safe for their life and health. This is one of the fundamental human rights that guarantees everyone the opportunity to live in conditions that do not threaten health and life due to the negative impact of the environment. This right includes the right to live in ecologically clean areas, breathe fresh air, consume food that is safe for health, the right to unpolluted land and water, etc.

Large-scale air, water and soil pollution has become one of the key environmental threats under martial law, causing significant damage to the health and lives of citizens. The constant shelling of industrial facilities and settlements has resulted in the release of a significant amount of toxic substances into the environment. These harmful chemical compounds have penetrated the soil layers, drinking water sources, and the air, causing numerous health problems among the population, including respiratory diseases, skin lesions, and cancer.

The hostilities in Ukraine have caused a significant deterioration in air quality. Large-scale explosions, fires at infrastructure facilities, and the destruction of industrial plants and chemical warehouses are accompanied by emissions of a large number of toxic substances, including carbon monoxide, heavy metals, and numerous other hazardous substances that cause irreparable damage to the health of the Ukrainian people, including an increased risk of chronic diseases of the respiratory and cardiovascular systems. According to environmentalists, fires in forests, cities, and oil depots shelled by Russians at the beginning of the full-scale war have released almost 50 tons of harmful emissions into the air, and thousands of hectares of forests in Donetsk, Luhansk, Zaporizhzhia, and Kharkiv regions have burned down. Wartime is accompanied by an increased risk of spreading acute intestinal infections transmitted through water, including hepatitis A, cholera, shigellosis, etc. In particular, during the hostilities, a significant number of sewage treatment plants in cities on the Azov

Sea coast were destroyed, which led to sewage entering rivers and the sea and mixing with groundwater, thus causing the population to lack clean water for domestic use and drinking.

It is also worth mentioning the damage caused by the hostilities to the soil, in particular, to its most fertile type, black soil. Thus, areas subjected to shelling often become unsuitable for agricultural use due to the accumulation of toxic chemicals from munitions. These compounds can remain in the soil for a long time, migrating into groundwater and plants, which creates a risk of toxins entering the food chain. This means that food grown on battle-affected land can be unsafe to eat and cause significant harm to human health..

In addition to the direct damage caused by the war, the ongoing conflict significantly complicates the implementation of environmental protection measures in the affected regions. Lack of stability and security threats prevent environmental services and humanitarian organizations from accessing the affected areas.

Despite the existing challenges, Ukraine is taking concrete steps to overcome environmental problems. The Government of Ukraine is gradually stepping up its efforts in the field of environmental protection by adopting new regulations, strengthening control over compliance with environmental legislation, increasing funding for environmental projects, and expanding cooperation with the public sector and academic institutions. A number of important environmental regulations were approved. In particular, the Law of Ukraine “On Prevention, Reduction and Control of Industrial Pollution” was adopted, which aims to introduce an optimized, transparent and modern approach to the control and reduction of industrial pollution [2]. International organizations, including the United Nations Environment Programme (UNEP), are also actively involved in this process, providing support for the cleanup of contaminated areas, rehabilitation of damaged ecosystems, and implementation of sustainable environmental practices.

The International Register of Damage has a new form of application for environmental damage, which was adopted by the Council of the Register of Damage Caused by the Aggression of the Russian Federation against Ukraine on February 21, 2025 and approved by the Conference of the Register of Damage Participants. According to it, the definition of "environmental damage" includes any harmful impact on fauna, flora, soil, water, air, ecosystems formed by these elements, as well as on the characteristic features of the landscape and natural resources or on the interaction between these factors. In agreement with the experts of the CF "Ecology. Law.Human", this wording narrows the concept of "environmental damage" and may complicate or create conflicts or unequal interpretation of cases in which Ukraine has the right to claim compensation for environmental damage. This is due to the fact that, first, the environment has the ability to regenerate itself, and it is impossible to record environmental damage in the context of military operations, especially in a timely manner. Therefore, it can be quite difficult to prove the actual amount of damage in terms of environmental degradation and loss of environmental value. [3] Applicants must submit all relevant supporting evidence, as well as information on the details of the application and the methodology for determining the estimated amount of the claim. However, the Rules do not specify the evidence to be submitted. Given that this category of claims is one of the most difficult to prove, these issues need to be further regulated.

Claims for damage to persons or property that may arise from or result from damage to the environment, as well as claims for related humanitarian costs or demining and clearance of unexploded ordnance, are filed in other relevant categories. However, the Rules do not specify which ones. Allegations of theft of natural resources, i.e., the exploitation of natural resources for commercial gain, are filed in category B3.2 "Theft and/or misappropriation of natural resources".

The issue of establishing a compensation mechanism is also open, which, according to the Registry's Charter, should consider the merits of the application and award compensation.

Thus, the full-scale armed aggression against Ukraine, which began in 2022, has become one of the largest challenges for the environment and has violated the basic and most important environmental right of Ukrainian citizens - the right to a safe environment for their life and health. Ensuring environmental human rights in Ukraine is a complex process that requires a comprehensive approach and coordinated efforts of the state, the public and the international community.

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EXPERIENCE IN MONITORING RADIATION-HAZARDOUS SITES: LESSONS FOR ASSESSING THE IMPACT OF MILITARY ACTIVITIES ON THE GEOLOGICAL ENVIRONMENT

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Russia's full-scale invasion of Ukraine has created significant risks of disturbing geological environment and groundwater contamination. Damage to nuclear, industrial, chemical, and energy infrastructure poses severe threats through toxic and radioactive pollution.

Military actions frequently target or inadvertently damage facilities, releasing hazardous substances into surrounding ecosystems. The destruction and damage of chemical plants, metallurgical complexes, storage, and wastewater treatment facilities, such as those in Donetsk, Luhansk, and Mariupol, has led to uncontrolled discharges of toxic substances, including heavy metals, hydrocarbons, and radioactive isotopes into water bodies and soils [1]. Water systems have been intentionally targeted as strategic assets. Destruction of dams and diversion of rivers have been used as warfare tactics, influencing water access and contributing to flooding and groundwater contamination. In conflict zones like Donbas, military disruptions have halted drainage from coal mines, causing flooding and the leaching of toxic substances into groundwater systems. This problem is exacerbated by the hydrological connectivity of mines, spreading contamination across vast areas. Additionally, explosive devices used during military actions introduce not only mechanical destruction but also chemical toxicity. Explosives often contain substances like perchlorates, TNT residues, and heavy metals, which are highly persistent in geological environments. Over time, these pollutants can migrate through soil layers, reaching aquifers and entering the water supply. Their chemical stability makes them particularly dangerous, as they resist natural degradation, accumulate in the environment, posing long-term risks for the environment and the populations health [2].

Uncontrolled fires release contaminants into the atmosphere, spreading them to previously clean areas. Suppression efforts may worsen pollution – firefighting foams often contain PFAS, which are mobile, persistent, and bioaccumulative. Using them in contaminated zones exacerbates groundwater pollution and hinders recovery [3]. Post-conflict recovery generates additional challenges. Demolition of damaged structures produces hazardous waste, risking secondary contamination. Improper debris disposal can leach toxins into geological layers, complicating restoration.

Prior experience with monitoring and managing radiation-hazardous sites in Ukraine and worldwide provides a valuable foundation for addressing these risks. Decades of monitoring in areas like Chernobyl have led to development and use of advanced technologies and methods. Applying this expertise in conflict zones enhances early detection, response, and environmental risk mitigation. Systematic monitoring of groundwater and the geological environment in radiation-contaminated areas relies on internationally recognized principles, regulatory frameworks, and methodological approaches that ensure scientific validity and practical effectiveness. The analysis of best practices from countries such as the United States, Canada, Germany, Japan, and Ukraine — particularly in the context of long-term environmental monitoring in the Chernobyl Exclusion Zone [4] — highlights a number of key principles that are especially relevant for implementation in conflict-affected regions and during post-conflict recovery.

Importance of Structured Methodologies. The application of formalized procedures, such as the U.S. Environmental Protection Agency's Data Quality Objectives (DQO) process and the development of Conceptual Site Models (CSMs), is critical to designing scientifically based and site-specific monitoring programs. These frameworks facilitate hypothesis formulation, effective data collection, and informed decision-making under conditions of environmental uncertainty [5, 6].

Alignment with International Standards. The adoption of internationally recognized standards, such as the International Atomic Energy Agency Safety Standards Series, the ISO 5667 family of standards for water quality sampling, and American Society for Testing and Materials (ASTM) protocols, ensures consistency, reliability, and comparability of monitoring results. Adapting these standards to national contexts enhances integration with global safety frameworks.

Technically Justified Monitoring Network Design. The spatial distribution, depth, and density of monitoring wells must be based on a comprehensive understanding of the site-specific geological and hydrogeological conditions, which is achieved through developing and iteratively updating the CSM.

Modern Sampling and Analytical Techniques. The implementation of low-flow groundwater sampling methods, in-situ measurement of unstable parameters, and rigorous quality assurance and quality control (QA/QC) protocols significantly increases the reliability and representativeness of monitoring data. These practices are essential in dynamic and high-risk environments, such as areas affected by military conflict.

Advanced Data Management and Interpretation Tools. Robust data management systems incorporating Geographic Information Systems (GIS), geostatistical analysis, and predictive modeling are indispensable for identifying contamination trends, delineating high-risk zones, and supporting transparent and evidence-based decision-making.

Integration of Adaptive Management Principles. Monitoring systems must be capable of responding to evolving environmental conditions, including changes in hydrogeology, climate variability, and the emergence of previously unanticipated contaminant sources. The use of automated sensors, real-time data acquisition technologies, and remote monitoring platforms enhances system resilience, improves early warning capabilities, and supports long-term environmental sustainability.

Institutional Capacity Building and Interagency Coordination. For countries undergoing regulatory transformation, such as Ukraine, strengthening institutional capacities, improving interagency coordination, and investing in field, laboratory, and data infrastructure are essential for the effective implementation of international best practices.

Mentioned actions are crucial for aligning national environmental monitoring systems with global standards and ensuring the long-term protection of radiologically and chemically impacted environments in conflict-affected regions and during post-conflict recovery.

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FIRE HAZARDS AND TOXICOLOGICAL PROPERTIES OF VEGETABLE OILS

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This paper examines the processes of thermal degradation of vegetable oils during heating and the associated toxicological and fire hazard risks. The formation of harmful compounds – such as acrolein, polycyclic aromatic hydrocarbons (PAHs), and trans fats – is described, as well as their effects on the human body. Fire suppression methods for Class F fires are analyzed, including the use of fine water sprays and inert gases. Relevant experimental data are provided, confirming the effectiveness of modern fire extinguishing systems and the toxicity of products formed during repeated heating of oils.

Vegetable oils are widely used in the food, cosmetic, and chemical industries. Despite their organic origin, under certain conditions, they can pose significant risks to human health and the environment. Particular attention is paid to the fire hazards and toxicity of the products generated during the thermal decomposition of oils. According to [1], fires caused by the ignition of vegetable oils or animal fats are classified as Class F fires and exhibit specific combustion characteristics.

Fires resulting from the ignition of vegetable oils or animal fats used for frying are classified as Class F fires, as defined in [1]. This class is distinguished due to the specific conditions of ignition and extinguishment of such substances, namely:

- the combustion temperature typically exceeds 300 °C;
- the flammable liquid possesses high viscosity and heat capacity, complicating the cooling of combustion products;

- during extinguishment, the contact of water with hot oil causes instantaneous vaporization, leading to the expulsion of burning liquid – an effect known as explosive splattering [2].

Extinguishing with water is strictly prohibited! This rule is critical for personnel safety, as water not only fails to extinguish the fire but significantly exacerbates it. Modern methods for extinguishing vegetable oil fires include:

- water Mist Fire Suppression;
- water Mist combined with Inert Gases.

Water mist is a fire suppression system that produces fine droplets with diameters less than 100 micrometers. This system offers several advantages over conventional water jets:

- rapid temperature reduction – due to the large surface area of the fine mist, heat is efficiently removed from the ignition zone;
- fuel–oxygen isolation – the steam generated upon contact with a hot surface forms a barrier that partially blocks oxygen access;
- reduction of smoke and toxic by-products – fine droplets capture aerosols, improving evacuation conditions [3].

The authors of [3, 4] have demonstrated that water mist systems can reduce the surface temperature of oil from 360 °C to below its flash point (< 300 °C) within 30-40 seconds. Combined systems include: water mist + inert gases (nitrogen, CO_2, argon). An innovative approach involves combining water mist with the injection of inert gases. Such a system operates in three key ways:

- temperature reduction (cooling);
- reduction of oxygen concentration (below 15% – the level at which combustion becomes impossible);
- flame suppression by creating an oxygen-depleted atmosphere around the fire source.

In [2], it was shown that the use of nitrogen in combination with water mist can reduce flame intensity by 80-90% within the first few minutes of extinguishing, without the risk of re-ignition (see Table).

Table 1

Advantages of Modern Fire Suppression Methods

Suppression Method	Advantages	Disadvantages
Water Mist	Efficient cooling, low water consumption, safe for electrical equipment	Requires specialized equipment
Inert Gases	Leave no residue, inhibit combustion at the molecular level	May pose health risks in poorly ventilated spaces
Combined Systems	Highest efficiency, suitable for industrial kitchens and chemical labs	High installation cost

Upon heating vegetable oils, particularly with repeated use in cooking, thermal and oxidative degradation of triglycerides occurs. This leads to the formation of a number of hazardous compounds, including acrolein. Acrolein is produced by the dehydration of glycerol, a by-product of triglyceride breakdown. It is a volatile compound with a pungent odor that irritates the mucous membranes of the respiratory tract. Acrolein has been shown to have genotoxic and carcinogenic activity [5].

Polycyclic aromatic hydrocarbons (PAHs) form during overheating of oils (above 350 °C), especially in the presence of food residues or smoke. The most notable representatives – benzo[a]pyrene and chrysene – are classified as Group 1 carcinogens by the IARC [6].

Trans fats – trans-isomers of unsaturated fatty acids – are generated under high-temperature conditions, particularly in industrial processing. They negatively affect blood lipid profiles by increasing LDL (low-density lipoproteins) and decreasing HDL (high-density lipoproteins), thereby elevating the risk of cardiovascular diseases.

Laboratory studies on animals and epidemiological observations point to the adverse effects of long-term consumption of foods prepared using repeatedly heated vegetable oils, including:

- hepatotoxicity – lipid accumulation in the liver, hepatocellular inflammation;
- hypertension – repeated heating increases oxidized lipid levels that impair vascular reactivity;
- inflammatory responses – elevated levels of interleukin-6 (IL-6) and C-reactive protein;
- cell membrane damage caused by free radicals and lipid peroxidation (LPO).

In the study [7], laboratory rats were fed a diet containing repeatedly used oils. The results showed a significant increase in malondialdehyde (MDA) levels – an established biomarker of oxidative stress – as well as a decrease in antioxidant enzyme activity (catalase and superoxide dismutase). Thus, excessive consumption of repeatedly heated oils may have serious health consequences and requires further investigation and regulatory oversight.

The conducted analysis demonstrates that, despite their natural origin, vegetable oils, under conditions of prolonged or repeated heating, become a source of numerous toxic and carcinogenic compounds, such as acrolein, polycyclic aromatic hydrocarbons (PAHs), and trans fats. The formation of these substances not only deteriorates the organoleptic properties of food products but also poses a serious health hazard, causing hepatotoxicity, impaired vascular regulation, oxidative stress, and inflammatory responses. The presence of free radicals and lipid peroxidation products is closely associated with the development of chronic diseases, including atherosclerosis and cancer.

Special attention in this study is given to the fire hazards associated with the ignition of overheated vegetable oils, classified as Class F fires. It has been established that traditional extinguishing methods (particularly the use of water) are not only ineffective but also dangerous due to the risk of explosive splashing. In this context, modern fire suppression systems based on water mist and inert gases demonstrate high effectiveness, owing to their ability to rapidly lower temperature and block oxygen access.

Therefore, in order to mitigate both toxicological and fire-related risks associated with the use of vegetable oils, it is advisable to implement advanced thermal processing control technologies, ensure the regular replacement of oils, utilize specialized fire suppression systems, and develop appropriate national sanitary and fire safety regulations.

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THE BARRIER-FREE LANDSCAPING AS A WAY TO INCLUSIVE PUBLIC SPACE

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In the modern world, the concept of barrier-free accessibility is becoming increasingly important in various spheres of society, especially in the context of creating public spaces that should be accessible and convenient for all categories of the population. Barrier-free accessibility involves the removal of physical, social and psychological barriers that prevent full participation in public life. It is an integral part of inclusiveness, a concept that aims to ensure equal rights and opportunities regardless of age, physical abilities or other characteristics. One of the most important areas of application of these principles is the greening of public spaces, as green areas not only provide aesthetic value and comfort, but are also a key factor in maintaining the health, social interaction and psychological well-being of city residents.

Greenery as a part of urban space is traditionally seen as a factor in improving the microclimate, reducing air pollution, creating natural centers of biodiversity and recreation. However, in order for these benefits to be available to all citizens, public green spaces must meet the requirements of barrier-free accessibility. This means that the design of parks, squares, botanical gardens, and other green spaces should take into account the diversity of users, from people with disabilities, war veterans, children, and the elderly to people with temporary mobility impairments. The barrier-free landscaping includes a number of technical solutions, including smooth and stable path surfaces, no sharp changes in height, tactile and sound guides for the visually impaired, comfortable places to rest, accessible toilets, adapted playgrounds, and inclusive navigation elements [9].

It is important to emphasize that barrier-free green space is not only a technical issue, but also a deeply social one, as it is the accessibility of green spaces that promotes social inclusion of vulnerable groups. People with disabilities, veterans, internally displaced persons, and the elderly often face barriers that make it impossible for them to fully visit parks or even leave their homes. In the context of post-war Ukraine, this problem is of particular importance. The war has led to an increase in the number of people with health problems, and has increased the number of displaced people and those in need of psychological support. Green public spaces can become one of the most important platforms for rehabilitation, socialization, and psychological support [8].

The psychological impact of nature on humans is a proven science: staying in green areas reduces stress, improves mood, and increases cognitive function. For veterans and other people with trauma or post-traumatic stress disorder, access to natural spaces is an important part of rehabilitation [5]. Therefore, the creation of barrier-free parks and squares is not only a social duty, but also an investment in the health of the nation.

Ukraine's postwar recovery offers unique opportunities for rethinking urban space. However, reconstruction based on old models may not take into account new challenges and needs. This is a chance to integrate the principles of sustainable development, inclusiveness, and barrier-free accessibility into urban planning. In particular, greening projects can and should be part of a comprehensive reconstruction, where accessibility will be one of the key criteria for the quality of space [9]. To do this, it is necessary to take into account international standards of universal design and adapt them to Ukrainian realities.

In Ukraine, the regulatory framework for barrier-free accessibility is still underdeveloped in terms of public green spaces. Basic standards such as DBN B.2.2-40:2018 “Inclusiveness of Buildings and Structures” regulate the requirements for building infrastructure, but do not detail the specifics of greening [1]. At the same time, international experience offers more in-depth recommendations. For example, European countries are actively implementing standards that include tactile paths, Braille information signs, play areas adapted for the disabled, and safe routes for wheelchair or walker use [3]. In the United States, the Americans with Disabilities Act (ADA) requires that all public spaces be accessible, and the relevant regulatory authorities oversee compliance with these requirements [7].

It is also important to note that barrier-free landscaping is an integrated approach that includes interdisciplinary cooperation between architects, landscape designers, urbanists, sociologists, and doctors. A successful example of this approach can be found in the Netherlands, where parks are planned with special routes with adapted surfaces to facilitate the movement of wheelchairs, special places for rest with ergonomic benches, and information systems for people with visual impairments [4].

In Ukraine, the first local initiatives are already emerging that implement the principles of barrier-free landscaping in the cities of Lviv, Kyiv, and Kharkiv. However, these projects need to be scaled up, systematically supported, and included in the national urban development policy. This is especially relevant in the context of rehabilitating war veterans and supporting internally displaced persons, for whom comfortable and accessible green space is not only a matter of quality of life but also of social adaptation [6].

For the successful implementation of barrier-free landscaping in Ukraine, it is necessary to strengthen the legislative framework, create specialized guidelines and standards that take into account the social, environmental and economic characteristics of our country. It is also important to implement training programs for urban, architectural, and landscape design professionals that will help shape their professional level with inclusive approaches. Public involvement, including representatives of vulnerable groups, should be a priority in project planning and implementation. A separate task is to introduce monitoring systems that will allow assessing the quality of accessibility of green spaces and making prompt adjustments.

It is important that barrier-free landscaping is harmoniously combined with sustainable development, as the use of nature-based solutions, the use of local plants, eco-friendly materials, and the rational use of resources create not only comfortable but also environmentally safe public spaces. This is in line with the overall goals of the European Green Deal, which aim to improve the quality of life, enhance the urban environment, and combat climate change [2].

Thus, barrier-free landscaping is one of the key ways to create an inclusive public space, which is especially relevant for Ukraine in the period of post-war reconstruction. It not only promotes social justice, improves the quality of life, and improves the health of the population, but also becomes the foundation for building sustainable, comfortable, and modern cities. The development of this sphere requires a systematic approach, legislative support, interdisciplinary cooperation, and active public participation, which is the task of both scientists and practitioners.

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TOXICOLOGICAL ASPECTS OF THE INFLUENCE OF ROCKET FUEL ON THE ORGANISM

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Today, warfare is mainly accompanied by the use of missile attacks. When an explosion occurs when a missile hits a target or is explosively neutralized in the air, most of the rocket fuel burns out. However, when a rocket falls without exploding, hundreds of liters of toxic fuel spills and spreads in the soil, atmosphere, and water bodies.

The purpose of the work was to analyze the data on the danger to humans of heptyl, as the most common representative of the hydrazine class, which is used in rockets as a fuel.

Heptyl - 1,1-dimethylhydrazine (1,1-DMG) belongs to substances of the first class of toxicity. It has carcinogenic, embryotoxic, gonadotoxic, allergenic effects. This compound causes poisoning by any route of entry into the body. The polytropy of its toxic action includes damage to the nervous system, immunotoxicity, impaired hematopoiesis, causes toxic diabetes mellitus, liver damage.

It has been shown, that unsymmetrical dimethylhydrazine is carcinogenic to animals, leading to the development of angiosarcomas, skin cancer, lung, pancreas, liver, adrenal glands, colon and other tumors [1]. The carcinogenicity for humans has not yet been proven, therefore it is classified as a potential carcinogen (2B carcinogenic risk group) [2].

When exposed to humans, dimethylhydrazine has a weak ammonia odor, felt at a level of 0.01 mg/m^3, in a concentration of 0.05–0.08 mg/m^3, is felt as a strong ammonia odor, sensitive individuals can feel a concentration of 0.003 mg/m^3. A concentration of 240 mg/m^3 is considered to be tolerable for humans for 10 minutes, for 30 minutes — 120 mg/m^3, for 60 minutes — 70 mg/m^3 [3].

When entering the body at a dose of 10–20 mg/kg, the mild poisoning may develop. Cases of acute poisoning have been described when staying in an atmosphere polluted to 2.6 mg/m^3 for 1–2.5 hours. Acute poisoning in humans occurs mainly in production (72%), often combined with exposure to nitrosodimethylamine (9%) and nitric acid (42%). The main route of entry into the body in industrial conditions is inhalation (92%), in a third of cases, skin contact was noted. The latent period lasts from 30 minutes to 24 hours or more. About 85% of poisonings are mild, with a mortality rate of 2%, and in moderate and severe cases - 15% [3,4,5]. Mild poisoning in affected individuals manifestation appears after several hours (days) after the inhalation contact with heptyl. Nausea, vomiting, abdominal pain, chills, headaches occur. Insomnia appears, appetite is lost, in some cases an increase in the liver is noted, some victims have diarrhea. The phenomenon of irritation of the mucous membranes of the upper respiratory tract and eyes is moderately expressed. There is a tendency to tachycardia, arterial hypertension. The duration of the disease rarely exceeds 5–6 days [5,6]. The moderate degree of poisoning is characterized by toxic encephalopathy, hepatitis and nephropathy. Severe adynamia, weakness is accompanied by severe headaches, vomiting, diarrhea, chills, fever, muscle pain. On the 4th–5th day, jaundice appears, massive bleeding from the gums. Dysproteinemia, hemolytic anemia are registered in the blood, bilirubin content increases, liver function disorders are detected. Recovery is delayed up to 3–4 weeks. Severe poisoning is manifested, in addition to the listed signs, by convulsive syndrome, severe circulatory disorders, and the gradual development of liver and kidney failure. Symptoms of severe poisoning develop on the 4–5th day [4,5,6], often ending by the death.

People who work under conditions of exposure to 1,1-DMG for 6 months have impaired liver function, increased activity of alanine aminotransferase in the blood serum, and fatty degeneration is detected during liver biopsy [6]. Development of hepatotoxic effects during chronic exposure involves impaired antitoxic, excretory, glycogen-forming, and deaminating functions of the liver. These disorders were manifested by changes in various biochemical parameters, increased transaminase activity, decreased total protein, and decreased alkaline and acid phosphatase activity. Dynamics of biochemical blood parameters in 28 military specialists who worked under the influence of 1,1-DMG at a concentration in the air of the working area of 50–80 times higher than acceptable concentrations in the air for 2–3 hours in a day at least for 2.5 months was studied. After the completion of work on draining the rocket fuel components, the military personnel had a significant increase in the serum levels of creatinine, total bilirubin, ALT, ACT, LDH and a significant decrease in the levels of gammaglutamyl transpeptidase (γ-GTP), alkaline phosphatase and calcium, 1,1-DMG was present in blood and urine[6].

In the air, water and soil, heptyl is easily oxidized, forming more dangerous compounds. Thus, nitrosodimethylamine is 10 times more toxic than heptyl, dangerous for humans in any way entering the body, disrupting the activity of many organs and systems. Its maximal allowable concentration in the air of the working area is 0.01 mg/m^3. It is a proven carcinogen (group 2A). It is spontaneously converted in the environment forming dimethylamine, ammonia, formaldehyde. Nitrosodimethylamine is characterized by poly toxicity (neurotoxicity, nephrotoxicity, hepatotoxicity, effects on hematopoiesis) and long-term effects (carcinogenicity, embryotoxicity). This compound can cause poisoning not only by inhalation, but also when ingested through mucous membranes and skin [6].

When inhaled, it causes severe irritation of the respiratory tract with subsequent inflammation, which occurs 10 hours after the latent period. The severity of the clinical picture is determined mainly by the resorptive effect of hydrazine. The most pronounced disorders are noted in the central nervous system, blood, liver, kidneys. Symptoms of poisoning develop 30-90 minutes after contact with the poison. Signs of irritation, clonic-tonic convulsions, comatose state appear. When emerging from a coma, the development of psychosis with delirium, auditory and visual hallucinations is often observed. The state of psychosis may last for several days. The clinic of acute intoxication develops against the background of impaired cardiovascular system functions (bradycardia, collapse). A characteristic manifestation of intoxication is methemoglobinemia, hemolysis. The maximum decrease in the content of erythrocytes in the blood is noted on the 10th day. The liver and kidneys are often affected, which manifests itself in the form of acute toxic hepatitis and toxic nephropathy, which are noted 48 hours after the poison enters the body [7].

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ENVIRONMETALLY FRENDLY STRUCTURE OF FIREFIGHTING AND EMERGENCY-RESCUE VEHICLE EXPLOITATION MODEL WITH RECIPROCATING ICE THAT OPERATES ON MIXTURE OF BIODIESEL AND PETROLEUM FUEL

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Ecological safety (ES) is a fundamental element of national security at both global and local levels. Its evaluation, particularly through complex criteria-based assessments, plays a key role in the final stage of the ecological safety management system (ESMS) within the framework of civil defence [1]. These considerations underscore the relevance of the present research [2]. The ES of firefighting and emergency rescue vehicles (FERV) has been the subject of numerous studies by both Ukrainian and international researchers, highlighting the growing relevance of criteria-based approaches to evaluating the ES level of such systems. This relevance is further amplified by the pressuring need to address the fuel crisis driven by the depletion of fossil fuel reserves. A viable solution lies in the adoption of alternative fuels, with biodiesel being a primary candidate [1]. Developing advanced mathematical models for complex ES level assessments of FERVs with diesel reciprocating internal combustion engines (RICE) operation requires validated simulation data. This includes, in particular, models for pollutant formation and transformation in exhaust gas flows, using tools such as Blitz-PRO – an open-source ICE cycle simulation platform [3].

The study aligns with national strategic documents, including Presidential Decree № 722/2019 dated 30.09.2019 «About the Sustainable Development Goals of Ukraine for the period up to 2030» [4], and the «Regulation on the Organization of Environmental Support of the SES of Ukraine», approved by Order № 618 dated 20.09.2013 [5].

Purpose of the study. To develop a model for the accident-free operation of FERV equipped with RICE, and to optimize the structure of this model by considering the fuel and ecological efficiency of the operation process when using both conventional diesel fuel and blended fuels containing biodiesel. **Object of the study.** The accident-free operation process of FERVs powered by RICE. **Subject of the study.** The optimized structure of the operational model, with an emphasis on fuel and ecological efficiency when using both petroleum-based diesel and biodiesel-blended fuels.

Concept of the Exploitation Model

RICE-powered power plants (PP), including FERV and other specialized equipment operated by divisions of the SES of Ukraine, are significant sources of ecological hazard. These hazards determine the ES level of their accident-free operation [1,2].

To perform a complex assessment of the effectiveness of measures aimed at ensuring compliance with legislatively mandated ES levels – within the framework of the ESMS – it is recommended to apply the complex fuel and ecological criterion (K_{fe}) developed by Prof. Ihor Parsadanov (NTU "KhPI") and further enhanced in [1]. Such an assessment requires the existence of an exploitation model tailored to the purpose and operational conditions of the RICE-powered systems. Currently, such model does not specifically exist for FERVs. The suggested exploitation model has been developed based on an averaged operational duty duration diagram of the State Fire and Rescue Departments (SFRD) of Kharkiv [2] (see Fig. 1) and includes six key operational segments (polygons): **1. Call Waiting** – the standby period in which the unit is on alert and awaiting deployment. **2. Call Forwarding** – the stage of dispatch and coordination, involving communication and routing to the incident. **3. Combat Deployment** – mobilization and travel to the emergency site under operational readiness. **4. Emergency and Rescue Operations** – active firefighting or rescue efforts utilizing engine-driven equipment. **5. Clotting of Equipment** – post-operation cooldown, deactivation, and securing of equipment. **6. Return to Location** – travel back to the base or station following mission completion.

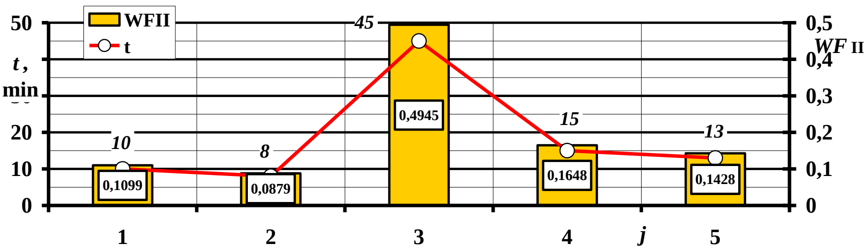

Figure 1. The developed exploitation model polygons parameters [2]

This research has been conducted within the framework of the scientific project "Development of a Methodology for Complex Assessment of the Environmental Impact of the Operation and Use of Special Equipment under Conditions of Military Aggression" (State Registration No. 0124U000374). The study utilized resources from the VCU library system, including electronic journals, databases, and interlibrary loan services, accessed through participation in the Non-Resident Academic Associates Program, co-sponsored by the College of Humanities and Sciences at Virginia Commonwealth University and the Davis Center for Eurasian Studies at Harvard University during the 2024–2025 academic year.

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JUSTIFICATION OF RATIONAL UNITS OF MONETARY EQUIVALENTS OF ECOLOGICAL SAFETY LEVEL INDICATORS OF FIREFIGHTING AND EMERGENCY-RESCUE VEHICLES EXPLOITATION PROCESS

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Ecological safety (ES) is a critical component of national security on both global and local scales. Particular emphasis is placed on the economic aspects of the complex, criteria-based assessment of ES levels, which constitutes the final stage of the ES management system (ESMS) within the broader framework of civil defense system. These assessments serve as a foundation for management decisions in the field of civil defense service, relying on a specialized methodological framework [1]. The relevance of the study arises from this context. Moreover, the results may contribute to the development of methodologies for forecasting the operational costs and service life of firefighting and emergency rescue vehicles (FERV) equipped with reciprocating internal combustion engines (RICE) [2]. This is particularly pertinent in scenarios where enhancing ES involves transitioning to the use of alternative, renewable motor fuels [3]. **Purpose of the study.** To provide a calculated grounding for the selection of rational units of measurement for the monetary components within the complex fuel-ecological criterion structure, used to assess the ES level of the exploitation process of power plants (PP) with RICE. **Object of the study.** The monetary components of ES level indicators related to the operation of PP powered by RICE. **Subject of the study.** The choice of appropriate units for expressing the monetary components and approaches for incorporating inflationary effects into their quantitative evaluation. The mathematical framework for the complex fuel-ecological criterion K_{fe} was originally developed by Prof. Ihor Parsadanov (NTU "KhPI") [4]. Current exchange rate data for major currencies relative to Ukrainian hryvnia are available on the official website of the National Bank of Ukraine [5]. The study aligns with national strategic documents, including Presidential Decree № 722/2019 dated 30.09.2019 «About the Sustainable Development Goals of Ukraine for the period up to 2030» [6], and the «Regulation on the Organization of Environmental Support of the SES of Ukraine», approved by Order № 618 dated 20.09.2013 [7].

Methodological Basis and Price Variants for Diesel Fuel

In the study, several historical variants of the price per kilogram of diesel fuel (P_f) have been calculated to justify the choice of appropriate monetary units for the K_{fe} criterion. These include: A) 1.81 ₴/kg – as recorded at the time of the publication of the monograph [4] (2003); B) 0.34 $/kg – USD equivalent of the Variant A; C) 23.08 ₴/kg – as recorded at the time of the publication of the monograph [2] (2018); D) 0.871 $/kg – USD equivalent of the Variant C; E) 29.40 ₴/kg – as recorded at the time of the publication of the monograph [1] (2019); G) 1.153 $/kg – USD equivalent of the Variant E.

The calculations have been performed using the D21A1 autotractor diesel engine (type designation 2Ch10.5/12 in accordance with ISO 3046-1:2002) as the reference model. Its technical specifications are provided in [1]. The exploitation model applied was the 13-regime standardized steady test cycle, as defined by UNECE Regulation № 49 [1]. The initial dataset for this study has been derived from the analysis of bench motor tests, as described in studies [1-3], for the 2Ch10.5/12 autotractor diesel engine. This dataset includes the distribution of monetary components of the K_{fe} criterion across the engine's operational regime field.

To account for inflation in the chosen unit of expression for the value equivalents of the K_{fe} criterion, the study suggests using the mathematical framework of the Consumer Price Index (CPI). The CPI for the US dollar was 175 in 2003 and has since increased to 254 [1]. This inflationary adjustment is represented by formulas (1) and (2).

$$z_j = Z_j(t) \cdot CPI_{\$}(t)/100, \quad (1)$$

$$CPI = \sum\left(Q_i^t \cdot P_i^t\right) / \sum\left(Q_i^0 \cdot P_i^0\right) \cdot 100. \quad (2)$$

In the context of the study, index j denotes the type of monetary costs ($j = e$, f or fe), with t representing the current date. Z_j corresponds to the monetary costs in units of \$/(kW·h). Index i refers to the type of product, and index 0 represents the magnitude for the base period (for USD, the base period is 1982–1984, where the $CPI = 100$). The total quantity of produced goods is denoted by Q, and P represents the price of the produced goods in US dollars.

This research has been conducted within the framework of the scientific project «Development of a Methodology for Complex Assessment of the Environmental Impact of the Operation and Use of Special Equipment under Conditions of Military Aggression» (State Registration No. 0124U000374). The study has utilized resources from the VCU library system, including electronic journals, databases, and interlibrary loan services, accessed through participation in the Non-Resident Academic Associates Program, co-sponsored by the College of Humanities and Sciences at Virginia Commonwealth University and the Davis Center for Eurasian Studies at Harvard University during 2024–2025 academic year.

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THE JOINED EFFECT OF FLUORIDE AND LOW DOSES OF RADIATION ON ENERGY METABOLISM AND MORPHOLOGIC CHARACTERISTICS OF LIVER TISSUES

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Nowadays the constant deterioration of the ecological situation, especially in times of war, requires the clarification and assessment of the toxicity of all environmental factors. The problem of exposure to low doses of radiation simultaneously with other environmental factors has become relevant, taking into account their possible potentiating interaction [5; 6]. Radiation danger has two main sources of occurrence during war: an attack on a country's nuclear energy facilities and an attack with tactical nuclear weapons on any infrastructure or residential buildings [1]. The aggressor's troops struck the Chernobyl and Zaporizhia nuclear power plants in Ukraine in March 2022. The worst-case scenario could lead to the destruction of the reactor's containment and cooling system, and a large amount of radiation would be released into the air. Therefore, the study of the direction of metabolic reactions of the organism modified, in addition to the action of small doses of radiation, by the influence of factors of a non-radiative nature is of unquestionable interest for the preservation and increase of adaptive potential.

Fluorine is the most active of all known chemical elements used in modern technologies, including rocketry and electronics [7]. The understanding of the role of energy metabolism disorders in the dynamics of a wide variety of processes that are systemic for the functioning of the human organism is particularly actively deepening. Current evidence suggests that fluoride induces mitochondrial membrane depolarization in all tissues; this, in turn, causes a decrease in ATP formation and will be associated with an increase in the production of reactive oxygen species by this organelle [2, 3]. Namely, the resistance of erythrocytes to the effects of hydrogen peroxide is one of the integrative indicators that can reflect the resistance of cell membranes to oxidative stress.

The aim of our research was to evaluate the state of energy metabolism and changes in morphologic characteristics of liver tissues and in rats with chronic fluoride intoxication exposed to ionizing radiation.

Fluoride intoxication was induced by oral administration of sodium fluoride (10 mg/kg) for 30 days. Rats were exposed to ionizing radiation four times (every other day) at a single dose of 0.25 Gy (total absorbed dose – 1 Gy) during the fourth week of sodium fluoride administration. The animals were decapitated on the 31st day from the start of the experiment with pronounced dental fluorosis. The results of the content of lactic and pyruvic acids, peroxide resistance of erythrocytes, and medium-mass molecules were statistically processed with the determination of probability according to the Student's t-test using Microsoft Excel, which is part of the Microsoft Office package, and RStudio software. The liver tissues specimens underwent electron microscopy examination.

It was revealed disturbances of anaerobic energetic metabolism in animals with chronic fluoride intoxication, in particular, the lactate content was reduced by 26.3%, and pyruvate was increased by 2 times. A specific property of fluorine is its ability to inactivate glycolysis enzymes: hexokinase, enolase, phosphoglucomutase, as well as succinate dehydrogenase, enzymes of the cytochrome system [4, 7]. Besides, an increase in the content of medium-weight molecules and an increase in H2O2-induced hemolysis of erythrocytes under the influence of fluorides were also noted. At the same time, the membrane-damaging effect is associated with the activation of lipoperoxidation reactions, which significantly modifies energy and plastic metabolism, changes the permeability of cellular and subcellular membranes, disrupts membrane transport, and is manifested in a moderate increase in the concentration of medium-mass molecules in blood serum. Medium-mass molecules are characterized by an immunosuppressive effect, have the property of influencing the productivity of tissue respiration, suppressing the ability of tissues to accumulate and transform energy, and change the permeability of cell membranes and membrane transport.

The fractionated irradiation of animals in a total dose of 1 Gy caused an increase of lactic and pyruvic acids in blood, an increase in both erythrocyte hemolysis and the content of medium-mass molecules (by 72% and 25.4%, respectively). The joined effect of chronic fluoride intoxication and low doses of radiation had a more pronounced damaging effect compared to the single effect of fluoride intoxication or ionizing radiation. Particularly, an increase in the content of lactic and pyruvic acids in comparison with intact animals was found by 42.8% and 2.2 times, respectively.

The ultrastructure of hepatocytes and sinusoidal hemocapillaries under conditions of fluoride intoxication is changed, namely, a significant electron density of hepatocytes was recorded, containing a large number of peroxisomes, autophagolysosomes, vacuoles, microbubbles, and large lipoprotein droplets. Significant amounts of mitochondria with fragmented cristae were found, which may lead to a decrease in oxidative phosphorylation. Fluoride significantly reduces tissue respiration in the liver according to literature data [7]. The morphophysiological changes we detected may indicate a nonspecific disruption of oxygen supply to cells under conditions of extreme stress.

It is worth noting that a marked effect of a disturbance in the energy metabolism during the joined action of chronic fluoride intoxication and ionizing irradiation was indicated by ionizing radiation, but fluoride intoxication was demonstrated with the following effects: an increas of cell membrane resistance to hydrogen peroxide, as well as an enhance of medium-mass molecules content.

Thus, ionizing radiation has a significant effect on the disruption of energy metabolism under the joined action of ionizing radiation and sodium fluoride, and fluoride intoxication is reflected in the enhancement of peroxidative hemolysis of erythrocytes and an increase in the content of medium-mass molecules in the blood.

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FORMATION OF CHEMICAL SAFETY COMPETENCIES AMID CONTEMPORARY SECURITY CHALLENGES

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The importance of personal safety in modern conditions is continuously growing across all areas of human activity, especially where risks related to the use of hazardous chemicals are present. The significance of this issue in Ukraine is reinforced by the adoption of the law "On Chemical Safety and Chemical Product Management" [1], which also aligns with Ukraine's international obligations in this field.

Civilians in Ukraine face potential exposure to hazardous chemicals due to the ongoing war. Reports indicate that russian forces have used chloropicrin and CS gas (tear gas) in frontline areas. Moreover, attacks on chemical plants and storage facilities could release toxic industrial chemicals, including ammonia, chlorine, and nitric acid.

The high level of urbanization, industrial and agricultural sector development, environmental pollution, and existing technogenic and military threats highlight the need to develop safety competencies not only among specialized professionals and military personnel but also among the general population. A key factor in forming these competencies is maintaining high motivation regarding personal responsibility for one's safety and that of others.

Nowadays, various hazardous chemicals, including dual-use substances, are used across different fields. Therefore, it is crucial to ensure high-quality training for specialists who can work safely with chemicals and create a secure environment for themselves and others. The core element of such training is developing integrated knowledge, skills, and procedures that facilitate accident prevention, emergency response, and personal safety.

The formation of safety competencies aligns with the UN Sustainable Development Goals, particularly: Goal 3 – *Good Health and Well-being*; Goal 4 – *Quality Education*; Goal 6 – *Clean Water and Sanitation*; Goal 12 – *Responsible Consumption*; Goal 13 – *Climate Action*.

Additionally, it complies with European qualification frameworks in the fields of health protection and environmental safety. Achieving this goal requires a comprehensive approach, incorporating educational, awareness-raising, and instructional efforts. In terms of education, safety training should begin in schools, particularly through courses such as "Health, Safety, and Well-being", as well as chemistry classes in secondary education [2, 3]. A sociological survey conducted in the autumn semester of 2024 among first-year students at Ivan Franko National University of Lviv revealed concerning findings: 60% of students were trained in gas mask handling, 43% had practiced putting on a gas mask, and only 20% knew their correct gas mask size. This level of preparedness remains insufficient given the current security challenges.

These findings highlight the need for higher education institutions to integrate chemical safety topics not only into the training of specialists in chemistry, ecology, and industrial safety but also across other disciplines. The additional rationale for such integration includes:

1) many hazardous substances are used not only in industrial settings but also in daily life;

2) destroyed buildings release asbestos and toxic particulates, increasing the risk of lung cancer and mesothelioma;

3) chemical contaminants from warfare seep into groundwater, leading to long-term exposure through food and drinking water.

To strengthen chemical safety education, essential topics should include classification of hazardous chemicals, labeling and identification of chemical substances, protective measures against hazardous chemicals, emergency response protocols for chemical incidents, and first aid procedures for chemical exposure.

1. Classification of Hazardous Chemicals

Understanding chemical classifications allows individuals to identify risks before exposure, anticipate potential dangers, ensure proper storage and transportation, and select appropriate protective measures. In an emergency, classification knowledge helps choose neutralization methods or organize evacuation plans based on the nature of the threat.

2. Labeling of Hazardous Chemicals

Chemical labeling follows the standards of the Globally Harmonized System (GHS) for classification and identification [4]. Familiarity with hazard pictograms and signal words enables immediate risk assessment and ensures correct handling, storage, and disposal, preventing accidents and environmental contamination.

3. Protective Measures Against Hazardous Chemicals

Protection involves the use of both collective and individual safety measures, with priority given to collective protection strategies. Proper use of safety equipment minimizes exposure risks and enhances rapid and effective emergency responses.

4. Emergency Response Protocols for Chemical Incidents

Knowledge of action algorithms allows for developing evacuation plans, accident localization strategies, and rapid response procedures. In crises, individuals trained in emergency protocols can efficiently organize evacuations, administer first aid, and mitigate hazards.

5. First Aid for Chemical Exposure

A structured approach to chemical injury response helps individuals remain calm and act confidently, maximizing the time window before medical professionals arrive. These skills are critical not only for specialists working with chemicals but also for domestic chemical safety. Prompt first aid measures are crucial for preventing severe health consequences and ensuring survival.

Conclusion

Developing chemical safety competencies is critical for modern education, particularly in training specialists across various fields. Given rising technogenic risks, industrial development, and the widespread use of chemicals in daily life, acquiring knowledge of chemical classification, hazard labeling, emergency response, and first aid is not merely a professional skill but a fundamental aspect of life and environmental safety.

Only a systematic and integrated approach to education, combining scientific training, practical knowledge, and motivation for safe behavior, will enable effective responses to contemporary challenges in chemical safety and sustainable development.

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UDC 614.84

FIRES AT OIL DEPOTS DUE TO SHELLING: ENVIRONMENTAL RISKS OF FOAM EXTINGUISHING OF FLAMMABLE LIQUIDS

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Abstract. The intensification of armed conflicts has led to an increased frequency of targeted attacks on oil depots, posing not only immediate threats to human life and infrastructure but also long-term environmental consequences. Foam extinguishing, a widely used method for suppressing flammable liquid fires, has proven effective in emergency response. However, the use of synthetic firefighting foams - particularly those containing per- and polyfluoroalkyl substances (PFAS) -introduces complex ecological risks. This paper examines the environmental impacts of foam suppression used during oil depot fires caused by military shelling, focusing on soil and water contamination, air pollution, and implications for public health and biodiversity [3].

Introduction. In recent years, warfare has increasingly involved the deliberate targeting of critical energy infrastructure, including oil storage facilities. These attacks result in large-scale fires involving gasoline, diesel fuel, and crude oil. The standard response to such fires includes the use of aqueous film-forming foams (AFFF), especially due to their efficacy in suppressing hydrocarbon fires. While effective for firefighting purposes, AFFFs are often composed of fluorinated surfactants known to be persistent, bioaccumulative, and toxic.

Nature of the Environmental Risks. Foam extinguishing agents act by forming a blanket that isolates the fuel surface from oxygen, thereby suppressing combustion. However, runoff from foam application, especially in open environments, can lead to significant environmental degradation. The primary risks include [1]:

− Soil contamination: Foam constituents can percolate into soil layers, altering microbial communities and reducing soil fertility.

− Groundwater pollution: PFAS compounds are highly mobile in subsurface environments, reaching aquifers and contaminating drinking water sources.

− Surface water pollution: Foam-laden runoff can enter rivers, lakes, or reservoirs, causing acute toxicity in aquatic organisms.

− Airborne emissions: Thermal degradation of foam and hydrocarbons can emit toxic gases and particulates into the atmosphere.

− Ecosystem disruption: Accumulation of foam chemicals in plants and animals can lead to trophic magnification and biodiversity loss.

Toxicological and Chemical Concerns. AFFF formulations often contain PFOS, PFOA, and related compounds, which are resistant to environmental degradation. Even small concentrations (parts per trillion) can cause health effects in humans and wildlife, including liver damage, developmental disorders, immune suppression, and carcinogenic effects. These compounds are known as "forever chemicals" because they do not naturally break down and remain in ecosystems for decades.

Case Studies and Empirical Observations. Data from regions experiencing military conflict (e.g., Ukraine, Syria, and parts of the Middle East) indicate that large-scale fires at fuel depots can result in widespread environmental contamination. In Ukraine, for example, fires at bombed fuel depots near populated areas have led to documented PFAS infiltration in nearby water bodies. In some cases, residue from firefighting foam was detected kilometers away from the site due to wind and water dispersion.

Regulatory and Legal Frameworks. Many countries have yet to regulate firefighting foam usage in the context of war-related environmental damage. However, international agreements such as the Stockholm Convention on Persistent Organic Pollutants and the

EU REACH regulation are increasingly addressing PFAS control. There is growing advocacy for including environmental war crimes under international criminal law, with particular attention to the use of harmful chemical agents during armed conflict [4].

Alternatives and Mitigation Strategies. Efforts are underway to develop fluorine-free firefighting foams (F3), which demonstrate comparable extinguishing capacities but with lower environmental persistence and toxicity. Moreover, best management practices include containment of runoff, use of absorbent barriers, rapid soil remediation, and post-incident ecological assessments.

Conclusions and Recommendations. Foam extinguishing of flammable liquids during oil depot fires caused by shelling represents a significant environmental hazard. The risks associated with PFAS-based firefighting agents necessitate urgent reconsideration of emergency response protocols. The following actions are recommended [2]:

– Phasing out PFAS-based foams and transitioning to environmentally safer alternatives.

– Developing rapid deployment containment systems to prevent runoff into natural ecosystems.

– Mandating environmental impact assessments after each large-scale firefighting event.

– Integrating military environmental responsibility into international humanitarian law.

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ANTI-EROSION EFFICIENCY OF PARK AND FOREST PARK PLANTATIONS IN THE CITY OF LVIV

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Soil erosion is one of the main factors of land degradation, which negatively affects agricultural and forest lands, as well as pastures [1, 2]. The productivity of agricultural lands decreases due to the reduction of the humus horizon, where the largest amount of nutrients is concentrated. Soil erosion also negatively affects forest ecosystems, leading to a decline in plant species diversity and disrupting the stability of the entire ecosystem [2]. The stability and biodiversity of pastures are also reduced due to soil erosion, which increases their vulnerability to drought [2].

Urban erosion differs from erosion in agricultural landscapes due to the increased kinetics of water flows, which are directly related to changes in the physical properties of the land surface: asphalting, concreting, paving, and soil compaction, etc. The intensification of soil erosion in the territory of Lviv is primarily caused by areas with complex terrain conditions. As a result of rapid urbanization, part of the suburban forests became enclosed within residential developments and over time were transformed into parks and forest parks (Stryskyi, Shevchenkivskyi Grove, Zalizna Voda, Citadel, Pohulyanka forest park, and others) [5]. Soil compaction due to intensive recreational load, deterioration of the water regime caused by global warming, leads to increased surface runoff and the activation of soil degradation processes [6].

The problem of reliably protecting soils from erosion is largely due to the difficulties of accurately determining their intensity at a specific point in space and time. Since the end of the 20th century, various models, in particular RUSLE (Revised Universal Soil Loss Equation), have been widely used to assess and mathematically and cartographically model potential soil loss due to water erosion. The Universal Soil Loss Equation is a mathematical equation based on six main factors that determine the intensity of erosion processes [1]:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P,$$

where A – average annual soil loss, t/(ha·year); R – rainfall erosivity factor, MJ·mm/(ha·h); K – soil erodibility factor, t·ha·h/(MJ·mm·ha); L – slope length factor (dimensionless); S – slope steepness factor (dimensionless); C – cover-management factor (dimensionless); P – support practice factor (dimensionless).

The *C*-factor is characterized by the greatest variability, which is why there is no consensus among scientists regarding the anti-erosion effectiveness of different types of phytocoenoses. Thus, in the literature review [1] for forest vegetation, the values of the vegetation cover factor *C*=0.001…0.048, pastures *C*=0.01…0.1, and shrub communities 0.005…0.9 are presented. The study [2] provides the values of the C-factor for a mountainous region of Nepal: forest lands – *C*=0.03; shrub phytocenoses – *C*=0.03; meadows – *C*=0.01; agricultural lands – *C*=0.21; barren land (without vegetation cover) – *C*=0.45. The average *C*-factor values for different land use types, taking into account the seasonality of vegetation development, are presented in the study [6]: bare land – *C*=0.35; dense forest – *C*=0.001; sparse forest – *C*=0.01; arable land – *C*=0.5; dense grassland – *C*=0.08; sparse grassland – *C*=0.2. In [4], the values of the *C*-factor depending on projected vegetative cover are presented: pastures – from 0.003 (projective cover (95-100%) to 0.04 (projective cover (60-80%)); forest – from 0.001 (projective cover 75-100%) to 0.003…0.01 (projective cover 20-40%).

The *C*-factor largely depends on the degree of anthropogenic load, in particular soil trampling and the preservation of grass cover. Thus, in the Ivan Franko Park (Lviv), tall specimens of *Aesculus hippocastanum* L., *Fraxinus excelsior* L., *Carpinus betulus* L., *Acer platanoides* L. grow in the area near of rotunda. The projective cover of the tree layer is about 95%, due to which the understory space has a low level of illumination. This negatively affects the growth of the lower layers of the plant community. In addition, the grass cover is severely damaged due to trampling and intensive mowing. The area has a noticeable surface slope, and there are signs of water erosion of the soil, in particular, tree roots have been washed away. Consequently, the high projective cover of the tree layer does not guarantee high anti-erosion efficiency of the phytocenosis.

Another area on the park's periphery is represented by a lawn lined with a border of *Spiraea japonica L.* The grass cover is well developed, systematically mowed, and aesthetically pleasing. Its formation is influenced by *Lolium perenne* L., *Festuca rubra* L. s.str., *Poa pratensis* L., and also features species such as *Viola odorata L.*, *Lysimachia nummularia L.*, *Taraxacum officinale* Webb. ex Wigg., *Aegopodium podagraria* L., *Bellis perennis* L., and others. The preservation of the vegetation cover from trampling is facilitated by a protective curb, the presence of a pathway network along the perimeter of the area, and a sufficiently high level of insolation in the understory space. No signs of water erosion are observed here due to the high projective cover of the lower tier of the plant community.

The vegetation cover factor C should be considered as a combination of the next subfactors CC and Sc [3]:

$$CC=1-Fc\cdot exp(-0.3281\cdot H) \quad (2)$$

$$SC=exp(-0.035\cdot M) \quad (3)$$

where CC – subfactor of tree canopy cover; SC – subfactor of grass cover; Fc – projected cover of the tree layer and perennial plants, %; H – the plant height, m; M is the projected cover of annual species less than 20 cm in height and mulch.

Example 1: The plant community is characterized by a projective canopy cover of 70%, H=20 m, and the projective cover of the herb layer of 80%. Solution: CC=0.90, SC=0.06, C=0.90·0.06=0.054.

Example 2: the plant community is characterized by a projective canopy cover of 90%, H=20 m, and a projective cover of the herb layer of 30%. Solution: CC=0.87, SC=0.35, C=0.87·0.35=0.305.

Therefore, to prevent and reduce the intensity of soil water erosion, it is essential to first maintain the preservation of the grass cover. In the conditions of parks and forest parks of Lviv, where there is a high level of recreational load, to increase the illumination in the under-tent space, it is advisable to establish groups of woody plants with an openwork crown.

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UDC 502/504

ASSESSMENT OF RADIATION BACKGROUND INDICATORS AT HOUSEHOLD WASTE LANDFILLS (UKRAINE)

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According to the current legislation, waste disposal is carried out at landfills that meet the requirements of the legislation and whose technological equipment ensures the protection of groundwater, extraction and disposal of biogas and leachate, control of emissions into the air, and pollution of soil and groundwater [1]. However, the state of the waste management sector in Ukraine demonstrates a situation that requires specific measures and solutions that are currently being developed and implemented. Of the more than 9 million tonnes of solid waste generated in 2023, 0.41% was sent to: recycling facilities - 0.41%, waste processing plants - 3.01%, composting sites - 1%, incinerators - 1.51%, and landfills - 83.37% [2].

Given that household waste landfills in Ukraine are environmentally hazardous facilities that adversely affect the air, surface and groundwater, soil, flora and fauna, monitoring their environmental impact is an important component of scientific research. However, very few studies have investigated the radiation background at landfills and in areas adjacent to landfills [3, 4].

With the increased use of radioactive materials in everyday life, medicine and industry, there is a risk that certain sources of ionising radiation may end up among ordinary waste. Due to inadequate waste sorting, a significant amount of hazardous waste, including electronic and electrical equipment, batteries, accumulators, thermometers, medicines, etc., often ends up in landfills with household waste. They increase the environmental risk of landfills, which increases the role of monitoring environmental components in the surrounding areas. If improperly controlled, radionuclides can penetrate the soil, groundwater and air, which poses a threat to both nature and people living near landfills.

Radioecological monitoring in Ukraine gained popularity as a result of the Chornobyl accident in 1986. The consequences of the disaster spread over vast distances and caused significant damage to the environment [5].

As part of the radioecological monitoring, measurements of the radiation background (equivalent dose rate) of four landfills were carried out: Dunayivtsi, Malashivtsi, Khmelnytskyi, and Kremenets. The measurements were carried out on four sides of the horizon using the envelope method and for comparison in a background clean area (at a distance of 1 km from the facilities). A leading Gamma-Scout radiation measuring device was used, which is characterised by high measurement accuracy and allows recording α-, β- and γ-radiation.

According to the obtained measurements of the radiation background made at the points shown in Figure 1, diagrams were created (Fig. 1).

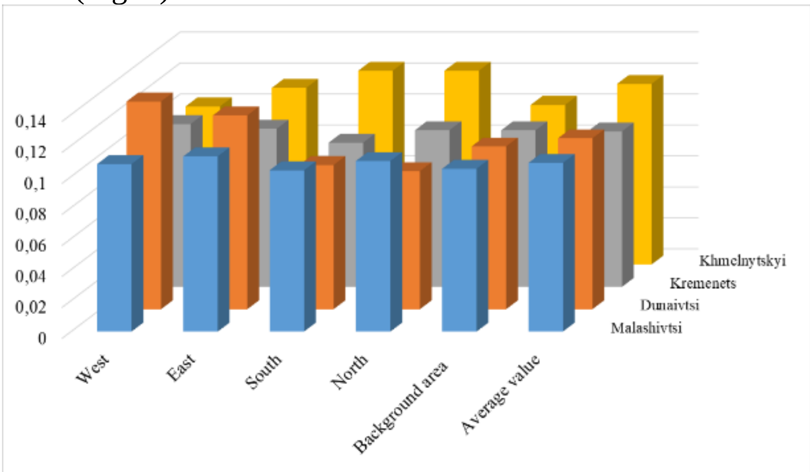

Figure 1. Radiation background indicators at landfills (μSv/h) from different sides of the horizon: Malashivtsi landfill, Dunaivtsi landfill, Kremenets landfill, Khmelnytskyi landfill

Analysing the results and taking into account the radiation background standard of 0.3 μSv/h, we see that there are no exceedances at any of the landfills [6]. However, the indicators fluctuate on different sides of the horizon. In particular, to understand the results, we performed mathematical processing of the results, in particular, we calculated the standard deviation of the results of the radiation background at landfills, taking into account the indicators from four sides of the horizon and fluctuations in the radiation background indicators relative to the average value, the value in background areas, and the local value from the official resource (Table 1) [7].

Table 1

Fluctuations in radiation background levels at waste landfills

	Malashivtsi landfill	**Dunaivtsi landfill**	**Kremenets landfill**	**Khmelnytskyi landfill**
Average value	0,005	0,110	0,005	0,011
	Exceeding the background value			
West	1,029	1,276	1,040	0,990
East	1,076	1,190	1,010	1,107
South	0,990	0,886	0,921	1,214
North	1,048	0,848	1,000	1,214
	Exceeding the average value			
West	0,993	1,215	1,047	0,876
East	1,039	1,134	1,017	0,979
South	0,956	0,844	0,928	1,073
North	1,011	0,807	1,007	1,073
	Exceeding the local value			
West	0,900	1,340	1,167	0,850
East	0,942	1,250	1,133	0,950
South	0,867	0,930	1,033	1,042
North	0,917	0,890	1,122	1,042

According to the above data, we can see that the most significant indicators of radiation background are at the Khmelnytskyi landfill. The values on the northern and southern sides exceed both the average and background values, as well as the local value. At the Dunaivtsi landfill, the eastern and western sides exceed all 3 indicators. At Kremenets landfill, the indicators also exceed the established values on three sides of the horizon: west, east, and north. At Malashivtsi landfill, the background value is exceeded on the western, eastern and northern sides, and the average value is exceeded on the eastern and northern sides. However, all values are lower than the local value.

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MANAGEMENT APPROACHES TO SUSTAINABLE AGRICULTURE AND ENVIRONMENTAL SECURITY AMID CLIMATE CHANGE AND MILITARY CONFLICT

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Modern agriculture in Ukraine faces unprecedented challenges driven by global climate change, anthropogenic pressures, and the consequences of ongoing military conflict. Under such conditions, the agricultural sector plays a pivotal role in ensuring both food and environmental security for the country. This necessitates the development of effective approaches to managing sustainable agricultural development and strengthening ecological safety in the face of emerging realities, which lends substantial theoretical and practical significance to research in this field [1].

Climate change has long become a reality for agriculture in the Steppe zone. Observable trends include an increase in average annual temperatures by 1.6–2.4°C, prolonged droughts lasting 50–80 days, torrential downpours with intensities of 25–33 mm per hour, soil erosion, and declining soil fertility. Simultaneously, the war has led to the degradation of soil cover, physical destruction of infrastructure, landmines on agricultural fields, deforestation of protective shelterbelts, and contamination with chemicals and petroleum products. These factors severely limit the potential for stable agricultural production and demand new approaches to agroecological system management [2].

Dnipropetrovsk Oblast lies within a zone of high mineral extraction activity, covering an area of nearly 200,000 hectares. This contributes to intensified anthropogenic pressure on lands designated for agricultural use, land reclamation, and environmental protection purposes [3]. The issue of land reclamation is becoming increasingly critical in light of a recently signed international agreement between Ukraine and the United States concerning the joint extraction of rare earth minerals, which prioritizes national economic, financial, and property interests.

Irreparable environmental damage has also been caused by the aggressor’s destruction of the Kakhovka Reservoir dam, which eliminated the irrigation system across 1.5 million hectares, with dire consequences for the entire ecosystem. Given that the loss of irrigation water will inevitably lead to intensified drought conditions, it is proposed to maintain fallow land at 5–15% of total sown area, prioritize winter cereals (utilizing moisture most effectively) at 30–35%, and expand sunflower cultivation to 25–30% using hybrids with high resistance to diseases and pests. Additionally, a differentiated tillage system should be implemented, consisting of moldboard plowing (20%), chisel tillage (25%), shallow disc cultivation (25%), zero tillage (18%), among others.

A significant portion of the structural and organizational issues in Steppe farming systems – driven by both environmental and military factors – exacerbate the threat of critical increases in weed infestation and the harmfulness of dominant steppe ecotypes. Another pressing issue is the transformation in weed species composition. Forty years ago, Ambrosia artemisiifolia accounted for only 6% of weed flora, whereas over the past 15 years, it has risen to 90–98%. This dynamic forces the continued use of herbicides from the same chemical class, accelerating the weed's adaptive capacity – an especially concerning development due to its allergenic properties. Against the backdrop of these species and chemical transformations, the need to implement crop rotations based on herbicide diversity becomes urgent.

Given the current situation, immediate organizational and technological measures must be undertaken to mitigate the environmental degradation of agricultural production environments and contain the scale of technogenic and military pollution of farmland. These measures should include: conducting contour soil surveys on agricultural lands to identify and remove low-productivity and erosion-prone areas from active cultivation, converting part of them into bio-conservation zones with high restoration potential and recreational value; scientifically substantiating and implementing an optimal cropping structure based on ecological criteria and crop placement in rotations, favoring species with high phytosanitary immunity, tolerance to reduced tillage, strong phytocenotic resistance, and favorable market prospects; reducing herbicide-treated areas by minimizing the potential for weed propagation through agronomic practices and cultivation of highly competitive crops; technologically substantiating models for using crop residues in rotations to achieve a positive humus balance in soils through physicochemical regulation of humification processes.

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UDC 574:509.3

UNDERLYING SURFACE AS A FACTOR OF INFLUENCE ON STRENGTHENING THE "HEAT ISLAND" EFFECT OF THE URBAN ENVIRONMENT

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Modern cities are characterized by a significant predominance of artificial surfaces over natural ones, which significantly affects the formation of the local microclimate. According to research, in the central parts of large cities, artificial surfaces can occupy up to 60-80% of the total area [13]. This feature of the urban environment is one of the key factors in the formation of the "heat island" effect.

The *object* of the study is the thermal regime of different types of urban surfaces in the conditions of the formation of the "heat island" effect in the city of Lviv. The *subject* of the study is the temperature characteristics of paved and unpaved areas of the urban area under different insolation conditions.

For the research, typical urban locations in the central part of Lviv were selected with different types of covering, including both artificial (asphalt, paving stones, paving slabs) and natural (grass) surfaces. Measurements were carried out in September 2024 under the following conditions: air temperature - +28°C; air humidity - 23%; wind speed - 5 m/s; atm. pressure - 740 mm. Hg.

Measurements were carried out for the following types of surfaces in open areas and in shaded areas: asphalt pavement, paving stones, paving slabs, mowed grass, unmowed grass.

The research methodology takes into account the main factors affecting the temperature regime of urban surfaces and allows us to obtain a comprehensive picture of the thermal state of different types of coverage in the urban environment.

Analysis of the temperature regime of paved areas shown in Figure 1(Fig. 1).

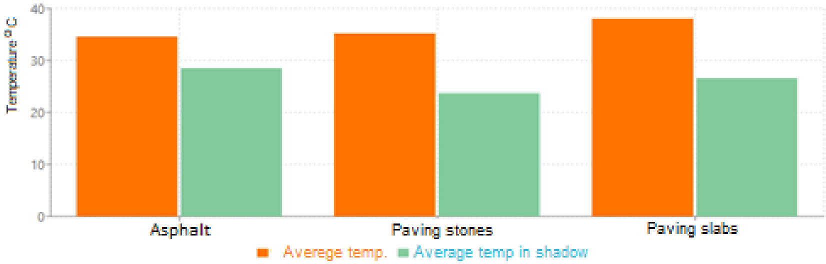

Figure 1. Temperature indicators of different types of surfaces in the central part of Lviv

The results of the research demonstrate a significant variation in temperature indicators on paved areas of various types. The asphalt pavement on V. Chornovola Avenue showed the highest temperature values among all the studied paved surfaces with an average temperature of 37.82°C at an air temperature of 28°C. At the same time, the maximum values reached 41.8°C. On the same day, slightly lower indicators were recorded on the asphalt pavement on Svobody Avenue - the average temperature was 31.41°C, which is explained by the peculiarities of the development and the presence of tall trees, which shade the asphalt-paved street for a certain part of the day. Therefore, despite the measurements of the asphalt pavement area in the unshaded part of the avenue, the temperature indicators were lower, since they were not exposed to direct sunlight throughout the day.

The paving slabs we examined on Shevchenko Avenue and in Zamarstynivskyi Park showed average temperatures of 34.75°C and 35.65°C, respectively.

The temperature of the paving slabs on the square in front of the I. Franko Lviv National University averaged 38.06°C, which is close to the asphalt pavement on V. Chornovil Avenue.

Temperature regime of grass cover shown in Figure 2(Fig. 2).

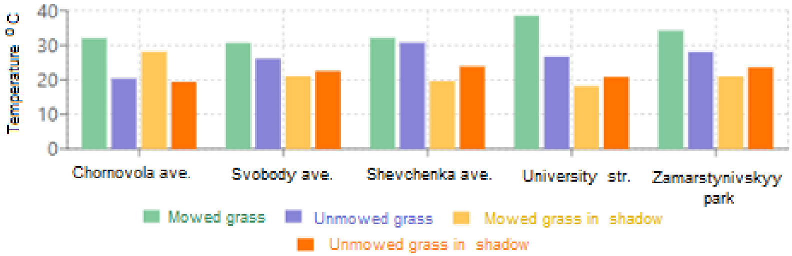

Figure 2. Temperature indicators of grass cover (mowed and unmowed)

Studies have shown a significant difference in temperature between mowed and unmowed grass areas. On Chornovola Avenue, the average temperature of mowed grass was 31.97°C, while that of unmowed grass was only 20.35°C. A similar trend was observed in other locations, although with different intensities. On the University street, the difference was especially noticeable: mowed grass had an average temperature of 38.5°C, while unmowed grass had an average temperature of 26.69°C.

Comparative analysis of locations shown in Figure 3 (Fig. 3).

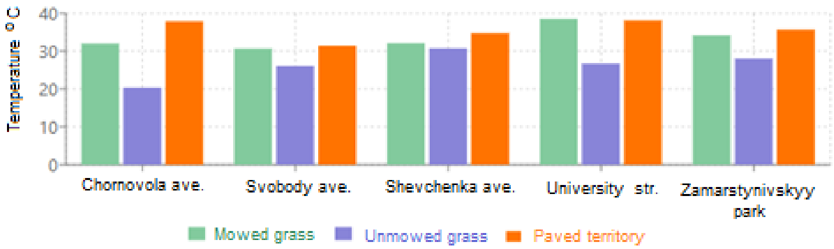

Figure 3. Comparative analysis of temperature indicators of research objects

The highest temperature indicators were recorded for paved surfaces in areas with dense construction and intensive traffic (Chornovola Avenue and the area on the University Street). In park areas and in areas with lower construction density (Zamarstynivskyi Park), temperature indicators were somewhat lower.

Svobody Avenue demonstrates the lowest average temperatures of paved surfaces among the studied locations, which may be due to periodic shading of surfaces created by green spaces and surrounding buildings.

The conducted studies allow us to draw the following key conclusions:

– the type of coating has a decisive influence on the formation of the thermal regime of the urban area. Artificial coatings demonstrate significantly higher temperature indicators compared to natural surfaces;

– the height of the grass cover is an important factor in regulating the temperature regime. Unmowed areas have a significantly lower temperature compared to mowed ones;

– local development conditions and the nature of land use significantly affect the formation of the thermal regime of urban surfaces.

Based on the results obtained, it can be recommended to increase the area of green areas in the urban environment and create shaded areas as effective measures to reduce the heat load in the urban environment.

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SECTION 3
SAFETY, RISK MANAGEMENT, AND EMERGENCY RESPONSE

UDC 614.844; 614.845

IMPACT OF ADDITIVES ON THE FIRE SUPPRESSION EFFICIENCY OF AEROSOL AGENTS

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It is known that salt additives have a significant impact on the fire-extinguishing effectiveness of aerosol-generating compositions that are environmentally acceptable.

KCl, K2SO4, NaHCO3, MgCO3,·3H2O, CaCO3, and K2C2O4 were investigated as inorganic additives. These substances are commonly used in pyrotechnics. They could potentially enhance the fire suppression efficiency of aerosol agents since their powders exhibit sufficiently high fire-extinguishing properties. Moreover, these substances are readily available [1].

Diphenylamine (DPA), polyethylene polyamine (PEPA), urea, and dicyandiamine (DCA) were studied as organic additives. These substances are also used in pyrotechnics. In the presence of these substances, a positive effect could also be expected in terms of increasing the fire-extinguishing efficiency of aerosol agents. As is known, nitrogen-containing organic substances of this class (amines, amides) contribute to a decrease in the rate of combustion of organic substances. Therefore, they work as inhibitors [2].

The experimental results showed that in all cases, an increase in the number of additives, both inorganic and organic, led to a deceleration of the combustion process of the aerosol-generating composition (AGC) and a reduction in flame intensity. All additives reduced the efficiency of AGC-to-aerosol conversion, and when their content exceeded 5–6%, the charges either failed to ignite or the aerosol formation efficiency was significantly diminished. The fire-extinguishing concentration of the aerosol did not significantly change with the amount of fire-suppressing additive.

It is worth noting separately that the introduction of additives into AGC based on epoxy resin had a negative effect. Even a 1% additive reduced the conversion rate from 86% to 70–55%, and when 2–3% was added, the AGC samples either failed to sustain combustion or the burning ceased rapidly. This indicates that the inclusion of inorganic substances in the composition of the AGC absorbs a significant portion of the heat released during combustion. As a result, the conversion efficiency of the AGC into final aerosol components decreases, which in turn leads to a reduction in the fire suppression effectiveness of the aerosol [3].

Organic additives in concentrations of 1–3% do not exhibit a noticeable impact on either the conversion efficiency of the aerosol-generating composition (AGC) or the minimum fire-extinguishing concentration of the aerosol. The effect of these additives becomes more apparent at concentrations around 5%, while further increases to 6–10% lead to unstable AGC combustion and a significant decrease in the efficiency of AGC-to-aerosol conversion.

Additives of all tested organic substances have a more pronounced effect on the combustion behavior of AGC charges compared to inorganic additives. Combustion slows down, and the intensity of the visible flame front decreases. The most notable positive influence was observed with the addition of DCDA and urea. While additives of DPA, PEPA, and urea also result in a reduction of AGC conversion efficiency, this effect is less significant than that caused by inorganic additives. The fire-extinguishing properties of the resulting aerosol slightly deteriorate when DPA and PEPA are introduced, whereas urea primarily affects only the reduction of AGC-to-aerosol conversion efficiency [4].

The addition of DCDA significantly enhances the overall efficiency of the aerosol-generating composition (AGC), both by reducing the minimum fire-extinguishing concentration of the aerosol and by increasing the AGC-to-aerosol conversion efficiency.

It was found that when charges burn without a confining shell, the flame spreads across the entire exposed surface of the charge, which is likely the reason for the high combustion rate observed in open space. A similar effect was observed by the authors of this study.

The improved overall efficiency of AGCs containing DCDA can be attributed to the fact that DCDA requires very little oxygen to burn—specifically, 1 gram of oxygen can combust 0.88 grams of DCDA. For comparison, the substances with the lowest oxygen demand for combustion are carbohydrates; for example, 1 gram of oxygen combusts 0.94 grams of lactose. Furthermore, during thermal decomposition, DCDA releases a large volume of gases, thus acting as a gasifying agent [5].

The results of these experiments demonstrated that the most effective additives are those that promote the gasification of the aerosol-generating composition (AGC), namely DCDA and urea.

An increase in DCDA content up to 10% significantly reduces the efficiency of the AGC: combustion becomes unstable, spontaneous flame extinction may occur, and the AGC-to-aerosol conversion rate drops to 50–40%. Increasing the urea content to 10% leads to an even greater reduction in the combustion rate of the charge, with an almost complete absence of a visible flame front. Although the combustion of such AGC becomes highly unstable and the conversion efficiency decreases to 70–72%, the minimum fire-extinguishing concentration of the aerosol remains virtually unchanged.

Based on the experimental results, the most effective AGC formulation was identified with the following component ratio: $KClO_4$:KNO_3:sucrose: DCDA = 60:10:30:5. This formulation was taken as the basis for further studies aimed at developing an industrial prototype and addressing technological challenges in fire suppression. To validate the correctness of the selected formulation, the optimal composition of the AGC was also confirmed through mathematical modeling.

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UDC 504.064.3:504.4.054

METHODOLOGY FOR BACKWARD TRACING OF OIL SLICKS TO UNDERWATERSPILL SOURCES

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Introduction. Oil spills onto the surface of a large body of water often result in the formation of thin film slicks, the spatial distribution of which can be detected using satellite imagery. However, determining the exact coordinates of a underwater spill source without physical access to the disaster area remains a challenging task. This paper presents a methodology for backward tracing of oil slicks based on Sentinel-1 radar data and Sentinel-2 optical imagery, considering the morphology of dark cores, meteorological and hydrodynamic factors, and models of vertical ascent of dispersed oil fractions [2].

Materials and Methods. Sentinel-1 radar images (IW mode, VV+VH polarization, spatial resolution ~5 m × 20 m) were processed using EO Browser (Sentinel Hub). Sentinel-2 optical images (processing level L2A, resolution 10 m/pixel) were used for verification. Geovisualization was performed in Google Earth Pro and Umap. Archived meteorological data from Meteoblue (wind and hydrodynamic fields) were used to account for environmental influences on the direction of pollution dispersion. The methodology is based on the detection of dark cores—stable zones of SAR signal absorption interpreted as surface markers of a submarine spill source. [1].

The displacement of the slick head was calculated based on the coordinates of the dark core center and the direction of the

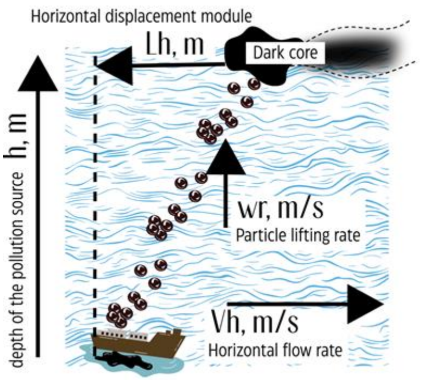

Figure 1. Scheme of dark core displacement relative to the underwater pollution source under the influence of the current

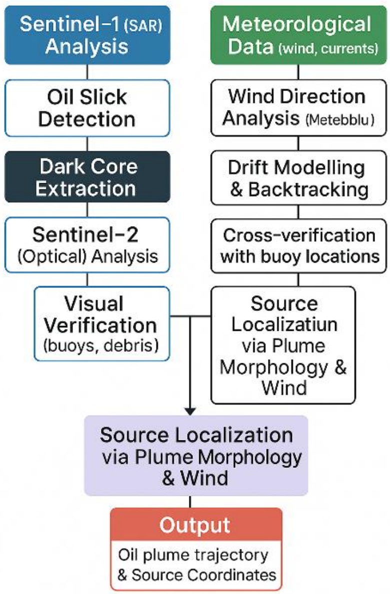

Figure 2. Block diagram of the integrated methodology for tracing an oil slick

submarine current (Figure 1):

$$Lh = (h \times vh)/wr, \quad (1)$$

where: Lh — horizontal displacement magnitude (m), h — source depth (m), vh — horizontal current velocity (m/s), wr — particle rise velocity (m/s) [2].

The location of the source was determined using the following formula:

$$P_{source} = P_{head} - Lh \times dir, \quad \textbf{(2)}$$

where: P_{source} — calculated coordinates of the source, P_{head} — coordinates of the dark core (determined from SAR), dir — normalized vector of horizontal current direction [3].

A morphological analysis of the slick (tapering pattern) was then performed, followed by backward tracing to the dark core, correction using archived meteorological data (Meteoblue), and verification with Sentinel-2 optical imagery (presence of signal buoys, debris) (Figure 2). A complicating factor is the potential coalescence of slicks from multiple sources, which is considered as a morphological indicator.

Results. Application of the methodology to the "Volgoneft-212/239" tanker incident made it possible to:

– localize the submarine spill sources (Figure 3);

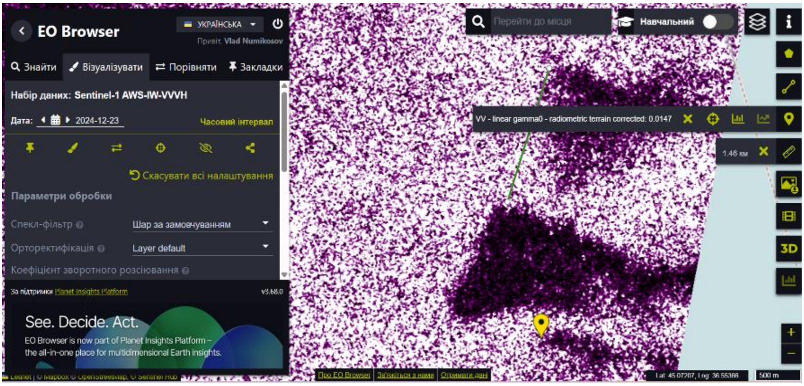

Figure 3. Localization of submarine spill sources based on the stable dark core zone in the Sentinel-1 SAR image (VV, 23.12.2024): 1-Lat: 45.05928, Long: 36.53598; 2-Lat: 45.07207, Long: 36.53134; 3-Lat: 45.08449, Long: 36.53701

– determine the coordinates with an estimated accuracy of 40–150 m, depending on the source depth, submarine current velocity, and the quality of SAR georeferencing [3] (Table 1);

– build an interactive map of debris and slick drift; detect film slicks up to 20 km in length; confirm the effectiveness of the dark core displacement model combined with meteorological correction [4].

Table 1. Coordinates of submarine spill sources

Sentinel-1 AWS-IW-VV+VH (coordinate system: WGS-84)			
	Spill source ID	**Latitude, B**	**Longitude, L**
As of 18.12.2024:	1.	45.05916	36.53761
	2.	45.07224	36.53143

Sentinel-1 AWS-IW-VV+VH (coordinate system: WGS-84)			
	Spill source ID	**Latitude, B**	**Longitude, L**
As of 23.12.2024:	1.	45.05928	36.53598
	2.	45.07207	36.53134
	3.	45.08449	36.53701
As of 31.12.2024:	2.	45.07200	36.53139
	3.	45.08459	36.53751

The evaluation of the effectiveness of backward slick tracing confirms the reliability of SAR-based identification of dark cores as stable markers of submarine spills, even under complex hydrodynamic conditions [1]. The modeling results and observations are consistent with the findings described in the works of Fingas [5], which emphasize the importance of accounting for the vertical ascent of emulsified particles and the influence of weather conditions on the formation of surface oil slicks.

Conclusions. The proposed dark core tracing methodology is effective for determining the coordinates of submarine pollution sources without physical access. It is based on a combination of SAR analysis, hydrodynamic modeling and optical verification [2, 4]. The application of such approaches is recommended for monitoring submarine spills in crisis regions, including areas affected by military conflict.

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UDC 342.9

STRATEGIC GUIDELINES FOR THE INNOVATIVE DEVELOPMENT OF CRITICAL THINKING TOOLS, COGNITION TOOLS, METHODS OF SPECIAL ANALYSIS OF DECISION-MAKING AND SITUATIONAL MANAGEMENT TECHNOLOGIES FOR RESPONDING TO CRISIS SITUATIONS IN TIME OF WAR

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«In one’s own house, — one’s own truth,
One’s own might and freedom».
Taras Shevchenko, excerpt from the poem «To my fellow-countrymen, in Ukraine and not in Ukraine, living, dead and as yet unborn»

At the dawn of the twenty-first century, the world community has finally entered the era of a new innovative civilizational development of «Industry 4.0». The latest ideas, innovations, knowledge, and scientific developments have become the cornerstone, the fundamental basis for the development of culture, education, science, medicine, and the economy of the world's leading countries [1, p.13].

These processes of civilizational development also lead to the aggravation of contradictions and the emergence of crisis situations at both global and regional levels, which necessitates conflict prevention, protection of material and spiritual values of humanity and nations from the harmful effects of war, terrorist acts (traditional and cyber ones), serious crimes and other threats and dangers.

In order to prevent and counteract such threats and dangers, it is «necessary to introduce into modern creative education, science and practice of the new millennium the means of critical thinking, cognition tools, methods of special analysis of decision-making and technologies of situational management of response to both typical and crisis situations», that is, the implementation of the convergence of the solar knowledge society as a determining factor in contemporary civilizational development [2, p.17].

The convergence of the solar knowledge society «is a powerful educational platform, a sunshine of civilization development, where the conceptual foundations of eternal ideas, dreams, images of education and science development in the modern conditions of Ukraine's development are laid, where the worldview and philosophical guidelines of humanity, justice, professionalism, readiness to defend the Motherland and situational management of response to both typical and crisis situations in Ukraine, Europe and the entire world are formed» [2, p. 18].

According to Ukrainian scientist, Dr. Halyna Mykhailivna Sagach, culture is a leading factor in the constitution of the people as an «individual hypostasis of humanity», the disclosure of their ethnic portrait, and the unique expression of general cultural experience, it is a powerful factor in the development of a person as a creative, active, holistic, harmonious personality. Culture stands as an alternative to death, granting existence the status of a meaningful life event, serving as the core of personal identity, the boldness of thought, and the creativity of the spirit, realized through illuminated meanings and insightful states of a harmonious personality [2, p.121].

Since culture does not include everything that is produced by humans (descriptive position), but only what is qualified as the achievements of the culture of certain epochs, which can be a measure of humanity, creative self-development and freedom (normative position), that is, not all products of human activity are constituted as part of culture [3, p.19].

Therefore, according to the Ukrainian scientist, philosopher Serhii Borysovych Krymskyi, culture transforms historical experience in signifying the values of life, creativity, spirit, into a symbolic system of communication of social meanings, beliefs and ideals, the hierarchy of the highest human qualities, the formation of the human world in terms of goodness, truth, and beauty [2, p.121].

This position is also supported by a well-known Ukrainian scientist and journalist Anatolii Moskalenko, who believes that social experience is summarized in the values of life, which «in an abstract form accumulate people's ideas about good and evil, about what is useful, convenient, profitable, about the most effective ways to meet needs, which can be the goal of a person's life». A person, realizing personal needs or a certain social group to which he or she belongs (family, group, people, nation), uses social values due to the lack of personal impressions and own experience to navigate in the complex conditions of social life, to shape ideals, and defining life goals — transforming specific needs into interests [4, pp.78-79, 200].

Of course, the fulfillment of both individual and social needs in accordance with cultural values ensures not only the survival of society, but also its harmonious development.

However, every culture is destined to decline with the loss of the life-giving source of access to truth (spirituality) in the global flow of change. That is why the right to human life, according to the scientist, founder of the school of supramental psychology Vasyl Andriiovych Chumachenko, is inseparably linked to the right to personal development [5, p. 8-9].

Given the above, we consider that the foundation of any culture — whether universal or ethnic— lies in the formation of the individual, fostering the development of their spiritual and moral capacities, which in turn constitute the spiritual and moral values of culture.

According to the renowned educator Hryhorii Vashchenko, spiritual and moral values (criteria of morality) define the nature of the moral system (culture) not only in its fundamental principles but also in its details [6, p.16].

This position is confirmed by the analysis of eternal themes, ideas, and literary archetypes conducted by Mykola Ilnytskyi, who writes: «Eternal images, world images are literary figures that, in terms of the depth of their artistic generalization, transcend specific works and the epoch they reflect. Such characters include Prometheus, Don Quixote, Hamlet, Faust, Don Juan, and others. Born out of certain historical conditions, they simultaneously concentrate on important features of human character, situations and conflicts that are repeated in new social contexts. Eternal images, in their artistic specificity, contain a universal dimension — fundamental aspects of existence — which is why they have found resonance in numerous literary traditions». [7, p. 3].

This passage discusses recent global political efforts to end Russia's aggression against Ukraine, highlighting comments from Russian officials about the need to address the root causes of the war—without openly disclosing them. It is noted that these root causes were outlined as early as 1941 by the writer and political analyst Yurii Lypa in his geopolitical work «The Destiny of Ukraine». Lypa argued that the goal of such a war is the «destruction of art, science, and even the very name of the adversary. He described this conflict as a campaign driven by a closed ideological system, a total war, an invasion by an order, and a racial conquest during the migration of peoples. According to Lypa, this reflects the style of totalitarianism rather than universalism. Eisler's new Bolshevik «International» sounds like Chinese, heavy monumentalism» [8, pp. 30-31].

Based on the worldview principles, we will show two ways of world development. «The first is an innovative, noble path of civilizational development of a society that harmoniously develops in the celestial ocean in order to achieve happiness, joy, health, wealth, well-being, prosperity and profit. This is the progressive development of the world. The second is a destructive, aggressive, thieving path that takes place in the bloody ocean. This is a regressive, aggressive, negative path of development, which is built on aggression, ignorance, corruption, theft, abuse, gloating, i.e. it exists where aggression, war, terrorism, and crime prevail. Therefore, the priority is the convergence of the solar knowledge society, which determines the innovative harmonious development of humanity in the celestial ocean» [2, p. 411].

«Eternal ideas», «eternal images», and «universal archetypes» have always inspired brilliant minds to create the extraordinary, captivating, harmonious, and transformative solar knowledge society — a foundation for civilizational progress, shaping educational and philosophical peaks that guide humanity toward the triumph of good over evil [2, p.23].

Meanwhile, the security aspect of the convergence of the solar knowledge society should facilitate the assessment of proposed socio-legal changes, anticipate potential threats, risks, and dangers, and provide structured mechanisms, procedures, and preventive measures to counter these challenges. This approach relies on critical thinking tools, specialized decision analysis methods, and situational management technologies for effective crisis response [2, p.201].

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INTEGRATION OF MODERN TECHNOLOGIES (INNOVATIONS) INTO THE TRAINING OF BORDER UNIT OFFICERS FOR OPERATIONS IN CONDITIONS OF RADIOLOGICAL, CHEMICAL, AND BIOLOGICAL CONTAMINATION. IMPLEMENTATION OF NATO STANDARDS

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The development of professional competence of future border guard officers for action in conditions of radiological, chemical, and biological contamination (RCB contamination) is driven by today's challenges. In particular, the documented use of chemical weapons by the armed forces of the Russian Federation against Ukraine poses new challenges and requirements for the State Border Guard Service of Ukraine in terms of protecting its personnel from weapons of mass destruction. To date, over 7,600 instances of the use of prohibited chemically hazardous substances by the enemy against the units of the Security and Defense Forces have been recorded, with three cases submitted to the OPCW.

To properly carry out combat support activities, partners consistently provide modern means of RCB protection, which require proper training in their use.

At the Madrid and Vilnius summits, NATO members mandated the Alliance to assist Ukraine in developing its own plan to transition to NATO standards and achieve full operational compatibility.

In September 2023, NATO and Ukraine agreed on the Concept of the Roadmap for Interoperability with a hybrid approach based on NATO defense planning and partnership processes. The developed interoperability requirements are to guide Ukraine's decision-making and ensure long-term compatibility between

Ukraine's forces and NATO through integration into security reform and defense planning processes.

Such requirements include institutional prerequisites for the professional military education and training system.

The initial requirement for interoperability is that the professional military education (PME) system prepares all relevant Security and Defense Forces to perform their tasks effectively and efficiently in accordance with their mission.

Short-term requirements (0–3 years):

– Maintain a unified military education system for the entire security and defense sector with officer and NCO courses at levels L1–L5, and implement a unified course planning system across all sector components by 2026;

– Modernize the personnel management system by 2027, including the implementation of NATO BI-SCD 075-007 standard "Education and Training", course certification per NATO standards, PME system auditing, transformation of collective training in line with NATO requirements (0458-3; 075-2; 075-3), optimization of educational institutions, and implementation of distance learning;

– Ensure the teaching of NATO operational planning procedures at all PME levels in accordance with NATO Directive by 2027;

– Develop new unit training cycles and modernize educational institutions to meet new requirements by 2027.

These requirements also address CBRN (chemical, biological, radiological, and nuclear) protection and the corresponding training of military personnel, since interoperable standards span from individual soldier capabilities in RCB conditions to the actions of specialized units.

According to Standard IO 1202 "Individual Soldier Capabilities," the initial requirement is to enhance soldier survivability, situational awareness, and reduce lethality. This is achieved through various training methods aimed at developing practical individual skills.

To implement Standard IO 3108 "Land Combat Capabilities," troops must be able to operate for at least three days under CBRN conditions without capability degradation. The SBGSU has introduced recommendations accounting for the impact of PPE on the physical and psychological endurance of personnel, and provides guidance on maintaining combat readiness in contaminated environments.

Standard IO 7201 "CBRN Protection" outlines specific requirements for basic and advanced CBRN protective equipment. As part of implementing these requirements, SBGSU has adopted a list of recommended equipment according to STANAG 2352: individual dosimeters, detectors, gas masks, protective clothing, and decontamination kits.

Short-term requirements (0–3 years) include:

- Training on testing grounds with live agents;
- Incorporating CBRN scenarios into joint exercises, including civil-military cooperation;
- Maintaining effective civil-military interaction to mitigate large-scale CBRN consequences;
- Provision of individual protection equipment (STANAG 2352, 2520, 4548);
- Creation of an effective alert and reporting system (STANAG 2103, ADatP-3);
- Training commanders and analysts on CBRN issues at all command levels.

Mid-term requirements (up to 10 years):

- Deployment of portable, networked, multi-agent detectors for chemical and radiation detection;
- Equipping units with modern remote detection systems (autonomous or vehicle-mounted);
- Deployment of collective protection (COLPRO) systems for critical assets;
- Provision and enhancement of specialized CBRN forces and decontamination tools (STANAG 4653);

– Establishment of a CBRN information exchange mechanism between national centers and CBRN experts by early 2028.

A crucial element in this process is proper personnel training, which should rely on the use of modern, innovative learning methods focused on the development of professional competence, enhancement of practical readiness for military-professional activities, attainment of high professional mastery, and accumulation of hands-on experience under conditions of war and terrorist attacks.

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INFORMATION TECHNOLOGIES FOR FORECASTING "MAN-MADE" RISKS

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In today's world of rapid scientific and technological progress, active industrialization, urbanization and growing global interconnections, the risk of technological disasters is growing. Technogenic risks associated with the functioning of complex technical, industrial, energy and transportation systems are increasingly affecting both the environment and the socio-economic stability of society. In such conditions, forecasting of man-made threats becomes a critical tool for ensuring public safety, sustainable development of territories and preservation of critical infrastructure. Of particular importance is the introduction of modern information technologies (IT), which allow not only to record events after the fact, but also to proactively identify potential sources of risk and model scenarios.

Forecasting technological risks with the help of information technology is a complex multi-level process that involves collecting, processing, storing, analyzing and visualizing a large amount of data obtained from various sources: sensor networks, satellite systems, digital platforms for monitoring industrial facilities, weather stations, geophysical observations, video surveillance systems, etc. In this context, the key role is played by working with Big Data, which contains heterogeneous, dynamic and voluminous information that is constantly updated in real time. Effective processing of such data involves the use of machine learning and artificial intelligence technologies. These tools allow you to identify hidden dependencies, nonlinear relationships between variables, and create adaptive predictive models. For example, neural networks can be used to model the probability of an accident at a critical infrastructure facility, taking into account dozens of parameters that cannot be simultaneously covered by a conventional analytical approach. In addition, classification and regression analysis algorithms allow for risk segmentation by degree of probability and potential damage, which is extremely important for prioritizing response measures.

It is also worth noting the significant contribution of geographic information systems (GIS), which allow the integration of spatial and thematic data to model the development of technological situations in specific geographical conditions. GIS can be used to accurately identify areas of potential damage in the event of an explosion, chemical release or fire, taking into account topography, climate conditions, population density and infrastructure. This creates a cartographic basis for making informed decisions on evacuation, localization of consequences, and informing the public. Digital platforms that combine analytics, modeling, visualization, and management tools in a single information environment deserve special attention. This approach makes it possible to create so-called digital twins of objects - virtual models of real systems that allow for simulation, virtual training, checking the effectiveness of security measures, and assessing the consequences of changes in the technological process. Thanks to digital twins, it is possible not only to increase the reliability of forecasts but also to optimize management decisions before the real event occurs. In the energy sector, for example, digital models are used to predict overloads in power grids, assess the technical condition of equipment, and identify the risks of generator or transformer failures. In the mining industry, IT solutions help predict the likelihood of cave-ins, landslides, and breakthroughs, which saves lives and reduces economic losses.

Information technology also contributes to the creation of an open, transparent and integrated system of interaction between all participants in the risk management process - government agencies, the private sector, academic institutions, international organizations and civil society. Online monitoring, public dashboards, mobile applications, and other digital services provide prompt access to up-to-date information, which allows for quick response to changing situations and informed decision-making. At the same time, the digitalization of risk management requires special attention to cybersecurity. The vulnerability of digital systems to cyberattacks, disruptions, or data manipulation may become an additional source of threats that should be taken into account in the overall forecasting system. Reliable protection of information platforms, ensuring data integrity and continuity of digital services are necessary conditions for their effective use in the context of security. Effective implementation of IT solutions for forecasting technological risks requires not only a technical base but also a systematic approach at the level of public policy. This includes: creating a regulatory framework that promotes innovation; building a national data infrastructure; investing in the development of human capital - cybersecurity specialists, analysts, IT engineers; and creating a culture of digital literacy among officials and citizens. In addition, it is important to ensure sustainable international relations to share experiences, implement best practices, and coordinate actions in the event of cross-border threats.

It is also worth emphasizing the need for an interdisciplinary approach to the development and implementation of IT solutions in the field of technological risk forecasting. The combination of knowledge from the fields of information technology, ecology, engineering, sociology, urban studies, and economics allows for more comprehensive and realistic models. For example, to assess the consequences of a man-made accident, it is not enough to know the technical characteristics of the facility - it is also important to take into account the behavioral reactions of the population, transport accessibility, the sustainability of social services, and the capabilities of the healthcare system. Thus, the future of risk forecasting is increasingly associated with the integration of interdisciplinary data and methods. A separate area of development is the use of cloud technologies and the Internet of Things (IoT) concept to ensure continuous 24/7 monitoring. Sensors placed in industrial facilities, water supply, energy supply or transport infrastructure transmit data to centralized processing systems, which allows for instant detection of abnormalities and response before a critical situation occurs. The use of mobile IT solutions makes it possible to disseminate warnings to the public in a convenient format - through notifications, interactive maps, and recommendations for action.

In summary, we can say that information technology is shaping a new security paradigm - proactive, predictive, integrated and dynamic. Investing in IT to predict technological risks is an investment in future resilience, readiness for challenges, and preservation of human potential. Thus, information technology is not only a technical tool, but also a strategic resource for creating an effective system for forecasting and managing industrial risks. They ensure the transition from a reactive to a proactive management model, where decisions are made on the basis of data, simulations and forecasts. It is IT solutions that can provide a solid foundation for creating adaptive, safe and sustainable socio-technical systems that can withstand modern challenges and prevent disasters before they occur.

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INNOVATIVE SOLUTIONS FOR MANAGING TECHNOLOGICAL RISKS

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In the modern world, technological risks have become an integral part of the functioning of industrial society. Urbanization, intensification of production, increased energy consumption, and the use of hazardous substances and technologies lead to increased vulnerability to accidents, disasters, and emergency situations of a man-made nature. Effective management of these risks requires the introduction of innovative approaches based on modern advances in science and technology, an interdisciplinary approach, and the digital transformation of management systems. In this regard, there is a growing need to introduce new technological solutions that allow not only to identify and assess man-made risks at early stages, but also to respond promptly to threats, ensuring a high level of security for the population and infrastructure.

Innovative solutions for managing technological risks cover a number of areas, including digital monitoring platforms, the use of artificial intelligence, big data-based decision support systems, the integration of the Internet of Things (IoT), geographic information systems (GIS), and predictive modeling. Thanks to the development of sensor networks, it has become possible to collect real-time data on the condition of technical facilities, the level of environmental pollution, microclimate parameters, vibrations, and other indicators that are crucial for identifying potential threats. Processing the information using machine learning algorithms allows not only to detect abnormalities but also to predict the development of events, taking into account the multifactorial influence of variables.

Artificial intelligence is opening up new horizons in risk management by automating the analysis of complex technical and environmental data, identifying hidden patterns and creating adaptive response models. For example, the chemical industry is already implementing intelligent early warning systems that can timely signal the threat of an explosion or hazardous substance leakage, offering optimal evacuation or response scenarios. The development of digital twins - virtual copies of critical infrastructure - is also extremely relevant, as they allow to simulate the behavior of the system in an emergency, identify its weaknesses and take preventive measures in time.

The integration of geographic information systems into the process of man-made risk management allows visualizing the territorial distribution of hazards, modeling scenarios of the spread of harmful factors (for example, pollution clouds or waves of damage from an explosion), and coordinating the actions of response services. GIS platforms provide rapid mapping of the situation, which is especially important when decision-making time is limited. At the same time, the latest communication systems, including 5G technologies, allow for faster information exchange between critical infrastructure facilities, control centers, and mobile response teams, which is a key factor in reducing the consequences of accidents.

Another promising area of innovative technological risk management is the use of autonomous drones and robotic systems capable of inspecting hard-to-reach or dangerous areas, assessing the condition of structures after disasters, and providing real-time feedback. Such systems can not only reduce the risk to personnel's lives but also speed up the process of localizing and eliminating the consequences of accidents. The use of robotics is especially effective in areas with high levels of radiation, toxic pollution, or the likelihood of a second collapse.

Managing technological risks also requires new approaches to building a safety culture at the level of organizations and society as a whole. Modern digital learning tools, virtual and augmented reality can be used to simulate crisis situations and train staff to act in a threatening environment. This format of training promotes better assimilation of information and the development of practical skills necessary for decision-making under stress.

Innovations in the field of technological risk management require cross-sectoral cooperation - the public sector, business, the scientific community and civil society. Only an integrated approach, with the pooling of resources, expertise and technologies, can achieve sustainable results. Legislative incentives for innovation, support for security research, implementation of digital security and cybersecurity standards, and development of public-private partnerships - all these elements should form the basis of a national strategy for managing technological risks.

At the same time, it is important to understand that the introduction of innovations in the field of industrial risk management is not only a technical or technological process, but also a social and managerial transformation. An extremely important factor in the effectiveness of the latest solutions is the training of personnel capable not only of using modern systems but also of thinking critically, making responsible decisions under conditions of uncertainty, and coordinating the actions of interdisciplinary teams. Modern industrial safety management should be flexible, adaptive and open to change. It is also important to take into account the ethical dimension of innovations: the issues of data confidentiality, transparency of algorithms, and responsibility for decisions made with the participation of artificial intelligence should be clearly regulated both at the level of individual organizations and within the framework of public policy.

In addition, international cooperation is becoming increasingly relevant in the context of transnational man-made threats, such as accidents at energy facilities, river and sea pollution, and technical disasters that may have transboundary consequences. Participation in international initiatives, data exchange, use of common response protocols and mutual recognition of safety standards contribute to strengthening global resilience to technological threats. Thus, an innovative approach to managing technological risks should include not only technology but also systemic modernization of governance, education, legal and international institutions, forming a new security paradigm in the digital transformation era.

Thus, in the context of rapid technological development, technogenic risk management is transforming from a reactive model to a preventive one based on data, forecasts, and digital interaction. Innovative solutions can significantly reduce the vulnerability of critical systems, increase the level of preparedness for crisis situations, and minimize socioeconomic losses. The formation of a national ecosystem of innovative technological risk management is not only a challenge but also an opportunity to create a safe and sustainable environment for future generations.

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USE OF MODERN EQUIPMENT FOR EXTINGUISHING ELECTRIC VEHICLES

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The fourth scientific and technological revolution, which began in the mid-20th century, has led to the rapid development of information and telecommunication systems, artificial intelligence, informatization of society and many other aspects of human development. The development of modern technologies provides great benefits to mankind, even if we consider a small time period of 10-20 years, which usually make our world better and more perfect. However, quite often, the introduction of new technological innovations fails, especially at the initial stages of operation, which can lead to a number of problems and the threat of emergencies.

Recently, humanity has begun to think about alternative energy sources that can replace hydrocarbon fuels. An undeniable leap in recent years has been made in the automotive industry. One of the most striking examples is the rapid growth and development of vehicles powered by alternative energy sources, among which vehicles running exclusively on electricity attract special attention. In the near future, such vehicles should completely replace traditional ones powered by internal combustion engines. Along with the introduction of new technologies, the number of threats and hazards to human life and health is also growing, and fire and rescue units must respond to them.

Due to the increasing use of electric vehicles, there is a problem with the procedure and general methodology for extinguishing lithium-ion batteries, which pose a major fire hazard.

The aim of the study is to analyze the world experience, technical means and approaches to extinguishing LIEBs (rechargeable batteries) in order to develop recommendations for the personnel of fire and rescue units on actions to be taken when extinguishing such fires.

One of them is the latest Rosenbauer BEST fire extinguishing system. Rosenbauer's high-voltage electric vehicle battery fire extinguishing system is a system for safe, efficient and rapid extinguishing of batteries based on lithium-ion technology. It enables direct cooling of battery modules or cells within modules and thus quickly stops the spread of thermal radiation from the cells.

The system consists of two main components - an extinguishing unit and a control unit (total weight of about 65 kilograms), which are connected by hose lines (Fig. 1).

Figure 1. Exterior of the Rosenbauer BEST fire extinguishing system and an example of its use

The fire extinguishing unit is placed on the battery and, if necessary, fixed with a jack on the car body or other points. It is best to place it on the underside of the vehicle. The control panel triggers the penetration of the needle-like tool into the battery case from a safe distance (up to 8 meters), while water is dispersed into the battery through the perforated nozzle.

Thanks to the piercing element's "shot" speed (8 milliseconds), it can quickly pierce all currently known battery cases. The water then fills the entire battery case (25-50 liters/min), providing fast and efficient cooling, thereby stopping the combustion itself and preventing re-ignition.

Table 1. Technical data of the Rosenbauer BEST extinguishing system

Water flow	32 l/min at 7 bar. (8 gal/min at 100 psi). Flow range from 25 l/min at 4 bar (6,6 gal at 60 psi) up to 50 l/min at 15 bar (13 gal at 215 psi)
Length hose	8 m as standard (315 in)
Air supply	2x 1l / 300 bar (0,26 gal / 4350 psi)
Weight ext. unit	Approx. 21 kg (46,3 lb)
Weight control unit	Approx. 22 kg (48,5 lb
Weight hose package	Approx. 24 kg (52,9 lb)

Once the battery cells have cooled down to a safe temperature range, the extinguishing agent can remain in the battery during transportation and at the place of possible quarantine. This means that water can be pumped into the battery at any time. The effectiveness of this fire extinguishing system is further proven by the reduced amount of water required compared to an alternative method of drowning the vehicle, which showed that 20 to 30 tons of water were required to achieve an equivalent result. With Rosenbauer BEST, the effective use of water to extinguish a vehicle's battery is approximately 2 tons of water, which ensures the use of only one fire and rescue vehicle tank.

Having disclosed the peculiarities of using this fire extinguishing agent for the purpose of eliminating the ignition of electric vehicles, it is promising and effective for use by fire and rescue personnel in eliminating such dangerous events. It is expedient to further consider the effectiveness of the use of refractory tackle, punch barrels and container-type export modules for the elimination of emergencies with the ignition of electric vehicle electrical systems.

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THE RELEVANCE OF FIRST AID TRAINING IN THE CONTEXT OF CIVILIAN PROTECTION DURING EMERGENCIES UNDER CONDITIONS OF MILITARY ACTIONS

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The global development of human civilization, while undeniably beneficial, has generated numerous threats to the vital interests of individuals, society, and the state. Many of these threats stem from technogenic and natural domains that can lead to emergencies, deteriorating living conditions, loss of lives, and environmental contamination. In such situations, resource expenditures to localize and mitigate the consequences significantly increase. Among the key factors that may exacerbate the adverse impact of technogenic emergencies, particularly in the context of armed conflict and attacks on critical infrastructure, are nuclear facilities, sources of ionizing radiation, and sites that pose chemical, explosive, or fire hazards across Ukraine.

Given these risks, especially amidst the ongoing war in Ukraine and its severe consequences, public preparedness to administer first aid becomes extremely important. The continual shelling of civilian infrastructure, along with active hostilities, frequently leads to injuries where timely and effective first aid can mean the difference between life and death.

A fundamental objective in addressing this issue is ensuring the earliest possible initiation of pre-medical assistance to victims. Contemporary medical science has established the concept of the "golden hour" - the first 60 minutes after a traumatic event - during which timely medical aid is critical for preserving life and health. [1]War inevitably leads to an increase in the number of wounded and injured. Without adequate first aid knowledge, even minor injuries can escalate into serious complications. In emergencies, time is of the essence; therefore, a prompt response is vital. Understanding first aid procedures enables civilians to act swiftly, such as stopping bleeding or responding to circulatory arrest. [2]

A substantial increase in the number of individuals capable of providing first aid alleviates the burden on healthcare professionals and facilities, which is particularly important when medical resources are scarce during wartime. Additionally, the integration of psychological first aid is crucial for effective assistance, especially during large-scale emergencies and military operations. In light of these considerations, public policy regarding the protection of life and health must prioritize the dissemination of first aid knowledge not only among those legally mandated to provide it but also across the general population.

As outlined in Order No. 1349 of the Ministry of Health of Ukraine dated June 12, 2019, the Regulation on the Medical Specialized Civil Protection Service was approved. This service operates within the civil protection forces and is responsible for providing medical assistance during emergencies and potential terrorist threats, both in peacetime and during special periods. [3]

One of the core tasks of this service is to train non-medical personnel in first aid methods and skills applicable during emergencies. Therefore, the organization of first aid training should follow standardized programs developed by professionals.

Despite the clear relevance and increasing demand for such knowledge, the percentage of civilians equipped with essential first aid skills remains critically low, highlighting systematic shortcomings in the national approach to first aid training that require urgent resolution at the state level.

Another critical challenge lies in the lack of unified training programs and adequate logistical resources. Existing educational curricula are often non-standardized and fail to align with contemporary international standards and protocols. This applies not only to secondary and higher education but also to the training of police and emergency responders. The absence of standardized programs results in inconsistent training quality. Furthermore, limited availability of training equipment - such as mannequins, simulators, and expendable materials - hinders the acquisition of essential hands-on skills for effective first aid delivery. These skills should be developed to a level of automatism and strict adherence to action algorithms.

There is also a pressing need for systematic knowledge refreshment and skills updates, as a single training session is insufficient to ensure long-term preparedness. It is vital to incorporate the experiences of combat medics into civilian training programs as well.

For non-medical personnel obligated to provide first aid under their job duties, it is critically important that training be standardized, unified, and as simplified as possible. Programs should be based on internationally recognized protocols with proven efficacy and structured according to a phased learning model (e.g., basic level, first responder, etc.). [4][5]

Development of a comprehensive national program should include standardizing training, ensuring logistical support, focusing on practical skills and periodic refreshment, incorporating innovative teaching technologies, and creating a national responder registry.

In conclusion, due to the ongoing war and constant threats of shelling in Ukraine, addressing these systemic issues through a national strategy that emphasizes first aid training for civilians is essential. State efforts, in coordination with NGOs and medical institutions, will enhance public safety and improve the resilience of communities during emergencies, ultimately contributing to more effective civilian protection in times of crisis.

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PROVISION OF MEDICAL ASSISTANCE TO VICTIMS IN CHEMICALLY CONTAMINATED AREAS

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The provision of medical assistance to victims in zones of chemical contamination represents a critical element within the broader system of emergency response. It requires a systematic, stage-based approach, taking into account the physiological and pathological impacts of toxic substances on the human body to effectively reduce morbidity and mortality rates. In the context of modern industrial development, the risks associated with chemical accidents are significantly elevated, necessitating comprehensive preparedness and clearly defined medical response protocols.

Chemical emergencies may arise in various scenarios, including accidents at industrial facilities, transportation infrastructure, or pipeline systems. These incidents often involve the release of hazardous chemical substances (HCS) into the environment. Among the most dangerous are chlorine, ammonia, hydrogen cyanide, phosgene, sulfur dioxide, and other agents capable of rapid atmospheric dispersion and wide-area contamination. Their presence in air, soil, or water systems poses a direct threat to human health and ecological stability. The primary physiological targets of HCS exposure are the respiratory tract, mucous membranes, dermal surfaces, and ocular tissues.

Typical symptoms of acute chemical exposure include mucosal hyperemia, swelling, burning pain, pruritus, respiratory difficulty, coughing fits, and excessive mucus or bloody sputum production. Additional signs may encompass hoarseness, dry throat, epistaxis, rhinorrhea, and chest tightness. Individuals with preexisting respiratory conditions (such as asthma or chronic obstructive pulmonary disease) often experience exacerbations. Ocular exposure can result in conjunctivitis, inflammation, corneal opacity, and iritis. Prolonged or high-dose exposure may provoke systemic toxic manifestations, such as headache, dizziness, generalized weakness, and impaired cognitive function due to central nervous system involvement.

The environmental and public health consequences of a chemical release are profound. Beyond the immediate threat to human life, HCS can cause mass mortality in animals, destruction of agricultural crops, soil degradation, and long-term ecological imbalance. In certain cases, the substances involved may be reactive or explosive, introducing additional hazards such as infrastructure destruction, fire outbreaks, and obstruction of rescue operations. These challenges demand a coordinated, interdisciplinary response with a focus on rapid triage, contamination control, and immediate medical stabilization.

The overarching objective of medical intervention in chemically contaminated areas is threefold: to mitigate the toxic effects of exposure, stabilize the physiological condition of affected individuals, and prepare them for subsequent specialized treatment. This process begins with the prompt identification and classification of the incident as chemical in nature. Following this, a critical step is the organized evacuation of victims from the "hot zone"—the area of direct exposure—to a designated safe zone located upwind and on elevated ground, where contamination levels are significantly reduced. In cases where evacuation is not feasible, individuals are advised to remain indoors with all windows and doors tightly sealed to prevent further exposure.

Effective communication throughout all response phases is vital. Clear, empathetic interaction reduces anxiety, increases compliance with decontamination procedures, and minimizes the risk of psychological trauma, including post-traumatic stress disorder. Furthermore, appropriate communication plays a crucial role in preventing panic and maintaining order during mass evacuation or triage procedures.

Subsequent to evacuation, victims are functionally categorized according to severity of condition and need for assistance [1, p. 9]:

– Category C1: Individuals capable of independent movement and decision-making.

– Category C2: Individuals requiring moderate assistance due to physical limitations.

– Category C3: Critically affected victims exhibiting altered consciousness or life-threatening conditions.

A fundamental component of decontamination and initial medical care is the immediate removal of contaminated clothing. Studies have shown that clothing removal alone can eliminate up to 80–90% of external contamination. This step must be performed without delay, prior to the arrival of specialized hazmat teams. The removed garments must be treated as hazardous waste and disposed of in accordance with biosafety protocols. Decontamination procedures are rendered largely ineffective if this initial step is omitted, as chemical agents retained in clothing fibers may cause ongoing exposure or cross-contamination [1, p. 15].

Emergency decontamination should commence immediately following clothing removal. For the majority of chemical agents, dry decontamination is preferred due to its simplicity and speed. It typically involves absorbent materials such as towels, gauze, or specially designed wipes. Wet decontamination is indicated in cases of exposure to corrosive powders or liquid chemicals. The recommended protocol for both methods is the “10:10 technique” [1, p. 22], wherein each body area is blotted for 10 seconds and then wiped for another 10 seconds. Special attention must be paid to open wounds, which serve as direct portals for toxic absorption into systemic circulation.

Once emergency decontamination is completed, mass decontamination is conducted for all affected individuals. This typically involves passage through a water tunnel or shower system equipped with nozzles to provide full-body rinsing. The process must last no less than 15 seconds and requires active scrubbing from head to toe. It is critical that this phase follows the complete removal of clothing. Upon exit, victims must thoroughly dry themselves using disposable towels, which are subsequently treated as contaminated waste [1, p. 17].

The final phase of decontamination, referred to as technical decontamination, entails thorough washing using warm water, soap, and disposable sponges. This procedure should last approximately 60–90 seconds and ensures the removal of any residual chemicals from the skin’s surface [1, p. 19]. For critically ill patients or those with limited mobility, technical decontamination must be performed under the direct supervision of trained specialists. After drying, victims are wrapped in clean thermal blankets and transported to medical facilities for advanced care. In cases where hair is confirmed to be contaminated with persistent or highly toxic agents, partial or complete shaving may be warranted to eliminate the risk of prolonged dermal exposure [1, p. 40].

In conclusion, the provision of medical aid in zones affected by chemical contamination is governed by the principles of urgency, scientific rationality, interagency coordination, and adherence to strict safety protocols. Its success is contingent upon the preparedness of emergency medical teams, the availability of personal protective equipment (PPE), efficient logistics, and the capacity for rapid, evidence-based decision-making. Only through such a comprehensive and proactive approach can the lives and health of affected populations be adequately safeguarded [2, p. 51].

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