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RISK ASSESSMENT FOR THE DEVELOPMENT OF THE EXEMPLIFIED TERRITORIES

The paper explores the risks associated with exempted and liberated territories that were previously used for certain industrial, commercial, agricultural or other activities. Such territories were captured or used by military forces during the war and then liberated or abandoned and left unattended, or were disturbed by natural disasters, man-made accidents, etc. The aim of the article is to analyze the possibility of their further use and rehabilitation.

The following indicators of risk sources can be identified in such areas: presence of explosive objects; level of soil and water contamination; presence of chemical, biological or radiation contamination; degree of damage to infrastructure and building structures; risk of dangerous situations and accidents; impact on the health and safety of the local population; possibility of spreading infectious diseases; presence of unexploded or uncontrolled explosive materials; risk of re-invasion by enemy forces; potential environmental damage; and potential environmental impact. Based on the analysis of these indicators, they were summarized and grouped into six main risk indicators: demining of territories; efficiency of demining and disposal of remnants of military equipment, mines, etc.; safety and efficiency of demining and disposal technologies; degree of contamination of the demined territories after demining and disposal; level of safety assessment of the population living in these territories; return of vital infrastructure. An expert assessment methodology was applied, which includes an analysis of the severity of the consequences and the likelihood of their occurrence. The risks were ranked using the method of pairwise comparisons. The results of the study can be used to develop strategies for the further use and rehabilitation of the affected areas.

The results of the study indicate the need for systematic monitoring and control of the exempted and liberated territories in order to prevent possible environmental and socio-economic problems. To ensure sustainable development and conservation of natural resources, due attention should be paid to the issues of environmental safety and rehabilitation of these territories. Further research in this area will allow developing more effective strategies for the use and rehabilitation of exempted areas, taking into account current environmental and socio-economic challenges.

Keywords: *exempted and released territories, risk assessment, method of pairwise comparisons, sustainable use of territories, environmental safety, sustainable development*

Introduction. The growing relevance of the problems associated with brownfields is determined by a combination of factors, such as increasing urbanization, the shortage of available land, and the need to effectively utilize and rehabilitate already used areas. Brownfields are land plots that have lost their original functionality due to exploitation, pollution, or abandonment due to explosions, accidents, wars, and other negative events that have caused environmental pollution and other forms of damage. In Ukraine, the problem of exempted areas is becoming increasingly relevant in the context of large-scale military operations, rapid urban development and, in this regard, the need for rational use of land resources. Risk assessment in the development of areas liberated from hostilities is important to ensure human safety and restore environmental sustainability of the regions. This analysis will help to develop effective strategies for rehabilitation and restoration of the areas liberated from hostilities, taking into account the requirements of sustainable development and conservation of natural resources.

Ukraine currently has 174,000 square kilometers of land potentially contaminated by explosive ordnance, including the temporarily occupied territories. The World Bank estimates that the possible cost of surveying and cleaning up these areas is over $37 billion. Given the ongoing hostilities, the final figures for the scope of work remain uncertain.

The main purpose of demining is the safe removal of mines, explosive materials, remnants of weapons and explosive devices from certain areas to protect civilians.

Humanitarian demining covers a wide range of activities aimed at eliminating the threats posed by explosive hazards. These activities include technical surveys, mapping, clearance, marking, post-clearance documentation, communication with local communities on mine action and handover of the cleared area. Demining can be carried out by a variety of organizations, such as non-governmental organizations, commercial companies, national mine action authorities or military units. This process can be carried out both in an emergency mode and under normal conditions [1-2].

Humanitarian demining is about more than just removing the danger from mines and other explosive hazards. It is about enabling people to return to their homes and live in safety, and about rebuilding the economy and the country as a whole. It is also about ensuring food security in the world. Mine clearance is the first step in the restoration of our country and an important prerequisite for the return of everyday life on the de-occupied land. This process includes a number of operations, such as non-technical survey, technical survey, environmental impact study, medical survey, organization of communications, checking transport routes, cooperation with the administration and, finally, land return.

Non-technical surveys play a key role in humanitarian demining activities, as it is a process that involves collecting and analyzing information about a potentially hazardous area. Its main goal is to confirm the existence of a threat, determine its type and extent, and establish the perimeter of the danger zone without the need for physical intervention. The main purpose of this process is to provide information about potentially hazardous areas and confirm their status through thorough inspection and analysis.

After completing the non-technical survey, it is necessary to review the classification of the suspected area and identify one or more confirmed hazardous areas. If the data from the non-technical survey is confirmed, you can proceed directly to the registration procedure.

Identify hazardous areas, improve the accuracy of the hazardous area assessment, and eliminate doubts about the reliability of the hazardous area information.

After completion of the non-technical survey, it may be necessary to clarify the boundaries of the territory, and if necessary, an estimate of the approximate boundaries should be made.

The information obtained from the non-technical survey is presented in the form of reports, maps with a differentiated global positioning system (which is a key element of geographic data of hazardous areas), and marking of all hazardous areas with visual confirmation of the presence of mines.

The main objective of a technical survey is to gather sufficient information to accurately determine the requirements for future demining operations. This includes aspects such as:

- Prioritizing future demining operations;
- Identification of obstacles such as vegetation, logistics, communications, etc;
- Identification of areas to be cleared during future demining operations;
- Analysis of local soil conditions, including soil type, density and hardness;
- Identification of mine patterns and types, including their location and position;
- Assessment of fragmentation and overall level of metal contamination;
- Selecting the appropriate means of mine clearance;
- Identify areas suitable for different demining methods, such as manual or mechanical equipment;
- Estimating the time required to complete future clearance operations.

The purpose of the technical survey is to minimize risk during all activities associated with this procedure. The technical survey is performed using probes and drones to determine the presence of an explosive hazard and the size of the hazardous area, if any. Fencing and marking of the hazardous area is intended to reduce the risk of unintentional entry into the area. Gathering more accurate information about the size of the hazardous area may lead to a reduction in its initial size by clarifying and identifying accessible routes.

All organizations engaged in demining in accordance with international standards should have medical capacities that ensure the provision of safe and effective medical care in the event of accidents or incidents, as well as mechanisms for the repatriation of injured workers.

Before any demining operation begins, an adequate level of medical support and a detailed casualty evacuation plan must be in place that all team members fully understand and follow. The team should be prepared to collect casualties and provide basic medical care within the first 5 minutes. Mine action organizations should ensure adequate communication before and during all operations. No demining action should be initiated unless effective communication can be maintained between on-site personnel and appropriate support elements. Communications support should be in place at all stages of operations and include periods of movement between sites.

There is a variety of demining techniques around the world, such as manual demining, metal detectors, trained animals, drones, robots and specialized machines. The choice of approach depends on the type and number of mines, geographical conditions, available resources and technological capabilities.

Manual demining is a traditional method of detecting and removing mines, carried out by specialists who carefully scan the area for explosive devices.

Machine demining is an effective way of detecting and removing mines over large areas of land, using special machines that can locate and remove mines.

The use of robotics for demining is becoming increasingly common as it helps reduce the risk to human life. Different types of robots can be used depending on specific conditions and needs. Drones are becoming increasingly important in the demining process and can be used to perform a variety of tasks depending on their equipment and configuration. This helps to reduce the risk to people.

APOPO, an organization based in Belgium, has developed a unique approach to using rats for demining.

These "sapper rats", known as HeroRATs, have been trained to detect mines and other explosive devices.

The author analyzes the global experience of restoring de-occupied territories. As an example, the war in Croatia ended in 1995. Over the years, the country has rebuilt its economy and joined NATO and the EU. The only thing that reminds us of the war is the mine danger. Of the 13,000 square kilometers (23% of the territory) contaminated by 2 million mines, 3% remain. They will be neutralized by 2026. 30 years after the end of the war. Thus, the Balkan experience allows Ukraine to assess the scale of future demining.

Purpose and objectives. The purpose of the study is to assess the risks of the demined areas for their full restoration for further use.

Summary of the main research material. In order to assess possible risks in the de-occupied territories, it is necessary to establish the main criteria by which the analysis will be carried out. The process of clearing areas and objects from explosive hazards, which is carried out to ensure the safety of the population, is the main task of humanitarian demining. This is accompanied by certain processes of clearing landmines, unexploded bombs, and toxic zones.

The experience of countries with a mine problem shows that 10 years of active hostilities account for 1 year of demining, and one day of intense hostilities accounts for 30 days of demining. Experts estimate that full demining of Ukraine could take 10-15 years. The consequences of the use of mines and explosive ordnance can be classified into four main categories:

● Humanitarian consequences include:
● deaths and injuries that can lead to disability;
● obstacles to access to hospitals, water, food and humanitarian assistance;
● Impeded free movement of people, as well as the return of refugees and internally displaced persons.
● The social and psychological consequences include:
● a sense of fear, despair, depression, and family tensions;
● increased levels of aggression and tension in society.

Economic impacts include:
● destruction of infrastructure and roads, loss of fertile agricultural land
● costs of restoring water and energy supply;
● the burden on the healthcare system due to injuries and increased disability;
● Additional costs for demining;
● losses in tourism, etc.

Environmental impacts include:
● damage to flora and fauna
● Long-term effects, such as changes in regional ecosystems.

As you can see, the contamination of territories with mines and explosive devices negatively affects the overall development of the country, and this applies to all citizens at risk. Therefore, maintaining security and reducing contamination of the de-occupied territories is the main task of an effective demining process. Therefore, the most important and essential indicators that we propose to use to assess the risks of the demined territories are the following: demining of territories; efficiency of demining and disposal of remnants of military equipment, mines, etc.; safety and efficiency of demining and disposal technologies; degree of contamination of demined territories after demining and disposal [5-8]; level of safety assessment of the population living in these territories; return of vital infrastructure [5-13].

It is proposed to use the Failure Mode and Effects Analysis (FMEA) methodology to assess the risks of the exclusion zone for their full restoration for further use [3-4]. This methodology is an effective tool for assessing risks and system safety. It allows identifying technical problems and their consequences in complex systems, as well as assessing various risks by their nature, severity and time of occurrence.

The main idea behind the methodology is an expert assessment of the problem. Even with a limited amount of data, experts can effectively assess risks. The risk assessment is performed by ranking using the RPN (Risk Priority Number), which is calculated as the product of the ranks obtained for the severity of consequences (A), the probability of detection (B), and the frequency of occurrence of emergencies (E). Risks with the highest RPN values are eliminated first.

The expert group was asked to consider possible risks in demining the de-occupied territories.

The experts were asked to rank the impacts using pairwise comparisons. A pairwise comparison is a sequential comparison of each key element with each other: if X is more important than Y, the former is assigned a score on a scale from 1 to 9, and the latter the opposite value; if X and Y are equal, 1 point is assigned. The indicators include:

● Demining of territories (x_1);
● Efficiency of demining and utilization of remnants of military equipment, mines, etc (x_2);
● Safety and effectiveness of demining and disposal technologies (x_3);
● The degree of contamination of the exempted territories after demining and utilization (x_4); [5-8]
● The level of safety assessment of the population living in these areas (x_5);

● Return of vital infrastructure (x_6).

For each criterion, a matrix of conjugate characteristics was compiled and the value of the priority P_k and the total value of all priorities P were determined.

$$P_k = \sum_{i=1}^{6} x_i, k = \underline{1, n}; \quad (1)$$

$$P_i = \sum_{k=1}^{n} P_k, i = \underline{1, x_i}; \quad (2)$$

here n is the number of independent experts.

The priority value was normalized for each impact using the formula:

$$P_{k\_rel} = P_i / \sum P_i. \quad (3)$$

The expert ranking of priorities was performed in descending order (from 10 to 0), with the highest score assigned to the most dangerous impact. The results of the expert evaluation of the features by the severity of the consequences and the probability of non-detection are presented in Tables 1 and 2 with the participation of one expert. The matrices of conjugate signs by severity of consequences and non-detection, based on the assessments of all 16 experts, are presented in Tables 3 and 4.

Table 1 Table of ranking by weight of consequences by one expert

	Pairwise comparison assessment results					
Impacts	X_1	X_2	X_3	X_4	X_5	X_6
X_1	1,00	3,00	5,00	8,00	9,00	9,00
X_2	0,33	1,00	3,00	5,00	9,00	2,00
X_3	0,20	0,33	1,00	5,00	9,00	3,00
X_4	0,13	0,20	0,20	1,00	5,00	4,00
X_5	0,11	0,11	0,11	0,20	1,00	7,00
X_6	0,11	0,50	0,33	0,25	0,14	1,00

Table 2 Rating table by non-detection by one expert

	Pairwise comparison assessment results					
Impacts	X_1	X_2	X_3	X_4	X_5	X_6
X_1	1,00	3,00	2,00	4,00	1,00	9,00
X_2	0,33	1,00	3,00	4,00	2,00	9,00
X_3	0,50	0,33	1,00	3,00	2,00	7,00
X_4	0,25	0,25	0,33	1,00	5,00	3,00
X_5	1,00	0,50	0,50	0,20	1,00	9,00
X_6	0,11	0,11	0,14	0,33	0,11	1,00

Based on the obtained matrices of conjugate attributes using the FMEA method, the factors are ranked according to the total RPN criterion (Table 5), the value of which is defined as the product of ranks A, B, E:

$$RPN = A \cdot B \cdot E. \quad (4)$$

The RPN risk score indicates the relationship between the factors that lead to danger. Risks with an RPN significantly higher than the permissible value of 125 are prioritized for elimination. If any of the A, B, or E indicators are 9 or 10, risk reduction measures should be taken. An RPN value of 40 to 100 is considered a medium risk, and an RPN of less than 40 is considered a low risk. Correction parameters for risk reduction are developed in the following order: first, the causes of accidents are eliminated (reduction of parameter E); then the degree of consequences is reduced (reduction of parameter A); and finally, a high probability of detecting accidents due to this cause is ensured (reduction of parameter B).

Results of the assessment of expert opinions on RPN:

- Demining of territories (x_1) -720;
- Efficiency of demining and disposal of remnants of military equipment, mines, etc. (x_2) - 504;
- Safety and efficiency of demining and utilization technologies (x_3) - 224;
- The degree of contamination of the demined areas after demining and utilization (x_4) - 210;
- The level of safety assessment of the population living in these areas (x_5) - 180;
- Return of vital infrastructure (x_6) - 60.

Table 3 Matrix of conjugate characteristics by severity of consequences (A)

	Assessment results *Pk*																		
№	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	*Pi*	∑Pi	Pk_rel
X_1	35,00	30,00	5,45	13,80	26,00	33,00	29,00	12,75	28,00	30,00	16,20	30,00	31,00	32,00	30,00	30,00	412,20	1419,78	0,290
X_2	20,33	18,33	5,56	16,00	19,33	24,25	21,33	12,53	18,20	18,33	19,48	18,33	28,33	28,33	25,33	27,50	321,52		0,226
X_3	18,53	13,53	11,83	20,00	20,67	21,70	20,25	7,92	13,75	11,53	13,53	11,53	12,37	20,48	11,45	5,25	234,31		0,165
X_4	10,53	15,68	3,60	11,83	19,43	16,70	14,95	14,50	16,50	18,39	18,25	18,39	7,27	13,45	8,31	20,83	228,61		0,161
X_5	8,53	9,77	27,00	15,50	1,80	2,44	2,49	2,48	13,49	16,42	9,20	16,42	4,20	4,57	3,20	4,38	141,88		0,100
X_6	2,34	2,15	30,00	1,56	6,84	2,56	2,61	16,53	1,73	1,80	2,07	1,80	2,21	2,00	2,71	2,35	81,26		0,057

Table 4 Matrix of conjugate characteristics by probability of non-detection (B)

	Assessment results *Pk*																		
№	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	*Pi*	∑Pi	Pk_rel
X_1	20,00	15,00	24,00	22,00	10,40	28,00	25,00	18,58	17,58	22,50	20,00	30,00	31,00	24,00	29,00	31,00	368,07	1239,81	0,297
X_2	19,33	10,50	13,33	11,33	2,84	17,33	17,50	9,65	13,34	15,42	4,45	18,33	15,20	20,33	16,25	19,25	224,40		0,181
X_3	13,83	15,83	17,33	12,33	2,98	17,75	12,33	8,64	10,86	12,66	4,38	11,53	10,33	10,64	9,31	7,64	178,38		0,144
X_4	9,83	9,08	3,70	7,35	12,53	8,92	8,83	17,40	11,51	11,45	13,00	18,39	11,94	13,68	12,61	20,50	190,74		0,154
X_5	12,20	8,28	3,56	11,17	30,00	3,67	2,80	19,20	24,20	20,50	8,75	16,42	10,48	8,88	9,89	4,69	194,69		0,157
X_6	1,81	2,45	3,98	11,62	16,00	2,34	2,88	7,03	8,14	8,70	7,03	1,80	2,65	2,21	2,68	2,21	83,53		0,067

It can be concluded that the most important indicator with a high severity of impact (RPN > 125) is the demining of territories [9-13]. It should be noted that it is difficult for specialists to assess the degree of contamination of the contaminated territories in terms of sanitary and epidemic hazards and the degree of danger to the population living in these territories.

The choice of the direction of restoration and further use of the mined areas should be made taking into account the minimization of risks associated with demining and humanitarian demining. First of all, this concerns human safety. To ensure sustainable development and efficient use of natural resources, it is extremely important to pay due attention to environmental safety and rehabilitation of territories.

Table 5 RPN rating table

Implications		A		B	E	RPN
X_1	0,29	10	0,30	8	9	720
X_2	0,23	9	0,18	7	8	504
X_3	0,17	8	0,14	4	7	224
X_4	0,16	7	0,15	5	6	210
X_5	0,10	6	0,16	6	5	180
X_6	0,06	5	0,07	3	4	60

Conclusion. In the work, the risks of the exempted territories were assessed using the Failure Mode and Effects Analysis methodology for their full restoration for further use. The main indicators of risk sources are determined: Demining of the territories; Efficiency of demining and disposal of remnants of military equipment, mines, etc.; Safety and efficiency of demining and disposal technologies; Degree of contamination of the ex-exploded territories after demining and disposal; Level of safety assessment of the population living in these territories; Return of vital infrastructure support.

Possible scenarios and their combinations are identified, covering a wide range of risks, such as technical, environmental, social and economic. Based on the rating of experts' indicators, matrices are formed to assess the impact of various sources of risk. According to the expert opinions on the Risk Priority Number, it was found that the indicators with increased severity include: Demining of territories RPN = 720; Efficiency of demining and disposal of remnants of military equipment, mines, etc. RPN = 504; Safety and effectiveness of demining and utilization technologies RPN = 224; Degree of contamination of the exempted territories after demining and utilization RPN = 210. The obtained results will be used to select the optimal direction for the restoration and further use of the exempted territories.

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ОЦІНКА РИЗИКІВ ДЛЯ РОЗВИТКУ ЕКЗЕМПТОВАНИХ ТЕРИТОРІЙ

В роботі досліджуються ризики, пов'язані з екземптованими та звільненими територіями, які раніше використовувалися для певних промислових, комерційних, сільськогосподарчих або інших діяльностей. Таки території були захоплені або використовувалися військовими силами під час війни і потім були звільнені або покинуті та залишені без нагляду, або були порушені внаслідок природних катастроф, техногенних аварій тощо. Робота ставить за мету проаналізувати можливість їхнього подальшого використання та реабілітації.

На таких територіях можна виділити наступні показники джерел ризику як наявність вибухонебезпечних об'єктів; рівень забруднення ґрунту та водних ресурсів; наявність хімічних, біологічних або радіаційних забруднень; ступінь пошкодження інфраструктури та будівельних конструкцій; ризик появи небезпечних ситуацій та аварій; вплив на здоров'я та безпеку місцевого населення; можливість розповсюдження інфекційних захворювань; наявність незбережених або неконтрольованих вибухових матеріалів; ризик зворотного вторгнення ворожих сил; потенційна екологічна небезпека внаслідок забруднення навколишнього середовища. З аналізу наведених показників їх було узагальнено та згруповано в шість основних показників ризику: розмінування територій; ефективність розмінування та утилізації залишків військової техніки, мін та ін.; безпека та ефективність застосування технологій розмінування та утилізації; ступінь забруднення екземптованих територій після розмінування та утилізації; рівень оцінки безпеки населення, яке проживає на цих територіях; повернення життєвого інфраструктурного забезпечення. Застосовано методику експертної оцінки, що включає в себе аналіз тяжкості наслідків та ймовірності їх виникнення. Ранжування ризиків проводилося за допомогою методу парних порівнянь. Результати дослідження можуть бути використані для розробки стратегій подальшого використання та реабілітації екземптованих територій.

Результати дослідження вказують на необхідність систематичного моніторингу та контролю за екземптованими та звільненими територіями з метою попередження можливих екологічних та соціально-економічних проблем. Для забезпечення сталого розвитку та збереження природних ресурсів необхідно приділяти належну увагу питанням екологічної безпеки та реабілітації зазначених територій. Подальші дослідження в цьому напрямку дозволять розробити ефективніші стратегії використання та реабілітації екземптованих територій з огляду на сучасні екологічні та соціально-економічні виклики.

Ключові слова: *екземптовані та звільнені території, оцінка ризиків, метод парних порівнянь, стале використання територій, екологічна безпека, сталий розвиток*.

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