Factors affecting the demining process

Фактори, що впливають на процес розмінування

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Purpose: is to analyze the factors affecting the demining process of the contaminated with explosive objects territory during the terrain reconnaissance, making safe lanes in minefields, complete (humanitarian) demining in order to take them more fully into account when conducting research on ensuring the effectiveness of the remote-controlled demining system.

Method: analysis, synthesis.

Findings: The article analyzes the main factors that affect the effectiveness of the Defense Forces' tasks of terrain reconnaissance for the presence of explosive objects and demining, as well as the creation and operation of a remote-controlled demining system.

Paper type: theoretical.

Мета роботи: аналіз факторів, що впливають на процес розмінування забрудненої вибухонебезпечними предметами території під час розвідки місцевості, створення безпечних смуг у мінних полях, повного (гуманітарного) розмінування з метою їх більш повного врахування при проведенні досліджень. забезпечення ефективності дистанційної системи розмінування.

Результати дослідження: проаналізовано основні фактори, що впливають на ефективність виконання завдань Силами оборони з розвідки місцевості на наявність вибухонебезпечних предметів та розмінування, а також створення та функціонування дистанційно керованої системи розмінування.

Тип статті: теоретичний.

Key words: combat operations, explosive objects, demining.

Ключові слова: бойові дії, вибухонебезпечні предмети, розмінування.

1. Introduction

The war of the russian federation against Ukraine led to the fact that Ukraine has become one of the most polluted countries in the world with explosive objects. As of December 2022, the so-called "mine pollution" in Ukraine covered about 170 thousand square kilometers – about 40% of the country's total territory, which is incomparable even with Syria and Afghanistan, that is, more than a quarter of the country's territory [1]. In addition, the constant shelling of the Ukraine's territory by the Russian Federation, including remote mining systems, leads to new destruction and an increase in the area contaminated with explosive devices (ED).

In these conditions, the issue of performing both combat tasks of terrain reconnaissance and making safe lanes in minefields, as well as complete (humanitarian) demining of the area as a whole, became very acute.

2. Data and methods

The analysis of the tasks of terrain reconnaissance for the presence of explosive objects, making safe lanes in minefields, complete demining in modern military conflicts, peacekeeping operations and in the war of the russian federation against Ukraine [5-9] shows that at the current stage, the intensity of the mine weapon use significantly exceeds the pace of reconnaissance and demining. This fact, taking into account the growing trend of the use of improvised explosive devices (IEDs) and a large number of other unexploded ordnance, in the leading countries of the world has long been perceived as a global problem, the solution of which requires an integrated approach [2,3]. As

a result of this state, the effectiveness of demining tasks is significantly reduced. The analysis of demining tools shows that currently there is no technical tools that would ensure the fulfillment of the requirements for prompt and high-quality detection of IEDs [4]. This determines the further widespread use of the manual demining method, which is extremely dangerous.

Therefore, taking into account all of the above, in the practice of reconnaissance of the area for the presence of explosive objects, making safe lanes in minefields, complete demining, the need to improve the quality, efficiency and safety of the processes of searching, detecting, destroying or neutralizing explosive objects, is significantly intensified. Such a question is especially acute in relation to the development of promising means of terrain reconnaissance, in particular, means of searching and detecting explosive objects, creating remote-controlled demining complexes and functioning of the remote-controlled demining system. In order to eliminate these problematic issues, it is first of all advisable to analyze the factors affecting the demining process as a whole.

The analysis of the works devoted to solving the issue of increasing the efficiency of demining processes shows that they sufficiently substantiate the ways of solving the specified problem. The well-known works [5-11] are devoted to highlighting the results of scientific research aimed at modeling processes and substantiating requirements for means of searching and detecting explosive objects by various methods, aspects of remote destruction of explosive objects are considered. Materials [11] give the results of theoretical research of methods of aerial reconnaissance of mined areas. However, they consider partial scientific problems, do not fully take into account some factors affecting the effectiveness of detecting explosive objects, have a number of limitations and require additional research, in particular, in the direction of the functioning of the remote-controlled demining system. Therefore, the issue of taking into account the most important factors affecting the effectiveness of the remote-controlled demining process, especially taking into account the experience of the russian federation's war against Ukraine, remains relevant and requires further research.

The purpose of the article is to analyze the factors affecting the demining process of the contaminated with explosive objects territory during the terrain reconnaissance, making safe lanes in minefields, complete (humanitarian) demining in order to take them more fully into account when conducting research on ensuring the effectiveness of the remote-controlled demining system.

3. Results and Discussion

The experience of the russian federation's war against Ukraine shows that the enemy widely uses explosive objects in the form of minefields, improvised explosive devices, group and individually installed mines [12-14]. The most common practice is when sabotage and reconnaissance groups of the aggressor's army pre-study the locations and types of minefields installed to protect the positions of our troops or the advance routes of reserve groups and then install improvised explosive devices on the advance routes, which in most cases are extremely difficult to detect. In order to cover the flanks and areas where the troops are located in today's conditions of a long front, the enemy is completely mining the terrain.

Recently, the enemy has most widely started to use the remote method of mining the terrain with both anti-tank and anti-personnel mines, in particular by the "Zemledelie-I" system [13]. The peculiarity of such mining is the unsystematic placement of mines and the special danger of mines, which have different operating principles of target sensors (seismic, tensile, pressure, optical). These mines can be set both in the self-destruction mode after different periods of time, and without self-destruction, which carries an additional danger for military personnel and civilian population [14].

Thus, the peculiarities of the use of explosive objects based on the experience of local wars, armed conflicts of the late 20th and early 21st centuries and the russian federation's war against Ukraine are:

- installation of a large number of engineering ammunition;
- use for road mining of anti-tank, anti-personnel mines, self-made fragmentation explosives from artillery and other ammunition, which are installed on the roadside;
- widespread use of remote mining systems to solve the problem of isolating areas, disrupting logistical support;
- intensive installation of small groups of mines and individual mines (explosive mines and mine traps);
- unsystematic installation of both minefields and group and individual mines;
- widespread use of controlled mines (explosives and traps);
- lack of records (forms) of the installation of mine-explosive barriers;
- widespread use of improvised explosive devices, in particular not only by specialists of the engineering troops, but also by the personnel of various arms of the military (wide use of offensive and defensive hand grenades on tension or under the load of a staple);
- mining of infrastructure facilities, abandoned equipment, dead soldiers, etc.

Taking into account the above, it can be stated that the process of demining¸ which consists of the tasks of terrain reconnaissance for the presence of explosive objects, making safe lanes in minefields (complete clearing of the territory), neutralization or destruction of explosive objects is quite a complex task and requires taking into account the most important factors in order to ensuring the necessary efficiency and safety of task performance for the personnel of demining teams. Let's consider the factors affecting the demining process.

Factors affecting the demining process of troops (forces) actions, in a general approach, include [15]:

- the first group: factors determined by their properties;
- the second group: factors characterizing the methods and conditions of the troops (forces) use.

The factors of the first group have internal signs of the expediency of using component systems of a higher level to perform demining tasks in specific conditions of interfering influences.

The factors of the second group include:

- distribution of partial tasks and resources;
- spatio-temporal scope of tasks;
- methods of management and planning;
- interaction and communication between subsystems;
- ways, modes and regularity of using system elements.

The factors that determine the conditions for performing demining tasks consist of:

- natural factors;
- factors that are the result of active actions of the enemy, own troops and neighbors;
- limiting factors (political, economic aspects; humanitarian law).

The conducted analysis showed that the capabilities of troops (forces) to perform demining tasks in an armed conflict are influenced by a number of different factors. To facilitate their research, it is advisable to group the factors in accordance with the nature of their influence on the process of tasks performance of supporting the troops (forces) actions. Such groups of factors in the study in relation to the possibilities of performing the tasks of demining the area and objects while supporting the troops (forces) actions are divided into external and internal.

External factors include:

- composition, combat, maneuver and fire capabilities, likely nature and spatial scale of the enemy's actions, their capabilities;
- type and density of use of mine-explosive barriers and other types of explosive objects, characteristics of the environment hiding explosive objects;

- composition, nature of the troops (forces) operations, their place and role in the operation (combat operations), their staffing;
- physical-geographical and weather conditions of the operational area.
- Internal factors [15] include:
- staffing status of demining units;
- training level of personnel;
- moral and psychological state of personnel;
- organization of demining tasks (in particular, their operational efficiency);
- comprehensive provision of the demining process while supporting a group of troops (forces) actions;
- availability and condition of engineering weapons.

It should be noted that external factors determine the influence of the external environment and can be both useful (contribute to the successful completion of demining tasks) and harmful (counteract success), and internal factors, which are determined by the personal characteristics of a group of troops (forces), as a rule, include to the managed and reflect the influence on the course and result of demining tasks, in general.

Let's consider the influence of some factors on the functioning of remote-controlled demining tools as a component of the remote-controlled demining system.

The most difficult case of functioning of remote-controlled demining tools during search, detection, identification, extraction, destruction (disarmament) is the case when explosive objects are in different environments that hide them. These objects have two characteristic features: their properties are significantly different from the properties of the natural environment in which the search is carried out, information about the location of the object before the start and during the search has, as a rule, random nature. One of the main factors in searching for objects of artificial origin on the background of the natural environment that makes possible to detect them.

For example, let's consider the influence of the environment that hides explosive objects.

The main types of environment that hides explosive objects can be:

- soils of different composition and humidity (the most typical case);
- fresh water of rivers and lakes;
- seawater;
- vegetation;
- snow and ice;
- building materials (brick, concrete, etc.).

Their main characteristics are: density, hardness, electrical conductivity, dielectric and magnetic permeability, reflection and radiation coefficients in the visible (0.4–0.76 μm) and infrared (0.76–1000 μm) ranges of electromagnetic waves and others [5, 16].

One of the essential characteristics for detecting explosive objects is the specific absorption of probing electromagnetic waves in the masking (opaque) layer of the environment, which hides explosive objects [5, 16]. It should also be noted that the energy potential of portable active electromagnetic search systems (radar, induction, etc.) reaches 140–160 dB. When the thickness of the layer of the environment hiding the objects is more than 0.2–0.3 m, their detection in wet soil (clay) is possible at > 1 m, in dry sand at > 0.2 m, and in dry snow or vegetation at > 0.02–0.03 m. At the same time, the signal loss in this layer does not exceed 20–30 dB, which is normal for the practice of using subsurface radar systems.

The most important for searching for various objects are unmasking signs of detection. The current state of existing methods of search, detection and identification in the extraction, destruction or disposal of explosive objects is characterized by a wide variety. Their analysis shows that each of them has its own limitations. Of course, in this case, it is necessary to take into account

both a priori information about the search object (size, material, etc.) and the properties of the environment that hides it [17].

Another important factor is the depth of explosive objects immersion into the environment that hides them. Depending on this, possible deepening parameters are determined, which include the depth of penetration and the distance of the lateral displacement.

Entrance channels in the soil can remain not only from shells and mines, which are launched by ground systems. For example, when incendiary aerial bombs of a caliber of 50 kg or more sink into the soil and trigger, due to insufficient high-explosive action, there is no funnel, but entrance channels in the soil are the same as from shells and mines launched by ground systems.

However, the increase in the number of factors that are taken into account during studies of ensuring the effectiveness of the demining process can lead to the complication of calculations, in particular, the process of remote-controlled demining. When choosing them, it is advisable to take into account the degree of their influence on the demining process effectiveness.

4. Conclusion

Thus, it can be noted that today the issue of demining during military operations, as well as after the liberation of territories, is very acute. In these conditions, the search for the most effective methods and tools of demining and the creation of an effective demining system, in particular a remote-controlled one, which should ensure high efficiency of the demining process and the safety of the sappers' personnel, is underway.

The paper defines the list of factors affecting the demining process and gives an example of the influence of one factor – the environment that hides explosive objects.

The results of the analysis show that to ensure the necessary effectiveness of demining tasks, it is necessary to take into account the factors affecting this process in order to clarify the parameters of demining tools to determine promising directions for their development. The direction of further research is to take other factors into account when justifying the parameters of the remote-controlled demining system.

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6. Competing interests

The authors declare that they have no competing interests.

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