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## Integrating Humanitarian Demining with Remote Control Tech in Educational Process

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### ABSTRACT

The aim of the work is to investigate the possibility of introducing the system of humanitarian demining into the educational process of higher education institutions (HEIs) of Ukraine. The introduction of modern equipment against improvised explosive devices explosive items, for example remotely controlled ones, was also studied. Methods used: content analysis, semi-structured interviews, and self-assessment of the sapper's competence. The conducted research for the first to describe the results of the possibility of introducing a system of humanitarian demining in HEIs of Ukraine, where it has not yet been introduced. It was found that educational institutions for military training in various fields have sufficient material and technical resources for professional training of demining personnel. It is also proposed to renew or renovate the demining equipment, as well as introduce a project activity on the development of remotely controlled mechanisms against explosive items into the educational process. The results can be useful to researchers and teachers who are working on updating the content of education in accordance with the current security needs. Further research should be conducted on the monitoring of new demining equipment.

KEYWORDS: mine detection, sappers, UAV operators, higher education, deciphering, mine clearance, international cooperation.

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## Integración del desminado humanitario con la tecnología de control remoto en el proceso educativo

### RESUMEN

El objetivo del trabajo es investigar la posibilidad de introducir el sistema de desminado humanitario en el proceso educativo de las instituciones de educación superior (IES) de Ucrania. También se estudió la introducción de equipos modernos contra artefactos explosivos improvisados, por ejemplo los controlados a distancia. Métodos utilizados: análisis de contenido, entrevistas semiestructuradas y autoevaluación de la competencia del zapador. La investigación realizada fue la primera en describir los resultados de la posibilidad de introducir un sistema de desminado humanitario en las IES de Ucrania, donde aún no se ha implementado. Se constató que las instituciones educativas de formación militar en diversos campos cuentan con suficientes recursos materiales y técnicos para la formación profesional del personal de desminado. También se propone renovar el equipo de desminado, así como introducir en el proceso educativo una actividad de proyecto sobre el desarrollo de mecanismos controlados remotamente contra objetos explosivos. Los resultados pueden ser útiles para investigadores y docentes que trabajan en la actualización de los contenidos de la educación de acuerdo con las necesidades de seguridad actuales. Se deben realizar más investigaciones sobre el seguimiento de nuevos equipos de desminado.

**PALABRAS CLAVE:** Detección de minas, zapadores, operadores de UAV, estudiantes de nivel superior, descifradores, remoción de minas, cooperación internacional.

### Introduction

More than 100 million explosive items remain active on the planet. They pose a threat to both the military and the civilian population. After the full-scale invasion of Russian troops on the territory of Ukraine, more than a million hectares of the country's territory were contaminated with explosives. During March 2022 alone, about 55,000 explosive items were identified and destroyed (Hameed, 2022). As Ukraine is an agricultural country, and a large part of it is contaminated with explosives, this not only poses a threat to agricultural workers, but also affects economic productivity.

Therefore, the issue of finding a safe, effective, fast and inexpensive way of demining is relevant (Looney, 2021). Remote demining using robots and UAVs is one of them (Pryshchenko, 2022). It was proved (Tuohy, 2023) that the earlier the attention of students

is drawn to the technical and social aspects of humanitarian mine action, the more effective it will be. In the educational process, students may get acquainted with mine action not only during lessons on relevant academic subjects, but also through their participation in research projects on this issue, in public events, conferences, etc. (Tuohy, 2023). Besides, it may encourage the design and manufacture of new demining equipment.

The issue of providing highly qualified specialists and high-precision safe technical equipment for humanitarian demining still remains unresolved despite a significant number of studies on mine action, demining equipment, including the equipment with remote control. The aim of the work is to investigate the possibility of introducing the system of humanitarian demining into the educational process of higher education institutions (HEIs) of Ukraine. The aim was achieved through the fulfilment of the following research objectives:

- 1) Study the readiness of military educational institutions of Ukraine and teaching staff to introduce the system of humanitarian demining into the educational process;
- 2) Study the degree of implementation of the practice of developing remotely controlled equipment for combating explosive items during the preparation of research projects.
- 3) Determine the role of professional training of sappers, UAV operators, decipherers on level of development of their demining competencies.

#### Literature review

Since 2014, Ukraine has come up with such countries as Yemen (Step, 2022), Somaliland (Njeri, 2022) in terms of contamination with explosive items, and one of the most contaminated countries in the world since 2022. As the report (Step, 2022) shows, abandoned explosives have the greatest impact on the quality of life and health of the civilian population, especially children.

The international Organization for Security and Co-operation in Europe (OSCE) plays an important role in maintaining peace and preserving the territorial borders of the countries of the world (Mihr, 2023). International cooperation on the mine action issue is also supported by other international organizations. For example, the Iraqi Health and Welfare Organization is an international non-governmental organization (Wilkinson, 2023). It is engaged in mine action in nine countries of the world, including with the involvement of women. About fifteen international donor organizations support mine

action in Angola (Hegedűs, 2022). In Ukraine, humanitarian demining organizations from 3 countries supported mine action until 2022 (Garbino, 2019). Demining on the territory of Ukraine is carried out by bomb technicians of different forces — police, army, navy (García Bedoya, 2019).

Demining territories is the key to peace and security on the planet. The clearance of territories from explosive items is a necessary condition for the protection of life, peace-building, recovery and development, for example, agricultural land use, clearing transport links, and improving trade and market activities (Schindler, 2023). The relationship between demining, humanitarian, social and economic benefits was proved (Ikpe, 2022). The connection between demining and the achievement of sustainable development is also indicated (O'Brien, 2022).

Humanity used various methods of demining. For example, demining in Afghanistan, Cambodia and Thailand was carried out with the support of the Japanese government using unmanned vehicles equipped with anti-personnel mine detection sensors (Sato, 2005). Sensors that can detect explosives have been developed as a result of implementation of the research projects by private companies and university research groups funded by the Japanese government. Looney (2021) considered a unique aerial blasting technique combining a rover, several UAVs and soft robotics. Petrişor (2022) used the energy method and the Lagrangian mechanics to improve the design of a tracked mobile demining robot. In the article by Oladunjoye (2022), a omnidirectional mobile robot with a screw drive is presented, which is capable of navigating different terrains. Ultra-wideband pulsed ground-penetrating radar sounding with artificial neural network approaches was also carried out to search for anti-personnel mines (Pryshchenko, 2022). Besides, remote technologies such as high-resolution cameras are used to assess and monitor the results of humanitarian demining (Killeen, 2022; Ibrahim, 2021). Multispectral, hyperspectral, thermal methods are widely used for remote sensing of contaminated areas. Otagaki (2022) studied the possibility of using the phenomenon of nuclear quadrupole resonance, which is a radio frequency technology for the remote detection of explosives. Data obtained using ultra-wideband radar, an MLP filter, and an oscillatory neural network are used for the detection of subsurface objects (Peleshchak, 2023).

An important measure of mine action is educating the population about the dangers of explosive ordnance (Al-Shukri, 2022). Its purpose is to change the behaviour of society to a safe one. This will allow to preserve the population without stopping activities aimed at social and economic recovery.

The safety of clearing areas of explosive items depends on the experience of the sapper and his/her ability to identify unexploded ordnance. To solve this issue, Hameed (2022) suggest using augmented reality technologies when training professional sappers.

Specialists must have the necessary competencies to carry out demining. Evans (2022) mentions 31 such competencies, and Rodikov (2013) adapted the national system of sapper competencies to the international requirements. In the educational process, students can be introduced into mine action through their participation in research projects on this issue, preparation of term papers, participation in public events, conferences, cooperation with industrial enterprises, academic institutions and the use of ways of attracting students, in particular, paid internships and providing scholarships (Tuohy, 2023), participation in robotics competitions of various levels (Brançalião, 2022). Students majoring in engineering, physics, humanitarian sciences, and forensic experts can be involved in such types of work. The latter will make it possible to establish a relationship between humanitarian mine action and humanitarian forensics.

## 1. Methods

### 1.1. Design

The research was conducted in four stages.

The first stage provided for a content analysis of curricula, professional training programmes, working educational plans, educational and methodological guidelines, sets of models and methods, educational, methodological and material support of educational institutions of the sample.

The second stage involved a content analysis of academic publications in specialized editions of educational institutions of the sample.

On the third stage, semi-structured interviews were conducted with the teachers of the educational institutions of the sample.

The fourth provided for a self-assessment of the level of sapper (mining) competencies among graduates of different years of military HEIs of Ukraine.

## 1.2. Sample

The sample included 12 military HEIs, military training faculties of four universities, and military training departments of 15 universities of Ukraine. A sample of 67 teachers of higher education institutions took part in the study with more than 3 years of teaching experience. A total of 103 military personnel who graduated from different military HEIs of Ukraine in different years were also involved. Of them, 31 were professional sappers (experimental group), the other 72 served in other types of troops (control group).

### *Methods*

The methods used in the work are: content analysis of the content of educational documentation and professional publications of HEIs of the sample, semi-structured interviews of teachers, self-assessment of sapper competencies.

## 1.3. Data Collection

The search for information for content analysis was carried out with the help of the digital search function, on the official websites of specialized publications of educational institutions using the following keywords: “mining clearance”, “humanitarian demining”, “sappers”, “remotely controlled equipment”, “against explosive items”, “UAV”, “UAV operators”, “target load”. Articles published from 2014 to June 2023 were considered.

In May 2023, semi-structured interviews were conducted among teachers and students of the sample. The received answers are divided by topics: 1) obstacles to the implementation of the humanitarian demining system using remotely controlled equipment against explosive items during the training of personnel (sappers, UAV operators, decipherers); 2) propositions for increasing the effectiveness of the process of implementing the humanitarian demining system using remotely controlled equipment against explosive items into the educational process.

The teachers' attitude to the issue of introducing a humanitarian demining system using remotely controlled equipment against explosive items and the possibility of training personnel in demining was studied according to the adapted (Colton, 2022) and author's methodology, which is based on the materials presented in the study by Rodikov (2013).

A self-assessment of the professional competence of sappers, UAV operators, and decipherers by category both of graduates of the relevant fields and of graduates of other majors of HEIs was carried out (Rodikov, 2015). The evaluation was carried out on a five-point scale, where 1 – I mostly do not have it, 5 — I definitely have it.

#### 1.4. Data Analysis

Data processing and analysis was implemented using Statistica software. Reliability was assessed using Cronbach's alpha coefficient. Validity is determined by the Kaiser test.

#### 1.5. Research Ethics

The survey was voluntary, anonymous, free of charge, with obtained written consent of the research participants.

### 2. Results

The content analysis of curricula, professional training programmes, working educational plans, complexes of models and methods, educational and methodological guidelines of the educational institutions of the sample identified only 3 courses related to demining: countermeasures against improvised explosive devices, combat use of engineering and demining units, military units, weapons and equipment of the engineering forces, where higher school students are introduced in the educational process to the use of equipment intended for demining. This is not enough under the conditions of hostilities on the territory of the country and the need for demining specialists.

The content analysis of academic specialized publications of sampled educational institutions established that only five out of 17 specialized publications in the last eight years have published a total of about 140 articles on the development of remotely controlled equipment against explosive items, technical components UAV, target load, etc. Moreover, one study on building sappers' competencies was found. So, the interest in devices intended for remote demining on the part of both teachers and higher school students was established.

A survey of teachers of the sampled educational institutions was conducted in order to determine the availability of conditions in educational institutions for the introduction of a system of humanitarian demining using remotely controlled equipment against explosive items. Table 1 presents the results of this survey.

However, as the semi-structured interview showed, the work of higher school students on the creation of equipment against explosive items that can be controlled remotely in the selected institutions is either not carried out at all (68%), or is at an initial stage (18%), or has certain results that still require further testing and research (14%). This is related to a number of problems pointed out by the teachers during the interviews (Table 2).

**Table 1:** Results of the semi-structured interview

Nº	Question	Percentage of positive answers
1.	Are there educational units in the educational institution where you work that train professional sappers, UAV operators, decipherers, and explosive ordnance disposal specialists?	12
2.	What teaching experience do you have?	
	from 3 to 10 years	28
	from 11 to 20 years	56
	from 21 to 30 years	16
3.	Do you have demining experience? (This can be the experience of demining during participation in peacekeeping missions after anti-terrorist operations in peacetime, anti-terrorist operations, etc.)	34
4.	In your opinion, is the material and technical support in the educational institution sufficient to train mine clearance personnel (UAV operators, sappers, decipherers)?	
	– study rooms	86
	– laboratories	56
	– classes	94
	– training grounds	34
	– educational and methodical documentation	58
	– teaching materials	33
5.	Is it possible to use appropriate protective equipment during the practical training of demining personnel?	72
6.	Is it possible to use equipment for searching explosive items during the practical training of demining personnel?	28
7.	Is it possible to use means of identification of explosive items during the practical training of demining personnel?	32
8.	Is it possible to use means of discarding and disposal of explosive items during the practical training of demining personnel?	26
9.	Is it possible to use means of destruction of explosive items during the practical training of demining personnel?	24
10.	Is it possible to use means of orientation, fixation and marking of areas	36

	contaminated with explosive items during the practical training of demining personnel?	
11.	Is it possible to use a sapper's working tools during the practical training of demining personnel?	18
12.	Rate the closeness of performing practical demining tasks to the real conditions on a five-point scale	
	1-do not correspond to reality at all	12
	2 - do not correspond to real ones	16
	3 - partly do not correspond to the real ones	22
	4 - mostly correspond to the real ones	38
	5 - fully correspond to real conditions	12
13.	Is it possible to use virtual reality to replace real dangerous conditions when training mine clearance personnel at the initial stages?	68
14.	Do you have demining experience?	30
15.	Do you consider it necessary to train personnel in demining in military educational institutions?	48
16.	Do you think it is possible for students to design new remote controlled equipment for discarding and disposal of explosive items?	32

Table 1 and Figure 1 show that the selected educational institutions have an average of 30% of the material and technical support for training staff in demining. The inconsistency of the conditions for performing practical demining tasks with the real ones, which is 88% according to the teachers, can be partially compensated by the use of virtual reality, which is possible in 68% of cases. Moreover, 30% of teachers have experience in demining, which is a necessary condition for the training of sappers. A third of teachers consider it possible and appropriate to design new remote-controlled equipment for detection and disposal of explosive items (for example, UAVs), testing, and studying its effectiveness and safety.

The teachers provided the following propositions for the introduction of a system of humanitarian demining using remotely controlled equipment against explosive items into the educational process:

- 1) creation of special divisions in educational institutions for the training of demining personnel (UAV operators, sappers, decipherers);
- 2) encouraging higher school students to design and build remotely controlled equipment against explosive items, for example, UAVs, as one of the most promising directions, studying their target load, efficiency, and safety;
- 3) financing the creation and research of the created equipment;
- 4) participation in contests for receiving relevant prizes, grants, scholarships;

5) establishment of international cooperation, including with non-governmental organizations.

Table 3 presents the results of the self-assessment of the competencies of sappers (demining) carried out by graduates of different years of military educational institutions of Ukraine.

**Figure 1:** The results of the assessment of the conditions for the implementation of the humanitarian demining system in the educational process

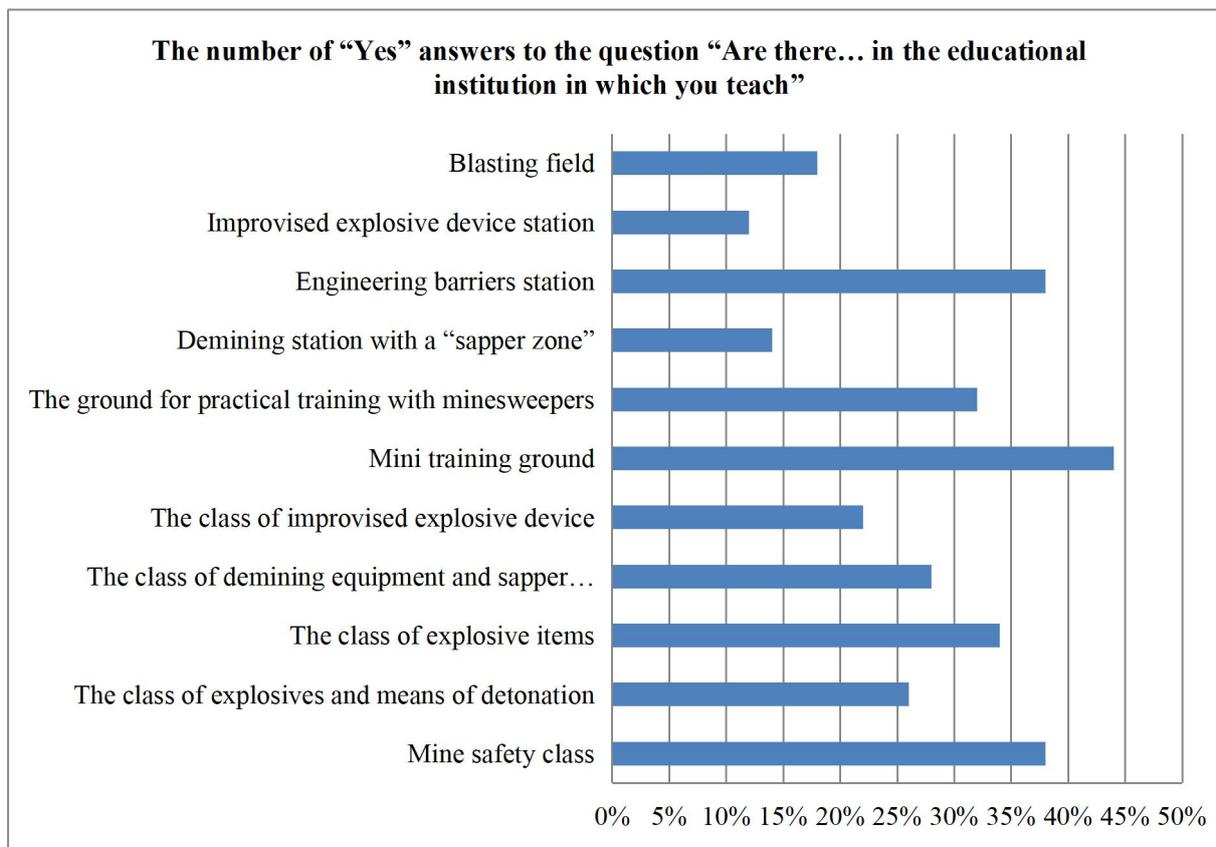


Table 3 shows, the graduates of military educational institutions who majored in demining have a significantly higher level of professional competence than military personnel who received education in other specialties. Therefore, it is important to introduce the humanitarian demining system into the educational process of HEIs where it has not been introduced. Moreover, new remotely controlled equipment of finding and neutralizing explosive devices is less studied by demining specialists. So, it is important to pay due attention to the issue of training the servicemen, both current and future, in particular, the basics of using remotely controlled equipment against explosive items.

**Table 2:** Obstacles to the creation of the equipment against remotely controlled explosive items

The indicated problem	Percentage of study participants who indicated a problem
The need for specific equipment, which is usually expensive and not available in educational institutions	76
The need for experimental testing of the equipment against explosive items created by students, which is a complex process, as it requires simulators of explosive items. If this equipment uses, for example, UAVs, its use on the territory of Ukraine must be coordinated with special services during the period of martial law	38
The need to check on real explosives, which requires the involvement of special services and obtaining a number of permits, in accordance with the legal framework, the availability of test sites for carrying out demolition operations	32
The impossibility of developing a universal means of neutralization of remotely controlled explosive items, which could be used on different types of soil, of different mineralization; on soils with different humidity; on soils with different types of surface (relief, vegetation, with stones, gravel, etc.). Besides, the equipment should detect and neutralize both metal and plastic, silicone and other explosive items.	20
Other	11

The reliability of the obtained data was 0.78, the validity was 0.81, which indicates the acceptability of the obtained results.

The variance  $d$  which ranged from 142 to 435 was calculated using the mathematical methods: it acquired values. It resulted from the heterogeneity of the sample caused by conducting research among military personnel with different experience in demining, who were graduates of different military educational institutions with different teaching, educational, methodological and technical resources, different sets of models and training methods. The root-mean-square deviation for the same research parameter for different educational institutions of the sample was different.

Table 3: Results of self-assessment of the sappers' competence (demining)

Question	Control group			Experimental group		
	Proportion of "yes" answers	Assessment of the relevant competence		Proportion of "yes" answers	Assessment of the relevant competence	
		M	SD		M	SD
Can you, if necessary, plan to clear the area of explosive items?	12	1.3	0.7	77	4.1	1.1
Can you arrange to clear the area of explosive items?	6	1.2	0.6	74	4.0	1.1
Do you know how to organize special training of personnel in the techniques of searching for explosive items?	3	1.2	0.3	74	4.1	1.0
Do you know how to organize a special training of personnel for actions aimed at neutralizing or destroying explosive items?	0	1.1	0.3	71	3.8	0.9
Are you able to organize special training of personnel in safety measures during the disposal and destruction of explosive objects?	6	1.3	0.4	74	4.0	0.9
Can you control the quality of performance of assigned tasks by personnel?	3	1.4	0.5	77	4.1	1.1
Can you monitor compliance with safety rules during demining operations?	6	1.6	0.6	80	4.2	1.0
Do you know how to keep records of the work performed by the staff?	3	1.2	0.4	80	4.2	1.1
Can you complete the task of demining explosive items?	6	1.5	0.5	88	4.3	1.2
Can you search for explosives?	12	1.7	0.7	91	4.4	1.2
Can you defuse explosives?	3	1.3	0.4	88	4.1	1.0
Can you destroy explosive objects?	9	1.5	0.6	91	4.2	1.1
Do you distinguish explosive substances by their characteristics and properties?	18	1.8	0.7	94	4.4	1.0
Do you know the rules for handling explosives?	33	2.4	0.9	94	4.5	1.0
Do you know what are the means of detonation?	30	2.1	0.8	94	4.6	0.9
Do you know how to use the means of detonation?	27	2.3	0.9	91	4.3	1.1
Do you distinguish explosive items by purpose, type, classification, structure, regular and non-regular use?	18	1.9	0.7	94	4.4	1.2
Do you distinguish the means of searching for explosive items by type, structure, and method of application?	12	1.6	0.5	88	4.2	1.0
Do you know the methods of reconnaissance and demining of the area and objects?	15	1.7	0.8	91	4.3	1.1
Do you know the methods of destruction	9	1.6	0.5	91	4.2	1.1

(neutralization) of explosive items?						
Do you know the basic safety measures that must be followed during demining and when working with explosive items?	30	2.7	0.9	97	4.5	0.9
Can you make detonating tubes, detonating cord nets and detonate them?	6	1.3	0.5	91	4.2	1.1
Do you know how to calculate, make and lay networks, check the serviceability of detonators, detonate charges electrically?	3	1.2	0.3	88	4.0	1.2
Do you know how to use explosives detection equipment?	12	1.4	0.5	91	4.1	1.1
Do you know how to use remotely controlled equipment for searching for explosive items, for example, UAVs?	6	1.3	0.4	80	3.7	1.2
Do you know how to use remotely controlled equipment for the disposal of explosive items?	0	1.0	0	77	3.5	1.1

### 3. Discussion

It is important to inform the population in a timely manner about the threat of explosive items and form a correct safe behaviour in society in order to preserve the life and health in the areas of recent hostilities (Al-Shukri, 2022). On the other hand, it is equally important to quickly and efficiently clear the territory of explosive items.

The accuracy of remotely controlled technical equipment against explosive items is quite high. Karsch (2022) developed and determined the effectiveness of using an inexpensive radar with a synthesized aperture in demining. It was found that the accuracy of classification of explosive items by this radar is 95%, and the error of locating them is about 5 mm. Petrișor (2022) established the high efficiency of mobile robots when performing humanitarian demining operations. Kim (2022) found that robots are convenient for the use in demining because they can work on the surface and underground, in water, in the air, or outside the atmosphere. Kim (2022) studied the developed autonomous multi-robot system. Pryshchenko (2022) proved the possibility of using artificial intelligence, ultra-broadband pulsed ground radar for detection and identification of explosive items.

The variety of demining equipment requires the training of personnel (UAV operators, sappers, decipherers) for their use, adapting to the specifics of the area that must be cleared of explosive items.

As an experiment, the personnel of the Armed Forces of Sweden received training on explosive substances with the help of virtual reality (Kim, 2022). It was found that sappers can learn to identify explosive substances with the help of virtual reality even before finding themselves near real ones.

As this study showed, the vast majority of military educational institutions of Ukraine included in the sample do not train specialists in humanitarian demining. However, it was found that a third of them have the technical and material support for this.

The self-assessment of the sapper's competencies conducted by graduates of different military educational institutions of Ukraine showed that the level of qualification of a professional sapper is significantly higher than that of other military branches. Therefore, in view of the high demand for specialists in this field, it is appropriate to introduce a system of humanitarian demining in military educational institutions, in particular with the use of remotely controlled equipment against explosive items. For this purpose, it is worth using the recommendations provided by Rodikov (2015): create appropriate units in military educational institutions with academic and teaching staff who have appropriate professional training and experience in demining for at least three years. It is important to replenish existing means of demining with new ones. This task can also be partially solved when higher school students prepare diploma projects, for example, by offering them topics on the development of remotely controlled equipment against explosive items, UAVs, determining their target load, etc. A similar practice exists in some countries. For example, Looney (2021) presents the results of the work of seven undergraduate students who proposed the use of soft robotics in humanitarian demining.

## Conclusions

The territory of Ukraine has been heavily contaminated by explosive substances, which hinders the productive life of its population. Therefore, the issue of quick, safe and high-quality humanitarian demining of the territory of Ukraine is urgent. The author of this paper proposes the introduction of a humanitarian demining system using remotely controlled equipment against explosive items into the educational process of military educational institutions in order to solve this issue. The study found that a third of military educational institutions of Ukraine included in the sample have the necessary material and technical support for this. Not all institutions have academic and teaching staff of

appropriate qualifications with the necessary practical experience in demining. It is also proposed to carry out research projects on designing, manufacturing and studying the effectiveness of remotely controlled demining equipment. This research may be useful for researchers who are working on finding ways to safely clear areas of explosive items. Further research should be conducted on the monitoring of new, safer and more effective demining equipment in order to ensure the anticipatory nature of the training of demining personnel. It is also worth constantly updating training programmes for sappers, UAV operators, decipherers in keeping with the times and future prospects for the application of their skills and abilities.

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