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STUDY OF THE CONTAMINATION OF THE TERRITORY OF THE REPUBLIC OF LITHUANIA WITH UNEXPLODED EXPLOSIVES

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Annotation. These days, contamination of the territory of Lithuania with explosives is still a relevant issue, because even though it has been more than 70 years since the war is over, the Explosive Ordnance Disposal Company of the Juozas Vitkus Engineer Battalion often has to collect and neutralize the explosives remaining from war. The article discusses the larger battles of the First and Second World War and the Wars of Independence, and the locations of former Russian military bases as possible causes of explosive contamination in the territory of Lithuania. The dynamics of emergency calls and explosives found in the period between 2007 and 2017 was also reviewed, confirming the relevance of the problem. Maps of the contamination of the territory of Lithuania, battles that took place and places of former Russian military bases have been prepared. They prove that the First and Second World War and the Wars of Independence as well as the locations of Russian troops' deployment are indeed the main causes of explosive contamination of the territory of Lithuania. The article also presents and discusses the influence of climate on explosives being raised to the surface of the ground. What is more, a weak relationship between the number of calls to deminers, and an average relationship between the depth of ground freezing and the index of construction work performed are established.

Keywords: explosives, territory, contamination, threat.

INTRODUCTION

There are often reports of explosions that sometimes even take human lives, in countries where no hostilities are taking place at the time. In one case, it could be human error in dealing with explosives or even terrorist acts by hostile citizens. But there are also explosions caused by explosive remnants of war, and Lithuania is no exception. Lithuania's geographical position

between eastern and Western Europe and the fact that it is on the way to the ports of the Baltic Sea made it a transition area for several fronts during the First and Second World Wars. This means that there were many military battles in our territory. Occasionally a fired projectile of an artillery or a mortar or a dropped aerial bomb would not explode. In addition, several military bases were deployed in Lithuania, which became the main targets during the war. As ammunition dumps would be blown up, explosives would sometimes scatter around the area. And sometimes, as troops would be pulling out of Lithuanian territory in a hurry, some of the ammunition would simply be dropped or blown up. Such a legacy of the First and Second World War and occupations poses a major threat to our society. Unexploded projectiles or other explosives found on farms and construction work sites halt infrastructure development, construction or agricultural work. In rare cases, negligent handling of an accidentally detected explosive results in loss of human life. Attention is also drawn to the fact that decaying explosives affected by environmental conditions contaminate the soil and groundwater[1], which is why soil contamination with explosives is still a relevant problem in Lithuania even today, as it is not known where and how many explosives could be found. Explosives found while performing ordinary daily works in the country reveal that explosive contamination is still relatively high and may take many years to neutralize.

The aim of the article is to identify areas most densely contaminated with explosives in Lithuania.

Objectives:

1. To identify the locations of major battles and deployed military bases in Lithuania as major causes of explosive contamination.
2. To investigate the explosive contamination of the territory of Lithuania.
3. To evaluate the correlation between the number of emergency calls for deminers between March and April and the depth of soil freezing during that period.
4. To evaluate the correlation between the number of emergency calls for deminers and the construction work index.

The **object** of the study is the explosive contamination of the territory of Lithuania.

Study methods: The methods of statistical analysis and document analysis have been applied to data evaluation and analysis.

[1] Buller, M. F. Romanko, T. V. Mezhevich G. V., Robotko V. A. 2014, *Екологічні ризики тривалого зберігання піроксилінових порохів.* Вісник КрНУ імені Михайла Остроградського. Випуск 4/2014 (87).

CAUSES OF EXPLOSIVE CONTAMINATION IN THE TERRITORY OF LITHUANIA

World wars and various other military conflicts have intensified in Europe and on other continents, resulting in areas being contaminated with explosives and other munitions. The cause of this contamination can be battles or minefields, prepared for the defence, or even hastily destroyed ammunition dumps to prevent them from being used by enemies. In this regard, two groups of explosive remnants of war are distinguished:

- "Unexploded ordnance means explosives which have been loaded, loaded with detonating fuses or otherwise prepared for use in an armed conflict. They could have been shot, planted, fired or set to explode but did not explode"[2];
- "Abandoned explosives mean explosives not used in an armed conflict and abandoned or discarded by one of the parties to the conflict and no longer under the control of the abandoning or disposing party. Explosives that are left unexploded may be loaded, with a detonating fuse, or otherwise prepared for use or unloaded and unprepared"[3].

These concepts distinguish the two main causes of explosive contamination. The first concept defines explosives that were prepared or even used in battles or other conflicts, but either has not worked or has not exploded, as one of the causes of explosive contamination. And the second concept gives a second possible cause of contamination - explosives would sometimes be stored and kept, but for some reason would not be used, and would thus be either left or discarded.

When considering the reason for the occurrence of explosives due to the battles that took place on the territory of Lithuania, account should be taken of the battles of the First and Second World War, in which various standard explosives were used. In the summer of 1914, starting with the very first days of First World War, Lithuania found itself in an area of intense battles[4]. Artillery guns and mortars were also used during the Wars of Independence that took place after the First World War, from 1918 to 1920. It can also be seen that aerial bomb were also used.

During the Second World War, when the territory of Lithuania was located between two fronts, various large-scale battles took place here. During said battles, a wide range of explosives, such as artillery, mortars and aerial bombs, were used. As the Germans invaded the East and the Soviets attacked at the end of Second World War, there were many tank battles

[2] Protocol on Explosive Remnants of War to the Convention of 1980 of the United Nations on Prohibitions or Restrictions on the Use of Certain Conventional Weapons which may be deemed to be Excessively Injurious or to have Indiscriminate Effects (Protocol V), 2004
[3] Idem.
[4] *Pirmasis pasaulinis karas*, https://www.vle.lt/Straipsnis/Pirmasis-pasaulinis-karas-5007.

and artillery attacks taking place in the territory of Lithuania. Evaluating the areas of the Wars of Independence and the Second World War (see Figure

Figure 1. Larger battles that took place in Lithuania (Green - battles of First World War, blue - Wars of Independence, red - battles of Second World War)

Figure 2. "Rusijos karinių pajėgų išsidėstymas Lietuvoje" ("Location of Russian troops in Lithuania"), Surgailis, 2005, p. 99.

green dots signify the battles of the First World War, red dots signify and blue dots signify the battles of the Second World War), it can be seen that the main battles of both World Wars are distributed across the entire territory of Lithuania. Fewer battles took place at the northern and southern borders of the country.

As mentioned above, not only explosives used in battles, but also war ammunitions left behind or discarded for some time are the cause of explosive contamination of the area. After the Second World War, Russian troops were stationed in Lithuania. Units of the occupying party occupied about 1.2% of Lithuania's territory, i.e. 68 thousand ha. This included various military bases, warehouses, military polygons scattered all over Lithuania (see Figure 2): Coast Guard Division, located in Klaipėda and Telšiai; Airborne Division, located in Alytus, Kaunas, Marijampolė and Kalvarija; Jet fighter-Bomber Regiment in Šiauliai; Motorized Riflemen Division in Vilnius and Ukmergė; Training Airborne Division in Jonava; Heavy Artillery Regiment in Plungė; Rocket artillery Regiment in Telšiai; Warehouse in Pabradė and others. In addition, large stores of fuel, clothing and ammunition were deployed in Kazlų Rūda, Pagėgiai, Kaunas and Klaipėda. A number of military sites and even explosives depots were deployed in densely populated areas in Vilnius[5]. Thus, military units were most numerous in Kaunas and Kaunas District, Vilnius, Klaipėda, Šiauliai, Jonava and Panevėžys and the surrounding areas. The lowest number was located in north-eastern Lithuania.

[5] Surgailis, G. (2005). *Rusijos kariuomenės išvedimas 1990–1993*. Vilnius: Generolo Jono Žemaičio Lietuvos karo akademija.

Figure 1. Larger battles that took place in Lithuania (Green - battles of First World War, blue - Wars of Independence, red - battles of Second World War)

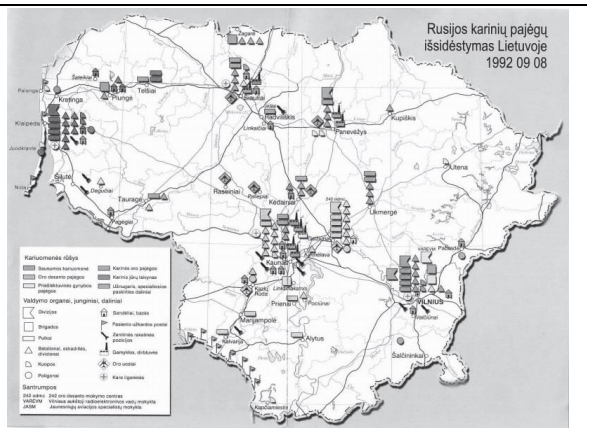

Figure 2. "Rusijos karinių pajėgų išsidėstymas Lietuvoje" ("Location of Russian troops in Lithuania"), Surgailis, 2005, p. 99.

In conclusion, military conflicts have long-term consequences even after they are over. Dangerous explosives, whether left unexploded or not, pose a threat to the civilian populations of those countries even at a time when they are no longer expected to be encountered. Sources indicate that either battles took place or troops have been deployed in almost entire territory of Lithuania, so even today it is still possible to find them in certain areas of former military bases or locations of various battles.

STUDY METHODOLOGY

Data on explosive contamination of the territory of Lithuania were obtained from the archive of Explosive Ordnance Disposal Company (SNK) of the Juozas Vitkus Engineer Battalion. Content analysis of statistical documents was chosen as the data collection method: "Document content analysis is a formalized way of examining documents highlighting the characteristics of the text and providing their content assessment based on the calculation of features that are relevant to the researcher and which can be generalized".[6]The Explosive Ordnance Disposal Company (SNK) Database collects and stores data on calls in the territory of Lithuania when explosives are found. The period between 2007 and 2017 was chosen for the study used in this work. Non-maritime territory of Lithuania was chosen, except for existing polygons. Since the Explosive Ordnance Disposal Company (SNK) is the only body to neutralize the explosives found, the whole territory of Lithuania can be considered as the sample

[6] Kardelis, K. (2016). *Mokslinių tyrimų metodologija ir metodai.* Vilnius: Mokslo ir enciklopedijų leidybos centras.

of the study. The data obtained were processed by *MS Excel* by sorting them out by year and month; by districts of Lithuania; by a type of explosives; by the number of emergency calls; by the amount of explosives found. The quantity of explosives found during the selected period is divided according to the administrative division of Lithuania. For the purposes of calculating the density of explosive contamination of each administrative unit, i.e. the quantity of explosives found per one hundred square kilometres of the area, the quantities of explosives for each year of the survey period shall be summed by area and divided by the area of a certain administrative unit and then multiplied by 100:

$$A = \frac{(b1+\cdots+b11)}{c} \times 100, \quad (1)$$

where: A - density of explosive contamination, number of explosives in 100 sq. km.;
b1, b11 - amount of explosives found in the period of the years in question, pcs.;
c - area of the territory, sq. km.

As there is no officially approved scale for explosive contamination in Lithuania, the study found that: slight contamination - 10 or less explosives per 100 sq. km.; moderate contamination - from 10 pcs. to 100 pcs. per 100 sq. km.; heavy contamination - 100 and more psc. of explosives per 100 sq. km.

Based on Lithuania's administrative division, six major cities are distinguished: Vilnius, Kaunas, Klaipėda, Šiauliai, Panevėžys and Alytus. As a result, we will calculate the density of explosive contamination in regions of smaller area per square kilometre, that is, using the first formula, but without multiplying by a hundred.

Based on the obtained results a map of the intensity of explosive contamination of administrative units of the territory of Lithuania according to the set scale is drawn. By comparing the created map with the maps of battlefields of the First and Second World War and location of dislocation of Russian military bases provided in the theoretical part, the relationship between explosive contamination and the possible causes of explosive contamination are sought, i.e. the assumptions are made.

The study examines the factors affecting the exposure to unexploded ordnance in the territory of Lithuania. It is assumed that the area's vegetation and the landscape is associated with explosives detection. Meanwhile, the other three factors - climate, depth of explosive and

land use - are interrelated. To check the influence of the climate factor on the number of calls, the data of the average temperature in January and the maximum depth of ground freezing is taken from the database of the Lithuanian Department of Statistics and compared with the number of calls to explosive sites in March and April. The data of March and April shall be taken presuming that the frost is no longer in the soil at that time.

When examining the factor of the depth of explosive, the seasonality of emergency calls is reviewed. Daily work in winter and spring penetrates the surface of the ground in different ways. Monthly averages of emergency calls over the period from 2007 to 2017 are taken to determine seasonality:

$$D = \frac{e}{f}, \quad (2)$$

where: D - monthly average of emergency calls, pcs.; e - sum of emergency calls for the respective month of 2007-2017, pcs.; f - the number of years.

Next, when examining the land use factor, the dynamics of the number of calls is compared with the completed construction works, the data of which is also taken from the database of the Lithuanian Department of Statistics. This comparison will show the possible dependence of emergency calls to a found explosive site on the construction works taking place in Lithuania. Lithuania has always been an agricultural land, so agricultural work moves the surface of the country's soil every year. Meanwhile, works related to infrastructure development moves deeper layers of the soil's surface. By comparing the number of calls to explosives sites with the depth of ground freezing and the index of construction works performed, a correlation coefficient is calculated which shows the statistical relationship between these variables. The correlation coefficient is calculated by *Excel* using the formula:

$$\text{Correl}(X,Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}, \quad (3)$$

where: Correl (X,Y) – correlation coefficient; $\bar{x}$ and $\bar{y}$ – sample mean.

This coefficient is always in the range [-1,1]. When the correlation coefficient is obtained, the strength of the connection is analysed.

DENSITY OF THE EXPLOSIVE CONTAMINATION IN THE TERRITORY OF LITHUANIA DURING 2007–2017

The Explosive Ordnance Disposal Company of the Engineer Battalion is the only unit engaged in the neutralization of explosives found in the territory of Lithuania. In the diagram (see Figure 3.), the sum of calls and quantities of explosives found shows that both quantities change proportionally between 2007 and 2017. Deminers were called 1014 times in 2007 and 7150 pieces of various explosives were found, and in 2017 deminers we called 923 times and 5218 pieces of explosives were neutralized. In addition, 14248 explosives were neutralized in 2013, and the number of calls increased significantly in 2014, from 985 calls in 2013 to 1416 calls in 2014. It can be concluded that the problem of explosive contamination is still relevant in Lithuania. The study then examines which areas are most contaminated with explosives and what is the relationship between contamination and its causes.

According to the Lithuanian administrative division, the quantities of explosives found are unevenly distributed: several areas can be distinguished, with significantly small or big quantities. Explosive contamination is unevenly distributed in Lithuania (see Figure Figure 4. Having compared this map with the map of larger battles that took place on the territory of Lithuania (see

Figure 1. Larger battles that took place in Lithuania (Green - battles of First World War, blue - Wars of Independence, red - battles of Second World War)

Figure 2. "Rusijos karinių pajėgų išsidėstymas Lietuvoje" ("Location of Russian troops in Lithuania"), Surgailis, 2005, p. 99.

) it can be seen that many of the areas that are heavily contaminated with explosives coincide with the areas where the battles that took place. For example, a large tank battle near Raseiniai can be considered a cause of explosive contamination in that area. During the period under review, 3401 explosives were neutralized in Raseiniai district. Wars of Independence and battles of the First World War took place near Vilkaviškis and Kalvarija, and 4433 and 261 explosives were found in these areas in the period between 2007 and 2017, respectively. Fewer battles took place at the northern and southern border of Lithuania (Pakruojis, Pasvalys and Druskininkai districts), therefore during the period under review, they were only slightly contaminated with explosives, while Joniškis, Biržai, Varėna and Šalčininkai districts were moderately contaminated. The districts of Vilnius, Kaunas and Panevėžys can be distinguished. During the war, there were also battles in these areas, but today we cannot classify these areas as heavily contaminated. It should be noted that the map of explosive contamination was

compiled more than 60 years after the Second World War. Cities such as Vilnius and Kaunas expanded considerably after the war, and highway construction works were in progress between Vilnius and Panevėžys, suggesting that explosives were heavily collected and neutralized in this area of Lithuania.

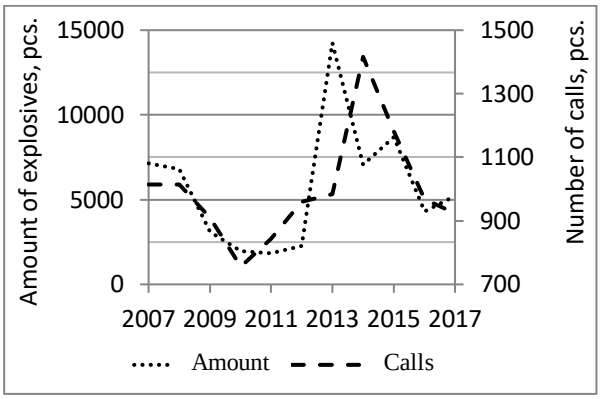

Figure 3. Change in number of explosives found in Lithuania and emergency calls in 2007–2017

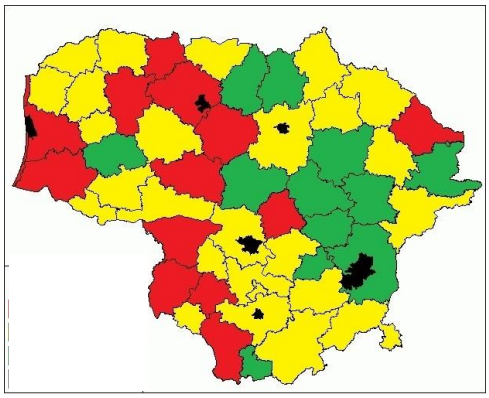

Figure 4. Contamination of the territory of Lithuania with explosives.
(Red - heavily contaminated areas, yellow - moderately contaminated areas, green - lightly contaminated areas, black - major Lithuanian cities).

Having compared the map of explosive contamination of Lithuania (see Figure Figure 4.) with the map of the layout of the Russian military forces (see Figure 2), it is obvious that explosive contamination of the southwest of Lithuania coincides not only with the battles that took place there, but also with the Russian military units at the border. The same can be said about Jonava, Šiauliai and Radviliškis districts where battles took place and Russian military bases were deployed. During the period between 2007 and 2017, 1164, 4562 and 1646 explosives were found in these areas, respectively. There were few battles in Šilutė district, but zenith missile bases (2376 explosives) were deployed in that area. No major battles were mentioned in Telšiai district, but ammunition dumps were deployed. During the period under review, 1566 explosives were neutralized in Raseiniai district.

It is also possible to mention north-eastern Lithuania, where Russian troops were not deployed and larger battles took place around Zarasai only. Therefore, only 160 pieces of explosives were found in Zarasai per 100 sq. km.

Based on Lithuania's administrative division, six major cities are distinguished: Vilnius, Kaunas, Klaipėda, Šiauliai, Panevėžys and Alytus. The specific density of explosives found in these cities per square kilometre was chosen because of the small size of the cities compared to

the districts, which in most cases do not exceed 100 sq. km. except Vilnius (401 sq. km) and Kaunas (157 sq. km). The lowest explosive contamination in the selected period was in Panevėžys - 0.8 explosives per sq. km. Meanwhile, the most contaminated city in 2007–2017 was Klaipeda - 27 explosives per sq. km. Vilnius (20.1 pcs.) and Alytus (16.6 pcs.) are not far behind (see Figure 5).

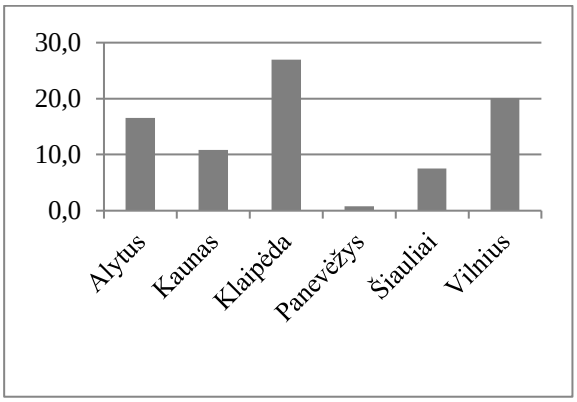

Figure 5. Arithmetic average amount of explosives found in 2007-2017 in 1 sq. km.

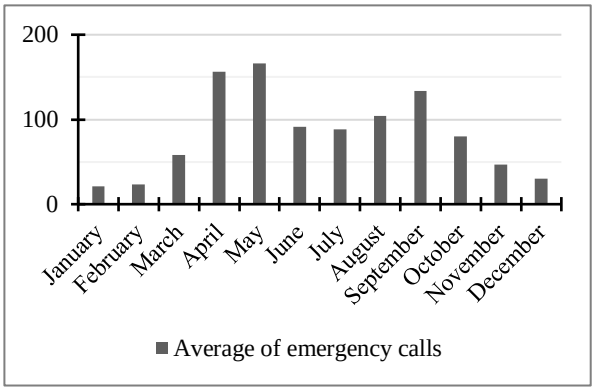

Figure 6. Average of emergency calls between 2007 and 2017

Looking at the maps of the battles that took place on the territory of Lithuania and the location of the Russian military forces, that are provided in the article, it can be seen that during the Second World War Klaipėda was heavily bombarded and during the occupation a large Russian military force was deployed in that city. Vilnius, as the capital of Lithuania, was also severely affected during the wars and, of course, the military units were also heavily deployed here.

One of the factors influencing the possibility of encountering unexploded explosives is the use of land and the accessibility of the area. Some of the areas with the lowest amount of explosives found in the period of 2007-2017 are: Ignalina, Molėtai, Anykščiai and Druskininkai. These areas are rich in lakes, wetlands, peatlands and forests, and so 65 and 56 explosives were found in these areas, respectively, over the period between 2007 and 2017. These areas cannot be said to have the least amount of explosives, but the natural conditions in said areas do reduce the risk of human exposure to an unexploded ordnance.

The number of calls made to Explosive Ordnance Disposal Company (SNK) to the locations where the explosives were found is used to investigate factors affecting human encounter with explosives left over from wartime. They are more reflective of human explosive encounters because they reflect the very fact of the encounter, rather than the amount of explosives neutralized during a single call, which can range from several units to several

hundred. The monthly distribution of mine clearance calls to explosives detection sites in 2007–2017 is presented in Figure 6.

In Lithuania, agricultural and infrastructure development works are carried out at depths of up to 5-6 meters. Considering that considerable quantities of explosives are found more than 60 years after the last battles in Lithuania, and 15 years after the withdrawal of Russian troops from the country, it can be said that explosives are brought to the surface. This is mainly due to the freeze-thaw cycle. Using statistics from the Lithuanian Department of Statistics on maximum freezing depths for the period 2007-2017 and the distribution of calls by months (see Figure 7), it appears that the number of calls is related to the maximum freezing depth. This is confirmed by the calculated correlation coefficient (0.35), which is considered a weak dependence if based on the scale.

The depth of the ground frost in the territory of Lithuania is not directly dependent on the average January temperature, because the frost is influenced by the amount of precipitation, thickness of the snow cover and other factors. With this in mind, only the effect of ground freezing depth on the number of calls from March to April is considered. The diagram shows that the curve of area's maximum freezing depth and the number of calls to deminers to a site of an explosive are disproportionately plotted on the chart. But the same tendency can be noticed: as frost holds up for several consecutive winters, the number of emergency calls increases at the end of that period. According to the calls to mine clearance experts to the locations where explosives were found for the period 2007-2017, there is a clear seasonality. In January, February and December, i.e. in winter, the number of calls to deminers to sites of explosives found is much lower. Meanwhile, in April, May, August and September, i. e. in the spring, late summer and early fall, the number of calls increases.

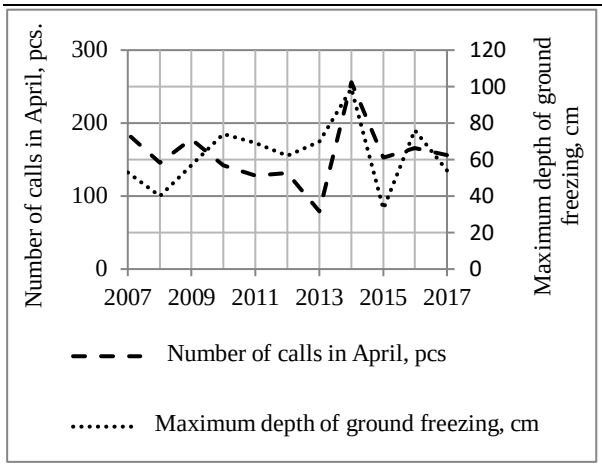

Figure 7. Call dependence on ground freezing

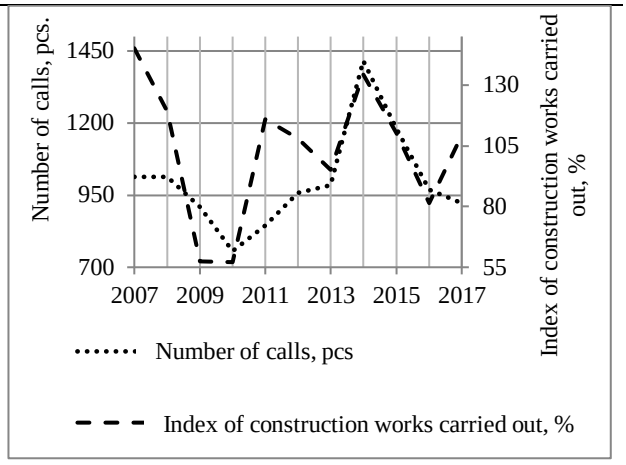

Figure 8. Changes in the number of calls and construction work index performed in 2007–2017.

For example, comparing an average number of calls to deminers to explosive sites in May during the period 2007-2017 with that in January, the latter is almost eight times higher (21 in January and 166 in May). Thus, it can be seen that the months with the highest number of explosives found are the most productive both in agriculture and in infrastructure development. This means that it is during these months that the earth works begin and that, with ever greater movement, the ground raises unexploded standard explosives to the surface. This suggests that even a not-so-deep penetration of the soil allows for greater number of explosives to be found. Because agricultural work is carried out every year and explosives are still found, it seems that the frost still pushes the explosives to the depth that can be reached during the work.

In addition, construction works are usually started in the spring. They penetrate the ground much deeper than agricultural works do, so infrastructure development also has an impact on the amount of explosives found. After comparing the annual data of explosive clearance calls to explosives detection sites with the data provided by the Lithuanian Department of Statistics, it is noticeable that the falling indices of construction works, showing the dynamics of construction works, decreased significantly between 2007 and 2009 (see Figure 6.). The number of calls to deminers to explosive sites was also decreasing. In 2008, an economic crisis started and lasted until 2011. The chart clearly shows a significant decrease in the number of calls after 2008, as well as an increase after 2010, when the indices of construction work started to rise. Also, the convergence of the curves of the call indexes to the locations where the explosives are found and construction work performed is visible over the

period 2013-2016. The calculated correlation coefficient partially confirms the situation depicted in the graph. It is equal to 0.58 and belongs to a moderate dependence.

Summarizing the results, it can be said that explosive contamination of the territory of Lithuania is closely related to the battles that took place in the country and the locations of the former Russian military bases. Thus, the assumption that explosive contamination of the territory depends on the battles that took place in the area and the units of the occupying army deployed in certain location is correct. The emergence of new explosives to the surface is also partly decisive on climate change (freezing and thawing), and while performing agricultural and construction works these explosives are dug to the surface.

CONCLUSIONS

After analysing the sites of the First and Second World Wars and the explosives found during the period of 2000-2006, the connection between the battles that took place, the former bases of the occupation army in the territory of Lithuania and the contamination of these areas with explosives can be confirmed.

In areas with the lowest density of explosive contamination, the amount of explosives found may be influenced by the limited availability of the area (wetlands, peat bogs, woods, lakes, reserves).

There is no direct correlation between the number of calls for deminers in March-April and the depth of ground freezing. The resulting correlation coefficients fall within the range of weak or even very weak correlation scale (0.28; 0.29; -0.4; 0.23; 0.04; -0.15).

Even low-level penetration of the earth during agricultural work increases the chance of finding explosives. This is also affected by frost, which raises explosives to a depth that can be achieved when different works are being carried out. Meanwhile, having compared the indices of construction works with the number of calls, a moderate correlation was obtained (0.58).

REFERENCES

1. Almond, R. J. (2005). Projectile Attack of Surface Scattered Munitions Comparing Closed Form Theory with Live Trials. Propellants, Explosives, Pyrotechnics, 30(3).
2. Buller, M. F. Romanko, T. V. Mezhevich G. V., Robotko V. A. (2014). Екологічні ризики тривалого зберігання піроксилінових порохів. Вісник КрНУ імені Михайла Остроградського. Випуск 4/2014 (87).
3. Craig, W. E. (2012). Army National Guard Training Center: Regulation Ammunition Procedures and Logistics. Annville, Pennsylvania.
4. Dicken, P. (2007). Global Shift: Mapping the Changing Contours of the World Economy. London: Sage.
5. Kardelis, K. (2016). Mokslinių tyrimų metodologija ir metodai. Vilnius: Mokslo ir enciklopedijų leidybos centras.
6. Licht, H. H. (2000). Performance and Sensitivity of Explosives. Propellants, Explosives, Pyrotechnics, 25.
7. Pirmasis pasaulinis karas, https://www.vle.lt/Straipsnis/Pirmasis-pasaulinis-karas-5007.
8. Protocol on Explosive Remnants of War to the Convention of 1980 of the United Nations on Prohibitions or Restrictions on the Use of Certain Conventional Weapons which may be deemed to be Excessively Injurious or to have Indiscriminate Effects (Protocol V), 2004.
9. Surgailis, G. (2005). Rusijos kariuomenės išvedimas 1990–1993. Vilnius: Generolo Jono Žemaičio Lietuvos karo akademija.
10. Ammunition Handbook: Tactics, Techniques, and Procedures for Munitions Handlers (2001). United States Department of the Army, Washington.
11. Field manual. Unexploded Ordnance (UXO) Procedures (2006). United States Department of the Army, Washington.
12. Handbook on the Management of Ordnance and Explosives at Closed, Transferring and Transferred Ranges and Other Sites (2002). United States Environmental Protection Agency.
13. Wilkinson, A. (2001). Stockpile Management: Surveillance and Proof. In Conventional Ammunition in Surplus.
14. Zecevic, B., Zecevic, N.,Terzic, J., Miroslav, S. (2015). Researching Influence of Climatic Environmental Parameters on Performance of Large Caliber Ammunition during Storage. ICOEST International Conference on Environmental Science and Technology, Sarajevo.

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