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Ukraine – environmental aspects of humanitarian demining

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Abstract

In 2021, Ukraine produced such an amount of food that it would have been possible to feed about 400 million people, not counting the population of Ukraine. The strategy for the development of the agricultural sector of Ukraine envisages providing food for 1 billion of the world's population by 2030. However, the aggression of Russia on February 24, 2022, and the subsequent hostilities led to the contamination of agricultural lands with a significant amount of Explosive Remnants of War (ERW), which requires humanitarian demining. This article is devoted to the review of the humanitarian demining process from the point of view of its impact on the environment and the determination of the main components affecting the production of agricultural products. In the first period of the demining process, there will be a significant decline in the production of agricultural products. This decline will be determined by the reduction in the area of cultivated agricultural land due to the danger of explosion. In the course of the demining and liquidation of ERW, the area of land will increase, as will the volume of production, but the quality of products will decrease due to the presence of heavy metal compounds and explosive residues in it and the deterioration of the quality of the soil itself. Therefore, after the liberation of Ukraine's territory, contaminated by mines and ERW, taking into account its importance as the world's granary, the demining time is of great importance and Ukraine will be very grateful for any help that will reduce it.

Keywords:
humanitarian demining; unexploded ordnance; environment; agricultural land; foods.

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Ukraine is located in the central part of Eastern Europe at the intersection of transport routes from Europe to Asia and from the Scandinavian countries to the countries of the Mediterranean region. Most of the territory of Ukraine is located in the western part of the East European plain, while the plains occupy 95% of Ukrainian territory. Thanks to a warm climate, a good topography (about 60% of agricultural land is flat, and another 35% has an angle of inclination between 1° and 3°) and the presence of large areas of black earth (a third of the world's reserves), Ukraine has extremely favorable conditions for agricultural production. Thus, according to the results of the 2021 (pre-war) year, the foreign trade turnover of agricultural products and food products exported by Ukraine reached more than $35.4 billion (Minagro 2022).

Russia's military aggression, which began on February 24, 2022, led to significant environmental pollution. The conflict has destroyed vast areas of agricultural land, burned forests, and destroyed national parks. The Ministry of Ecology of Ukraine estimates the financial damage caused to the environment of Ukraine from February 24, 2022, to February 20, 2023, at 51.45 billion US dollars (Guillot, Zimmermann and Coi 2023). More than 13 percent of the total territory of Ukraine is contaminated by mines and unexploded ordnance (UXO). Approximately 10 percent of agricultural land in Ukraine is contaminated with explosives (Chandler 2022).

After liberation, the territories of former battles are saturated with explosives in the form of unexploded and abandoned ammunition and minefields. The process of their elimination, in turn, will lead to a negative impact on the environment.
The purpose of this article is to review the demining process from the point of view of its impact on the environment and to identify the main components affecting the production of agricultural products.

1. The impact of the demining process on the environment

1.1 Indirect impact

The environmental impact of explosive remnants of war (ERW) can be direct or indirect (Hofmann and Rapillard 2015, 4). Indirect impacts are those that occur at times and locations other than the original location or detonation of the device. Figure 1 schematically illustrates the chain of environmental impacts that may result from the consequences of armed conflict. Indirect impact on the environment is accompanied by the population's fear of possible explosion (explicit or imagined). In this case, the population leaves agricultural regions, moving, as a rule, to urban and suburban areas (Hamad, Kolo and Balzter 2018, 2). The area of arable land and the area of pastures is decreasing, and as a result, the quantity and quality of food products are decreasing too. An indirect effect is also the action of explosive devices that remain in the soil and change its properties, usually in a negative way (Garbino 2019, 2).

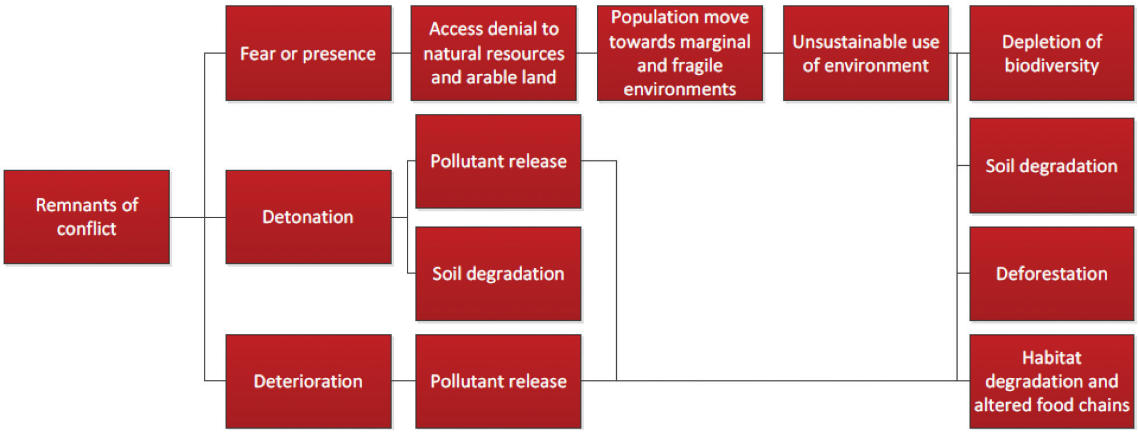

Figure 1: Environmental impact chain of remnants of conflict (GICHD 2014)

1.2 Direct impact

The on-the-spot (direct) impact of ERW can be defined as their impact on the environment at the time and place of explosion.

Disposal of mines and ERW consists of two stages: the search for devices and the actual elimination itself. Moreover, humanitarian demining differs from the military one in many respects. The standard to which clearance must be achieved is at least a 99.6% successful detection and removal rate and 100% to a certain depth, according to International Mine Action Standards (IMAS).

Searching for UXO causes pressure on the environment due to the presence of personnel and the setting up of temporary camps. The mere presence of demining personnel in the field and in temporary field camps can lead to the overexploitation of local resources such as water, wood, or food and the generation of waste that, if not properly managed, can lead to lasting environmental degradation long after the camp had left.

The search is usually carried out with the help of metal detectors and probes, sometimes with the help of trained animals (dogs and rats) that detect the presence of explosives by smell. In order to find and release UXO, it is necessary to prepare the territory, namely: the upper fertile layer of the earth is cut; while the root system of plants is damaged, low-growing plants (bushes, etc.) are destroyed to gain access to the likely location of explosive devices. Exposing the surface of the earth leads to the thinning of the fertile layer and the possible formation of erosion.

In principle, there are methods of non-contact search for explosive devices using, for example, thermal infrared (TIR) sensors (Fardoulis, Depreytere and Guthrie 2022), but they work more or less reliably only when UXO is slightly buried. Manual clearing remains the preferred tool, especially in densely vegetated areas where the main environmental challenge is to preserve as much vegetation as possible. However, manual cleaning is time-consuming and tedious, so mechanical systems can be used to speed up the process (GICHD 2004, 3).

Although the machines have significant potential to increase the efficiency of mine clearance, they have a negative impact on the soil and the ecosystem. Different mechanical systems (milling systems, flails, or converted agricultural equipment) are used to till the soil in search of remnants of the conflict (Dorn 2019, 3-7). This inevitably disturbs and often destroys the soil.
The soil can be moved to another location where it can be spread evenly over a large flat surface and then tested for explosives or evidence of explosives. When using chains and cutters, the soil passes through these systems, even if it remains in the same place after processing. The consequences of such practices can take the form of various types of erosion, changes in soil composition, reduction of soil fertility, and contamination by machine oil and fuel.

Mechanical systems remove or destroy vegetation, which in turn can lead to increased water runoff and wind erosion. Tillage increases the rate of wind erosion by dehydrating the soil and breaking it into smaller particles that can be picked up by the wind. The removal of vegetation also reduces the amount of organic matter, which is important for the stability of the soil structure. It is clear that less fertile soils are naturally associated with losses in agricultural production.
Soil degradation occurs when changes in its depth or physical or chemical properties degrade its quality. During mechanical demining, the organic layer as well as the soil surface is usually treated, and the physical or chemical properties and structure of the soil may be altered or damaged. This again can affect soil fertility, rooting potential, and water-holding capacity.

The disposal of collected mines and ERW is a separate issue. For decades, such munitions were destroyed by burning or detonating in the open air – so-called opening burning and open detonation (OBOD) (EPA 2019, 1-2). There are a number of munitions disposal methods (OSCE 2008); (EPA 2019, 12-17), but many of them require stationary conditions, which involve the transport of dangerous explosive devices and significant amounts of energy, so the OBOD method is still widely used.

At the same time, the presence of emissions of reaction products, remnants of explosive particles, and ammunition fragments that pollute the environment is observed (Figure 2). A mine or ERW explosion causes soil degradation by destroying its structure and disrupting its stability, causing local compaction and increasing the susceptibility of fertile topsoil to erosion (Figure 3). Soil is a living ecosystem and a finite resource, which means that its loss and degradation cannot be recovered in a human lifetime: depending on the ecosystem, this period can take 1,000 years to form just 3 centimeters of topsoil (Berhe 2007).

1.3 Long-lasting impact

When considering the issue of the elimination of mines and ERW, it is impossible not to mention the places of intensive artillery and rocket attacks, as well as the places of destroyed ammunition depots. In terms of their harmful impact on the environment, they are no different from minefields.

The explosives contained in the ammunition can be in different states after their detonation (Figure 4).

1. Unexploded – the ammunition has not exploded, although its frame may be damaged and the explosive is in free contact with the environment.
2. Low-order detonation – explosion of ammunition, while the part of unexploded explosives is in the range of 27-49% (EPA 2012, 18).
3. High-order detonation – a mass of unexploded explosive is in the range of $2 \bullet 10^{-3}$–$7 \bullet 10^{-7}$% and, in principle, can be neglected (Walsh, et al. 2010).

Figure 2: Pollution of the environment during the destruction of munitions by OBOD (EPA 2019)

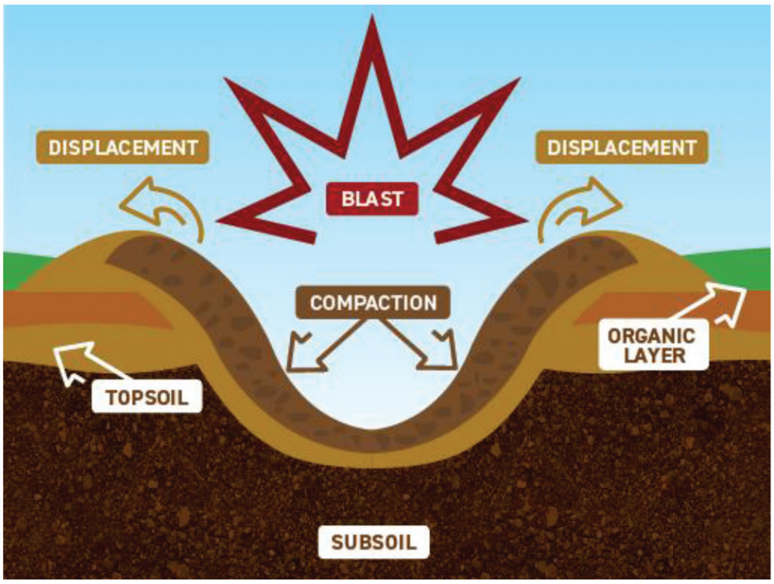

Figure 3: Impact on soil from explosive ordnance detonation (Frost 2021)

Figure 4: Different states of ordnance during the detonation (SAS 2022)

4. Detonation by «sympathy» – detonation of explosive in unexploded ordnance under the action of a shock wave from exploding ordnance (Taylor and Weale 1932). It is usually accompanied by low-order detonation.

Low-order detonation occurs in about 2.5% of cases even in new ammunition. The usage of outdated ones leads to the fact that from 10 to 30% of the explosive weapons used, dropped, fired, or launched do not explode as intended and many other explosive ordnance are abandoned in various locations (GICHD 2021, 21-26). In the process of liquidation of both mines and the rest of the damaged or abandoned ammunition, the metals that are part of them may enter the environment (GICHD 2021, 42-48; SAS 2022): aluminium into explosives filling; lead, antimony and arsenic (added to lead into small-arms cartridges), cadmium and zinc (a protective coating on ammunition shells), mercury (mercury fulminate into primers and detonators), tungsten, nickel, copper and cobalt (in the form of an alloy for cores of armour-piercing projectiles).

The danger to humans and the environment depends on the type of metal and its dose. The danger of a type of metal is conveniently displayed using the concept of a reference dose proposed by the American Environmental Protection Agency USEPA «...oral reference dose (RfD) – an estimate, with uncertainty spanning perhaps an order of magnitude, of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime...» (Wikipedia). In addition, some metals are carcinogens. Carcinogenesis is an increased risk of cancer during a person's lifetime as a result of exposure to carcinogens. The danger of a carcinogen is determined by the value of the so-called slope factor (SF), which represents the degree of the carcinogenic risk increase with increasing a dose per unit and is a value that describes the danger of carcinogen. The values of RfD and SF for metals included in the ammunition are shown in Table 1.

TABLE 1: RfD and SF for metals which may be part of the ammunition
(IRIS, last updated on December 19, 2016)

Metal	RfD (oral) (mg/kg-day)	SF (oral) (mg/kg-day)$^{-1}$	Affected human organ
Al	1.0		Central nervous system (CNS)
Pb	0.0035	0.047	CNS, blood, reproductive and immune systems
Sb	0.0004		Respiratory organs
As	0.0003	1.5	Skin, CNS, cardiovascular, immune, hormonal systems (diabetes), gastrointestinal tract
Cd	0.0005	0.38	Kidneys, hormonal system
Zn	0.3		Biochemical properties of blood
Hg	0.0003		Kidneys, CNS, reproductive, immune, and hormonal systems
W	0.0025		Liver, cardiovascular system, gastrointestinal tract, blood, body weight
Ni	0.02		Liver, cardiovascular system, gastrointestinal tract, blood, body weight
Cu	0.019		Gastrointestinal tract
Co	0.02		Blood

In addition to heavy metals, mines and ammunition contain substances that in turn also pollute the environment. These include explosives and propellants (Pichtel 2012). Explosives are classified as primary, secondary, or tertiary based on their susceptibility to initiation. Primary explosives are highly sensitive to initiation and include silver azide and mercury fulminate. Primary explosives are often used to initiate secondary explosives in a so-called firing train. Common secondary explosives include N-methyl-2-4-6-trinitrophenylnitramine (tetryl), 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) and their mixtures. Tertiary explosives (common specimen – ammonium nitrate) are so insensitive to shock that they cannot be detonated by reasonable quantities of primary explosive and instead require a secondary explosive. In military ammunitions, tertiary explosives are rarely used (Agrawal 2010, pt. 2).

Solid propellants for guns, artillery, and mortars comprise low-explosive materials formulated to burn at a controlled rate and produce gases that propel rockets or accelerate projectiles from guns. Propellant ingredients are nitroglycerin (NG), nitroguanidine (NQ), nitrocellulose (NC), 2,4-dinitrotoluene (2,4-DNT) and perchlorate (Agrawal 2010, pt. 4). The values of RfD and SF for organic compounds included in ammunition are shown in Table 2.

From the above materials, it can be concluded that ERWs damage and pollute the environment, and this process can take decades. Let us consider the current state of humanitarian demining in Ukraine and the prospects for its development.

TABLE 2: RfD and SF for explosives and propellants which may be part of the ammunition (IRIS, last updated on December 19, 2016)

Substance	RfD (oral) (mg/kg-day)	SF (oral) $(mg/kg\text{-}day)^{-1}$	Affected human organ
TNT	0.0005	0.03	Enlarged spleen, immune system damage. Other harmful effects include reduced male fertility and a risk of cancer.
RDX	0.003	0.11	Damage to vital organs such as the liver and kidneys, pathology of red blood cells, and irritation of epithelial tissues
HMX	0.05		Harmful to the liver and central nervous system
Tetryl	0.004		Rash, skin irritation, dry cough, nasal irritation, headache
NG	0.03		Hypotension, venous pooling, increased vasodilatation, and reduced cardiac output can be expected, tachycardia and palpitations too
NQ	0.1		Whole body effects
NC	3 000		Whole body effects
DNT	0.002	0.68	Muscular incoordination, cyanosis, central nervous system depression, and respiratory depression followed by death.
Perchlorate	0.0007		Endocrine system

2. Organization of humanitarian demining in Ukraine

The work on humanitarian demining is coordinated by the National Mine Action Agency (NMAA). It asserts a plan of humanitarian demining activities for the year and also carries out coordination, sets priorities, and allocates areas for demining. The process of humanitarian demining includes the following activities (DSTU 2019):

– non-technical survey – collection, analysis, and assessment of information about the territory to determine it as a suspected dangerous area or a confirmed dangerous area and processes for the removal, reduction, or cleaning of areas for their further effective use without the use of technical means;
– technical survey – collection, and analysis of data using technical means on the presence, type, distribution, and surroundings of mine/ERW contamination sites to better determine the presence or absence of mine/ERW contamination and to support prioritization of land unblocking and decision-making processes;
– manual demining – involves the detection, neutralization (destruction) of all threats associated with mines/ERW, without the use of mechanized means and mine detection dogs;
– area of hostilities cleaning – systematic and controlled cleaning of dangerous areas;
– informing the population about the risks associated with mines and ERW – a set of measures to increase the level of awareness of dangerous areas residents with the order of actions and safe forms of behavior, aimed at reducing the risks of injury and death due to detonation on mines/ ERW.

Each type of activity is certified.

The state does not finance humanitarian demining – and this is, in principle, a normal practice for «mined» countries. All projects are paid for by international donors. Another issue is that complete dependence on donors creates uncertainty in future funding. With Ukraine, it seems, there are no such problems – the sums allocated for demining are only increasing. A mine action operator usually works directly with the donor for funding and receives approval from the NMAA to work in certain areas.
The reason why donors (not the state) pay for the work – is the high cost of the full demining cycle: \$3–4 per square meter (non-technical survey – \$130 – 180 per hectare), while the salary of the demining specialist – \$1000–2000 per month.

The main problem of Ukraine is the huge potentially mined areas that should be surveyed: it is about 174 thousand sq. km. Since it is impossible to cover the entire territory at once, priority was given to agricultural land. By the end of the 2023 year, Ukraine intends to put into operation up to 165,000 hectares of land (1,650 sq. km). Altogether, the four-year demining plan envisages the priority commissioning of about 470,000 hectares (4,700 sq. km) of agricultural land (Nabozhnyak 2023).
In Ukraine, there are about 1,600 demining specialists, and at least 5,000 more are necessary. In such conditions, in order to speed up the demining process, there is a question of relaxing the procedures that regulate demining according to international standards, which, by the way, is opposed by foreign partners (Nabozhnyak 2023).

These standards include IMAS 07.13, published in 2017. It is the only international mine action standard to be dedicated to environmental management in mine action. It recognizes that shortcomings in environmental management can cause adverse short- and long-term environmental impacts, resulting in direct harm to the affected communities and reducing the positive results and outcomes expected to arise from mine action operations (Frost 2021, 13; IMAS 2017).

According to IMAS 07.13, mine action operations must be conducted in a manner that minimizes the negative impact on the environment and is safe for demining specialists and other people. Mine action planning must identify and assess relevant environmental aspects and identify appropriate and effective measures to mitigate negative environmental impacts. The NMAA and operators must take all reasonable steps to ensure that the environment in which mine action operations are conducted remains in a condition in which it is fit for its intended use after mine action operations have ceased. The NMAA should determine reasonable environmental mitigation measures based on cost-benefit considerations of various demining methods. Particular attention should be paid to the environmental conditions that are necessary for the continuation of safe human activities after the completion of mine action operations.

The standard establishes a number of general and minimum requirements for environmental management in the mine action sector. The standard does not require the application of specific practical environmental mitigation measures but is a document that provides the NMAA with the tools to identify them. However, Annex C of IMAS 07.13 provides a useful list of some practical measures that may be used by NMAA and the mine action operator.

Conclusions

By analyzing the environmental aspects of the demining process, it can be predicted that after the liberation of the agricultural territories, where military operations were previously conducted and which are contaminated by mines and ERW, in the first time period there will be a significant decline in the production of foods. This decline will be determined by the reduction in the area of cultivated agricultural land due to the danger of the mine/ ERW explosion.
In the course of the demining and liquidation of ERW, the area of land will increase, as will the volume of foodstuff, but their quality will decrease due to the presence of heavy metal compounds and explosive residues in it and the deterioration of the soil quality, especially if a decision is made to abandon the procedures provided for by IMAS 07.13. This process strongly depends on the time of demining, since the transition of harmful substances into the soil and their subsequent participation in the food chain is stretched over time.

Therefore, after the liberation of the territory of Ukraine contaminated by mines and ERW, taking into account its importance as the world's granary, the demining time is of great importance and Ukraine will be very grateful for any help that will reduce it, especially if the demining process is to be carried out taking into account requirements of IMAS 07.13.

References

Agrawal, J.P. 2010. *High Energy Materials: Propellants, Explosives, and Pyrotechnics.* Weinheim: WILEY-VCH Verlag GmbH&Co.

Berhe, A. Asefaw. 2007. "The contribution of landmines to land degradation." *Land Degradation & Development* 18 (1): 1-15. doi:https://doi.org/10.1002/ldr.754.

Chandler, Karen. 2022. *The Evolving Crisis in Ukraine – How Different Parts of the USG Are Reacting in Real Time.* https://www.state.gov/panel-the-evolving-crisis-in-ukraine-how-different-parts-of-the-usg-are-reacting-in-real-time/.

Dorn, A. Walter. 2019. "Eliminating Hidden Killers: How Can Technology Help Humanitarian Demining?." *Stability: International Journal of Security & Development* Vol. 8 (Iss. 1, Article 5): 1-17. doi:https://doi.org/10.5334/sta.743.

EPA. 2019. "Alternative Treatment Technologies to Opening Burning and Open Detonation of Energetic Hazardous Wastes." EPA 530-R-19-007. https://www.epa.gov/sites/default/files/2019-12/documents/final_obod_alttechreport_for_publication_dec2019_508_v2.pdf.

—. 2012. "Site Characterization for Munitions Constituents." EPA-505-S-11-001. https://www.epa.gov/sites/default/files/documents/site_characterization_for_munitions_constituents.pdf.

Fardoulis, John, Xavier Depreytere and Jonathon Guthrie. 2022. *Proof: How TIR Imaging Can Locate Buried Cluster Munitions in the Iraqi Desert.* https://www.jmu.edu/news/cisr/2022/06/253/12-253-fardoulis.shtml.

Frost, Alex. 2021. *Mitigating the environmental impacts of explosive ordnance and land release.* https://blogs.icrc.org/law-and-policy/2021/12/16/environmental-impacts-explosive-ordnance/.

Garbino, Henrique. 2019. "The Impact of Landmines and Explosive Remnants of War on Food Security: The Lebanese Case." *The Journal of Conventional Weapons Destruction* Vol. 23 (Iss. 2, Article 6). https://commons.lib.jmu.edu/cisr-journal/vol23/iss2/6.

GICHD. 2004. *A Study of Mechanical Application in Demining.* https://www.gichd.org/fileadmin/uploads/gichd/Media/GICHD-resources/rec-documents/Mechanical_study_complete.pdf.

—. 2014. "Peacebuilding and Environmental Damage in Contemporary Jus Post Bellum." Seminar organised by the University of Leiden, 11-12 June 2014. https://www.gichd.org/fileadmin/uploads/gichd/migration/fileadmin/GICHD-resources/rec-documents/Do-no-harm-and-mine-action-Leiden-University-Jun2014.pdf.

—. 2021. *Guide to Explosive Ordnance Pollution of the Environment.* https://www.gichd.org/publications-resources/publications/guide-to-explosive-ordnance-pollution-of-the-environment-1/.

—. 2023. *Ukraine Faces Massive Explosive Contamination One Year into Conflict.* https://reliefweb.int/report/ukraine/ukraine-faces-massive-explosive-contamination-one-year-conflict.

Guillot, Louise, Antonia Zimmermann and Giovanna Coi. 2023. *The environmental scars of Russia's war in Ukraine.* https://www.politico.eu/article/environment-scars-russia-war-ukraine-climate-crisis/.

Hamad, Rahel, Kamal Kolo and Heiko Balzter. 2018. "Land Cover Changes Induced by Demining Operations in Halgurd-Sakran National Park in the Kurdistan Region of Iraq." *Sustainability* 10 (7): 2422. doi:https://doi.org/10.3390/su10072422.

Hofmann, Ursign and Pascal Rapillard. 2015. "Do No Harm in Mine Action: Why the Environment Matters." *The journal of ERW and mine action* 19.1: 4-9. https://commons.lib.jmu.edu/cgi/viewcontent.cgi?article=1031&context=cisr-journal.

IMAS. 2017. *Environmental Management in Mine Action.* https://www.mineactionstandards.org/fileadmin/uploads/imas/Standards/English/IMAS_07.13_Ed.1.pdf.

Minagro. 2022. *Za 2021 rik Ukrayina zbilshila zovnishnotorgovelnij obig sgprodukciyi ta prodovolchih tovariv.* https://minagro.gov.ua/news/.

OSCE. 2008. *Handbook of Best Practices on Conventional Ammunition.* https://www.osce.org/files/f/documents/5/5/33371.pdf.

Pichtel, John. 2012. "Distribution and Fate of Military Explosives and Propellants in Soil: A Review." *Applied and Environmental Soil Science* vol. 2012, Article ID 617236. https://doi.org/10.1155/2012/617236.

SAS, (Small Arms Survey). 2022. *Unplanned Explosions at Munitions Sites (UEMS)*. https://www.smallarmssurvey.org/database/unplanned-explosions-munitions-sites-uems.

Taylor, Wilfrid and Alfred Weale. 1932. *Mechanism of Detonation in Solid Explosives.* https://royalsocietypublishing.org/doi/pdf/10.1098/rspa.1932.0173.

Walsh, Marianne E., Susan Taylor, Alan D. Hewitt, Michael R. Walsh, Charles A. Ramsey and Charles M. Collins. 2010. "Field observations of the persistence of Comp B explosives residues in a salt marsh impact area." *Chemosphere* 78 (4): 467-473. doi:https://doi.org/10.1016/j.chemosphere.2009.10.021.