Norwegian People's Aid

Conflict and Environment Observatory

Assessing environmental degradation from explosive weapons in southern Ukraine

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Frontpage photo:
Stork fly over a burning field near the town of Snihurivka, Mykolaiv region on July 4, 2023, amid Russian invasion in Ukraine.
Credit: Anatolii Stepanov / AFP

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Norway

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Project summary

The use of explosive weapons in populated areas, or against civilian infrastructure, can generate a range of direct and reverberating environmental consequences that can harm people and ecosystems. While these consequences are common to many conflicts, their impacts on people are far better documented than those on the environment. This is despite many forms of environmental damage presenting risks to people's health, livelihoods and wellbeing. With communities and ecosystems under pressure from the triple planetary crisis of climate change, biodiversity loss and pollution, it is more vital than ever that we understand and address the environmental consequences of armed conflicts.

However, armed conflicts create substantial barriers to environmental research, and to research into the impact of environmental degradation on people: they can limit access to affected areas, destroy local capacities for environmental assessment, divert attention from environmental issues and generate new and complex environmental risks. In this respect, it is important that we develop new methodologies for documenting these forms of harm.

Russia's full-scale invasion of Ukraine has affected every part of its environment. This project sought to document one component of this harm – the relationship between explosive weapons uses and conflict pollution in two areas of Kherson and Mykolaiv oblasts in southern Ukraine where Norwegian People's Aid (NPA) is working. By using a mixture of remote analysis, field sampling and stakeholder interviews, the project was able to recover important data on the environmental consequences of the use of explosive weapons (EW) and on conflict-related pollution.[1] The study highlights significant pollution, infrastructure damage, agricultural threats, and ecological harm from the use of explosive weapons and their reverberating effects.

The project was also a pilot for a collaborative research partnership between a humanitarian mine action and disarmament organisation and environmental researchers. We believe that the methodology developed and applied can be further developed and expanded as part of a more holistic approach to the protection of civilians from the use of explosive weapons.

The views expressed in this report are those of the authors.

1 The destructive power of explosive weapons often causes severe damage to civilian and industrial infrastructure, resulting in the contamination of air, soil, and water resources, this is also called conflict pollution.

Introduction

In addition to the immense human suffering, the destructive power of explosive weapons (EW) often causes severe damage to civilian and industrial infrastructure, resulting in the contamination of air, soil, and water resources that is a form of conflict pollution. Severe pollution incidents caused by conflicts such as burning oil fires, spills and damaged industrial facilities, unexploded and abandoned munitions and military equipment, as well as rubble and demolition waste can all generate toxic remnants of war that pose a threat to civilians and the environment, both in the immediate and longer term.

The environment has often been referred to as a "silent victim" of conflicts. Yet the environmental degradation that armed conflicts generate can affect human health and livelihoods, and destroy ecosystems, undermining the vital services that they provide. In the midst of deteriorating planetary health, it is more important than ever that we minimise and where possible mitigate these forms of harm, but doing so is contingent on us understanding them.

It is challenging to conduct environmental assessments and research during conflicts due to security concerns and lack of access. Remote assessment methodologies are increasingly powerful, but to really understand the impacts of conflicts experts need to get access to affected areas. Field assessments – for instance soil and water sampling – can help to identify the scale of present pollution and risks, and priorities for remediation efforts. They can also help prioritise targets for further research and empower communities by providing them with information. This can help to reduce some of the impacts on people and the environment, and by documenting the impact, contribute to a better understanding of the relationship between conflict and the environment.

Documenting the environmental consequences of conflicts like that in Ukraine can help strengthen international law, environmental protection and the protection of civilians. It increases the understanding of the scale and extent of remediation needs and potential costs and could in the future support accountability processes.

The use of EW in populated areas creates intertwined and cascading patterns of civilian and environmental harm,[2] which are specific to the country context and continue long after hostilities cease.[3] In gathering environmental data to support assessments, remedial measures and relief and assistance, the project has been informed by the principles on the Protection of the environment in relation to armed conflicts (PERAC Principles),[4] and the Political Declaration on Strengthening the Protection of Civilians from the Humanitarian Consequences Arising from the Use of Explosive Weapons in Populated Areas (EWIPA Declaration), that acknowledges the environmental impact from EW.[5] Further work is needed to document these impacts and to ensure that EWIPA's environmental dimensions are taken into consideration during the implementation of the EWIPA Declaration. Collaborative studies like this project will have an important role to play in this objective.

This project was initiated by NPA and implemented together with the Conflict and Environment Observatory (CEOBS). NPA and CEOBS are working to strengthen the protection of the environment in relation to armed conflict, and to address both its humanitarian and environmental consequences.

The photo shows a crater and buildings damaged during a Russian missile strike, amid Russia's attack on Ukraine, in Mykolaiv, Ukraine February 7, 2024. Credit REUTERS/Viktoria Lakezina.

2 Conflict pollution, also referred to as the toxic remnants of war, constitutes toxic or radiological substances resulting from military activities that form a hazard to humans or ecosystems.

3 Massingham et al. (2023) War in cities: Why the protection of the natural environment matters even when fighting in urban areas, and what can be done to ensure protection. International Review of the Red Cross, No. 924, 2023

4 UNGA (2022) Draft principles on protection of the environment in relation to armed conflicts: https://legal.un.org/ilc/texts/instruments/english/draft_articles/8_7_2022.pdf

5 DFA (2022) Political Declaration on Strengthening the Protection of Civilians from the Humanitarian Consequences arising from the use of Explosive Weapons in Populated Areas: https://www.dfa.ie/media/dfa/ourrolepolicies/peaceandsecurity/ewipa/EWIPA-Political-DeclarationFinal-Rev-25052022.pdf

Project scope

The project aimed to identify and document conflict pollution associated with the use of EW in the soils and water of selected settlements in Ukraine's Kherson and Mykolaiv regions. The project gathered data on the immediate as well as reverberating effects of the use of EW. This included the destruction of critical infrastructure, impacts on human health, on food security through the consequences of EW use for local livelihoods and land use, and on their impacts on habitats and biodiversity.

Soil pollution can significantly affect human health, as well as water quality and the healthy functioning of soil and ecosystems. The use of explosive ordnance and destruction or damage to infrastructure and industrial facilities may release a range of pollutants. Damage to civilian infrastructure can leave people more exposed to contaminated soils and water. Contamination can also affect plants and animals, and the microbial functioning of soils, which can impact soil productivity.

The project used remote sensing, field surveys, community interviews and targeted soil and water sampling to develop **two field case studies** and conduct **three remote case studies** of conflict pollution and environmental harm. Areas were assessed for explosive ordnance hazards and only survey locations deemed low risk were visited. The selected sites were located in the Mykolaiv and Kherson regions, where NPA is conducting humanitarian mine action activities. The incidents selected were all part of CEOBS environmental incident database for Ukraine,[6] and had to be physically accessible. CEOBS launched its Ukraine incident database in March 2022 and at the time of writing held remote assessments of more than 2,000 environmentally significant incidents.

More details on the research methodology can be found in Annex 1.

Although part of the study took place in an area affected by the destruction of the Kakhovka Dam, the incident and any wider legal ramifications of the conflict were beyond the scope of the project.

Selected case studies

The field locations were chosen based on two different types of EW impacts, with distinct environmental and landscape context in Mykolaiv and Kherson regions:

1. Snihurivka community in the Mykolaiv region
    a. The area was under Russian occupation from March-November 2022 with shelling due to close proximity to the front line. Sporadic missile and drone attacks - and interceptions - have continued to affect the area to the time of writing.

2. Komyshany and Zymivnyk in Kherson region
    b. From March until November 2022 the areas were occupied. After 6 June 2023, the areas were flooded by the Kakhovka dam destruction and oil spills were recorded. The areas experience(d) shelling and missile attacks due to proximity to the front line.

Unfortunately, no pre-war baseline pollutant data was available for the selected soil and water sampling locations. However, this is not unusual in conflict contexts and can be mitigated to some extent by thorough assessment of potential pollutant sources nearby, and the characteristics of particular pollutants in the sampling areas.

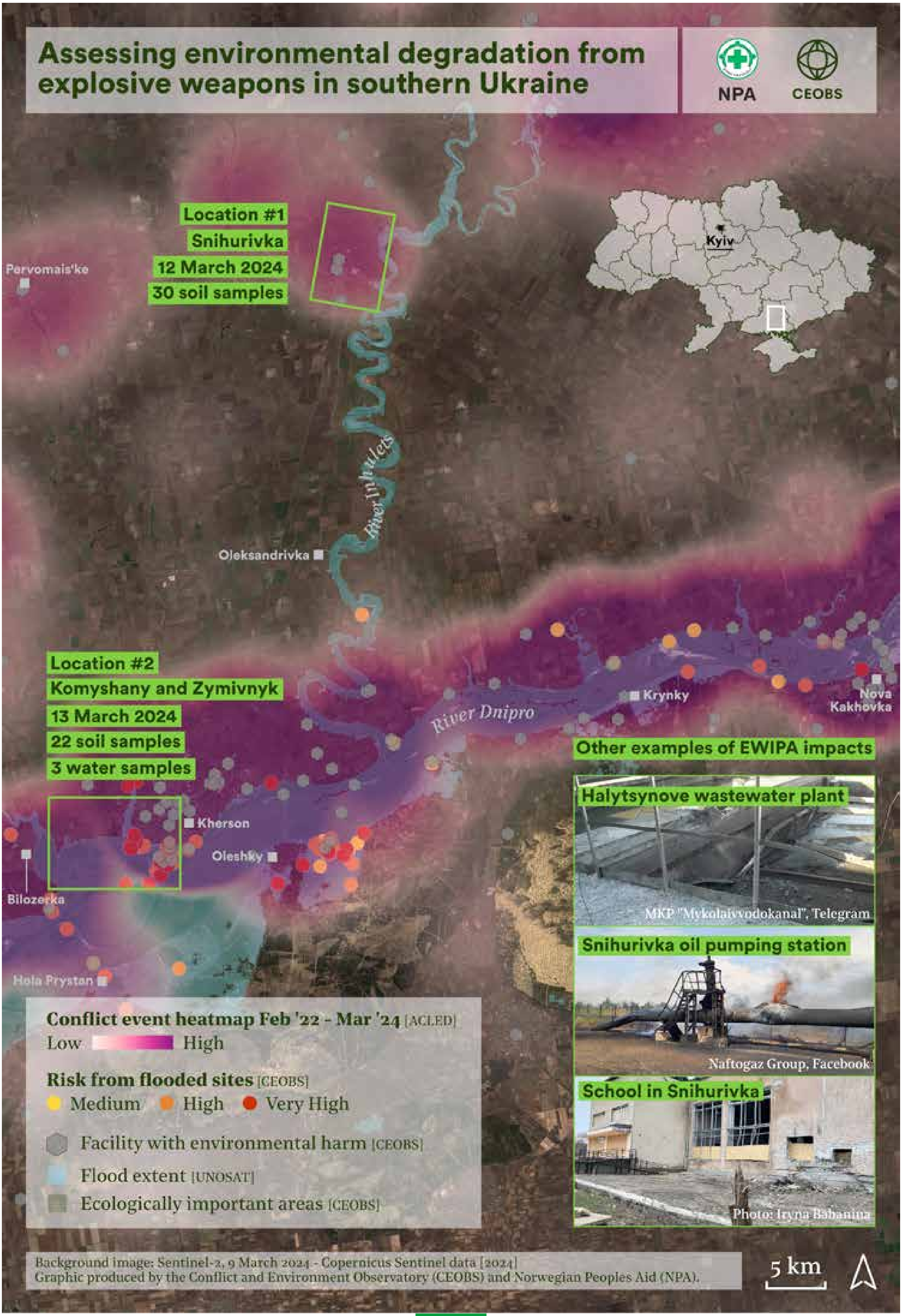
Selected case studies for remote sensing analysis:

1. Snihurivka oil pumping station, Mykolaiv region (incident category: oil, petrol or chemical leakages).
2. Snihurivka tomato processing plant, Mykolaiv region (incident category: conflict debris).
3. Kherson oil terminal, Kherson region (incident category: oil, petrol or chemical leakages).

The project provides a snapshot of the environmental and humanitarian situation in the research areas and allowed the testing of field protocols that can be used by humanitarian mine action operators like NPA, and other first responders and humanitarian organisations, wishing to integrate environmental assessments into their activities.

6 CEOBS has been remotely tracking and assessing incidents in Ukraine since February 2022. Its database is not publicly accessible but this interactive map features 25 incidents from the database that help illustrate some of the types of environmental damage that have been caused or exacerbated by the conflict, and the types of data that we gather: https://ceobs.org/ukraine-map

The figure shows an overview of the study areas highlighting conflict events, flood risks and environmental harm



Explosive weapons cause conflict pollution

Most munitions contain heavy metals and explosive chemicals that are toxic. Munition casings can contain heavy metals such as arsenic, chromium and copper, while inside metals are frequently used alongside explosives such as TNT, HMX and RDX. These explosives have varying degrees of toxicity for people and for different organisms, they also behave in different ways in the environment. TNT can break down into other toxic compounds such as DNT, while RDX can be very persistent in the environment. To complicate matters, their behaviour in the environment can differ depending on what kind of soil they are in. Heavy metals generally tend to be very persistent in the environment.

There is surprisingly little data on pollution from munitions constituents from their use in conflict settings and most of what we know comes from firing ranges. This means that studies like this one are very valuable. Even more so because understanding the risks they pose to people not only means first understanding how much contamination munitions leave but also how those contaminants can move through the environment and get into people, for example through drinking water or crops.

Ammunition abandoned by Russian Forces lies on a side of the road in Ukraine. Credit: AP.

The PERAC Principles and the EWIPA Declaration

The PERAC principles, or the Principles on the Protection of the Environment in Relation to Armed Conflicts principles, are a set of 27 principles outlining how the environment should be protected before, during and after armed conflicts, and in situations of occupation. They vary in strength from non-binding guidance, to reflecting binding international law.

There are a few things that are special about the PERAC principles. The first is that they were developed from a mixture of International Humanitarian Law (IHL), Environmental Law, Human Rights Law and other fields of law, as well as from the practice of states and non-state actors. The second thing is their temporal scope, they apply before, during and after armed conflicts, and in situations of occupation. The third thing is that they apply to both international armed conflicts, and non-international armed conflicts. The fourth thing is their scope, across 27 principles they cover a huge range of topics.

Before PERAC, the environment enjoyed limited protection under IHL, but that just applies during conflicts and occupations, and primarily in international armed conflicts. Now we have principles based on more bodies of law and other sources, across different parts of the cycle of armed conflicts and that address many more environmental problems.

To learn more, visit CEOBS' PERAC FAQ: https://ceobs.org/perac-principles-frequently-asked-questions

The EWIPA Declaration

The Political Declaration on Strengthening the Protection of Civilians from the Humanitarian Consequences Arising from the Use of Explosive Weapons in Populated Areas (EWIPA-Declaration) seeks to reduce harm to civilians from the use of explosive weapons in populated areas, and is a milestone achievement. It also addresses environmental considerations, and acknowledges that "the environment can be impacted by the use of explosive weapons, through contamination of air, soil, water and other resources". The declaration places effects on the environment as a factor that states must consider when planning and executing military operations, and if implemented well, the declaration will have a positive impact on both environmental and civilians protection.

A minor water body in Viryovchyna river valley, Zymivnyk, Kherson region, one of the study sampling spots. Credit: Iryna Babanina/CEOBS

Destroyed residential buildings in Snihurivka, Ukraine. *Credit: imageBROKER*

The sampling identified levels of pollution above maximum permitted concentrations for some contaminants, but these were not recorded at levels that posed immediate risks to local residents or demining staff. Nevertheless, the study identified environmental degradation associated with the use of EW and, at the time of writing, the study areas remained contaminated with explosive ordnance (EO), hindering safe access to land and delaying recovery activities. This study was a snapshot, and the findings should encourage further research in the affected communities to minimise any potential risks to people, livelihoods and ecosystems.

Critically, the collaboration between CEOBS and NPA demonstrated that environmental researchers and humanitarian organisations can cooperate to document the environmental dimensions of armed conflicts generally, and EW use in particular, also during conflict despite accessibility challenges. This should encourage holistic approaches that integrate environmental assessment in civilian protection programming, and in emergency responses and recovery planning. It also demonstrated the potential for such data to support local authorities whose capacity for environmental monitoring – where it existed – may have been constrained by the conflict and by EO contamination.

1. **Soil and water samples contained a range of pollutants associated with the war.**
   There was a correlation between the intensity of military activity and industrial damage linked to the use of EW, and higher concentrations of some contaminants. In Snihurivka in Mykolaiv region there is evidence that the use of EW had changed the physical, chemical and biological properties of soils. Soil pollutants, such as heavy metals and polycyclic aromatic hydrocarbons (PAHs) were recorded in concentrations that exceeded levels allowed in Ukraine.[7, 8] In both Komyshany and Zymivnyk in Kherson region we found hydrocarbons and elevated levels of heavy metals in soil samples, while water sampling indicated significant levels of contamination in the underlying groundwater.

2. **Damage to critical infrastructure from explosive weapons posed environmental risks.**
   The use of EW had caused severe damage to critical infrastructure in Snihurivka. This included: water treatment facilities, water towers and pumping stations, industrial plants, agricultural enterprises, irrigation canals, energy facilities and the railway station. Some 22% of residential properties and 90% of administrative buildings were also

7 Heavy metals found included: As, Ba, Cd, Cu, Hg, Sr and Zn. Polycyclic aromatic hydrocarbons (PAHs) are a group of more than 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. Many PAHs are known to be toxic and carcinogenic.

8 Ukraine has maximum permissible concentrations (MPC) for a list of specific contaminants, as set out under Order No. 1595 of the Ministry of Health of Ukraine and Resolution 1325 of the Cabinet of Ministers of Ukraine, which take into account background concentrations. Reference background concentrations from local soil samples collected away from known anthropogenic pollution sources were also used.

Credit: Norwegian People's Aid/Sean Sutton

damaged. The destruction had led to interruptions in water and power supply, and impacted soils and surface and groundwaters. Contamination from damaged wastewater systems poses the risk of waterborne diseases.

3. **Flooding exacerbated conflict pollution threats.**
   Our findings suggest that the Kakhovka Dam floodwaters mobilised pre-existing conflict pollution. The villages of Komyshany and Zymivnyk are agricultural and have no major industrial facilities. However, both were near Kherson oil terminal and Kherson's water treatment station, which were flooded following the destruction of the Kakhovka Dam in June 2023.

4. **Remote environmental analyses are a powerful tool for planning field assessments.**
   In preparation for the field sampling campaign, CEOBS undertook remote analyses of several facilities that were part of its database of environmentally relevant incidents in Ukraine. These analyses combined open-source investigation and Earth observation methods to assess the sequence of events at the sites and any potential environmental risks. The identification of these risks helped inform site selection for our field sampling campaign, and our understanding of its findings.

5. **Impact on agricultural livelihoods and food security.**
   We found that many fields still needed to be surveyed for landmines and other EO that in addition to threatening livelihoods and food security, risk polluting the land. The use of EW had damaged irrigation canals; in some cases, these canals had been used as trenches and defensive lines.

6. **Explosive weapons had damaged ecologically important areas.**
   We found that the use of EWs had caused direct physical damage to soils and triggered landscape fires. It had also led to uncontrolled discharges of pollutants from a range of environmentally risky infrastructure sites and facilities. In Snihurivka, Komyshany and Zymivnyk these forms of environmental damage had affected ecologically important wetland and riverine habitats.

These findings confirmed both the presence of conflict pollution and environmental degradation caused by the war. Although this was a limited study its findings contribute to the small but growing literature on the relationship between the use of explosive weapons, environmental harm and outcomes for human health and livelihoods. These forms of harm are ubiquitous to armed conflicts and documenting them is a key component of efforts to enhance the protection of the environment in relation to armed conflicts.

RECOMMENDATIONS

People line up at a distribution station for clean water in Mykolaiv, Ukraine, where Russian forces destroyed pipelines and a pumping station depriving the city of clean tap water. Credit: Thomas Peter Reuter

1. **Expand sampling to clarify potential exposure risks in the affected communities and identify measures to protect people and ecosystems, and prevent further contamination.**
   Our sampling identified elevated concentrations of some pollutants in soils in residential areas affected by the use of EW. Although some were above the maximum permitted concentrations for some contaminants, these were not recorded at levels that pose immediate risks to local residents or demining staff. Nevertheless, sampling where produce and crops are grown, or where nearby water quality may be at risk, would help clarify any potential exposure risks. For habitats damaged by the use of EW, longer term studies would be needed to determine the precise level of ecological harm.

2. **Undertake non-technical survey and mine clearance activities as soon as conditions allow.**
   Without intervention, some land in the communities, such as riverside and wetland areas, could remain contaminated by landmines and EO for years. This would place people and wildlife at direct risk of harm and leave discrete sources of pollutants, with explosives potentially leaching into soils through corrosion and leakage. Similarly, a lack of access due to unexploded ordnance will impede environmental management and remediation efforts. Future flood events could also mobilise mines and EO. Post-clearance soil sampling would help enhance understanding of the dispersal of metals and energetic materials from EW use.

3. **Enhance cooperation to support green recovery.**
   There is a need for closer cooperation between entities addressing the environmental and humanitarian consequences in areas affected by the use of explosive weapons. Enhancing cooperation, particularly in the fields of data collection and sharing, and integrating environmental analysis in plans for early recovery and response, would improve green recovery planning and implementation in affected areas. Recovery strategies might include land-use management plans, and in some cases pollutant containment or treatment. These should be tailored to the site, to the contaminants present and to local capacities.

4. **Support interdisciplinary research on the harm from explosive weapons use.**
   Donors should support research into the combined environmental and humanitarian impacts of EW use, both to better understand the full scope of potential harms and to ensure that data is available to those working to address the consequences. By identifying the impact of EW on local communities and ecosystems, projects like these helps inform the implementation of the PERAC principles, and the

Credit: Norwegian People's Aid/Sean Sutton

Credit: Norwegian People's Aid/Sean Sutton

EWIPA Declaration, and support national authorities with environmental management and risk mitigation.

5. **Strengthen and implement international law to minimise and address harm to people and the environment.**
   Growing conflicts, the widespread use of explosive weapons and the urgency of the triple planetary crisis make it imperative that the international community work harder to enhance legal frameworks protecting the environment in relation to armed conflicts and ensure that they are implemented. Data and awareness are key for influencing the environmental conduct of militaries and for ensuring that environmental harm is understood and addressed. Access to environmental information is a core component of environmental human rights and particularly important for ensuring that affected communities are empowered to make decisions that affect them as part of recovery processes. Russia's war in Ukraine has raised the profile of the lack of accountability for wartime environmental damage. Consideration should be given to how humanitarian disarmament actors could contribute to this objective through both advocacy and data collection.

Understanding the findings: Maximum permissible concentrations (MPCs)

Ukrainian legislation establishes maximum permissible concentrations (MPCs) for a list of specific contaminants. MPC is commonly understood as a concentration of a substance in the topsoil that does not cause adverse health effects upon prolonged exposure.

MPC values are set out under Resolution 1325 of the Cabinet of Ministers and Order No. 1595 of the Ministry of Health, the latter also highlights specific health concerns for a few selected pollutants, such as carcinogenic, mutagenic and reproductive toxicity effects. These documents do not establish separate MPC values for different intended uses of soils, nor do they consider specific soil types or chemical properties, such as pH or organic matter content.

Detailed case study overview

1. SNIHURIVKA TOWN AND COMMUNITY

Snihurivka community was occupied between March and November 2022 and heavily damaged by fighting. It is one of the most severely mine and explosive ordnance (EO) contaminated frontline communities along the right bank of Dnipro. Its pre-war population was 21,000, and 50% of the population had left by early 2023. At the time of NPA and CEOBS' visit, the community was still being regularly targeted by missiles and strike drones.

1.1 Destruction of industrial facilities

By 1st January 2023, most enterprises in the community had been damaged by EW or looted by Russian forces during the occupation. Serious losses had been reported among the 13 top employers in the area, these included agrarian and agro-industrial enterprises, not all had restored their operations.

Energy and industrial facilities in the community that posed environmental risks if damaged include three petrol stations in Snihurivka, the Mykolaivoblenergo energy facility, the Ukrtransnafta oil pumping station in Kobzartsi village and a tomato processing plant. No data was available on damage from EW and associated environmental impacts from any of the area's private agricultural enterprises, even though numerous cases of damage were evident.[9]

Snihurivka police department destroyed by shelling.
Credit: Iryna Babanina, CEOBS

A non-residential building in the center of Snihurivka destroyed by shelling. *Credit: Iryna Babanina, CEOBS*

An enterprise in Snihurivka damaged by shelling.
Credit: Iryna Babanina, CEOBS

Damaged Snihurivka train station.
Credit: Iryna Babanina, CEOBS

9 During interviews, community officials said they had no definite information about the damage to facilities containing pesticides, fertilisers or biological waste, such as fermented grain; therefore, any associated environmental risks had not been assessed.

1.2 Destruction of infrastructure and its impact on the community

Around 22% of residential properties and 90% of administrative buildings had been damaged, as well as essential infrastructure such as the railway station. Power, gas and water supplies in Snihurivka were lost at the beginning of the occupation; the local hospital was the only facility with a water tower and a generator.[10]

Water towers had been damaged and looted, and the water pumping station required clearance after explosive devices were planted by retreating Russian forces.[11] The community's shallow public wells were generally unsuitable for drinking supply and had been sealed before the full-scale invasion. The water in deeper municipal and private boreholes was of better quality but pumping equipment required a power supply.[12]

The area around the community's power lines had also been heavily mined, delaying the restoration of power while the State Emergency Service of Ukraine (SESU) cleared explosive devices. Pre-war, around 50% of the municipality's infrastructure, including Snihurivka's water treatment plant, had deteriorated to the point of obsolescence – a vulnerability exacerbated by damage from the use of EW. The community's water supply network was also affected by the Kakhovka Dam floodwaters, with nine flooded wells requiring clean-up. The community undertakes its own water sampling, as obliged by Ukrainian law,[13] and is seeking funding to drill new boreholes.

The destruction of the Kakhovka Dam

On 6th June 2023, the Kakhovka Dam, which held back the Kakhovka Reservoir, the southernmost reservoir downstream of the River Dnipro cascade, was breached. About 18 km^2 of water, 40% of Ukraine's annual consumption, was lost.

The flood affected 600 km^2 in the Lower Dnipro region, both on territories controlled by the Ukrainian government and those under Russian occupation. Numerous industrial sites were flooded, releasing a wide range of pollutants and contaminating soils in the flood zone. Water levels in Lower Dnipro tributaries rose. For example, the Inhulets river level rose by about 5.5 m, causing the river to reverse its flow, destroying four bridges and flooding 13 villages in the community of Snihurivka.[14]

Credit: AP Photo Evgeniy Maloletka

10 Pravda (2023) Як медики зі Снігурівки виживали в окупації: рятували людей, не зрадили клятві Гіппократа і чекали на ЗСУ https://www.pravda.com.ua/articles/2023/03/30/7395650

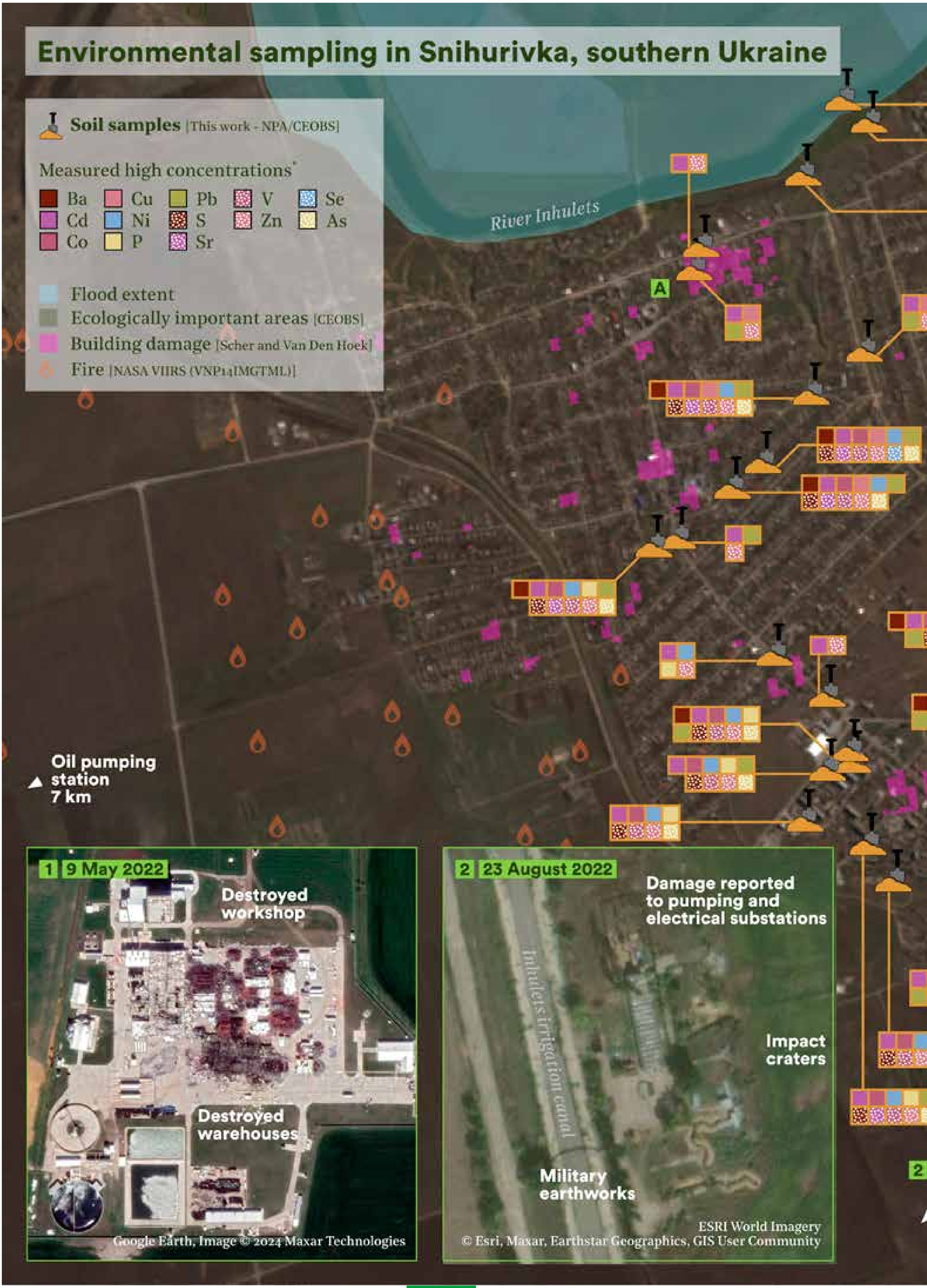
11 Suspilne (2023) На деокупованій Миколаївщині піротехніки розмінували понад тисячу гектарів прибудинкових територій https://suspilne.media/mykolaiv/366962-na-deokupovanij-mikolaivsini-pirotehniki-rozminuvali-ponad-tisacu-gektariv-pribudinkovoi-teritorii/

12 However, state groundwater monitoring and control programmes were not funded for 2021-23, and not expected to take place. See: Regional Report on the Situation of the Environment in Mykolaiv region, 2023, p.228: https://ecolog.mk.gov.ua/store/files/1697106633.pdf

13 Routine sampling results for basic safety parameters as of 25 January 2024: https://snigurivska-gromada.gov.ua/news/1706543569

14 Suspilne (2023) У Снігурівській громаді на Миколаївщині рівень води знизився. Підтопленими залишаються 13 населених пунктів: https://suspilne.media/mykolaiv/503293-u-snigurivskij-gromadi-na-mikolaivsini-riven-vodi-znizivsa-pidtoplenimi-zalisautsa-13-naselenih-punktiv

The figure gives an overview of the environmental samples collected in the area and results



Background image: Sentinel-2, 9 March 2024 - Copernicus Sentinel data [2024]. *Concentration data classified as 'high' if it exceeded a CEOBS determined threshold based Ukrainian and UK standards, and regional background concentrations. Note these are single point in time measurements for proof of concept - gridded sampling over time is needed to confirm polluted areas. Building damage derived from satellite radar phase changes until September 2023, c/o Corey Scher (CUNY, New York) and Jamon Van Den Hoek (Oregon State). Graphic produced by the Conflict and Environment Observatory (CEOBS) and Norwegian Peoples Aid (NPA).

The fighting in and around Snihurivka generated large volumes of debris and demolition waste. The community has struggled to deal with it; solid waste management was insufficient even before the war. Clean-up activities began in November 2022 after the area was liberated and most debris was transported to existing landfills without sorting. The contaminated floodwaters from the Kakhovka Dam affected 375 homes, creating an additional mixed waste stream. Debris clearance from war-damaged properties is expected to proceed when the community can allocate scarce funds for reconstruction.

1.3 The impact of explosive ordnance (EO) contamination on land use

By early 2024, around 10,000 hectares of community lands - 6.4% of its area - required non-technical survey (NTS), technical survey (TS) and clearance. At least 15 landmine accidents were recorded in the community by Armed Conflict Location and Event Database (ACLED) between 9th November 2022 and 9th December 2023. Those affected included military personnel, SESU staff, agricultural workers and local people collecting firewood and EO and booby traps on small private plots or households posed a particular concern. Prioritising land for clearance is challenging and farmers often try to remove landmines and other EO on their own, which can cause accidents.[15]

A household destroyed by shelling in Snihurivka.
Credit: Iryna Babanina, CEOBS

15 Farmers can request clearance. For land plots larger than 200 hectares, a demining request is filed to the Civil Protection Department of Mykolaiv Regional State Administration, for plots smaller than 200 hectares, to the community government's land department. SESU's standard is that land can be considered safe from explosive hazards if tilled at least three times.

During our visit community pastures and meadows were still considered dangerous and shelterbelts and forest strips had not yet been surveyed; there were many reports of cattle being injured or killed. Officials could not confirm whether mines or other EO had been mobilised by the Kakhovka floodwaters, but riverbanks were considered dangerous by default.

Fighting had damaged the canals of the Inhulets Irrigation System, with military forces using them as trenches and defensive lines; community officials highlighted the need for repairs during interviews. There was also concern over water quality in the River Inhulets due to legacy pollution and the periodic discharge of effluent from iron mining and industrial wastewaters from Kryvyi Rih. These sources mean that the river has a high level of mineralisation, and its flow requires management to support its ecological health – under typical conditions it was periodically "flushed",[16] without this, levels of pollutants in irrigation water may increase, affecting agricultural land.

Interviewees confirmed that some soil sampling had been undertaken by agrarian enterprises to obtain data for agrochemical passports for their land, but the results are not publicly available. Since 11th April 2023, agricultural land users have been legally able to apply for a land fee exemption for plots contaminated with EO or pollution.[17] Some sampling was also undertaken by the State Environmental Inspectorate after the Kakhovka flooding but neither its scope or results were reported to the community. Out of 417 flooded land plots, 230 applications were filed for compensation for crop losses; 210 were granted.

16 The River Inhulets, a tributary of the Dnipro, historically experienced environmental pressures. Its upstream section was used for drinking and industrial water supply in Kryvyi Rih; downstream - for irrigation in semi-arid districts of Mykolaiv region. Highly mineralised effluent from Kryvyi Rih's iron mining area was periodically discharged into the river. To decrease mineralisation and revitalise the river, Inhulets "flushing" was done on a regular basis. It involved the release of additional volumes of freshwater through the Karachunivske reservoir dam upstream before the start of the growing season. The "flushing" stopped in 2022-23 because the Karachunivske dam's sluice gates were damaged by a Russian missile strike in Autumn 2022. See: https://ceobs.org/ukraine-damage-map-karachunivske-reservoir-dam

17 Community officials said no NTS or sampling was required for these applications, and the land was considered contaminated on the basis of whether it could be used for its intended purpose. A commission was created by community officials to decide on each case; about 60% of cases were approved. A request can be approved, if there is no evidence that the land plot is used for commercial activity, there are no signs of cultivation or tilling, and there is evidence that the plot is contaminated by explosives.

1.4 Impact on ecosystems

Between May and August 2022, monitoring data recorded a significant increase in landscape fires linked to the use of EW; these were more difficult to manage because of the occupation, something that will have exacerbated their impact on habitats. Localised soil pollution is expected around destroyed military equipment, but local authorities had not reported any major oil or hydrocarbon spills or discharge into water bodies. During the Kakhovka flooding, no cases of mass fish deaths or detonation of migrated explosives were observed.

1.5 Soil sampling analysis in Snihurivka town

Snihurivka's soils were anticipated to have been impacted by the movement of military materiel, emplacement of landmines, and the shelling and bombardment of residential and commercial areas, which also resulted in fires that affected homes, industrial enterprises and infrastructure. Results from our sampling indicated elevated concentrations of some heavy metals, other inorganic pollutants and polycyclic aromatic hydrocarbons (PAHs), which could impact soil productivity and soil health.

Anomalous concentrations of total phosphorus (P), arsenic (As), lead (Pb), copper (Cu), cadmium (Cd), zinc (Zn), nickel (Ni) barium (Ba) and selected PAHs,[18] were identified from the sampling exercise compared to background concentrations or Ukraine's maximum permissible concentrations (MPC).[19] When compared to an appropriate MPC, recorded levels exceeded the MPC in the soils collected from residential and public areas. The source of these elevated concentrations is likely to be EW, and the targets they impacted. A previous study in Ukraine has also suggested a correlation between shelling events and elevated concentrations of these pollutants.[20]

Stork fly over a burning field near the town of Snihurivka, Mykolaiv region on July 4, 2023, amid Russian invasion in Ukraine. Credit: AFP

18 PAHs in the soil may result from combustion, including fires and from the use of EW. A sample from the city's railway station, which was destroyed by a shell/missile strike and fire, contained PAH concentrations above recorded background levels and the relevant MPC.

19 Between urban and rural areas, there can be large variation between background soil concentrations. Background levels are used as a first screening level by several countries to assess the significance of contamination, although do not necessarily relate to the overall risk associated with certain pollutants.

20 Ecoaction (2023) The impact of Russia's war against Ukraine on the state of the country's soil - Analysis results: https://en.ecoaction.org.ua/wp-content/uploads/2023/05/impact-on-soil-russian-war.pdf

Determinants	Summary commentary and observations
Total phosphorus (P),[21] arsenic (As),[22] PAHs (benzo(a)pyrene),[23] and sulphur (S).[24]	Regular exceedance of the relevant MPC, further delineation and assessment of mobility would define impact to soil health, or potential impact to nearby water quality. Occasional exceedance of the relevant MPC, or levels frequently recorded above reference background concentrations. Localised delineation and assessment of mobility would help define impact to soil health, including ecotoxicity, and nearby water quality.
Total lead (Pb),[25] cadmium (Cd),[26] barium (Ba),[27] strontium (Sr),[28] zinc (Zn),[29] copper (Cu),[30] manganese (Mn),[31] nickel (Ni) and cobalt (Co).	The soils sampled typically have high organic matter, high clay content and an average pH of around 7.9, which can help also limit the bioavailability and ecotoxicity of certain metals (e.g. cobalt, copper, nickel, and zinc).[32]
Total boron (B), chromium (Cr), vanadium (V).	Determinants were detected, but at concentrations either below the relevant MPC or unlikely to represent concentrations above background. The exception is vanadium, which is below the MPC but can inhibit plant growth and microbial functioning of soils, at low concentrations,[33] and warrants consideration for ecologically sensitive or agricultural areas.

21 The average total phosphorus sample value was 497 mg/kg (or 1,138 mg/kg expressed as P2O5), and levels above the MPC were found in the majority of soil samples analysed. The highest concentration of 2,287mg/kg (as expressed as P2O5) was recorded 80 metres from the burned railway station.

22 Arsenic can be found in munitions. In the samples collected in Snihurivka, it was recorded together with other metals (zinc), although the reference background recorded for arsenic already exceeded the MPC.

23 The MPC for the PAH, benzo(a)pyrene was exceeded in the majority of soil samples analysed.

24 Total sulphur exceeded the MPC (expressed as SO4-2) in 90% of samples. Elevated sulphur in soils may be due to atmospheric deposition from nearby mining and industrial sources.

25 Higher lead soil concentrations were found in soils from near transport and industrial sites (46-80 mg/kg), and may arise from historic emissions. Lead is also constituent of munitions, and anomalies were found around artillery impact sites (46-65 mg/kg), and near the destroyed railway station (87 mg/kg).

26 The MPC for cadmium was exceeded in localised samples. Elevated cadmium levels may also be linked to the munition types used, although historic field irrigation with water containing cadmium, cobalt and lead may have also impacted soil health.

27 Barium exceeded the relevant MPC in one collected soil sample, and was recorded above background concentrations at several sample locations. Barium is used as munition component.

28 Strontium was recorded above background concentrations in localised samples from public areas, and is a munition component.

29 Zinc was consistently recorded above the reference background concentration, and may have derived from the Inhulets irrigation system and is a component of mineral fertilisers.

30 Localised copper levels were recorded above reference background concentrations, including within an area with destroyed residential blocks, where S-300 anti-aircraft missile systems and cannon artillery were used.

31 The MPC for manganese was not exceeded, but levels exceeded the reference background concentration in localised soil samples.

32 An average soil organic matter was recorded at 5.5%, and a minimum clay content of around 30%.

33 For example, UK guidance sets an ecological soil screening value for vanadium of 19.0 mg/kg, based on an assumed a background vanadium concentration of 17.0 mg/kg in soil.

1.6 Remote site analysis: Snihurivka oil pumping station

Facility	Snihurivka oil pumping station
Date	March - August 2022
Summary of incidents	8th June 2022: shelling/missile strike starts a fire at an oil tank; burning oil leak smouldered for at least a week. 28th June 2022: damage to the pipeline connected to the pumping station in agricultural land to the north of the station causes localised spill and fire. 18th-26th July 2022: fire consumes and destroys two oil tanks.
Setting and local environs	Located amidst agricultural land, nearest residential location 1 km away, nearest water body, the River Vysun, 6.9 km away. The site is around 9 km from an ecologically important area: The Lower Inhulets River Valley (Emerald Network site code: UA0000321). Groundwater impacts not known, however offsite migration of oil, firewater and combustion products may pose risk to soils, and underlying groundwater.
Contaminants of potential concern	Hydrocarbons and combustion products from the fire and any firewater. These include metals (nickel, vanadium, cadmium, chromium, mercury, lead and zinc), PAHs, dioxins and furans (PCDD/F).
Impact	Significant physical damage, fire and oil spill. No surface water in close proximity but visible impact on soils that was confirmed by the State Environmental Inspectorate. Pollutants from the smoke plume during the fires may also have impacted soils and water. Sampling is recommended along the direction travelled by the plume. Groundwater abstraction location present on-site but not assessed.
Preliminary environmental screening	High risk (high uncertainty). Persistent ground contamination from oil spill and combustion products. Impacts on groundwater not known.

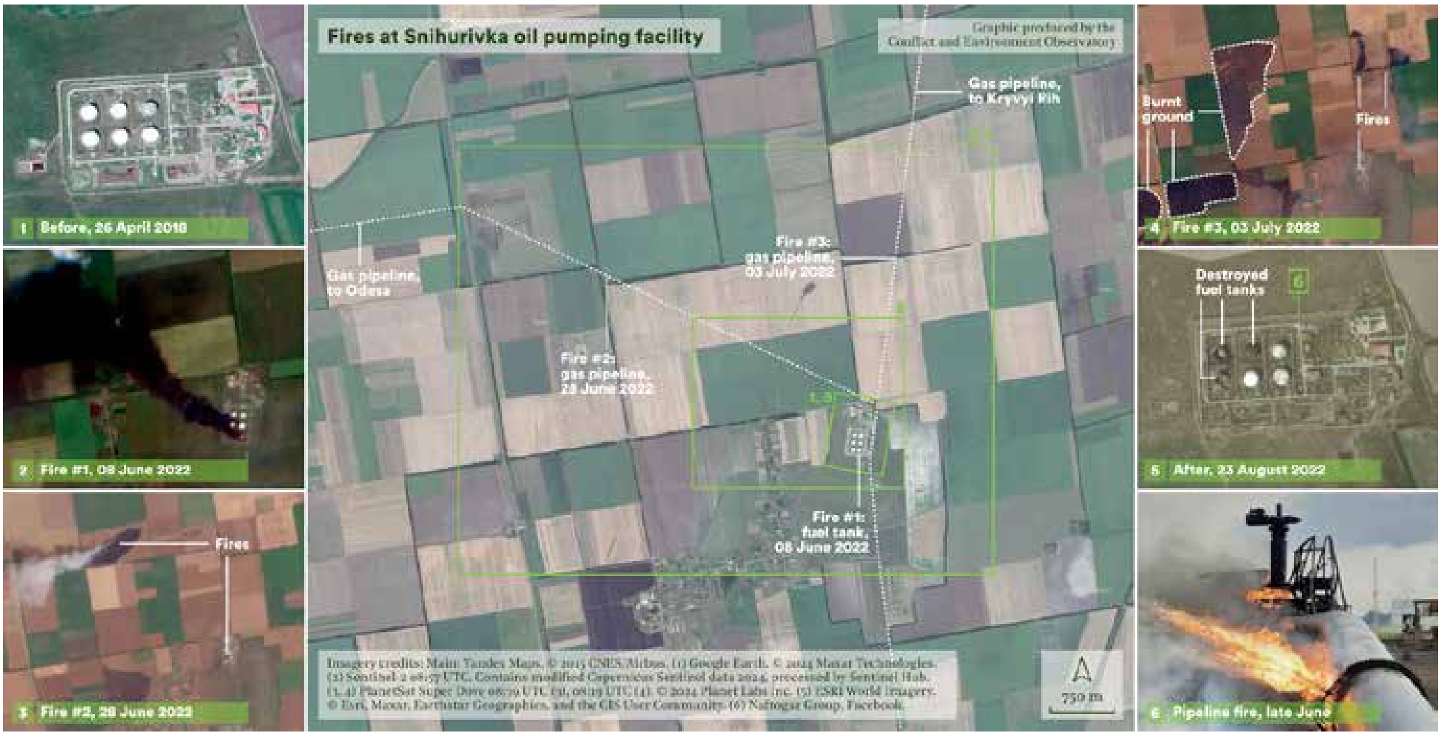
On 19th March 2022, Russian forces occupied Snihurivka. After Ukrainian forces took positions around Kobzartsi the oil pumping station became the frontline and was repeatedly shelled by artillery and Multiple Launch Rocket Systems (MLRS).

On 8th June 2022, the pumping station reservoirs were struck, resulting in a prolonged fire. One oil tank was destroyed, another severely damaged, an oil spill fire smouldered for several days. Imagery from the 8th of June reveals a smoke plume at least 2.3 km long. Further strikes during June 2022 caused fires and the destruction of oil reservoirs. Further shelling was reported on the 18th and 22nd July; by the 26th of July two more oil reservoirs had been destroyed. Imagery from the 23rd of August shows that three oil tanks had been completely destroyed. The adjacent field is speckled with EW crater marks.

Analysis of satellite imagery revealed that the pipelines leading to the pumping station were also damaged. On 28th June, a high-intensity landscape fire was detected nearby, along with a fire at the station itself. This is consistent with reports of pipeline depressurisation and ignition, resulting in oil spills at distance from the station. Intense fires can cause persistent damage to soils and leave them more vulnerable to erosion.

The recurring incidents without any possibility of containment or remediation caused air and soil pollution. A State Environmental Inspectorate survey on 11th May 2023 estimated the area polluted with hydrocarbons at 2,930 m^2, with soil concentrations of 17,850 mg/kg recorded: 35.7 times higher than the maximum permitted level.

Snihurivka oil pumping facility
110 kV substation
Fuel storage tanks
Settling pond
Water abstraction zone
Water tower
Fire pond (empty)
Abandoned reservoirs
Imagery: 26 April 2018. Google Earth. © Maxar Technologies.
Graphic produced by the Conflict and Environment Observatory
100 m



Fires at Snihurivka oil pumping facility
Graphic produced by the Conflict and Environment Observatory
Gas pipeline, to Kryvyi Rih
Gas pipeline, to Odesa
Fire #3: gas pipeline, 03 July 2022
Fire #2: gas pipeline, 28 June 2022
Fire #1: fuel tank, 08 June 2022
Fires
Burnt ground
Destroyed fuel tanks
1 Before, 26 April 2018
2 Fire #1, 08 June 2022
3 Fire #2, 28 June 2022
4 Fire #3, 03 July 2022
5 After, 23 August 2022
6 Pipeline fire, late June
Imagery credits: Main: Yandex Maps. © 2015 CNES/Airbus. (1) Google Earth. © 2024 Maxar Technologies.
(2) Sentinel-2 08:57 UTC. Contains modified Copernicus Sentinel data 2024, processed by Sentinel Hub.
(3, 4) PlanetSat Super Dove 08:19 UTC (3), 08:19 UTC (4). © 2024 Planet Labs Inc. (5) ESRI World Imagery.
© Esri, Maxar, Earthstar Geographics, and the GIS User Community. (6) Naftogaz Group, Facebook.
750 m

1.7 Remote site analysis: Skhidnyi tomato processing plant

Facility	Skhidnyi tomato processing plant
Date	8th May 2022
Summary of incidents	Shelling or missile strike on 8th May 2022 destroyed a tomato paste warehouse, generating 12,000 tonnes of organic waste mixed with burnt plastics, and a production workshop with processing and refrigeration equipment. An ensuing fire that lasted less than 24 hours. Mixed waste remained onsite from May-December 2022 with remedial work possible only after Russian forces withdrew.
Setting and local environs	Located amidst agricultural land, no water bodies nearby, warehouse area is paved. Site has its own water treatment facilities and is around 2.5 km from an ecologically important area: Lower Inhulets River Valley (Emerald Network site code: UA0000321).
Contaminants of potential concern	Organic waste, hydrocarbons, metals, asbestos and a broad range of combustion products from the burning plastics and equipment. These may include dioxins and furans (PCDD/F), PAHs, polybrominated diphenyl ethers (PBDEs); polybrominated dibenzofurans (PBDF), polychlorinated biphenyls (PCBs) and perfluoroalkyl and polyfluoroalkyl substances (PFAS).
Impact	Significant physical damage, and large volumes of debris and organic waste generated. Impact on soils or groundwater in proximity to the plant not known.
Preliminary environmental screening	High risk (high uncertainty). Impacts on local soil and groundwater not known.

The photos to the right (p. 25) show an overview of the Skhidnyi tomato processing plant. The first one is a satellite imagery of the plant before shelling. The second show a satellite imagery taken of the plant after shelling and photos, and reveal the near-complete destruction of its warehouses.

The incident generated a large volume of mixed waste including demolition waste, biological waste left to slowly decompose onsite, and incompletely burned plastic waste – most likely HDPE and PET. Damaged energy generating and production equipment onsite is a potential source of persistent organic pollutants.


Skhidnyi tomato processing plant
Production workshop
Warehousing area
Wastewater treatment plant
Imagery: 22 May 2022, ESRI World Imagery. © Esri, Maxar, Earthstar Geographics, and the GIS User Community
Graphic produced by the Conflict and Environment Observatory
50 m


Damage observed at Skhidnyi tomato processing plant
Production workshop
Warehousing area
Wastewater treatment plant
Imagery: 22 May 2022, ESRI World Imagery. © Esri, Maxar, Earthstar Geographics, and the GIS User Community. Photo credits: (top) INSHE.tv; (middle) MykolaivOblast-Info, telegram; (bottom) AgroPortal UA, Youtube. Graphic by the Conflict and Environment Observatory.
250 m
Destroyed production workshop
Destroyed warehousing area
Cumulative build up of waste

2. KOMYSHANY AND ZYMIVNYK, KHERSON REGION

Komyshany and Zymivnyk settlements were occupied between March and November 2022. Russian forces withdrew peacefully but almost immediately began attacking both settlements with artillery, missiles and drones from positions on the left bank of the River Dnipro 5-10 km away. A pre-war population of 10,560 had reduced to around 6,700 at the time of our visit. The settlements were considered a hard-to-reach area, and no humanitarian demining operators work there. SESU alone provided some mine clearance activities.

2.1 Destruction of energy facilities

The economies of Komyshany and Zymivnyk settlements are based on small and medium-scale agricultural production, with no major industrial enterprises. Some small-scale light industrial enterprises operated outside the settlements. Nevertheless, the area does have energy infrastructure objects that posed environmental risks. These include Kherson Oil Terminal ("Naftohavan") and its temporarily abandoned oil pipeline, which passes through the Zymivnyk and Shumenskyi districts of Kherson to Kherson Oil Plant, whose operations were also temporarily suspended.

In late 2022, the oil terminal was damaged by shelling, and in June 2023 its pipeline was damaged during the Kakhovka flood event, causing a massive oil spill around Zymivnyk and Komyshany. Media reports suggested that 250 m^3 of topsoil polluted with oil was removed and disposed of.[34] The area of the spill was targeted by the sampling exercise, alongside soils potentially affected by EW.

Oil spill sampling spot in Komyshany, near Bezmen lake.
Credit: Iryna Babanina, CEOBS

The location of the spill was confirmed by village council members and local residents and eight shallow soil samples were collected for analysis. All samples indicated levels of oil which exceeded the relevant MPC. Samples were taken nine months after the spill and considering natural biodegradation and attenuation of hydrocarbons in soils and migration with surface runoff, the initial concentrations would likely have been higher, yet residual contamination remains.

2.2 Destruction of essential infrastructure and impact on the community

Between November 2022 and April 2024, 77 incidents of EW use were recorded in Zymivnyk and Komyshany; some of which caused casualties and fatalities. Power lines were damaged on numerous occasions, while around 300 houses were damaged by shelling. The community's water supply - an abstraction point in nearby Chornobaivka – was looted and then damaged by shelling. This left the community dependent on trucked water as the water in local wells and boreholes is too salty for drinking or irrigation. We collected two water samples from private boreholes.

2.3 Land contamination with explosives and impact on land use

Local officials reported that limited mine clearance was undertaken by SESU upon the request of agrarian enterprises Driada LLC and Liubava farm. Some soil sampling was done by Kherson State Agrarian University but the results were never communicated by enterprise owners. After the Kakhovka flood event in June 2023 Ukraine's State Consumer Service and SESU undertook limited soil and water sampling. At the time of our visit, NTS had not been undertaken in Komyshany or Zymivnyk and all the flooded territories were considered unsafe because of the possible migration of landmines andother EO.

The wetland and riverine habitats adjacent to Komyshany and Zymivnyk are a part of the Lower Dnipro Emerald Network site, and close to the Dnipro River Delta Ramsar Site, which covers Bezmen and Rohozovate lakes. The delta and its wetlands perform important ecosystem services, including cleaning and retaining water, and supporting a diverse range of biodiversity, including many nationally rare and endangered species. Sampling points 35-38 were located close to the Ramsar site's boundary. A high risk from EO contamination prevented further sampling to the south, however the reported extent of the oil spill suggests that some of the site was affected. The presence of EO and regular shelling prevented further study of this area, which is also at increased risk from landscape fires ignited by munitions.

34 Ministry of Internal Affairs of Ukraine (2023) Igor Klymenko: rescuers completed the collection of oil products in the floodplain of the river in Kherson region: https://mvs.gov.ua/en/news/igor-klimenko-riatuvalniki-zaversili-zbir-naftoproduktiv-v-zaplavi-ricki-na-xersonshhini

2.4 Analysis of soil samples from Komyshany and Zymivnyk

Soils in the two areas have been degraded by intensive agricultural use, including through salinization associated with irrigation and the overuse of mineral fertilizers. They are also affected by pollutants from industries in Kherson and from the Kakhovka flood event. Soil erosion rates are high, the soil structure was heavily influenced by tilling and pH ranges varied from neutral to alkaline. Some elevated concentrations were recorded exceeding the MPC for manganese,[35] and hydrocarbons, and above reference background levels for zinc,[36] nickel,[37] cadmium,[38] and copper in collected soil samples.[39]

2.5 Water analysis for Komyshany and Zymivnyk

Groundwater conditions are influenced by a range of factors, including geology and rainfall. In Komyshany and Zymivnyk, groundwater levels and quality were also influenced by how much water flows down the Dnipro and, more recently, pollution associated with the conflict. The depth of the local aquifer is 22-34 m, and local boreholes reach 52-65 m, but the majority of water needs come from the River Viryovchyna and lakes in the River Dnipro's floodplain. These supplies are vulnerable to pollution and variations in seasonal flow, and there is no centralised sewage system in Komyshany and Zymivnyk.

Discrete water sampling identified elevated hydrocarbons, sulphate, zinc, nickel, iron, lead and manganese. Two private supply boreholes and a culvert were sampled. Hydrocarbons in the water samples also considerably exceeded the MPC of 0.3 mg/litre, indicating significant levels of contamination in the underlying groundwater and impact on surface water quality.

Recorded levels of iron, manganese, cadmium, zinc, nickel, lead, oil and other pollutants in the private borehole did not meet drinking water criteria. In the absence of sources, local people still use the water for hygiene and technical needs. For drinking water, the settlements depended on supplies from a borehole in the nearby town of Chornobaivka.

Russian forces had looted the borehole's pumps during the occupation, after which the supply network was damaged by shelling and communities remain reliant on trucked and bottled water for drinking.

A culvert and a mothballed pipeline near Zymivnyk, Kherson.
Credit: Iryna Babanina, CEOBS

35 The average manganese levels in soil samples was 615 mg/kg, which is above the reference background level. The relevant MPC was also exceeded in selected samples. Small quantities of manganese occur in some munition and grenades, but may also originate petroleum products.

36 Zinc content averaged 343 mg/kg, 5.5 times higher than background. At point 51, where residential buildings and infrastructure had been destroyed by shelling, zinc levels reached 532.3 mg/kg, 8.6 times higher than background.

37 Nickel content in the villages varied from 20 to 28 mg/kg and was more uniform than other heavy metals, levels in 40% of samples were within natural background.

38 Cadmium concentrations varied between 0.04-2.8 mg/kg; the average soil content was 0.5 mg/kg, exceeding background by 2.5 times. It exceeded permitted values by 1.3-1.9 times in places affected by cluster munitions and oil spills, and was generally concentrated in the 0-10 cm soil layer.

39 For the studied soils, we found a correlation between hydrocarbons and heavy metal concentrations (Cd, Zn, Ni and Mn), indicating that they accompanied the oil.


Environmental sampling in Kherson, southern Ukraine
Sampling Sites [This work - NPA/CEOBS]
Soil
Water
Risk from flooded sites [CEOBS]
Medium
High
Very High
Flood extent [UNOSAT]
Ecologically important areas [CEOBS]
Building damage [Scher and Van Den Hoek]
Fire detection [NASA VIIRS]
Measured high concentrations*
Pb
Cu
Ni
Fe
Petroleum products
Cd
Zn
Mn
Ammonia†
Chlorides†
Nitrates†
Nitrites†
Phosphates†
Sulphates†
Suspended substances†
†Water only
Chornobaivka airbase
Wastewater treatment
Komyshany
A
1 7 June 2023
Black slicks in floodwater emanating from industrial area
PlanetSat Super Dove 08:25 UTC. Planet Labs Inc (2024)
2 25 August 2023
Destroyed oil tank
ESRI World Imagery
© Esri, Maxar, Earthstar Geographics, GIS User Community

Background image: Sentinel-2, 9 March 2024 - Copernicus Sentinel data [2024]. *Concentration data classified as 'high' if it exceeded a CEOBS determined threshold based Ukrainian and UK standards, and regional background concentrations. Note these are single point in time measurements for proof of concept - gridded sampling over time is needed to confirm polluted areas. Building damage derived from satellite radar phase changes until September 2023, c/o Corey Scher (CUNY, New York) and Jamon Van Den Hoek (Oregon State). Graphic produced by the Conflict and Environment Observatory (CEOBS) and Norwegian Peoples Aid (NPA).

2.6 Remote site analysis: Kherson oil terminal ”Naftohavan”

Facility	Kherson oil terminal “Naftohavan”
Date	15th November 2022 – 14th December 2022; 6th June 2023
Summary of incidents	15th November 2022 - 14th December 2022: damage to one of the oil reservoirs. 6th June 2023: flooding and oil spill from the pipeline connecting the Kherson oil terminal and oil refinery (the refinery itself was above the flooding zone). Date unknown: shelling damage to the pipeline.
Setting and local environs	The oil terminal is located in close proximity to residential areas and the Dnipro River Delta Ramsar site and Emerald Network Lower Dnipro site. The terminal had been shut down for some time and probably deteriorated. The need for capital repairs and modernisation was identified in 2021. It is unknown how much oil remained in the pipelines and reservoirs and whether appropriate equipment shutdown procedures were followed during its closure.
Contaminants of potential concern	Hydrocarbons, metals and PAHs from the oil spill.
Impact	Soil and groundwater pollution in the nearby settlements of Komyshany and Zymivnyk, as confirmed by lab testing. During interviews with local officials they mentioned that oil pollution was also observed further downstream, near Bile Lake; this was outside the scope of the field mission’s study area.
Preliminary environmental screening	High risk (high uncertainty as to the pollution area). Soil and groundwater pollution with hydrocarbons, heavy metals.

Pre-war spills in the oil terminal area have been reported. Local media had reported an oil spill in December 2010, while the State Environmental Inspectorate had reported a chemical spill of around 2,000 m^2 in January 2011. The operation of the terminal was suspended in 2014 because of sanctions against its previous owner. In 2021, the OKKO oil company acquired the site, announcing plans to modernise and reopen the dilapidated site. Following Kherson’s de-occupation in November 2022, nearby residential areas were frequently shelled. Remote analysis shows that one of the terminal’s reservoirs was damaged between 15th November and 14th December 2022.

Local authorities stated that floodwaters damaged an oil pipeline connecting Kherson oil terminal and Kherson oil refinery. However, ACLED recorded 39 shelling incidents for Komyshany and Zymivnyk; between the earliest report on 12th October 2022 and the final incident before the flood event on 3rd June 2023. It was not possible to remotely establish the exact location of potential pipeline damage so it remains unclear whether it was caused or made more likely by explosive damage.


An oil slick is visible in the downstream Kakhovka floodwaters at Komyshany
The extent of the Kakhovka floodwaters and the presence of oil are observable using satellite imagery
Kherson
Black oil streaks are visible on the floodwaters surface
River Kosheva
07 June 2023
250 m
Imagery: PlanetSat Super Dove 08:25 UTC. (C) 2024 Planet Labs Inc.
Graphic produced by the Conflict and Environment Observatory


Damaged observed at Kherson oil terminal
Destroyed oil container
River Dnipro
Imagery: 25 August 2023, ESRI World Imagery. © Esri, Maxar, Earthstar Geographics, and the GIS User Community
Graphic produced by the Conflict and Environment Observatory
50 m

CONCLUSION

Armed conflicts severely impact the environment, affecting human health and ecosystems. This study on Ukraine by NPA and CEOBS highlights significant pollution, infrastructure damage, agricultural threats, and ecological harm from the use of explosive weapons and their reverberating effects. Armed conflicts make environmental research challenging, but despite these challenges we found that collaboration between environmental researchers and humanitarian organizations can document these impacts, providing data that can guide recovery efforts.

Although this was a limited study its findings contribute to the small but growing literature on the relationship between the use of explosive weapons, environmental harm and outcomes for human health and livelihoods. These forms of harm are ubiquitous to armed conflicts and documenting them is a key component of efforts to enhance the protection of the environment in relation to armed conflicts – and those who depend on it.

Recommendations in the report include expanding sampling, undertaking mine clearance, promoting green recovery, supporting interdisciplinary research, and strengthening international law to protect the environment in relation to conflicts. States and non-state stakeholders should step up their efforts to monitor the environmental consequences of armed conflicts to help minimise harm and support sustainable recovery.

A destroyed Russian tank in the Kherson region. Credit: NYT

Annex 1: Research methodology

1. Selection of case studies for fieldwork and remote analysis

The case study selection was based on several criteria. Logistical and safety support required that sites were located in NPA Ukraine's humanitarian mine action and disarmament programme's area of operation (Mykolaiv, Kherson and Sumy Oblasts). The incidents also needed to be in CEOBS' environmental incident database for Ukraine, and they needed to be physically accessible.

Two differing types of EW impacts were chosen, with distinct environmental and landscape contexts in Mykolaiv and Kherson regions:

Impact	Location
Hostilities; occupation from March until November 2022; shelling and missile attacks due to close proximity to the front line.	• Snihurivka community, Mykolaiv region
Occupation from March until November 2022; flooded by Kakhovka dam destruction, oil spill recorded; shelling and missile attacks due to close proximity to the front line.	• Komyshany, Kherson region • Zymivnyk, Kherson region

Three case studies were also chosen for remote sensing analysis:

1. Snihurivka oil pumping station (incident category: oil, petrol or chemical leakages).
2. Snihurivka tomato processing plant (incident category: conflict debris).
3. Kherson oil terminal (incident category: oil, petrol or chemical leakages).

The project consisted of the following stages: planning, desk research, field work, laboratory analysis of soil and water samples, analysis of results, preparation of report and recommendations. NPA head office, NPA Ukraine and CEOBS worked together at each stage of the project.

Field study and community interviews were undertaken in March 2024. Soil and water sampling were undertaken in areas assessed to be most impacted by fighting, such as in residential areas and infrastructure, and in areas close to the River Inhulets.

2. Limitations of the fieldwork

The fieldwork was limited to areas deemed safe to access, and made available through authority and land owners' permissions. Sampling locations were targeted positions and used to provide an initial assessment of ground conditions and patterns, as well as local water quality at selected locations. The sampling was not designed to show definitive levels of contamination and overall risk levels, which would require higher sampling densities to evaluate the distribution of contamination and the soil conditions. In addition, no portable handheld monitoring equipment was used to screen samples on site, with samples dispatched for off-site laboratory analysis. The analytical suite was also restricted to the capabilities of testing laboratories available in Ukraine. Trip blanks and duplicate water sampling was not carried out for this study.

3. Preparation and planning

A desk study was carried out to establish the environmental situation prior to Russia's full-scale invasion and assess: the movement of frontlines for the duration of the occupation; infrastructure damage by EW and its impact on civilians; and inform the selection of sampling locations.

Data sources:

• Conflict research resources (ACLED, ISW);
• Community planning and land use documents;
• Strategic Environmental Assessment report for Snihurivka community development programme till 2027 (2030);
• Comprehensive Restoration Program of Snihurivska community;
• General Plan of Komyshany;
• Data held by state authorities and results of official requests;
• Media and social media;
• NPA data on explosive ordnance contamination and mine victim incidents.

4. Research methodology for soil and water sampling
Soil sampling was conducted between 11th and 14th March 2024 in accordance with Ukraine's DSTU 4287:2004 standard, with composite shallow soil samples taken using the envelope method. The sampling depth was between 10 and 30 cm, depending on the type of soil, location and suspected contamination. Sample preparation involved the removal of roots and waste, with sample weighting from 0.2 to 2.5 kg. Water samples were collected from two household supply boreholes in Zymivnyk and Komyshany. One sample was taken from a River Viryovchyna tributary running through a concrete culvert near one of the soil sampling locations.

Soil samples were sent to either the Ukrainian Laboratory of Quality and Safety of Agricultural Products of the National University of Life and Environmental Sciences or the Soil and Waste Hygiene of the O.M. Marzieiev Institute of Public Health. The latter analysed soil and water samples from Komyshany and Zymivnyk using different methods

Due to security reasons and the proximity of the current frontline in March 2024, we were unable to access some locations, limitating the number of soil and water samples taken.

Fieldwork, 11th - 14th March 2024
In Komyshany, access was denied to one of the identified locations (municipal wastewater treatment installation) for security reasons by the facility staff. Komyshany and Zymivnyk are within 5 km of the River Dnipro, and close to the frontline, with a strengthened security regime for essential infrastructure and other relevant locations. This limited sampling opportunities, reducing the number of soil samples to 55 and water samples to 3 (Fig A4).

On 12th March, the field team interviewed community officials in Snihurivka who were responsible for land management and restoration. Soil sampling was targeted in areas most affected by fighting, such as in residential areas, near damaged civilian infrastructure, the destroyed railway station, a shelled agricultural enterprise, and near tributaries and in Inhulets riverside areas.

On 13th March, the field team travelled to Komyshany and Zymivnyk. The visit began with soil sampling in the suspected oil spill area, near Bezmen Lake. Three local residents indicated where they observed the spill, which helped to select sampling locations. Two samples of water from private water supply boreholes were also taken. Many residents had left the settlement, limiting the options for more extensive community interviews and access to household boreholes.

A meeting explaining the purpose of the visit and interviews was held with the local starosta (administrative body of the village), at which further points of interest and explosive ordnance hazardous areas were identified. Sampling locations included residential areas, riverside areas and the territory near the abandoned oil pipeline being the probable source of the spill.

On 14th March, the field team had a debriefing meeting with NPA mine action staff in Mykolaiv, and the soil and water samples were transported to the laboratories.

5. Interviews
Two in-depth qualitative group interviews were held to assess the cascading and reverberating effects of EW use, and to identify information gaps and further needs. Candidates were selected who had knowledge of the community damage assessment, and of the organisational and managerial challenges related to infrastructure recovery and land clearance. Two groups of community officials, three persons in each, were interviewed in Snihurivka on 12th March and in Komyshany on 13th March.

Key topics covered were the impacts of EW on community infrastructure and the associated environmental and human risks; the impact on industrial facilities and associated environmental risks; and the impacts on livelihoods and ecosystem services. The questionnaire was developed by CEOBS' researcher based on methodological studies on the cascading effects of EO use in populated areas (Wille and Baldo, 2021; Zeitoun and Talhami, 2016; Massingham et al., 2023).

6. Remote case studies
Remote case studies combined open-source investigation and Earth observation methods to assess the sequence of events and potential environmental risks. Satellite remote sensing data sources were used depending upon availability of data, the scale and nature of the damage caused, and the strengths and weaknesses of the data. The European Space Agency's Sentinel-2 was used, alongside other sources including NASA's FIRMS (Fire Information Resource Management System), and the more sporadic but Very High Resolution (3m) imagery available through Google Earth Pro. In addition, in depth analysis of media and social media channels were conducted to collect sufficient data to illustrate the remote cases.

Annex 2: Methods and applied standards

Determinant (soil)	Methods and applied standards	
	Ukrainian Laboratory of Quality and Safety of Agricultural Products	O.M. Marzieiev Institute of Public Health
Number of samples:	19	55
Particle size distribution	DSTU 7842:2015 Soil quality. Assessment of soil quality by particle size distribution. DSTU 4730:2007 Soil quality.	-
Exchangeable pH	DSTU ISO 10390:2022 (ISO 10390:2021, IDT).	DSTU ISO 10390-2007.
Organic matter (humus)	DSTU 4289:2004 standards pertaining to soil quality.	-
Metals and metalloids	Ag, Al, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe: ICP-AES (ISO/TS 16965:2013) in accordance with the DSTU ISO 13877:2005 standard for soil quality.	Pb, Cu, Ni, Cd, Zn, Fe, Mn: AAS using a KAS-120. 1 spectrophotometer.
	K, Li, Mg, Mn, Na, Ni, Pb, Sr, Tl, Zn, Be, Mo, Se, Ti, V, As, Hg, S, and P: ICP-AES (ISO/TS 16965:2013) in accordance with the DSTU ISO 13877:2005 standard for soil quality.	-
Trace elements	ICP-MS	-
Polycyclic aromatic hydrocarbons (PAHs)	HPLC (ISO 13877:1998, IDT), DSTU ISO 13877:2005 Soil Quality standard.	-
Hydrocarbons	-	MM No. 081/12-0116-09

Determinand (water)	Methods and applied standards:
	O.M. Marzieiev Institute of Public Health.
Number of samples:	3
Sulphate content	KND 211.1.4.026-95, MM No. 081/12-0177-05.
Phosphate content	Method Statement No. 081/12-0005-01.
Chloride content	Method Statement No. 081/12-0004-01.
Ammonium nitrogen content	KND 211.1.4.030-95, MM No. 081/12-0106-03.
Hydrocarbons	MPC No. 081/12-0645-09.
pH	MPC No. 081/12-0317-06.
Nitrite content	KND 211.1.4.023-95.
Nitrate content	KND 211.1.4.027-95.
Suspended solids	KND 211.1.4.039-95.

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