The Environmental Impact of the Ukraine Conflict

A Preliminary Review

UN environment programme

GRID ARENDAL

A UNEP Partner

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UNEP is the leading global environmental authority that sets the global environmental agenda. The organisation promotes the coherent implementation of the environmental dimension of sustainable development within the UN system and serves as an authoritative advocate for the global environment. UNEP is keeping the environment under review by providing policy advice, early warning information and promoting international cooperation. It is under this mandate and at the request of the Government of Ukraine, that UNEP in collaboration with GRID-Arendal has undertaken this preliminary and rapid review of existing information on the current conflict in Ukraine to inform and prepare for conflict-related environmental impact assessments.

Abbreviations

BC	black carbon
CBRN	Chemical, Biological, Radiological and Nuclear (disasters)
CEZ	Chernobyl Exclusion Zone
CLP	Classification, Labelling and Packaging (EU law)
CO_2	Carbon dioxide
COVID-19	Coronavirus Disease 2019
CWAs	Chemical Warfare Agents
DNT	dinitrotoluene
TNT	trinitrotoluene
EU	European Union
FAO	Food and Agriculture Organization
FAOSTAT	United Nations Statistics Division of the Food and Agriculture Organization
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas emissions
IDPs	internally displaced people
ISIL	Islamic State of Iraq and the Levant
JSC	Joint-Stock Company
KSE	Kyiv School of Economics
LLC	Limited Liability Company
LPG	liquefied petroleum gas
LULUCF	Land Use, Land-Use Change and Forestry
NASU	National Academy of Sciences of Ukraine
NGO	non-governmental organization
NORAD	Norwegian Agency for Development Cooperation
NPP	Nuclear Power Plant
NSDC	National Security and Defense Council of Ukraine
OECD	Organisation for Economic Co-operation and Development
OH	Operation Headquarters
OPCW	Organization on Prohibition of Chemical Weapons
OPs	obsolete pesticides
OSCE	Organization for Security and Co-operation in Europe
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PM2.5	particulate matter
RDX	royal demolition explosives
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU law)

RF	Russian Federation
SCR	Security Council Resolution (United Nations)
SNF	spent nuclear fuel
SOE	State-owned Enterprise
SPS	Sanitary and Phytosanitary
SSES	State Service of Emergency Situations
SSUFSCP	State Service of Ukraine for Food Safety and Consumers' Protection
TICs	Toxic Industrial Chemicals
TPP	thermal power plant
UA	Ukraine
UAROC	Ukrainian Association of Regional and Oblast Councils
UN	United Nations
UNEP	United Nations Environment Programme
UNITAR	United Nations Institute for Training and Research
USD	United States Dollar
USSR	Union of Soviet Socialist Republics (Soviet Union)
UXO	unexploded ordnance
VCM	vinyl chloride monomer
VX	venomous agent X
WWII	World War II

Executive Summary

Armed conflict is inherently destructive. Environmental damage that arises during conflict brings devastating consequences for natural resources, critical ecosystems and people's health, livelihoods and security. The containment, mitigation and remediation of environmental impacts is, therefore, an essential part of response to and recovery from conflict.

The United Nations Environment Programme (UNEP) is mandated to assist countries upon request, with pollution mitigation and control in areas affected by armed conflict or terrorism. Further, to aid in reducing environmental impacts from conflict, Member States adopted UNEA Resolution 3/1 to "work with national authorities and international organizations in the early identification of conflict pollution" and to "undertake field-based and post-crisis environmental assessment and recovery" in affected areas. The Government of Ukraine has requested assistance from UNEP in identifying the types of environmental impacts and assessments that will be required. This report was drafted as part of a preparatory process to assist Ukraine in recovery from the current conflict and to inform a comprehensive post-conflict assessment.

During the conflict that began on 24 February 2022, Ukraine has experienced considerable environmental destruction. Preliminary monitoring of environmental impacts since the outset of the invasion by the Russian Federation points to substantial damage to urban and rural environments across a wide geographic area. Numerous incidents have caused pollution to air, water and land and degraded nature. Environmental damage carries risks both to Ukraine and neighbouring countries. Extensive field assessment work will be required to establish the character, magnitude and significance of conflict-related environmental impacts and remediation requirements, including remote sensing and extensive ground-truthing, sampling and analysis, including in areas that (at the time of writing) are inaccessible due to ongoing hostilities. This assessment work will need to cover the full range of issues: impacts on nature, human health and safety, and biodiversity, urban centres burdened with hazardous debris, agricultural production facilities and chemical plants, fuel and metallurgical industries, waste and treatment facilities impacting terrestrial, freshwater systems and marine environments. Based on initial monitoring work, the country and the region risk being burdened with a toxic legacy long after the conflict ends, as it must.

An initial challenge in commencing this essential work is a lack of existing systematic studies of environmental impacts and risks associated with the types and complexity of conflict-related environmental damage experienced in Ukraine. Previous studies, while having some similarities to the current conflict such as impacts on energy and water infrastructure, differ in scale and complexity. The lack of such studies may be due to operational challenges, the mix of industry and land use, a lack of transparency relating to the types and composition of munitions and military vehicles and a breakdown of even the most basic environmental monitoring systems. Conversely, a wealth of environmental data and information is being collected by dynamic civil society actors – both national and international – and multiple international partners and the UN system.

This report was drafted and finalized while conflict had been ongoing for seven months. The report has made use of:

- reviews of official or peer-reviewed documentation on environmental and related human health impacts from selected past conflicts with some similar characteristics and issues with the current Ukraine conflict (including Chechnya, Gaza, Iraq, Syria, eastern Ukraine and Yemen)
- Information from the Government of Ukraine and limited remote sensing information
- non-verified reports from social media posts and regular media to help frame issues that may be encountered and hence the approach and assessment required.

As a result of this review, preparation for essential field-based assessment work can be better informed of some of the likely challenges as well as the expertise that will be required. The report has summarised issues and impacts across six broad categories: chemical industries and chemicals associated with armed conflict; fuel and associated infrastructure; waste and waste infrastructure; urban and critical infrastructure; and damage to agriculture and to nature. It also outlines governance and gender considerations and the assessment of cumulative impacts and system dynamics.

The report presents a snapshot – but by no means a comprehensive picture – of the damage inflicted on Ukraine's environment and the potential environmental and public health impacts, informing priorities for field-level verification work.

Initial information shows that Ukraine, already burdened by a host of legacy environmental challenges, is now facing a compounded, multi-dimensional environmental crisis that has either exacerbated existing issues or added new ones. Ukraine's government and society is grappling with multiple crises associated with chemicals, munitions and military equipment, the presence of a range of pollutants continuing to be released during the active phase of the conflict, damage inflicted to fuel storage facilities, industrial infrastructure, key infrastructure such as water, energy and waste management systems, urban areas, agricultural and natural areas. Assessing such damage will require a multitude of complex methods to establish the impacts and plan recovery activities.

It is essential that the ongoing conflict ends now to ensure greater damage to the environment and to people is averted. The obligation to protect the environment in times of armed conflict is reflected in international law and legal precedent, including in, but not limited to, the United Nations (UN) Charter, the Geneva Conventions and other Statutes and Conventions.

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[1] Under Article 2 of the UN Charter, all States have the obligation to refrain in their international relations from the threat or use of force against the territorial integrity or political independence of any State, and to settle their international disputes by peaceful means. Violations of the UN Charter may entail responsibility under international law to make reparation For example, **Security Council resolution 687 (1991), paragraph 16**, held Iraq liable on this ground for 'direct loss, damage, including environmental damage and depletion of natural resources' arising out of its unlawful invasion and occupation of Kuwait

[2] The Additional Protocol to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977, (i) by Article 35 prohibits to "employ methods or means of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment"; (ii) by Article 55 states that "1. Care shall be taken in warfare to protect the natural environment against widespread, long-term and severe damage. This protection includes a prohibition of the use of methods or means of warfare which are intended or may be expected to cause such damage to the natural environment and thereby to prejudice the health or survival of the population. 2. Attacks against the natural environment by way of reprisals are prohibited."

[3] Including, but not limited to, the 1998 Statute of the International Criminal Court (ICC), which treats armed attacks causing widespread, long term and severe harm to the environment as war crimes, and the 1976 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) prohibits the hostile use of environmental modification techniques having 'widespread, long-lasting or severe effects'.

About this Report

On February 24, 2022, the Russian Federation invaded Ukraine on several fronts. Since then, thousands of civilians have been killed or injured and millions of people displaced while humanitarian needs have escalated, and numerous human rights abuses and violations have been reported (UN 2022a). Millions worldwide also continue to face a three-dimensional global crisis of food (including fertilisers), energy and finance, a ripple effect of the war. The conflict has caused one of the fastest forced population movements since the Second World War (UNHCR 2022a). Nearly one third of the population – roughly 14 million people – have left Ukraine since the start of the invasion. A third of the population is estimated to be food insecure. The impacts of the conflict are being felt on some of the world's most vulnerable people and economies. The conflict is ongoing.

The report consists of two parts:

I. A rapid literature review of official and peer-reviewed literature on the environmental impact of past armed conflicts and war over the last thirty years and,

II. A summary, using available indicative information from international and Ukrainian sources, of the current environmental issues and their governance and management in Ukraine (existing environmental information prior to February 2022), organised around reported conflict damage and risks of adverse impacts on the environment and human health.

Due to limited time and scope, the review is not comprehensive but does provide insights on the most common damage caused by conflict and the associated impacts on human health and the environment.

Several government and non-government organisations have been collecting data on the environmental dimension of the Ukraine conflict. The Operational Headquarters (OH) at the State Environmental Inspectorate of Ukraine collects data on emergencies, damage and destruction and is dealing with the registration of conflict-related environmental loss and damage at the national level. The Ukrainian Association of Regional and Oblast Councils (UAROC) in cooperation with the State Ecological Academy has created the Centre of the Monitoring of the Impacts of War, mainly operating at the community level, but also in preparedness to respond to possible environmental, and Chemical, Biological, Radiological and Nuclear (CBRN) disasters. Ukrainian businesses have united around the UN Global Compact in Ukraine collecting data on environmental loss and damage of the private sector.

In addition, several international non-government organisations, such as the peace organization PAX, the Zoï Environment Network, the Conflict Environment Observatory (CEOBS) and IMPACT Initiatives are dealing with verification and visualization of data available from social media. The environmental network Zoï has presented maps of environmental damage of the current conflict in Ukraine. Various think tanks, like the Kyiv School of Economics (KSE), are dealing with sectoral loss and damage assessments with a strong focus on assessing losses due to degradation of natural resources. The World Bank in cooperation with the European Union and the Government of Ukraine, launched a Rapid Damage and Needs Assessment in August, as a preliminary stocktake of Ukraine's damage and losses, and to assess the scale of economic and social needs for Ukraine's survival during the conflict and its ability to prosper afterward (World Bank 2022a). At the same time, the Institute of the Geochemistry of the Environment of the National Academy of Sciences of Ukraine (NASU) is trying to conduct assessments of chemical pollution of soil and groundwater in various areas. The NASU Institute of the Environmental Economics and Sustainable Development is assessing the impact on the water sector.

A wealth of data exists from UN agencies and their partners each of which has been actively engaged in remote monitoring and data analysis work that will form part of more comprehensive assessment. One of the challenges is the volume of data and information that is flowing and being processed. Such data will need to be evaluated and analysed over time and will form the basis of subsequent reports.

As many sites remain inaccessible in Ukraine, limited opportunity exists to verify what has happened on the ground and on-line information is not always reliable. Therefore, the validity of much of the information in Part II of this report has not been established and the information contained therein needs to be viewed as indicative. Such indicative data is nevertheless useful to inform planning.

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Part I
Summary of the Environmental Impacts of War: A Rapid Review

Despite the protection afforded by several legal instruments, the environment continues to be a silent victim of armed conflicts worldwide. The United Nations Environment Programme (UNEP) has a long history of supporting countries and the world in assessing the environmental impacts of war and conflict. In addition, many international organizations and scholars have documented and analyzed the impacts of the range of damage inflicted on the environment when conflict and war occur. The prevailing findings from these assessments reveal that direct and indirect environmental damage, coupled with the collapse of institutions, lead to environmental risks that can threaten human health, livelihoods and security, and ultimately undermine peacebuilding processes. The analysis undertaken in such assessments is also vital to inform prospective environmental impacts assessments. They enable teams to identify and anticipate the types of impacts that are likely – and the nature of those impacts to inform the methods and approaches that can facilitate the effective protection and safety of communities and practitioners in the post-conflict process. This rapid review serves to provide a basis for both identification of issues and in establishing assessment approaches and methods for assessing the environmental impacts of the Ukraine conflict. The review has focused on events in the past 30 years in peer reviewed literature and where similar environmental aspects have been impacted.

1.1 Damage to chemical industries results in pollution

Damage to chemical industrial sites causes fires and releases pollutants into the air, water and soil, creating significant immediate and longer-term human health and ecological hazards through contamination. Such sites can contain a wide variety of toxic chemicals, creating a multitude of environmental risks. Emergencies during which toxic chemicals are released into the atmosphere and the surrounding area can be caused by: incidents at chemical plants; incidents on transport or product pipelines; attacks; hostilities during armed conflict (OPCW 2022).

Examples of documented damage to chemical industrial sites during previous conflicts, as well as associated release of pollutants and environmental impacts are summarized below.

1.1.1 Chemical industrial sites

A prominent and well-documented example is the damage to the Pancevo industrial complex in Serbia which was severely damaged during bombings in 1999 (REC 1999; Vukmirović *et al.* 2001). This complex included a nitrogen processing plant, a refinery, a petrochemical plant and a vinyl chloride monomer (VCM) plant housing a large variety of hazardous chemical materials, including ethylene-dichloride, ethylene, chlorine, chlorine-hydrogen, propylene and vinyl chloride monomers. The complex was severely damaged resulting in the release of a mix of hazardous chemicals into the atmosphere, local watercourses (including the Danube River) and soil. Pollution from the damage to the industrial complex in Serbia extended across other parts of Central and Eastern Europe (Vukmirović *et al.* 2001).

In northern Iraq, the Al-Mishraq sulphur mines and the sulphur processing complex near Mosul were bombed in 2003 and 2016 (UNEP 2007a; UNEP and UNOCHA 2016) resulting in fires on both occasions. The complex was one of the world's largest producers of fertilizer, and manufactured agrochemicals such as sulphur, phosphate and potash and several by-products such as sulfuric acid and alum. Attacks on these infrastructures resulted in increased air, soil, ground and surface water pollution (UNEP 2005; UNEP 2007a; UNEP and UNOCHA 2016).

In eastern Ukraine, between 2014 and 2017, potentially hazardous coke and chemical plants, power plants and chemical-related industries experienced operational disruptions due to armed conflict. During 2016-2017, conflict-related damage was reported in several facilities including: the Avdiivka Coke and Chemicals Plant, Toretsk Phenol Plant, the Donetsk State-Owned Chemicals Plant and the Stakhanov Ferroalloy Plant. In 2015, a fire at the Avdiivka Coke and Chemicals Plant resulted in the emission of coke gas with high concentrations of benzene, toluene, naphthalene, hydrogen sulphide, mercaptan, hydrocyanic acid and ammonia (OSCE 2017).

From a short-term perspective, potentially the most significant risk to humans is the exposure to and inhalation of toxic industrial chemical vapours. The vapours can concentrate at incident sites but also spread over long distances from the emission source and propagate by meteorological conditions. Hazardous concentrations of toxic chemicals in the atmosphere can last from several hours to several days, and subsequent contamination of soil and water can last longer. Exposure and human health effects depend on the properties of the substance, the dose received and the underlying health of the individuals, but in extreme cases, death from exposure to chemicals can occur (OPCW 2019).

1.2 Destruction of fuel infrastructure leads to release of chemicals and pollutants

Incidents at oil wells and storage facilities can trigger fires releasing heat and a range of air pollutants, including air toxics[1] (e.g. polycyclic aromatic hydrocarbons - PAHs) and particulate matter, black carbon (BC) aerosols and a variety of gases. Oil and fuel spills are another common result of damaged oil and fuel infrastructure.

During the first Gulf War in 1991, hundreds of oil well fires burned uncontrollably in Kuwait and affected air quality on a global scale. Tolba and Saab (2008) reported that more than 600 oil wells were destroyed or set on fire, resulting in the daily release of up to 500,000 metric tons of pollutants that affected the air quality of surrounding states. Later Zhou *et al.* (2018) refer to more than 700 oil wells burning between February and November 1991, causing a high peak of atmospheric black carbon concentration and ground deposition as far away as the Tibetan Plateau.

The destruction of oil tankers and terminals resulted in 6 to 8 million barrels of oil spilling into the Persian Gulf while 25 to 50 million barrels of oil were spilled on land (Tolba and Saab 2008). The oil spills, in combination with heavy metals released into the Gulf, resulted in elevated bird mortalities and damage to important feeding habitats of many species; some animals still showed elevated levels of zinc and copper a decade after the incident (Lawrence *et al.* 2015).

During the 34-day war between Israel and Lebanon in 2006, the bombing of the El-Jiyeh power plant in Lebanon resulted in the release of 10,000 to 15,000 tons of oil into the Mediterranean Sea, affecting the majority (150 km) of the Lebanese coastline and partly extending into Syria (Tolba and Saab 2008). The spill resulted in the deaths of seabirds, marine invertebrates and the local flora, and it was presumed to have also killed fish and sea turtles (Hanson 2018). Tolba and Saab (2008 p. 167) state that *"given the heavy type of oil contained in the storage tanks, a considerable proportion sank within the vicinity of the power plant, where it smothered biota and significantly impacted the seabed."*

During the First Chechen War (1994-96) most of the federal fuel and energy complexes were destroyed, resulting in many micro-oil refineries sprouting up all over the republic (Klimzov 2015). These micro-refineries along with the other basic infrastructure used for fuel storage, transportation and refuelling were the major sources of pollution in the region (Brownfeld 2008). At the end of the war, the amount of oil hydrocarbons in the lower reaches of the Terek River was already more than 500 times the permissible limit (Zonn 2001).

Witmer and O'Loughlin (2011) highlight the damage to oil infrastructure by aerial bombing during the Second Chechen War (1999-2009). Refineries, oil wells and storage tanks were reported to have been targeted, resulting in significant oil spills and groundwater contamination. Around 30 to 40 per cent of the total area of Chechnya was estimated to be polluted by oil products, contaminating soil to depths of up to two meters in some locations (UNEP 2002). Surface water was also affected: around 20,000 tons of oil spilled into the Terek and Sunzha rivers flowing from Grozny and affecting water supplies (Ingold 2002; Solomon 2018). Prevailing air currents moving west from Chechnya carried the smoke from fires and caused a high degree of pollution of air and surface waters in the Republic of Dagestan (UNEP 2002).

1.3 Waste management systems become overwhelmed by solid household and military waste

Destruction caused by armed conflict leaves behind building and munition debris, military vehicles, as well as unexploded ordnance and landmines. Weapons and explosives contain materials, heavy metals and organic pollutants that contaminate explosion sites and leach into the wider environment. After past conflicts, environmental monitoring efforts have shown elevated levels of heavy metals, and experts have highlighted the potential health risks.

[1] Air toxics are defined by the U.S. Environmental Protection Agency as toxic or hazardous air pollutants (HAPs) that cause or may cause serious health effects such as cancer, reproductive effects and/or adverse environmental and ecological effects.

Depleted uranium and toxic substances in common explosives can cause skin irritation, kidney failure and increase the risks of cancer. Unexploded ordnance and land mines threaten peoples' lives and livelihoods, and pose additional risks of contamination of the environment by a range of chemicals for significant periods of time after a conflict has ended. They can hamper reconstruction and clean-up efforts and render land unusable for agriculture putting pressure on other natural resources that remain accessible. Abandoned and destroyed military vehicles also contain toxic components (e.g. batteries and fuel) that pollute the environment. Building debris presents hazards like fine dust and asbestos. Debris itself poses a physical hazard and a severe waste disposal challenge; however, debris may also contain materials that could be recycled in situ for reconstruction efforts.

Armed conflict can also disrupt waste management and waste treatment facilities and storages. This can lead to harmful contamination of soil and water. Unsanitary waste disposal and unsafe storage of hazardous waste can have severe and long-lasting impact on human health and the natural world.

1.3.1 Waste management systems

The common issue of breakdown of waste management systems is compounded by the fact that conflict-related activities themselves also create large amounts of waste including hardware and medical materials as well as day-to-day waste generated by military forces. Around 4.5 kilograms of solid waste was generated per service member per day during the military operations in Iraq and Afghanistan (Neuhauser 2015). During these conflicts, disposal methods for solid waste ranged from the burial of hazardous waste to disposing of it into sewers or local freshwater sources. However, Neuhauser (2015) states the most widely used method for waste disposal during conflicts was burn pits – well known for producing toxic emissions.

The types of waste burned in burn pits and unsanitary dumpsites include plastics, batteries and other e-waste, medical supplies, as well as human and animal remains. Populations exposed to toxic smoke generated by fire in these circumstances have an increased risk of respiratory diseases, cancer and adverse births outcomes (Neuhauser 2015; WHO 2015). Smoke from burning e-waste can contain benzene, dioxins, mercury and polychlorinated biphenyls. Research in the West Bank identified a relationship between e-waste burn sites and increased risk of childhood lymphoma (Davis and Garb 2019).

During the 16-year civil war in Lebanon, unregulated dumping (open dumps) and burning of solid waste were the main methods of disposal, especially in rural areas, which caused serious pollution issues (ELARD 2004). Many illegal dumps in and around urban areas were also an issue in post-war Bosnia-Herzegovina; where a wide range of wastes were dumped on roadsides, into riverbeds and lakes as well as into abandoned quarries and mines, including a five-hectare open pit lake 30 metres deep (Calo and Parise 2009 p.70).

Illegal dumping of waste including vehicles and unregulated electronic waste can result in leaching of contaminants to soil, ground and surface waters affecting nature and human health.

Solid waste management often remains weak for several years after conflicts cease. Often management efforts and resources are initially focused on other sectors such as health, water and jobs (Calo and Parise 2009). Existing local landfills are often adapted for hazardous military waste disposal, and they usually lack proper pollution-prevention measures. For example, waste disposal sites in and around Herāt, Kandahar and Kabul in Afghanistan became health hazards because of their location near civilian settlements (UNEP 2003). The inflow of humanitarian aid (e.g. food, clothing and medical supplies) can also exacerbate waste management issues, especially when it comes to household waste due to the excess of packaging and other plastics (Calo and Parise 2009).

1.3.2 Military vehicles use and waste

Military vehicles warrant attention in their own right because of the specific impacts they can cause during their operation, and when they are destroyed and become debris. Literature on the impact of debris generated by the destruction or abandonment and subsequent degradation of military vehicles (specific to the context of armed conflicts) is scarce. However, it is likely debris will cause environmental pollution and associated health risks, some of which may be similar to risks related to the remains of munitions and ammunition, and others may be specific to components of vehicles (e.g. vehicle batteries containing lead or other toxic compounds).

Spills of fuels and compounds used in maintaining vehicles are one type of impact generated during operation (Lawrence *et al.* 2015). Hydrocarbons and metals associated with military vehicle use can result in environmental exposure and persistence in the environment for long periods resulting in uptake by biota (Lawrence *et al.* 2015). Other debris associated with the operation of military vehicles include fuel deposits, grease, paint, batteries, tyres and cables, which can all result in harm to both flora and fauna (Clark and Jorgenson 2012).

Heavy military vehicles consume a lot of fuel and produce many hundreds of thousands of tons of carbon monoxide, nitrogen oxides, hydrocarbons and sulphur dioxide (Solomon 2018). This applies to both ground vehicles and aircraft. Concentrations of military aircraft in a particular area can result in air pollution with fuel additives that include ammonium perchlorate, polyvinyl chloride, lead stearate, polybutadiene and polyethylene; furthermore, jet exhaust gases contain nitrogen oxides (Edeko 2011). Aircraft navigation systems also contain nickel-cadmium batteries. Cadmium is a highly toxic substance that is known to cause cancer and affect various organs, and it can be released to the environment in helicopter crash sites (UNEP 2007b).

Warships are excluded from all major international environmental regulations and hence very few studies exist on the environmental impacts of their use and destruction (Bilgili 2020). The operation and maintenance of warships also generates waste. In addition to the emissions and pollution associated with shipping in general, this waste can also contain the pollutants associated with munitions, including metals, which can end up in the water, especially when vessels are destroyed (Bilgili 2020). During times of conflict, naval ships are often strategic targets for deliberate destruction, raising the risk of pollution. Destroyed naval ships can result in oil contamination and thus pose a risk to marine ecosystems, and during active conflict there are limited options for mitigation or salvage operations. For this reason, unmanaged naval vessels can be a source of pollution over extended periods of time, for example if oil and other compounds remain on board and leak as the ship degrades (Lawrence *et al*. 2015).

1.3.3 Munition debris

Armed conflicts use large quantities of munitions containing heavy metals and depleted uranium, as well as explosive chemicals, all toxic even in modest quantities. These weapon components and their impact on human health and the environment are described below.

Depleted uranium

Depleted uranium is a high-density by-product of the enrichment process needed to transform naturally occurring uranium to fuel used for power generation or weapons. It is around 40 per cent less radioactive compared with naturally occurring uranium and is considered mildly radioactive (UNSCEAR 2008). Its main form of radiation is alpha radiation that does not penetrate healthy human skin; however, it does have the potential to cause radiation damage if inhaled or ingested (IAEA 2022).

Depleted uranium has a higher density than lead and has been used in some munition to increase its penetrating power and as tank armour (Lima *et al.* 2011). Its use was reported in both Gulf wars, in Bosnia and Herzegovina, Kosovo as well as in Serbia and Montenegro (Briner 2010). Depleted uranium in missiles forms a dust cloud on impact that has pyrophoric properties and will ignite, forming an aerosol of depleted uranium oxides that can enter the body through inhalation. The amount of dust created in this way depends on the target, with more dust created on hard surfaces such as armoured tanks or concrete walls (UNEP 2007b).

Depleted uranium can cause localized sediment and soil contamination and can affect a range of both aquatic and terrestrial species. Lawrence *et al.* (2015 p.451) state "In mammals, uranium toxicity can be highly detrimental to development, brain chemistry, behaviour, and kidney function". The level of toxicity largely depends on the amount ingested, but it is especially dangerous to the liver. The chemical toxicity of depleted uranium is considered a more significant issue than the possible impacts of its radioactivity (UNEP 2007b; Briner 2010).

Explosives

The most used explosives are organic compounds containing nitrogen are dinitrotoluene (DNT), trinitrotoluene (TNT) and royal demolition explosives (RDX).

DNT exists in six forms and is used in the production of both ammunition and explosives; it is also one of the materials used to produce TNT (EPA 2021a). It is a contaminant often present in soil, groundwater and surface water at sites containing buried munitions. The release of DNT into water is a significant environmental concern since it can remain in water for long periods of time, leading to human exposure. Other means of exposure include skin contact and inhalation as well as potential ingestion. Prolonged exposure to DNT can cause symptoms like nausea, vomiting, headaches, methemoglobinemia, jaundice and anaemia as well as hair and skin discolorations (Lima *et al.* 2011; EPA 2021a). Furthermore, DNT shows acute toxicity and has been identified as a probable human carcinogen (EPA 2021a).

TNT, a synthetic chemical, is the main component of ammunition, accounting for a substantial portion of explosives-related contamination at sites of both active and former military conflicts. TNT tends to mostly remain in soils, in places where munitions were used or buried. Just like DNT, TNT can be absorbed by the skin, inhaled or ingested

(e.g. by consuming produce grown in contaminated soil), has been identified as a possible carcinogen and prolonged exposure can result in a plethora of possible symptoms, from skin and mucous membrane irritation to liver and kidney damage (EPA 2021b). TNT can have carcinogenic and mutagenic effects, and one TNT metabolite can cause blood poisoning (Lima *et al.* 2011).

RDX is a highly explosive, white crystalline solid commonly used in plastic explosives and as a filler in most types of munition compounds. Because of its low soil sorption, RDX frequently leaches into and from soil. In areas where RDX has been used it is a common groundwater contaminant and can also bioaccumulate in plants, potentially impacting herbivorous life (EPA 2014). Exposure can occur through skin contact, inhalation or ingestion of contaminated water. The ingestion of RDX primarily affects the nervous system and can result in symptoms like seizures, convulsions, nausea and vomiting (Lima *et al.* 2011). Very little information is available on how long-term exposure to RDX affects human health.

Phosphorus bombs have also been used in past conflicts and are munitions that consist of white phosphorus or its mixture with other substances, as well as a mechanism for igniting them (Voie *et al.* 2010). They can explode both in the air and on impact with the ground. White phosphorus looks like wax, is colourless or has a yellow tint, glows in the dark and has a pungent smell of garlic (Weapons Law Encyclopaedia 2022). A blast wave can scatter matter over an area of several hundred square meters. The combustion temperature exceeds 800 degrees Celsius. Burning is accompanied by thick and acrid white smoke and continues until the phosphorus is completely burned out or until the supply of oxygen stops. The substance causes severe burns in humans and can lead to a painful death (Atiyeh *et al.* 2007).

Heavy metals

Heavy metals and metalloids are commonly associated with debris from military conflict, being common components of ammunition, with lead (Pb) having historically been the main component of ammunition and grenades. In addition, antimony (Sb), barium (Ba), nickel (Ni), zinc (Zn), manganese (Mn) and copper (Cu) have been used in smaller quantities. All these metals, except for zinc, are toxic and harmful to human health and the environment (Lima *et al.* 2011).

Studies demonstrate that residues from ammunition storage facilities, as well as locations where ammunitions were discharged or demilitarized, have increased the risk of exposure and damage to the environment and human health (Lima *et al.* 2011). Furthermore, decomposition of metal military waste and especially ammunition (due to its lead sulphide coating) can take up to 70 years (Lima *et al.* 2011). Newer weapons might have different metallic components. The assessment of risks posed by toxic metals from weapons requires knowledge about the weapons used, as well as their composition and the volume of missiles, grenades and ammunition deployed and the existing environmental condition.

It is important to understand how these toxic metals interact with and move through different components of the environment, as well as understanding existing levels of these substances. Evidence exists from previous conflicts of elevated heavy metals concentrations in soil impacted by weapons. Al-Najar *et al.* (2015) reported soil pollution in craters by heavy metals after intensive airstrikes on agriculture land in Gaza.

Heavy metals are well-known environmental pollutants and many have harmful effects on human health and the environment. Through the process known as bioaccumulation, heavy metals become stored in animal tissue and accumulate through trophic levels in food webs, with predators having higher concentrations. In humans, heavy metals can cause a variety of health conditions dependent on the metal in question, including the increased risk of cancer and birth defects and can cause impaired brain development and other neurological problems (Lima *et al.* 2011).

Considerable literature is available on environmental and human health impacts of metals and heavy metals (which is beyond the scope of this literature review), but less information exists on examples of impacts originating specifically from armed conflict debris. Manduca *et al.* (2019) reported metals to have been found in wound tissues of direct victims of conflict, including cobalt, uranium, mercury, barium, titanium, strontium, vanadium, arsenic and cadmium; while cobalt, uranium, mercury, barium, cadmium, molybdenum and tungsten were present in bomb craters. The study, which had a small sample size, indicated that pregnant women living closer to unmanaged waste sites following armed conflict had elevated levels of metal concentrations (mercury, barium, cobalt and vanadium) and an increased risk of preterm birth and birth defects.

Unexploded ordnance and landmines

All weapons have a failure rate, leaving unexploded ordnance (UXO) behind as a particularly challenging remnant of war. The rate of UXO and its subsequent effect depends on a variety of factors including the weapon's age, the quality of design and conditions at the point of impact (ICRC 2022). UXO can remain a hidden danger for decades after a conflict ends – unexploded bombs from World War One are still being discovered and cleared up to this day.

Neuhauser (2015) highlights the danger of cluster bombs, which consist of a main canister containing a large quantity of sub-munition or bomblets. Upon release from the air or the ground, the canister breaks apart and spreads the bomblets over a large area. One canister can release more than 600 bomblets (UNEP 2007b).

Unexploded cluster munitions are usually dispersed over wide areas and usually close to civilian population centres, where they can remain for a long period of time and can blow up at any time. The danger of accidental detonation of unexploded cluster munitions increases over time, as the fuse mechanism starts deteriorating, and this type of unexploded cluster bomblets, due to their size and appearance, can resemble toys and cause a particular danger to children, hence create a high-risk environment post-conflict (Neuhauser 2015). Cluster munitions were used in Lebanon in 2006, and in Iraq (2003-2006), Syria (2012-2018), Sudan (2015) and Yemen (2015-2018). The UN Convention on Cluster Munitions entered into force in August 2010 and prohibits all use, production, transfer and stockpiling of cluster munitions. It has more than 100 signatories, however some of the world's largest military powers are not parties to the convention (UN 2008).

UXO and landmines are major risks in a post-conflict environment and continue to be a cause of death or serious injuries long after an active conflict has ended and a threat to public health. In non-urban areas UXO and landmines may contaminate large areas of land and leave it unfit for agriculture. Like other munitions, they may contain metals and other contaminants (see previous sections) that can contaminate the surrounding areas upon explosion.

The Organization for Security and Co-operation in Europe's (OSCE) Special Monitoring Mission to Ukraine reported on the devastating effects of UXO and landmines in eastern Ukraine during January 2018 to October 2019 (OSCE 2019). They established that the conflict had, contaminated 15,000 km² (about half the area of Belgium) with UXO and landmines that prevented the free movement of people and caused deprivation of livelihoods and posed a challenge for infrastructure repairs and maintenance. During their reporting period, they catalogued 133 casualties, including 34 deaths caused by UXO and landmines. A quarter of the casualties were children.

In urban areas UXO and landmines create challenges for clean-up and reconstruction and need specially trained personnel to be safely removed. This was reported as a challenge in Mosul, Iraq (UNEP 2017) and Lebanon (UNEP 2007b). The OSCE Special Monitoring Mission to Ukraine reported successful use of unmanned aerial vehicles for monitoring and inspection of sites contaminated by UXO (OSCE 2021).

Nuclear waste

In the past, there have been no major incidents of damage to nuclear power stations during conflicts that have led to significant radioactive contamination. The civil accidents at Chernobyl and Fukushima have not been reviewed. However, some sources reviewed mention incidents of damage to nuclear research sites and other sites containing radioactive materials and waste.

For example, nuclear reactors at the Al-Twaitha nuclear research site (20 km from Baghdad) were destroyed during the 1991 Gulf War, and barrels with radioactive materials were looted during the 2003 conflict (Al-Shammari 2016). Soil samples from the site and the surrounding areas were contaminated by caesium-137 and cobalt-60 (sources of gamma radiation), and the fuel fabrication facility on the site was contaminated with uranium-238 and uranium-235. A risk assessment of estimated exposure from air and food to uranium-235 and concluded that communities living in the vicinity of the reactor were at an increased risk of developing cancers (Al-Shammari 2016).

In Chechnya, several facilities with radioactive sources, including a radioactive waste repository (the Grozny Radon) as well as chemical plants, hospitals and universities that contained radioactive waste were either damaged or abandoned during the war, and the theft of radioactive materials such as radioactive cobalt from the chemical plants was reported (Menon and Kumar 2019). Brownfeld (2008) also mentions the release of radioactive waste material from a damaged chemical plant. The National Academy of Sciences (2007) reported that several ionizing radiation sources were found in urban areas of Chechnya, and there were reports of health symptoms connected to radiation poisoning including skin redness, oedema and bloodshot eyes as well as deaths because of radiation poisoning.

The impacts of radioactive contamination in Chechnya were compounded by extensive pollution from multiple types of pollutants – it was estimated that 40 per cent of Chechen territory did not meet the safe environmental standards for living (Vucinic *et al.* 2012). Most of the contamination of this territory was by oil spills (discussed in the previous section), but also from other contaminants including sewage from destroyed sanitation infrastructure and the radioactive waste discussed here (Brownfeld 2008).

Mines and tailings

A significant amount of heavy industry in eastern Ukraine is associated with mining. The OSCE (2017) highlighted that between 2014 and 2017 conflict had negative impacts on mining operations, and destruction of equipment and interruptions to electrical supply resulted in mines flooding, with some coal mines becoming completely submerged. Such flooding increases risk of ground and surface water pollution. Old mines that had been in use for waste storage were also affected, adding to the complexity of the situation. During the 2014 conflict, power outages were reported at most mines in the Donetsk and Luhansk regions of Ukraine, increasing the risk for groundwater pollution as water pumps could not operate to ensure the contaminated mine waters did not mix with ground or surface waters (OSCE 2017; Ministry of Environmental Protection and Natural Resources of Ukraine 2017[2]).

Flooding results in an additional hazard as colliery gases, such as methane, can rise to the surface and result in explosions and release of other gases such as radon. This risk is much greater during the active stages of a conflict. Radon presents an additional hazard where groundwater is used for domestic or agricultural purposes (OSCE 2017). Major mine flooding can reach surrounding areas, endangering nearby buildings, other critical infrastructure and contaminate groundwaters (Ministry of Environmental Protection and Natural Resources of Ukraine 2017[2]).

Structural damage to mine tailing dams can result in release of tailings water typically contaminated with a range of metals and flooding causes contamination of surrounding agricultural soils and drinking water sources as well as in the loss of ecological habitats, flora and fauna (Roche *et al.* 2017). As a result of damage due to shelling, the tailings pond of the Inkor and Co Research and Production Association of the Phenol Plant Coke and Chemicals Enterprise (Donetsk oblast), which contained 400,000 cubic meters of waste, failed causing pollution of local drinking water sources (Kryvyi Torets and Siverskyi Donets rivers) (OSCE 2017).

1.4 Demolishing critical infrastructure and urban areas creates health hazards

Conflict in urban areas destroys residential buildings and critical infrastructure such as electricity and water supply systems. Remnants from damaged buildings often become a waste problem and this waste can be hazardous and structurally unsafe. Not only does damaged electricity supply deprive people of light and heating, but also interrupts a whole range of other services such as communication and water supply. Direct or indirect damage to water infrastructure, including wastewater treatment leads to the potential increase in waterborne diseases as well as environmental degradation through nutrient saturation in rivers, lakes and the ocean.

1.4.1 Residential buildings

The sources reviewed for this report do not contain a lot of quantitative information on damage done to residential buildings specifically, but this impact is alluded to by several studies in the context of describing wider damage to urban environments. The environmental impacts include the impacts from mixed building and munition debris and potential harmful materials such as asbestos used in construction, as well as the knock-on impacts caused by displaced persons, including overcrowding. UNEP (2009) highlights that during the 2008-2009 hostilities in Gaza, 2,692 buildings (mainly homes) were destroyed. Al-Lami *et al.* (2019) reports that during the Iraq conflict, the city of Mosul was left with more than 10 million cubic meters of heavily damaged buildings, affecting soil, air and water pollution levels in the city.

In Raqqa, Syria, 90 per cent of infrastructure was destroyed in heavy bombardments (Malsin 2017), and Lubin and Saleem (2019) concluded that between 45 and 57 per cent of Aleppo was damaged during the war between 2011 to 2017.

The environmental and human health impacts of damage to residential buildings has not been specifically discussed in the literature (i.e. separate from impacts on other infrastructure), but these impacts must be considered as part

[2] Previously the Ministry of Ecology and Natural Resources of Ukraine

of the cause of human health and environmental deterioration and should be included of any post-conflict impact assessment. Damage to residential buildings not only creates a lack of shelter, but physical injuries and trauma due to loss of life, home and possessions. This has immediate physical and mental health consequences, together with a lack of sanitation and clean water access, disrupted food and energy supply, overcrowding of remaining shelters in the short term and displacement of populations.

1.4.2 Demolition debris

Bombing of urban areas and infrastructure leaves large quantities of rubble behind, and this constitutes a hazard of both chemical and physical types because hazardous materials are often mixed within the debris, or because the rubble itself poses a physical obstacle and/or risk of physical injury. This section briefly considers the potential impacts of fine debris (i.e. dust), and then focuses on impacts of larger debris and rubble which can also contain UXO, asbestos, heavy metals, a range of other pollutants and sometimes human remains. In both cases, possible hazardous substances within the debris are considered, including those resulting from fire, given that physical damage from bombing very often occurs with fire damage especially with certain types of ammunition (UNEP 2009). A further point to note is that debris accumulation in urban areas not only hampers recovery activities but also affects other services; for example, blocking the access for waste collection vehicles causing the accumulation of additional waste dumped by the local population (Calo and Parise 2009).

UNEP (2009) conducted a post-conflict environmental assessment after the hostilities in Gaza from December 2008 to January 2009, establishing that bombs and shelling resulted in large volumes of demolition debris. More than 2,600 buildings were impacted, resulting in an estimated 600,000 tons of demolition debris. UNEP (2017) conducted a rapid scoping mission to areas retaken from ISIL in Iraq in 2017, with Mosul being the main city in this area. The mission report estimated 11 million tons of demolition debris in the city.

Debris from factories and other industrial sites can be particularly hazardous in nature. Burning and destruction of factories, such as the Company for Carton Mince and Industry in Lebanon (UNEP 2007), generate significant amounts of ash which can contain dioxins and other chemical compounds. Another example was the destruction of the Al Arz Lilnasiej textile factory, Lebanon which resulted in spills of machine oils as well as other special fluids. Such enterprises can have significant impacts on the environment and hence need to be assessed.

The report by UNEP (2009) from Gaza did not differentiate between debris originating from industrial and residential buildings, but highlighted the potential presence of industrial chemicals, medicines and contaminants from fire caused by bombs. The report stated fire emissions and residues pollute both the air and remaining rubble with polycyclic aromatic hydrocarbons (PAHs) or dioxins and furans, depending on the building material. UNEP (2017) describes debris in Mosul as a serious safety hazard since it contains UXO, landmines and booby traps and asbestos buried in the rubble.

The health hazards posed by physical danger and toxic materials in rubble are amplified in situations where large-scale, well-coordinated, professional and safe clean-up and removal operations are not possible due to a lack of resources, lack of safe access and breakdown of governance. UNEP (2017) highlighted that in Mosul the clearing of rubble following the conflict was initially based primarily on ad-hoc and private initiatives.

1.4.3 Electrical infrastructure

Some of the most critical infrastructures for people's safety and wellbeing is that which supports electrical power such as electricity generating power plants, power lines and transformer stations. Because this infrastructure is a strategic target during conflict, damage is likely to occur, and it can have significant impact.

The consequences of damage to electricity infrastructure can extend beyond the negative impacts of loss of power to parts of the population. Sowers and Weinthal (2021) report that, from 2010 to 2014 in Yemen, there were over 150 recorded attacks on energy infrastructure, including on gas and oil pipelines as well as electricity installations. One example is from eastern Ukraine in 2014, where the destruction of a bridge as well as power transmission lines completely isolated the Luhansk Thermal Power Plant from the national power grid (OSCE 2017). As a result, the power plant had to independently regulate its power grid frequency using high-sulphur and high-ash coal, deteriorating the air quality in the region. In Serbia, 150 tons of toxic pyralene transformer oils were released from a damaged station in Belgrade and leaked through a canal system, reaching local streams and rivers (REC 1999). Due to the use of Polychlorinated Biphenyls (PCBs) in transformers, when these are damaged they can pollute waterways with a small volume affecting millions of litres of water (REC 1999, p.12). PCB exposure can have adverse effects on the liver, kidney, endocrine system and neurodevelopment, and has been associated with diabetes mellitus (Faroon and Ruiz 2016).

1.4.4 Water and wastewater treatment facilities

One of the most vital forms of infrastructure in urban areas is that related to drinking water supply (water grids, pipes and pumping stations). Damage to water supply infrastructure and damage to infrastructure for wastewater treatment, can lead to contamination of the drinking water supply. Contamination of water supplies due to damaged water infrastructure is a recurring theme in studies of the impacts of conflict.

Sowers et al. (2017 p.9) describe an incident in 2016 in Syria, where government forces bombed a water pumping station supplying a quarter of a million people in eastern Aleppo.

UNEP (2009) describes that during 2008-2009, the Gaza wastewater treatment plant (Al Zaitoun) was damaged and more than 100,000 m³ of wastewater and sludge spilled in nearby agriculture land. Schillinger *et al.* (2020) describe another specific example of damage to sewage lines and a wastewater treatment plant in Israel during the 2006 Lebanon War, where large amounts of sludge were deposited directly into the Mediterranean Sea. As a result of the civil war in Lebanon, the existing sewage networks, especially in Beirut, were damaged, and the intermittent distribution of water enhanced the possibility of municipal water contamination, and the groundwater supplies in many areas of the country deteriorated (Khair 1994).

Damage to the Al-Rustamiyah wastewater treatment plant in Baghdad during the 1991 Gulf War led to the release of approximately 300,000 m³ untreated sewage into the Tigris River every day, a situation that was prolonged due to sanctions imposed on Iraq that hindered the import of spare parts for repairing the damage (Tolba and Saab 2008). During the recent conflict in eastern Ukraine, multiple disruptions have been reported in the operation of both regional water supply and water disposal systems and facilities, and incidents of the accidental discharge of pollutants into bodies of water (OSCE 2017).

The environmental consequences and human health impacts of wastewater and sewage spills are extensive. Damage that leads to contamination or interruption of established safe drinking water supply, and/or to loss of safe disposal and treatment of sewage and other urban wastewater, carries significant risks to human health from exposure to pathogens. Several examples illustrating these risks were available in the sources reviewed here (Sowers *et al.* 2017; UNEP 2009; Sowers and Weinthal 2021). In 2018, cholera outbreaks were reported in Yemen caused by shortages of clean drinking water, breakdown of sanitation systems and health services (Al-Mekhlafi 2018). It was estimated that half the population relied on unsafe sources in Yemen compounded by a lack of monitoring capacity (Sowers and Weinthal 2021). While in Gaza, diarrhoea cases increased and public health laboratories in Gaza noted that 12 to 14 per cent of water samples collected immediately after the hostilities were contaminated with coliform bacteria, including those indicative of sewage contamination (faecal coliforms) (UNEP 2009).

Warnings about disease outbreaks after critical infrastructure was damaged were also highlighted in Donetsk, Ukraine after a water filter station stopped operating (UN OCHA 2018). At the time of writing, eastern Ukraine is an area of concern due to potential outbreaks of disease from limited access to sanitation and access to safe water (UN OCHA 2022).

Damage to water supply and treatment infrastructure can also lead to the release of chemicals used in water treatment itself, which can be harmful to human health and/or the environment when released in an uncontrolled and concentrated manner. Zwijnenburg *et al.* (2019) point out that attacks on water filtration stations during recent conflict in eastern Ukraine have not only hindered access to drinking water for hundreds of thousands of civilians, but also pose a risk of the release of substantial amounts of chlorine, for example.

In terms of environmental impacts, Baba *et al.* (2021) studied groundwater resources and quality in Syria and concluded that conflict was one of the major sources of groundwater contamination. Direct dumping or spills of sewage into aquatic ecosystems (as reported in Lebanon in 2006 mentioned above, where sewage was dumped directly into coastal waters of the Mediterranean) can lead to nutrient overload of aquatic ecosystems, which can lead to harmful algal blooms, eutrophication and dead (anoxic) zones. The nutrients in sewage are not the only issue, however, as urban wastewater contains a mix of contaminants. The release of effluent from the Gaza wastewater treatment plant resulted in agricultural land and groundwater being contaminated with heavy metals (UNEP 2009). In conflict zones, the contamination load of inadequately treated wastewater (sewage and surface water runoff) will be compounded by the presence of contaminants from debris, and from contamination released from damage to other infrastructure amplifying the impacts of the loss of effective wastewater treatment facilities.

1.5 Destruction of agricultural assets and infrastructure has a ripple effect beyond the boundaries of a conflict zone

Damage to irrigation infrastructure and the destruction and contamination of agricultural land, including through deliberate placement of land mines, disrupts agricultural productivity and renders land unavailable for food or feed production. It also increases the risk of chemicals being taken up into food. This has direct impact on peoples' food security and livelihoods, exacerbating and prolonging hardship, contributing to pressures that lead to displacement of populations and potential disruption of international food supply chains.

The agricultural sector is of strategic importance for meeting basic human needs, which extends well beyond the geographical boundaries of conflict areas themselves. Impacts of conflict on agriculture are mentioned with relatively high frequency in the literature.

Several examples of impacts on agriculture relate to the impacts of the types of pollution that have already been discussed in earlier sections, including heavy metal contamination of soil from munitions. The impact from mine water after flooding and release of tailings water on surface and ground waters can also impact agriculture. Due to heavy metal contamination, thousands of hectares of arable land near the border between Romania and Yugoslavia became unfit for agricultural use (Edeko 2011). A study by Vidosavljević *et al.* (2013) found that the mean values of copper, zinc, nickel, lead, mercury, phosphorus and barium in agricultural soil samples from areas of high combat activity in Croatia were higher than in low combat activity areas.

Prior to the current conflict, the OSCE (2017) warned that the disruption to the pumping out of water at the Pervomaisk and Holubovsk mines in eastern Ukraine may result in the outflow of these mine waters into agricultural lands. Depending on the type of pollutants present in freshwater used in agriculture, experts point out the issue of the possible knock-on effect of salinization of agricultural land, leading to reduced crop productivity not just within the area directly affected by conflict, but potentially as a transboundary issue if the contaminated water flows to neighbouring countries.

A further serious risk to agriculture is posed by UXO, landmines, physical effects from bombing and the movement of military vehicles travelling over crops (Edeko 2011). In vulnerable environments, combined impacts on soil can cause long-term effects on nature, exemplified with damage caused during the first and second world war that are still negatively impacting the environment (Broomandi *et al.* 2020). Cumulative impacts (physical destruction, pollution and presence of explosives) can have long-term consequences, even in the event of a comprehensive demining of and disposal of munitions (OSCE 2017 p.13).

Conflict-related decreases in agricultural productivity is another influence, where land is abandoned due to reduced productivity and income, leading to poverty, loss of income, food insecurity and displacement (UNEP 2020). Again, interconnected chains of cause and effect can be complex, and impacts can be cumulative. For example, infrastructure damage can lead to water scarcity, reducing productivity or leading to the use of contaminated water. At the same time, the loss of some agricultural land to contamination and physical damage can lead to more intensive use of pesticides and fertilizers in remaining areas, further contaminating soil and groundwater (UNEP 2020).

Agricultural productivity can be the deliberate target of attacks and sabotage. Snyder (2020) describes how the Islamic State of Iraq and the Levant (ISIL) in Iraq deliberately destroyed rural irrigation infrastructure (water tanks and pipes), contaminated irrigation water supply with oil and contaminated or blocked wells with rubble, oil and other foreign objects. This was combined with other deliberate blockages of irrigation channels, the destruction of water pumping equipment (cables, generators and pumps) and the theft of pumps and other valuable components in a deliberate targeting of the rural environment underpinning Yezidi livelihoods. This had severe knock-on effects on the environment and food security. The loss of irrigation led to the destruction of trees and crops with subsequent loss of livestock.

Disruption of agricultural productivity can have impacts that cross international borders by disrupting global food supply chains and affecting food security globally. This is of particular concern when conflicts break out in areas that produce large amounts of export crops, as is the case in Ukraine. Although beyond the scope of this review, such disruptions, and their impact on food security as well as the global economy can severely impact security and stability globally and requires continuous monitoring and analysis.

1.6 Nature is a forgotten victim of conflict

Military actors often clear vegetation or otherwise disrupt ecosystems, to remove cover for enemy combatants, or make areas uninhabitable and force local populations to leave. This method can have major impacts on the land, water as well as the flora and fauna. Local communities reported the use of such tactics during Sudan's civil war (Tolba and Saab 2008) and in Iraq where wetlands were drained (Hanson 2018).

Security measures can also cause environmental alteration and degradation during land clearance for military bases, outposts, bypass roads and buffer zones (UNEP 2020).

Other conflict-related impacts on protected areas and important natural habitats are incidental. In Iraq, the movement of thousands of military vehicles, intensive fighting and air bombardments caused widespread and locally severe degradation of fragile desert ecosystems which could take many decades to recover (UNEP 2007). Some of these impacts extend over large distances, with rivers carrying pollution downstream.

In Chechnya, pollution (including noise) arising from the conflict had a substantial impact on the fauna in the region, affecting animal migration and destroying habitats. For instance, when the conflict spilled over the Chechen border, to the Dagestan republic, a significant loss of fauna in broad-leaf forests was observed (UNEP 2002). The migration of animals, especially large mammals, and predators, to neighbouring republics and Georgia was observed not only in conflict zones, but also around the bordering territories. As stated in the 2002 Caucasus Environmental Outlook, *"the number of wolves has significantly increased in the areas of Dagestan bordering with Chechnya, and their attacks on cattle have become more frequent"* (UNEP 2002 p.73). In some areas, the increased numbers of migrating animals resulted in the intensification of illegal poaching.

Several forest fires occurred in areas of Georgia during the 2008 conflict because of military activities. A 2008 rapid post-conflict study carried out by the OSCE and UNEP found that fires in forests increased instances of flooding, landslides and mudslides, especially in mountainous areas. Forest fires also affect nature due to the loss of wildlife habitats and some types of trees, which when weakened by fires, attract harmful pests that can proceed to attack surrounding healthy forests.

The example from Georgia illustrates that damage to nature can have indirect and follow-on impacts. Noise pollution caused by aerial assault can affect wildlife; it can have direct effects such as negative impacts on hearing abilities (e.g. eardrum rupture) in some species as well as secondary effects such as impediments in behaviour and population decline (Lawrence *et al.* 2015). Furthermore, aerial assault weapons can destroy habitat and wildlife and destabilize soils.

Indirect impacts are often mediated through socio-ecological connections, such as interaction between environmental degradation and the degradation of human systems of governance and/or changes to human behaviour patterns that result from conflict. Snyder (2020) describes that a loss of energy security drove deforestation during the conflict in Syria as trees were cut down for firewood and charcoal production, exacerbating deliberate forest fires and cutting down of trees as a way of targeting armed groups hiding in the forest. Snyder (2020) analysed deforestation using a time series of satellite images and estimated that Syria lost 20 per cent of its tree cover between 2012 and 2019.

The Ministry of Environmental Protection and Natural Resources of Ukraine (2017) reported the conflict in eastern Ukraine affected around 60 protected sites. Forest reduction in eastern Ukraine, due to both fires and illegal logging, has had major negative impacts on *"on the field-protective, soil-protective, water-protective, and recreational functions provided by forests and green spaces"* (OSCE 2017 p.13). The conflict affected biological diversity with reductions in rare animal and bird species, due to both mass poaching as well as habitat destruction (Ministry of Environmental Protection and Natural Resources of Ukraine 2017).

1.7 Environmental governance and management issues

Governance and law enforcement tend to be disrupted in war and conflict zones. Environmental laws, policies and regulations are often not adequately enforced. Protected areas and sensitive ecosystems suffer from combat manoeuvres and deliberate tactics to completely remove vegetation – examples include deliberate forest fires to remove enemy cover and the destruction of fragile desert ecosystems due to the movement of thousands of military vehicles. Damaged and disrupted waste management systems lead to inappropriate disposal of hazardous waste, including the burning of hazardous materials, putting health and environment at risk. Limited law-enforcement capacity can enable environmental crime, for instance illegal extraction of timber or minerals. The drivers and consequences of institutional and governance breakdown are multifaceted and manifold and were not reviewed comprehensively in this report.

Institutional and governance breakdown during wars means that environmental laws and practices are commonly unable to be implemented, conservation projects are suspended and protected areas often become part of the battlefield (Hanson 2018). Past conflicts in eastern Ukraine have resulted in the damage of roughly 60 natural protected areas, resulting from reduced staff, redirected funding and limited co-ordination which affects conservation and preservation efforts (OSCE 2017 p.13).

Conflicts can also have a detrimental impact on the capacity of national institutions to maintain environmental management and address environmental issues (UNEP 2020). This can also have negative impacts on civilian infrastructure maintenance (wastewater treatment facilities and solid waste management). In Gaza, for example, limited and disrupted institutional capacities combined with a shortage of energy and waste processing infrastructure has led to the contamination of soil, groundwater and the Mediterranean Sea by wastewater and solid waste (UNEP 2020).

The breakdown of institutions and governance can not only amplify existing impacts but can also create its own impacts. This is often the case for waste management which can amplify and be a driver of environmental degradation (UNEP 2007b).

1.8 Gender and social inclusion considerations in conflict environmental assessment

Gender and the environment profile in a peaceful context is well established. However, the gender and environment nexus in conflict related settings where the focus is on survival and the protection of women´s rights is less well understood. It is known that a changing climate affects everyone, but the world's poorest and most vulnerable populations often bear the brunt of its adverse outcomes. These outcomes are further heightened in times of conflict and unrest. The resulting environmental pollution and contamination with hazardous substances, like chemical spills and soil pollution, present differentiated risks to women, men and children in general and to women at the reproductive age and pregnant women in particular. Conflicts further stagnate efforts towards a green and sustainable economy and may erase progress made in the past. Environmental degradation such as natural habitat loss that has been impacted by the latest phase of the conflict in Ukraine is expected to disproportionately affect vulnerable groups of the society.

Issues such as outmigration and internal displacement, gender-based violence, including sexual violence and other forms of violent behaviour, are elevated during conflicts leading to various damaging forms of health outcomes (UN 2022b). Environmental degradation and health hazards have society-wide consequences, but these risks are most profound in vulnerable groups (UNEP 2019). Research also highlights the unique post-conflict challenges that women face (Puechguirba 2021).

In Ukraine, internal displacement and outmigration have been witnessed on an unprecedented scale. At least 1.5 million people had already been displaced after conflict began in the eastern Ukraine in 2014 (UNOCHA 2019). In August 2022, the United Nations High Commissioner for Refugees (UNHCR) estimated more than 6.9 million people migrated from Ukraine across Europe (UNHCR, 23 August 2022). The displacement has disproportionally affected women, children, older persons and persons with disabilities who seek safe shelters for survival (OHCHR 2022). The relationship to this and environmental change needs to be considered.

Finally, the vulnerability of women in conflict settings often jeopardize the vision that women play an equal role in society. Conflict also increases the number of those with disabilities due to injury. During and after conflicts, proactive interventions around natural resources, environment and climate change can provide significant opportunities to empower women politically and economically, and to strengthen their contributions to conflict prevention and peacebuilding in conflict-affected countries (UNEP *et al.* 2013).

1.9 Cumulative impacts - a necessary consideration for conflict environmental assessment

Cumulative impacts occur when multiple pressures coincide. An example is described in the above section on agriculture, where productivity is affected by the physical damage through military manoeuvres and explosives, the direct and indirect contamination of soil with multiple pollutants, the loss of agricultural land through contamination with explosive remnants (UXO and land mines) and the destruction of irrigation infrastructure.

Another example is the human health impacts of damage to water supply infrastructure, which need to be viewed in the context of cumulative effects from multiple pressures faced by people affected by conflict.

Looking specifically at pollutants, cumulative pollution impacts can arise both when a mix of hazardous material is released into the same environment (e.g. in the example of the Pancevo industrial complex) and when the same type of pollutant is released from multiple sources (e.g. heavy metals leaching into the environment from munitions debris as well as from damaged industrial sites).

Existing conditions have a bearing on the severity and type of impacts caused by particular types of damage. Local conditions such as soil porosity will affect how oil spills move through the environment. Pre-existing contamination, hazards or fragile infrastructure from previous conflicts (e.g. unregulated refineries, unsanitary landfills and weak environmental policy) will clearly affect the severity of any additional damage. Cumulative impacts can include impacts from pre-existing sources of contamination, and this can make assessment of impacts difficult, especially in cases with baseline information gaps. For example, World Bank data (2017) shows that the air quality in Syria has been unsafe due to elevated levels of fine particulate matter. In 2015, they show the annual mean concentration of particulate matter (PM2.5) to be 44 $\mu g/m^3$, which significantly exceeds the annual mean maximum limit set by the World Health Organisation at 5$\mu g/ m^3$ (WHO 2021). Poor air quality is a known risk for diseases such as ischemic heart disease, stroke, chronic obstructive pulmonary disease, asthma and cancer (WHO 2021). However, this type of atmospheric contamination can be generated by activities unrelated to conflict, and many places in the world have unsafe levels of this kind of air pollution without being in a conflict zone and which conflict could exacerbate.

1.10 System dynamics amplify the impact of conflict

Environmental and human health are connected, and both depend on well-functioning and balanced socio-ecological systems for their maintenance. Armed conflicts significantly disrupt these systems by simultaneously putting pressure on multiple human and environmental receptors. Humans are killed and injured while infrastructure and natural habitats are physically destroyed and contaminated through actions using instruments and weapons of conflict. Each of these immediate impacts triggers a chain of indirect impacts that meet and interact with each other, creating cumulative effects and feedback loops that can amplify the magnitude, scale, complexity and longevity of impacts on nature and human health.

The literature review summarized in this report illustrates some of these system dynamics with specific examples, such as the impacts of power outages described in the section on damage to energy infrastructure, and the complex human-environment cause-effect chains described in the section on agriculture. These examples illustrate that system linkages exacerbate cumulative impacts, because the consequences of immediate, direct damage from armed conflict create knock-on effects that create a series of additional pressures on the system - damage to energy infrastructure creates fuel shortages that impact directly on people, and that also affect the operation of water infrastructure, creating an additional impact on people (Sowers and Weinthal 2021).

Sowers *et al.* (2017) stress the widespread scale of infrastructure destruction in Syria, where the cities of Idlib, Hama, Homs, Aleppo, Deir Ez-Zor, Dara´a, Tadmur, Raqqa and Damascus and surrounding towns were destroyed along with critical infrastructure. Most of the infrastructure went out of service and has not been restored, which means that environmental pressures derived from unsound and ad-hoc solutions such as burning waste are proving to be persistent (Seifan and Alhosain 2021). Increased overall poverty is another vector of long-lasting environmental pressures.

System dynamics can also turn the effect of one impact into its cause (re-enforcing or a positive feedback loop). Environmental degradation, especially when exacerbated by weak governance, can contribute to social tensions, for instance over land and water resources, leading to more conflict. Some scholars have argued that environmental degradation in Syria served as both a trigger for, and consequence of armed conflict. Gleick (2014) describes conflicts

over water resources in the same region with heavy droughts and water shortages during the civil war that began in 2011. These relationships are highly complex, however, as Daoudy (2020) points out in her work on the origins of the Syrian conflict.

Another example of a positive feedback loop is from Chechnya, where the destruction of energy infrastructure and the breakdown of governance created conditions in which illegal oil trade was able to take place, and this illegal oil trade formed the financial base of Chechen separatists (Kilmzov 2015).

Deliberate actions can also include potentially unintended consequences affecting both short term and long-term environmental outcomes. For example, the consequences of sanctions placed on Iraq included the difficulty of importing spare parts for the rehabilitation of the Al-Rustamiyah wastewater treatment plant in Baghdad, which during the 1991 Gulf War released around 300,000 m^3 of untreated sewage into the Tigris River every day (Tolba and Saab 2008). Sanctions thus inadvertently prolonged and intensified environmental degradation, with downstream impacts on areas and peoples already severely affected by conflict and environmental degradation.

Accelerated reconstruction can cause significant environmental impacts, requiring large quantities of metals, cement and other construction materials to rebuild cities and city infrastructure potentially impacting other aspects of the environment such as nature and biodiversity from resource extraction. The impacts of post-conflict recovery warrant further attention but were beyond the scope of this work.

The information sourced for the review has helped establish existing environmental and human health conditions of Ukraine prior to February 2022, including the quality of environmental governance. An overview of ecological impacts, potential hazardous industries, power generation facilities, fossil fuel installations and mining activities has been undertaken to aid this effort and to inform any future assessments.

Part II

Review of Current Issues and Incidents to Inform Environmental Assessment

Information on environmental impact incidents in Ukraine outlined in the following sections has been gathered from a variety of national and international sources, including national authorities, media reports, national and international civil society groups and international organizations, including UN partners. Where relevant, information from social and other media outlets has been cited. While these reports require further verification and validation, they do assist in understanding the situation on the ground and support planning for future assessments.

2.1 Ukraine: context and country profile

Ukraine is a country in Eastern Europe, bordering Belarus to the north, Poland, Slovakia and Hungary to the west, Romania and Moldova to the southwest, the Russian Federation to the east and northeast and with a coastline along the Black Sea and the Sea of Azov to the south and southeast, respectively (EB 2022). It is the second-largest European country (600,000 km²) and has a population of approximately 43 million people (World Bank 2022b).

As of 1 January 2021, approximately 29 million people lived in urban areas of Ukraine, while the rural population exceeded 12.6 million. In particular, the population of Kyiv, Kharkiv, Donetsk, Lviv and Odessa agglomerations exceeded one million people each, while the population of other oblast centres (except Uzhgorod in Zakarpatska oblasts) exceeds 200,000 (Statista Research Department 2022).

The main economic sectors in Ukraine are agriculture, extraction of mineral resources and chemical industries. It is one of the world's largest producers of sugar beets and sunflower oil and has one of the highest outputs of grain and potatoes in Europe. In 2021, Ukraine's major agricultural export products were corn, sunflower seeds, sunflower oils, wheat, soya, rapeseed and fertilizers (FAO 2022a). Oilseed is the second most important subsector in Ukrainian crop farming. It also has a considerable livestock sector.

Ukraine's rich mineral resources (especially iron) form the basis of a large iron and steel industry, and iron ore coal and manganese are among the most important export products. Other minerals include titanium and bauxite. Coal mining is an important industry in Ukraine, with a main use of fuelling thermal power stations. Ukraine depends on fossil fuels and nuclear power for electricity, with hydropower accounting for less than 10 per cent. Despite rich coal deposits, Ukraine also imports oil and gas to meet its energy needs (EB 2022).

The country has heavy industries producing a range of goods including trucks, railway locomotives and freight cars, turbines and electric generators. Its chemical industry includes production of coke, mineral fertilizers, sulfuric acid, synthetic fibres, caustic soda, petrochemicals and pesticides (EB 2022).

Ukraine has various longstanding environmental problems. Historically the combination of rapid industrialization, intensive farming and lack of pollution control led to severe environmental degradation and pollution, which remain a challenge today (Ministry of Environmental Protection and Natural Resources of Ukraine 2022a). Coal burning industries in the east emit sulphur dioxide, hydrocarbons and particulate matter, creating serious air pollution. Several of the major rivers are polluted by agricultural runoff of fertilizers and pesticides, and household wastewater due to poor treatment. Pollution is also reported in the Sea of Azov and the Black Sea with a corresponding reduction in fish catches (EB 2022).

Governance of environmental issues in Ukraine is outlined in Annex I. The Ministry of Environmental Protection and Natural Resources is the main government institution responsible for the formulation and implementation of environmental policy in the country. The Ministry also supervises the work of the State Agency of Water Resources, State Agency of Forestry Resources, State Geological Survey Service and State Ecological Inspectorate of Ukraine. At the oblast, district or municipal administrative levels, special departments exist to implement the ecological policy at the local level.

Women and children comprise some 90 per cent of refugees, and 60 per cent of the internally displaced population are female, hence it is also important to understand the conflict-environment-gender nexus. A rapid gender assessment in Ukraine shows that the negative environmental impacts of the conflict – particularly on water, food and energy supplies – are adversely affecting women and girls. Data from 2021 shows that 37.5 per cent of female-headed households in war-affected areas experienced moderate or severe levels of food insecurity compared with 20.5 per cent of male-headed households. Impacts are disproportionately felt by people with intersecting vulnerabilities, including ethnic minority groups such as the Roma, displaced populations, pregnant and breastfeeding women, disabled populations and the elderly (UN Women and Care International 2022).

Women are, however, critical agents of change for the recovery and restoration of the environment. Women possess specific knowledge of key environmental sectors linked to their gender roles, have distinct social networks for communication of environmental plans and offer unique leadership and technical skillsets.

2.2 The chemical industry: chemicals management and issues

2.2.1 Existing information on the chemical industry and chemicals used in conflict

Ukraine's chemical industry has been and remains an important part of the Ukrainian economy, contributing three per cent to the national GDP. It accounts for 9 to 10 per cent of the industrial production. The domestic market of chemical products in Ukraine was estimated at USD10.6 billion in 2020 of which 74 per cent was imports and 26 per cent domestic production (Media report, Ekonomicheskaya Pravda, 6 June 2022).

The list of chemical enterprises of the State Emergency Service of Ukraine in 2021 shows 609 industrial facilities stored or processed more than 219,000 tons of toxic chemicals, including 3,200 tons of chlorine and 177,800 tons of ammonia.

Big industrial cities have the highest density of chemical industry including Chernihiv, Sumy and Shostka in the north, Cherkassy, Shebelinka, Kremenchug, Rivne and Bila Tserkva in central Ukraine, joint agglomeration of Severodonetsk, Rubezhne, and Lisichiansk in Luhansk oblast in eastern and Pivdennyi in southern Ukraine.

Some are connected to the ammonium pipeline Tolyatti (RF) – Odessa (UA) with a total length of 2,147 km. Roughly half of this pipeline (1,018 km) is in Ukrainian territory. Most of these locations (except Cherkassy and Pivdennyi in Odessa oblast) were in areas of heavy shelling during the first month of the conflict. The enterprises in Luhansk oblast are in the eastern part of the country with continuous hostilities.

The chemical industry requires high water consumption, so most of the plants are located near rivers or water reservoirs. The main cities with chemical industries are Cherkassy and Kremenchug; directly located on the Dnieper river, the cities of Chernihiv and Bila Tserkva, situated on the banks of the Dneiper river's major tributaries, and Luhansk oblast situated near the Seversky Donets river. The ammonium pipeline endpoint is in the port of Pivdennyi, Odessa. In the west of the country, the city of Kalush (Ivano-Frankivsk oblast) and several other locations along the Dniester River are the major centres of chemical industry.

The FAO ranks Ukraine to be one of the world's biggest pesticide consumers (around 100,000 metric tons per annum). Pesticides are imported from China and the European Union among other suppliers. Local producers are also manufacturing pesticides from imported active ingredients, pouring them from drums into smaller containers ready for local agrochemical use.

An estimated 8,230 tons of obsolete pesticides were stored across the country in 2020 (Ministry of Environmental Protection and Natural Resources of Ukraine 2022a). These pesticides can no longer be used for any purpose (FAO 2022b).

Meanwhile, the waste generated from the chemical industry amounts to 1,482,200 metric tons. At present, Ukraine does not have appropriate technologies nor capacity to treat or dispose of obsolete pesticides or other toxic chemicals. Pesticides were exported for disposal until 2014, then stopped and media reports suggest export resumed in 2020. The quantity of obsolete pesticides (OPs) stored per province/oblast is shown in Table 1.

Table 1 Quantity of obsolete pesticides and places of their storage in the region of Ukraine
(The Ministry of Environmental and Natural Resources of Ukraine 2020).

Region	Quantity of Warehouses	Qty of OPs, tons
Vinnytsia oblast (excluding Dzurinsky toxic chemicals landfill)	133	876.30
Dzurinsky toxic chemicals landfill	1	2,115.00
Donetsk oblast	4	14.90
Zhitomir oblast	128	598.50
Zaporizhzhia oblast	51	252.71
Kyiv oblast	24	298.94
Luhansk oblast	7	36.50
Mykolaiv oblast	6	226.87
Odessa oblast	80	558.85
Poltava oblast	27	61.83
Rivne oblast	28	46.82
Sumy oblast	60	535.31
Ternopyl oblast	5	12.78
Kherson oblast	18	1,796.38
Khmelnytskiy oblast	11	253.52
Cherkassy oblast	15	279.06
Chernihiv oblast	52	266.00
Total	**650**	**8,230.27**

No information is available about any large-scale incident in the ready-to-use nor obsolete pesticides storage facilities at the time of this report.

2.2.2 Classification of chemical hazards in Ukraine

OPCW divides chemicals with possible critical impact on humans and environment into two major groups: Toxic Industrial Chemicals (TICs) and Chemical Warfare Agents (CWAs). CWAs are defined by OPCW (2022), while examples of common TICs are listed by the Occupational Safety and Health Administration of the United States Labor Department outlines the most common TICs (OSHA 2022).

Two major categories of hazards were outlined in chemical security training materials provided by the OPCW on 9 June 2022:

- chemical hazards (significant contamination of soil and ground water and air pollution with severe impact on human health - carcinogenic and mutagenic effects, reproductive hazards, effects on lungs or blood, corrosion activity, reactivity in case of impacting on human health)
- possible physical danger (flammability and explosion hazard)

CWAs are toxic chemical compounds that can be used as main components of chemical weapons of mass destruction to contaminate territory and water. The main ways of spreading CWAs are by explosion, aerosol and smoke.

The OPCW (2022) classifies CWAs in terms of:

- their volatility as unstable (phosgene, hydrocyanic acid) or stability (mustard, lewisite, VX)
- the impact on a human as (i) leading to lethality (sarin, sulphur mustard), or (ii) leading to temporary disability (chloroacetophenone); or (iii) leading to irritation (adamsite); or (iv) used for training purposes (chloropicrin)
- the rate of impact: (i) fast-acting (sarin, soman, VX); or slow-acting, with a period of a so-called latent action (sulphur mustard, phosgene, adamsite)

2.2.3 Incidents with release of toxic industrial chemicals

By June 2022, the Operational headquarters at the State Environmental Inspectorate of Ukraine (2022c) had reported at least seven confirmed incidents of release of TICs caused by military activities (Table 2).

Table 2 Registered incidents of release of TICs according to the operational headquarters of the State Environmental Inspectorate

Industrial Site	Location	Date	Description of the Incident
Coke Plant	Avdiivka	March 13, 2022	Large fire caused by shelling.
Sumy Khimprom	Sumy	March 21, 2022	Release of ammonia; the gas cloud covered an area of 2.5 km^2.
SOE Khimprom	Chernihiv	March 23, 2022	Depressurizing of a tank with liquid ammonia (12 tons), followed by a fire in the working premises.
Scientific–Industrial Enterprise Zorya	Rubezhne, Luhansk oblast	April 5, 2022	Release of the 80 tons of nitric acid caused by the hit of storing tank. The radius of the affected area reached 3.5 km.
Severodonetsk Azot	Severodonetsk	May 5, 2022	Heavy shelling in the one of the largest ammonia producers in Ukraine.
Azovstal	Mariupol	May 29, 2022	Release of liquid ammonia due to the damage of pumping station. The radius of the affected area reached 2.5 km.
Ammonium pipeline Tolyatti – Odessa	Nearby town of Bakhmut in Donetsk oblast	May 30, 2022	Release of technical (low pressure) ammonium from a non operational by-pass pipe. At least six communities were under threat of chemical pollution.

For several locations a full assessment of the environmental and health impacts of these incidents is not possible due to ongoing hostilities.

2.2.4 Chemical warfare agents

The risk of the use of chemical warfare agents exists, with speculation and debate about their potential use. It is unknown whether phosphorous weapons for example, which have been widely used in past conflicts, have been used in the Ukraine. It is difficult to identify or distinguish between white phosphorus and the legal thermite-based ammunition using only photo/video material available.

Several social media posts have been published with video footage and news items claiming to be evidence of a deliberate release of CWAs at the Mariupol Azovstal plant.

Assessment teams will need to be aware of all potential reports to ensure the presence of potential CWAs can be considered in overall environmental impact assessment.

2.2.5 Pharmaceutical industry and associated infrastructure

Information regarding damage to pharmaceutical manufacturing plants is not available. However, a confirmed case of destruction of a warehouse with medicines and raw materials in the Makarov district of Kyiv oblast exists. The direct impact on the environment is currently being assessed by the State Environmental Inspectorate of Ukraine, while indirect impacts, for instance due to disruption in the production of pharmaceutical products in Ukraine, cannot be assessed at this stage.

2.3 **Damage to fuel and associated infrastructure**

Since the beginning of the current conflict, oil refineries and the entire oil and gas processing sector has been damaged.

Several missile strikes in April 2022 demolished the Kremenchug refinery (Media report, Ukrainskaya Pravda, 12 April 2022) – the only operational refinery in Ukraine with a capacity of three million tons of oil per annum (Media report, Segodnya, 4 2021) in Poltava oblast, while Shebelinka gas processing plant located in the epicentre of military clashes in Kharkiv oblast was forced to stop its operations in February 2022 (Media report, Reuters, 26 February 2022).

Reports on the extent of damaged or destroyed fuel reservoirs vary. Andriy Herus, a parliamentarian and the Head of the Parliamentary (Verkhovna Rada) Committee on Fuel and Energy stated during a briefing in the Crisis Media Centre on 5 May 2022 (Media report, Interfax Ukraine, 5 May 2022) that “about 15 different oil depots in Ukraine were destroyed or damaged as a result of missile strikes, which means that significant fuel reserves were destroyed, the storage of oil products was also complicated”. Meanwhile, the State Environmental Inspectorate of Ukraine has registered more than 20 cases of attacks on reservoirs with petrol, diesel, liquefied petroleum gas and mazut (fuel oil) (State Environmental Inspectorate of Ukraine 2022b). Wherever possible, investigations estimating damage to the environment are ongoing. The Environmental Inspectorate assessment included in situ soil tests and desktop estimates of air pollution based on quantitative analysis of stored and burnt fuel. However, the mandate of the State Environmental Inspectorate is to assess only direct impacts of damage to the environment in the oil and gas processing sector. Indirect impacts are therefore largely unknown.

2.4 **Status of the waste sector**

2.4.1 Existing information on waste and waste infrastructure

Ukrainian legislation specifies that waste, depending on the physical, chemical and biological characteristics of the entire mass or individual ingredients, is divided into four hazard classes:

- Class I — extremely dangerous;
- Class II — highly dangerous;
- Class III — moderately dangerous;
- Class IV — slightly dangerous.

The hazard class is determined in accordance with DSanPiN 2.2.7.029-99 "Hygienic requirements for handling industrial waste and determining their hazard class for public health" (Chapter 5), approved by the Ministry of Health in agreement with the territorial bodies of the Ministry of Environmental Protection and Natural Resources (Verkhovna Rada of Ukraine 2014). Traditionally, waste of Classes I to III is considered hazardous.

State Statistical Service's reporting showed that as of the end of 2020 the amount of accumulated waste was 15.6 billion tons including 12.2 million tons of waste of hazard classes I to III. The waste is stored in designated places or facilities, including on the land of enterprises operational during 2020 (Ministry of Environmental Protection and Natural Resources of Ukraine 2022a).

From a governance perspective, the Ministry of Environmental Protection and Natural Resources is responsible for management of all types of waste except municipal solid waste. The responsibility for municipal solid waste management is supervised by the Ministry of Development of Communities and Territories of Ukraine.

The largest volumes of waste are accumulated in waste disposal sites in three regions: 72.6 per cent of total waste in the Dnipropetrovsk region, 16 per cent in the Poltava region and 5.1 per cent in the Donetsk region (Table 3).

Table 3 Quantity of stored waste in Ukraine (except obsolete pesticides) up to 2019
(Ministry of Environmental Protection and Natural Resources of Ukraine 2022a)

Region	Waste I- IV Class		Waste I-III Class	
	Quantity, thousand tons	%	Quantity, thousand tons	%
Ukraine	15,635,260	100	12194,7	100
Cherkasy oblast	7,505.1	0	0	-
Chernihiv oblast	9,114.4	0,1	0	-
Chernivtsy oblast	3,566.6	0	0	-
Dnipropetrovsk oblast	11,345,562	72,6	185,7	1,5
Donetsk oblast	800,156	5,1	815,6	6,7
Ivano-Frankivsk oblast	6,744.2	0	30,6	0,3
Kharkiv oblast	10,834.3	0,1	117	1
Kherson oblast	1,407.6	0	0	0
Khmelnytsky oblast	9,480.1	0,1	0	-
Kirovograd oblast	4,651.3	0	7,3	0,1
Kyiv	76,709.4	0,5	14,8	0,1
Kyiv oblast	95,588.2	0,6	0,8	0
Lviv oblast	282,580.5	1,8	30,4	0,2
Luhansk oblast	56,862	0,4	746,2	6,1
Mykolaiv oblast	58,530	0,4	149,2	1,2
Odessa oblast	13,008.2	0,1	0	-
Poltava oblast	2,500,154	16	15,5	0,1
Rivne oblast	25,100	0,2	16,1	0,1
Sumy oblast	35,911	0,2	2401,4	19,7
Ternopyl oblast	611	0	–	-
Vinnytsia oblast	4,384.6	0	0	-
Volyn oblast	7,384.1	0	1,1	0
Zakarpatska oblast	2,430.7	0	–	-
Zaporizhzhia oblast	271,345.8	1,7	7658,9	62,8
Zhytomir oblast	5,637.5	0	1	0

Information from the State Statistical Services of Ukraine shows there were 8,376 enterprises which provided data on their waste generation in 2020. In total, these enterprises generated around 450 million tons of waste, while household waste amounted to roughly six million tons.

Data from the Ministry of Environmental Protection and Natural Resources of Ukraine (2022a) shows the largest amount of waste accounting for more than 84.6 per cent is generated in mining, metallurgy, coal and chemical industries and energy enterprises due to the dominant position of these sectors in the Ukrainian economy. The extractives industry dominates the volume of waste principally comprised from sludge and tailings. Meanwhile, the largest amount of waste per capita was generated in Poltava and Dnipropetrovsk regions. The volume of waste generation per capita exceeds one thousand tons in the following regions: Donetsk oblast, Zaporizhzhia oblast, Ivano-Frankivsk oblast, Kyiv oblast, Lviv oblast, Mykolaiv oblast, Vinnytsia oblast and the city of Kyiv.

Dnipropetrovsk and Poltava oblasts have suffered from regular missile strikes since the beginning of the current conflict, and hostilities have been ongoing in the Donetsk oblast since 2014.

2.4.2 Hazardous waste

An estimated 532,000 tons of hazardous waste of classes I to III were generated in Ukraine in 2020 (excluding waste generated in Crimea, Sevastopol, Donetsk and Luhansk oblast), which amounts to 0.12 per cent of the total waste generated in the country (Ministry of Environmental Protection and Natural Resources of Ukraine 2022b). These waste categories include used solvents, waste acids, alkalis or salts, chemicals, spent chemical catalysts and spent oils, wastes containing polychlorinated biphenyls, chemical sludges and residues, solidified, stabilized or glazed wastes.

The largest amount of hazardous waste (hazard classes I to III) was stored in disposal sites in Zaporizhia, Sumy, Donetsk and Luhansk (Table 3) regions. Meanwhile, the data of the Oblast State Administrations reports 8,230 tons of obsolete pesticides are stored in old and in many cases abandoned warehouses in 16 oblasts of Ukraine (Table 1). There were social media reports of partial demolishment of abandoned storage facilities of obsolete pesticides in Zaporizhzhia and Kherson oblasts, but this information requires additional confirmation from official sources.

Damage to a hazardous waste facility by a cruise missile was reported on 4 April 2022 in Kremenets district of Ternopyl oblast (the exact location is not available). Residues of the missile damaged six reservoirs holding mineral fertilizers. In situ tests found an excess of ammonia in the soil and in the Ikva river. Residents of the Kremenets district were advised not to use water from wells as drinking water.

Another issue is the significant amount of biological waste and animal by-products, mainly caused by losses of 15 per cent of the countries livestock (Media report, Landlord, 9 August 2022). Prior to February 2022, Ukraine had problems with incineration of animal and bird carcasses following disease outbreaks due to the lack of proper facilities. The situation has since further deteriorated. In many cases, local Sanitary and Phytosanitary (SPS) authorities prefer to bury dead animals in certified places, processing the carcasses with specific disinfectants. For example, four million chickens died at the largest poultry farm in Europe in Chornobayivka, Kherson oblast (Press release, MHP, 12 March 2022) because of damage to a local power plant, which led to the shutdown of the automated feeding system. Although the burial of such a significant amount of organic waste was carried out in accordance with the existing norms (including a specific disinfectant) and under the supervision of relevant authorities, it is a temporary solution and a proper disposal in a certified location will be required not later than in three years to avoid possible contamination of groundwater and soil.

Possible consequences of improper animal by-products management will pose a serious threat to both the environment and human health. Even though such cases are well-monitored by the State Service of Ukraine for Food Safety and Consumers' Protection (SSUFSCP), locations of such burials are not available to the public.

2.4.3 Radioactive waste: issues and impacts

Ukrainian legislation defines radioactive waste as radioactive material generated by human activities and with no prospects of further use. It is estimated that the total volume of solid and liquid radioactive waste in Ukraine is 2,960,000 m^3 and 42,340 m^3 respectively. More than 98 per cent of the radioactive waste in Ukraine was generated by the Chernobyl Nuclear Power Plant disaster in 1986 and is deposited in the Chernobyl Exclusion Zone (Ministry of Environmental Protection and Natural Resources of Ukraine 2022a). Spent nuclear fuel is not considered, as it has a special legal status and is not considered to be radioactive waste.

The State Nuclear Regulatory Inspectorate of Ukraine provided information on the state of radioactive waste in 2020, which had two main focal areas – radioactive waste management in the Chernobyl NPP Exclusion Zone and the waste

stored in the mainland. Storages in the Chernobyl NPP Exclusion Zone include: Buriakivka, Pidlisnyi, Vektor and III Stage of Chernobyl NPP.

The radioactive waste management in Ukraine is carried out by the Special State Enterprise RADON, which operates in Kyiv, Odessa, Dnipro, Lviv and Kharkiv (State Nuclear Regulatory Inspectorate of Ukraine 2022; Uatom 2022).

Since the 1970s and 1980s there have been several 'historical' objects (repositories) in Ukraine that contain radioactive waste, formed as a result of the military programs of the former Union of Soviet Socialist Republics (USSR), in particular Tsybuleve storage in Kirovograd oblast. As the government addresses safe storage of this waste and remediation of old sites, radioactive waste was forwarded to Buriakivka storage in Chernobyl Exclusion Zone. The remediation of the territory of Tsybuleve was completed in 2019 (State Nuclear Regulatory Inspectorate of Ukraine 2021).

Ukraine's State Register of Sources of Ionizing Radiation and the State Register of Radioactive Waste exchange information. For example, 719 spent radioactive sources were transferred to the State Corporation UkrDO Radon in 2014 as radwaste, and 241 users stored radioactive sources in 2014. More recent reports from the State Nuclear Regulatory Inspectorate of Ukraine (2019) shows that nuclear waste remains a challenge in the country. Since 2014, Ukraine has lost control of its research reactor in Sevastopol and its nuclear waste collection centre in Donetsk. Hence, no information about the radioactive waste is available and such waste may become a significant risk factor in the future.

2.4.4 Incidents with radioactive waste and incidents involving release of radiation

The Ministry of Environmental Protection and Natural Resources post the data from the Automated Radiation Control Systems on their website, reporting on various incidents related to threats to nuclear facilities. Some examples are listed below.

In February 2022, the Russian Federation took control of the Chernobyl nuclear power plant and other nuclear facilities in the Chernobyl Exclusion Zone (CEZ). The movement of military vehicles caused the dispersion of dust, leading to an increase in background radiation on 25 February 2022. By 1 April 2022, Ukraine lost control of the following radiation-hazardous facilities located in the Chernobyl Exclusion Zone (Ministry of Environmental Protection and Natural Resources of Ukraine 2022; State Nuclear Regulatory Inspectorate of Ukraine 2022):

- New safe confinement and Shelter
- Spent Fuel Storage Facility (SNF-1)
- SNF storage-2
- Liquid Radioactive Waste Processing Plant
- Chernobyl Solid Radioactive Waste Processing Plant
- Buryakivka radioactive waste landfill;
- Radioactive waste landfill '3rd stage of the Chernobyl NPP'
- Pidlisny radioactive waste landfill
- 'Vector' Industrial complex

On 27 February 2022, a powerful explosion occurred following a rocket attack in the Kyiv suburb of Pirogovo, near the location of the Central Production Site of the Radon Association that deals with disposal of radioactive waste. Although the background radiation has not increased, the storage of radionuclides requires additional assessment (Ministry of Environmental Protection and Natural resources of Ukraine 2022b; State Nuclear Regulatory Inspectorate of Ukraine 2022).

Rockets were fired at the Kharkiv Institute of Physics and Technology, where the Neutron Source nuclear reactor with 37 nuclear fuel assemblies was located on 6 March 2022 (Ministry of Environmental Protection and Natural Resources of Ukraine 2022b).

2.4.5 Tailing facilities

Four hundred and sixty-five tailing facilities are in Ukraine located either in natural or in artificial reservoirs, with a content of over six billion tons of waste from various industries. Almost half of all Ukrainian tailing storage facilities are in Donetsk and Luhansk oblasts, with 200 tailings storage facilities containing 939 million tons of waste; of these, 125 facilities are in territory not controlled by the Government of Ukraine (OSCE 2021).

Some tailing facilities are no longer operational but act as waste storage sites. Around three quarters are considered potentially dangerous and include hazardous waste from the past production (Averin *et al.* 2022). These tailings are abandoned, and no monitoring or control is in place for determining their technical condition or their impact on the environment. Many facilities are located very close to water bodies or towns.

The Ukrainian tailing storage facilities include nine with radioactive waste from the Pridneprovskiy chemical plant in Kamenskoye (Dnipropetrovska oblast), processing uranium for military and industrial use in the former USSR in the period 1949-91. After the closure of the plant in the 1990s, tailing storage facilities remained abandoned, although they are de facto on state-owned restricted territory. An assessment report (Tkachenko 2020) on this industrial site was prepared by Ukrainian experts and the international NGO Bellona in 2020.

Located near the city of Mariupol, the metallurgical plants (Azovstal Metallurgical Works) and other facilities including a sludge pond, a thermal power plant (TPP) ash collector and a cinder dump from an open-hearth and converter steelmaking plant, pose a significant risk of chemical pollution of the surrounding environment (OSCE 2017) and hence will require consideration following the conflict in this location.

2.4.6 Incidents affecting tailings storage facilities

The Operational Headquarters of the State Environmental Inspectorate does not have any confirmed information about significant damage to tailing facilities up until 31 May 2022. However incidents have been reported and include:

- Hostilities near Severodonetsk could have affected the tailing storage facilities of the Azot plant. This tailing storage facility contains 649,000 tons of solvents and sludge obtained from the regeneration of ion exchangers (sludge from the reagent solvents and wastewater) as well as magnesite sludge from the process of potassium nitrate production. Meanwhile, in situ testing and collection of evidence bases is currently impossible due to ongoing hostilities.

- Some media (including Russian sources and Reuters) report damage to one of the two tailings of the Avdiivka Coke Plant. While it has not been in operation since 2001, the OSCE inventory shows it contains 443,000 tons of phenol, sulfuric compounds, naphthalene and other toxic substances. In situ testing and collection of evidence bases is currently impossible due to ongoing hostilities.

- Satellite imagery indicate that the Azovstal steel plant has been damaged in the conflict (UNOSTAT 2022).

2.4.7 Solid household waste

In contrast to many European countries, Ukraine has a low level of processing, utilization and disposal of solid waste and a high rate of waste disposal in landfills (Kryzyna and Radchenko 2020). Non-engineered open landfills result in the contamination of soils with leachate, which leads to groundwater contamination and adversely affects human health. A significant part of these landfills are overloaded and do not meet sanitary and environmental standards. As of 1 January 2021, Ukraine has a total of 6,045 landfills and dumps covering 8,800 hectares of the country's territory (Ministry of Environmental Protection and Natural Resources of Ukraine 2022a).

The total amount of municipal solid waste collected during 2020 was 54 million cubic meters or more than 10 million tons (Ministry for Communities and Territories Development of Ukraine 2021). In 2021, Ukraine had 261 landfills exceeding their capacity and 868 landfills that did not meet environmental safety standards according to the Ministry of Environmental Protection and Natural Resources of Ukraine (2022a). The Ministry reported construction of at least 318 new landfills is needed. At the same time, due to non-standard solid waste management practices in settlements usually undertaken by the private sector, 22,600 unauthorized landfills were discovered in 2020, occupying an area of over 560 hectares, further confirming the challenges of past and future waste management in Ukraine.

2.4.8 Waste generation and management

Both legal and illegal landfills and hazardous waste dumps have been directly affected by the current conflict in Ukraine. Air and missile strikes throughout the country, coupled with intensive hostilities in the east, have resulted in thousands of tons of scrap metal and millions of tons of debris. Demolition debris will be described in the chapter on damage to urban areas. OECD (2022) notes that the ongoing operations have resulted in dramatic increases in waste generation including from damaged and abandoned military equipment and vehicles, shell fragments, building debris and uncollected medical or household waste. Some of this waste is hazardous and requires special handling.

Large scale displacement of people to the western parts of Ukraine has substantially increased pressure on waste management systems. The lack of fuel and a 70 per cent increase in diesel prices have made the transportation of municipal solid waste extremely costly and, in some cases, impossible. This problem is particularly relevant for the communities in the western part of Ukraine, located in the mountains or far from landfills, and who are hosting large groups of internally displaced people (IDPs). In many cases local authorities have decided to use nearby ravines or forests for illegal dumping of municipal waste. To prevent pollution of the environment and specifically transboundary rivers, this situation requires immediate attention and resolution.

2.4.9 Municipal solid waste management

Conflict has direct and indirect impacts on municipal solid waste management. Direct impact includes landfill fires caused by shelling, any other damage to the existing waste management facilities, or change in waste management processing due to the ongoing conflict.

No incidents impacting solid waste facilities caused by shelling have been confirmed by the OH. However, the State Service of Emergency Situations (SSES) released information, without stating the cause, of two fires at registered in the landfills in the village of Novy Petrovtsy of Vyshgorod district and in the nearby village of Tarasivka of Bucha district in Kyiv oblast on the 19 March. A similar fire was confirmed by the SSES on the same day in Inguletskyi district of Mykolayiv oblast caused by heavy shelling.

Direct impact also includes a change of morphological composition of waste both in urban and rural areas caused by the disposal of debris in municipal solid waste facilities and households' disposal of burned or destroyed belongings and construction waste from damaged properties.

2.4.10 Scrap metal

The volume of scrap metal due to destruction of armoured vehicles, planes and other machinery, coupled with scrap from destroyed infrastructure, for example steel bridges, will increase as fighting continues.

Destroyed military equipment and ordinary scrap metal are two different materials and make disposal of military equipment more challenging and costly. All scrap metal of military origin is the property of the state, and only units of the Armed Forces of Ukraine can collect such type of scrap. The process for sale or re-use of tanks, armoured vehicles or aircraft includes a procedure involving examination for explosives, sanitization, then moving materials to a storage site -often requiring special equipment- with inspection by the repair and restoration units of the Armed Forces of Ukraine.

Studies conducted by the scientific expert council of the association UAV tormet l (Media Report, Ukrrudprom, 9 May 2022) reported the volume of scrap metal consists of tanks (30 per cent), armoured vehicles for transporting infantry (40 per cent), vehicles for various purposes (15 per cent) and other equipment, including aircraft (up to 15 per cent). The volume of military equipment and equipment that can be considered to be scrap metal is estimated at 20,000 to 22,000 tons (Sheiko 2022). Significant numbers of armoured vehicles are in the Luhansk, Sumy, Chernihiv and Mykolaiv oblasts where heavy hostilities continue; hence, any waste management operations are currently not possible in the area (Media report, Delo.ua, 31 May 2022).

2.5 Destruction in urban centres and of critical infrastructure

All Ukrainian cities and towns consist of well-developed infrastructure, which includes central water supply and sewage processed in wastewater treatment stations. Over a hundred thousand apartment blocks in Ukraine are provided with heating and hot water via centralized district heating systems, more than 80 per cent of which are heated by natural gas.

Since February 2022, the infrastructure of towns and cities have been subjected to missile and air strikes, while the vicinities of several big cities, including Kyiv and Kharkiv, were conflict zones (Media report, Fontanka.ru, 24 February 2022). Conflict has caused significant damage to buildings and municipal infrastructure, railways, airports, administration buildings and educational facilities (National Recovery Council 2022; World Bank 2022a).

The Strategy of the Recovery of Ukraine indicates the damage to the Ukrainian municipal and transport infrastructure was substantial as of 13 June 2022 (Table 4) (National Recovery Council 2022). The estimates provided by the Ukraine Government, European Commission and World Bank to 1 June 2022 (World Bank 2022a) are also shown in Table 4.

Table 4 Estimated damage to infrastructure*
(Natural Recovery Council 2022; World Bank 2022a)

Infrastructure	Estimated Damage National Recovery Council	Estimated Damage World Bank
Roads, km	23,900	16,318 (national and local roads)
Residential buildings, mln m2	44.8	Residential units 816,157(total) 312,246 (destroyed)
Industrial enterprises, factories, units	256	
Civil airports, amount	11	
Rail infrastructure and rolling stock	6,300 km rail tracks 41 bridges	1,119 km rail lines 850 units
Railway stations		93
Healthcare institutions	656	
Bridges and bridge transitions	304	3 million m^2 National 428,470 m^2 local 63,072 m^2 railway bridges
Cars (number)	104,000	392,843 (private) 9,473 communal
Institutions of secondary and higher education (number)	1,177	1,885 178 (Destroyed)
Ports and Port Infrastructure	4	
Military airfields and airports (number)	12	
Administration buildings (number)	111	
Religious buildings (number) Cultural facilities (number)	141 203	Combined 268
Kindergartens (number)	668	
Shopping and entertainment centres (number)	20	
Storage infrastructure (number)	198	
Industrial fuel storages (number)	28	
Retail (number units)	2,910	

** Figures indicated in parentheses represent different units of measurement, as specified or different definitions (e.g., damaged vs. destroyed)*

2.5.1 Debris

Shelling in the northern, eastern and south-eastern parts of the country resulted in large amounts of debris in cities and towns. In some settlements, all buildings have been either damaged or demolished (The Office of the President of Ukraine 2022; Pereira *et al.* 2022). Asbestos is likely to be present in debris given the widespread use of asbestos in building materials and infrastructure in Ukraine with estimates of 60 per cent in roofing materials. It will need careful consideration in future assessment, recovery and reconstruction plans (UNDRR 2022).

Available unverified open-source information includes:

- The State Border Guard Service of Ukraine posted on their official social media in March 2022, stating that Volnovakha, a town in the Donetsk oblast with the population of 21,000 people, had experienced 90 per cent destruction of the town (Social media post, State Border Guard Service of Ukraine, 12 March 2022; Media report, Interfax Ukraine, 10 May 2022). Information on the quantity of destroyed buildings is not available.

- Kharkiv, the second biggest city of Ukraine, with a population of 2.6 million people, has ongoing conflict. A statement by Kharkiv's Mayor reported that as of 31 March 2022 at least 1,292 of mostly multi-story residential buildings were damaged or demolished (Media Report, Novoye Vremya, 31 March 2022). At least 239 administrative buildings, 70 schools, 54 kindergartens and 15 hospitals have been partly or destroyed.

- UNITAR published a satellite image of the city of Chernihiv which illustrated the damage to at least 21 per cent of the city (UNITAR 2022). Meanwhile, the Governor of the Chernihiv oblast stated that up to 3,500 buildings in the oblast were damaged and 80 per cent were residential buildings (Social media post, Governor of Chernihiv oblast 14 May 2022).

- Although only a few buildings in the city of Kyiv were damaged in attacks, the suburbs of Kyiv suffered more destruction (Media Report, Novoye Vremya, 31 March 2022). The administration of Kyiv oblast stated that preliminary operational information from the territorial communities of Kyiv region, 1,875 buildings were either significantly damaged (1,329) or destroyed (546). In the town of Makariv 28 multi-storied buildings, 441 private estates, 8 educational institutions, 4 health care institutions, 8 cultural institutions and 2 sports institutions were destroyed, and in the town of Borodyanka, 8 out of 29 multi-storied residential buildings were completely and 21 partially destroyed (Social media post, Kyiv Regional Military Administration, 16 April 2022).

- Mariupol has been significantly affected with most of the buildings damaged and more than 20,000 residents killed. The lack of burial services and management of waste has been exacerbated by heavy rains in the area. This will need particular attention when on ground assessments are able to be conducted.

2.5.2 Damage to urban water sector

Water supply and wastewater treatment facilities have been affected by hostilities. Examples of the damage to water supply infrastructure include:

- Damage to the major water supply pipeline in the city of Mykolaiv led to a reported critical situation with drinking water. As of 13 May 2022, the water supply was re-established (Media report, Ukrainskaya Pravda, 13 May 2022), however, problems with provision of drinking water remain.

- Artillery shelling resulted in damage to the third lift of the water pipeline of the Seversky Donets – Donbass canal, leading to termination of water supply in Donetsk and Luhansk regions. Gorlovka, Donetsk, Khartsyzsk and other settlements lost their water supply. This information was published on the official social media account of the Ombudsman Ms. Liudmila Denisova (Media report, Unian, 24 April 2022).

- The Mayor of Chernihiv, Vladyslav Atroshenko, reported damage to the city's water supply for more than three weeks (Media report, Hromadske, 29 March 2022).

- A major incident affecting wastewater treatment plants occurred due to the damage of the Zaporizhzhia city wastewater treatment station, located in the village of Vasilivka, and untreated wastewater leaked into the Dnieper River. The treatment plant is no longer operational (Media report, Zaxid.net, 14 March 2022). In situ analysis of the situation is currently impossible.

Other incidents reported by the State Environmental Inspectorate of Ukraine (2022a) include:

- Damage to the Severodonetsk city wastewater treatment station which could cause untreated wastewater discharging to Seversky Donets.
- Damage to wastewater treatment plants in Popasna (Donetsk oblast), Lisichansk and Rubizhne (both in Luhansk oblast) was recorded in early April 2022. However, further details are not available.
- On 19 April 2022, a wastewater treatment plant in Druzhkovka and the Velyko-Anadolska filtering station (both located in Donetsk region) were damaged. In situ analysis to evaluate the impact of these incidents on the environment is currently not possible.

2.6 Deepening food insecurity because of disruption to the agricultural sector

2.6.1 Overview of the sector

The agricultural sector of Ukraine is one of the main drivers of the national economy. With 41.5 million hectares of agricultural land covering 70 per cent of the country and around 25 per cent of the world's reserves of black soil, the agriculture is Ukraine's largest export industry, significantly contributing to global food security (International Trade Administration 2021). In 2020, the agricultural sector generated close to 9.3 per cent of GDP.

Agriculture without Land Use, Land-Use Change and Forestry (LULUCF) contributed to 12.8 per cent of overall greenhouse gas emissions in 2019 (UNFCCC 2021). The major sources of emissions in the agricultural sector of Ukraine are enteric fermentation and agricultural soils, generating 18.5 per cent and 75.7 per cent of the total emissions in the sector in 2019. Emissions have decreased by 51.1 per cent compared to the base year (1990), and by 4.1 per cent compared to 2018 (UNFCCC 2021).

Crop farming dominates the agricultural sector of Ukraine, accounting for 73 per cent of its agricultural output (US International Trade Administration 2021). Corn, wheat and barley are Ukraine's main grain crops and exported goods. Even in 2020 and 2021, during the COVID-19 pandemic and with atypical weather conditions such as abnormal heat and storms, all Ukrainian export contracts were fulfilled.

With a leading sunflower oilseed processing industry, Ukraine is ranked as the number one sunflower exporter in the world (US International Trade Administration 2021). Ukraine has also significantly increased the production of fruits and vegetables in the last few years, mostly for domestic consumption (FAO 2022a).

Developed crop production makes Ukraine one of the top consumers of pesticides (around 125,000 tons a year), with around 100,000 tons of crop protection chemicals imported (Media report, Latifundist, 6 May 2021). Local manufacturing is well-developed, but with total production at 10,000 to 20,000 tons, cannot cover the needs of the sector and is based on imported active ingredients. The pesticides market is also affected by illegal trade in chemicals, and the share of illegal pesticides can reach 25 to 30 per cent (UNEP and GRID-Arendal 2020).

Ukraine is also a major producer and exporter of mineral fertilizers, a sector significantly impacted by the rise in gas prices. The overall consumption of nitrate fertilizers reached 4.75 million tons in 2021 (Media report, Interfax Ukraine, 27 January 2022). The conflict in Ukraine has exacerbated a global cost-of-living crisis unseen in at least a generation and there are an additional 47 million acutely hungry people globally due to the ripple effects of the conflict (GCRC 2022).

In comparison with crop production, animal farming in Ukraine is less developed, with pig and poultry farming having the largest share of the sector. The National Academy of Agrarian Science of Ukraine reported that in 2021, for the first time ever, the sector faced the loss of 2.9 billion hryvnias (USD 101 million) (Media report, APK INFORM, 4 February 2021). Poultry producers together with several large farm crop producers became the drivers of green transformation in the sector, focusing on energy efficiency, implementation of climate-smart agriculture and carbon farming. One of the biggest poultry producers, MHP, even announced the goal to reduce greenhouse gas emissions by 35 per cent by 2030, compared to 1990 (Media report, Ukrinform, 25 November 2021).

The fisheries sector of Ukraine includes both marine and inland fisheries. Marine fisheries in the Sea of Azov and the Black Sea have already been affected by conflict since 2014 with a large quantity of marine bioresources in its waters.

On 7 February 2022, the President of Ukraine signed a landmark decree on the main directions of the Food Systems Transformation in Ukraine (Ministry of Economy of Ukraine 2022), aimed at achieving the Sustainable Development Goals in the agri-food sector. However, it is likely that these transformation plans will be disrupted.

2.6.2 Impact of the conflict on agriculture

Agricultural land has been affected by three major types of damage – physical degradation, pollution by chemical pollution from mines and affected industries as well as exploded ammunition. The heaviest shelling affected the black soils (chernozem). Construction of fortifications, explosion craters and compaction of soil by tanks' tracks and wheels of military vehicles caused damage to and physical degradation of soils.

The American corporation MAXAR released satellite images showing the consequences of shelling in Donetsk and Luhansk oblast with geographic coordinates (Social media post, Maxar, 6 June 2022), showing fields impacted by hundreds of artillery craters and a 40m diameter bomb crater in Dovhenke.

The ammunition and missiles residues in these craters may become a source of chemical pollution caused by heavy metals, missile and vehicles fuel and other toxic chemicals together with metal parts. These substances can potentially reach the groundwater, especially in certain areas of Kherson and Mykolaiv oblasts, where the ground water levels are only one to two metres below the surface, while the crater can be deeper (Certini *et al.* 2013). It should be mentioned that soil recultivation is currently impossible in most affected areas due to ongoing military activity.

Landmine contamination is a critical issue with reports of 30 million hectares of land in Ukraine being mined (Media report, Lenta.ua, 3 June 2022). KSE experts concluded that all farmlands in conflict areas would require a thorough inspection, and some of the territories require demining.

2.6.3 Food and grain storage

Food and grain storage facilities have become the targets of bombing (KSE 2022b). Damage to grain elevators and terminals can result in pollution of fresh and marine waters. The most illustrative example of this issue was the bombing of the Nika-Tera terminal in Mykolaiv used for transhipment of chemical goods and grain. It caused a fire in the city that most likely released harmful emissions (Media Report, Kharkiv Tribunal Nurnberg, 8 June 2022).

KSE made a quantitative analysis of the damage to animal farming (Neyter *et al.* 2022), stating that farm animals are dying due to farmers' inability to either access the farms or get animal food and provide animals with needed veterinary support and care as the direct result of hostilities. KSE states that *"The estimated number of animals that died due to the aggression of the Russian Federation is 42,000 of sheep and goats, 92,000 of cattle, 258,000 pigs and over 5,700,000 heads of poultry."*

Another potential environmental impact is damaged wastewater treatment facilities on large animal farms. For example, the damaged dam of a manure settling tank of the biggest pig farm in Donetsk, 'Bakhmut Agrosoyuz', was already considered one of the most critical threats to the Kalmius river basin (Media report, Interfax Ukraine, 30 August 2018). Further damage is likely but sampling is currently not possible due to the active conflict in the area.

2.6.4 Fisheries

Consequences for the Ukrainian fisheries sector are currently difficult to assess but assumed to be most significant for marine fishing. The Institute of Fisheries of the National Academy of Agrarian Science of Ukraine released some data on the state of the sector in May 2022 (Media Report, ZN.UA, 5 May 2022):

- Marine fishing, which was significantly reduced after the 2014 conflict, has de-facto ceased after the start of hostilities due to a blockade of the Black and Azov Seas. In addition, some fishing ports are either scenes of active conflict or remain contested, for example, in Mariupol, Berdyansk and Genichesk. Fishing is carried out at very small scale in limited parts of the Black Sea coastal zone.

- It will likely be difficult to restore the marine fishing quickly, even after the end of hostilities. Firstly, abandoned sea mines can pose a threat to navigation and the use of industrial fishing gear, and secondly, some marine industrial vessels that remained moored in the areas may be damaged or destroyed.

The inland fishing is also affected, not only due to the ban on fishing from boats on the main Dnieper reservoirs by military administrations, but also by the destruction of dams in two large Oskil and Pechenizky reservoirs in the Kharkiv oblast, followed by a major reduction in water levels (Media Report, UNN, 2 April 2022). The Institute of Fisheries of the National Academy of Agricultural Sciences have reported 1,997,500 fish have died since the current conflict began (Media Report, KHARKIVTODAY, 14 July 2022).

2.6.5 Beekeeping

Ukraine is one of the biggest honey producers in the world and a key exporter of honey to the EU with an increasing domestic market.

A statement of the Farm 'Znatniy Med' (Media Report, AgroPortal, 20 April 2022) reports losses in bee colonies in the northern (Kyiv and Chernihiv), eastern (Kharkiv and Poltava) and southern (Kherson and Nikolaev) oblasts of Ukraine could amount to 30 per cent. In addition, beehives, equipment and production lines have been lost. Some beekeepers were forced to leave their homes, leaving bee colonies without the necessary care (feeding and expansion), which in turn will have a negative impact on their further development.

Another negative indirect factor is the reduction in sunflower sowing by the large farms in 2022, which shifted crop production from oilseeds to cereals, which are not good sources of forage for bees. These factors will likely lead to a reduction in honey collection by around 25 to 30 per cent (Media report, UkrAgroConsult, 19 April 2022). Environmental consequences of such reduction in apiaries may be serious and requires further assessment.

2.7 **Nature is a casualty of the conflict**

2.7.1 Existing information on nature

The nature of Ukraine includes coniferous, mixed, broad-leaved forests, sub-Mediterranean sparse forests, forest-steppes, steppes, sub-alpine and alpine meadows (swallows, meadows), semi-deserts, sandy beaches, spits and dunes, ecosystems of rocky slopes, underground cavities (caves), swamps, salt marshes and salt marshes, freshwater rivers and lakes, brackish water lakes and estuaries (estuaries), salt lakes and bays, rocky sea shores, marine ecosystems of the Black and Azov Seas and the Kerch Strait. Various sources state the total area of forest in Ukraine amounts to 14.5 to 16 per cent of its territory; with identified primeval forests and ancient forests of the Carpathians (938 km2) among them. Other natural ecosystems make up 6 to 9 per cent of the country's territory. The ploughed area of Ukraine is one of the largest in the world. Two mountain systems with altitudinal belts are situated on the territory of Ukraine (the Carpathians and the Crimean Mountains). Ukrainian river basins include the Danube, Dniester, Southern Bug, Dnipro, Don, Vistula, the Black Sea and the Sea of Azov River basins.

There are more than 70,000 species of plants, animals, and fungi, including many rare and endemic species in Ukraine (Convention on Biological Diversity 2022). Biotic diversity as a component of general natural (landscape) diversity is the basis for sustainability and productivity (biomass) of natural ecosystems. Therefore, the biotic diversity of landscapes is an indicator of their functional state and the quality of ecological conditions, which shows the degree of stability and sustainability of the natural ecosystem. Meanwhile, the landscape diversity is a system of landscape complexes of different taxonomies, a variety of functional connections between them. Biotic and landscape diversity are mutually dependent.

Ukraine has a significant number of protected areas. The Emerald Network sites of Ukraine covers approximately 10 per cent of the country (WWF-Ukraine 2022) including nine natural and four biosphere reserves, 39 Ramsar sites (wetlands of international importance), 49 national natural parks, 45 regional landscape parks, 3,078 natural monuments, 2,729 nature reserves, 616 botanical and zoological gardens, arboretums and parks-monuments of horticultural art, 663 protected areas of national importance and 793 nature reserves tracts.

As noted earlier, there have been significant risks to nature in Ukraine. In its report 'State of the Environment in Ukraine in 2020', the Ministry of Environmental Protection and Natural Resources of Ukraine (2022a) highlighted that most of the threats to nature are associated with habitat degradation, unbalanced land use patterns, over-ploughing, illegal amber mining and low levels of forest cover contributing to further degradation. The current conflict is likely to exacerbate nature degradation even further.

2.7.2 Biodiversity and natural resources

The recent damage to Ukrainian nature and wildlife has been severe. Hostilities have taken place in all natural corridors of national importance except the Crimean and Carpathian ones, causing significant damage to landscapes and nature.

Twenty per cent of all nature conservation areas of Ukraine have been affected by the current conflict. Nearly a million hectares of protected areas have been impacted, and 812 specific sites in protected areas are under threat. Around 160 territories of the Emerald network with an area of 2.9 million hectares, 14 Ramsar sites, with an area of a little less than 400,000 hectares as well as four biosphere reserves are also under threat (Nature Reserve Fund of Ukraine 2022).

Other impacts include the number of displaced people finding shelter in conservation areas inadvertently causing damage to natural habitats with waste and wastewater degrading the environment (Nature Reserve Fund of Ukraine 2022).

Additional examples of impact on nature, wildlife and urban animals in Ukraine during the past six months are given below.

- On 18 March 2022, the analysis of images from the European Space Agency's Sentinel 2, showed an active fire was detected within the territory of a nature reserve (primeval forest) in Svyate, a 44 hectare protected area in the southern part of the city of Chernihiv (FIRMS:NASA 2022).

- Fires in the Luhansk region caused by heavy shelling resulted in forest burning in Kudryashivka, Kreminnaya, Chervona Dibrova and between Purdivka and Metelkin in the direction of Oleksandrivka (9 May 2022). The fire spread in the direction of Yampol and approximately 15,000 hectares were burned (State Environmental Inspectorate of Ukraine 2022b).

- Heroyske, Chulakivske, Ivanovske, Kardashinske forests, Holoprystansky forestry enterprise and the Black Sea Biosphere Reserve in the Kherson oblast were burning on 10 May 2022 (State Environmental Inspectorate of Ukraine 2022b). There were attempts to extinguish the fire and sweep the areas to prevent it spreading, but the strong wind and the insufficient equipment as well as personnel did not allow it and about 6,000 hectares were destroyed.

- Ukrainian Ombudsman Liudmila Denisova reported fires in the forests of Kinburn Spit Reserve (Media report, Ukrinform, 14 May 2022) – a protected area of national importance. The entire flora in this area was under threat of destruction, including the largest field of wild red orchids in Europe (more than 60 hectares), perennial trees, pink lakes and animals.

2.7.3 Livestock and pets

Some reports mention deliberate killing of farm animals, especially cows (Media report, Dairy Global, 29 April 2022). The journalist Maria Daniliuk reported animals were killed in the farm belonging to an agribusiness company. Published photos showed several cows walking among hundreds of dead cows lying in a trench. Project-Syndicate published an article in April 2022 on the non-human victims of armed conflict, where these incidents were referred to.

Animals - both captive, wild and domestic pets - are a significant part of urban ecosystems. Deaths of animals from cold, hunger and injury were confirmed in the contact zoo (Media report, TSN, 19 March 2022) and the Mykolaiv Zoo (Media Report, Novoye Vremya, 23 March 2022). Three hundred dogs are reported to have died in the Borodianka Kyiv oblast (Media report, The Village, 6 April 2022).

In several cases displaced residents could not take their pets with them to safer areas. This has caused the formation of packs of stray dogs in cities, which may not only increase the risk of rabies, but also pose a threat to humans and other animals. Volunteers have launched a nation-wide campaign on saving the abandoned pets (Media report, The Village, 19 April 2022).

2.7.4 Marine ecosystems

The Director of the Tuzlovski Limany Reserve Dr. Ivan Rusev reported the deaths of several thousand dolphins in the Black Sea over three months (Media report, Odessa News, 2 June 2022). This incident was also reported by several international media, including the New York Times (Media report, New York Times, 2 June 2022), citing Turkish, Bulgarian and Ukrainian scientists. Latest information from scientists estimate the deaths of around 3,000 dolphins in the Black Sea.

A missile attack on three marine drilling platforms in the Black Sea on 20 June 2022 resulted in a fire, but no confirmed information is available about marine pollution caused by these incidents (Media report, Delo.ua, 20 June 2022).

The General Staff of the Ukrainian Armed Forces claims 15 ships have been sunk in the open sea and in the port of Berdiansk some of which carried hundreds of tons of fuel (Media Report, Ukrinform, 27 June 2022). However, no information on damage to marine ecosystems is available.

2.8 Next steps in assessing the environmental impacts of the Ukraine conflict

This report highlights the significant task ahead in assessing and verifying the severity of environmental damage and its repercussions in Ukraine. The information provided is clear: a multifaceted environmental impact assessment is required.

Such an assessment will need to consider all aspects of the physical and social environment, including nature and biodiversity, exposure and public health risks. In addition, the complex socioeconomic and demographic factors affecting recovery, with a view to enhancing sustainable rebuilding, must be considered.

Environmental considerations are often overlooked in the post-conflict reconstruction phase, as governments and investors tend to prioritize quick recovery of infrastructure and economy. Given the nature of this conflict, this would be counterproductive to ensuring the achievement of inclusive and sustainable development. UNEP will support the Government of Ukraine, neighbouring countries and local and International partners in ensuring these issues, for the purposes of short, medium and long term recovery and reconstruction efforts are addressed and use best international practice and scientifically appropriate methods and standards.

The information presented in this report forms the basis for planning an assessment using both remote and on- ground assessment methods, considering both direct and indirect impacts. Issues to be addressed include the six categories outlined in Part I and II); specifically the multiple impacts across the environmental segments, locally and regionally, for example:

- Impacts on nature, biodiversity, cultivated or managed landscapes with economically significant resources (in particular, agricultural and forestry landscapes with their associated infrastructure, and water bodies) from a variety of direct impacts like the remnants of conflict such as unexploded ordnance, munitions and vehicles but also from air, soil and water contamination by chemical industry, fuel storage facilities and other types of infrastructure and activities specific to conflict;

- Impacts on the urban and built environment, with particular focus on critical infrastructure (including energy, wastewater and sanitation infrastructure, municipal solid waste management, transportation, and infrastructure supplying vital utilities to the population and including but not limited to the on-going fuel crisis, lack of personnel, change in demographics due to internal migration);

- The potential cumulative impact of multiple conflict-related damage to different ecosystems, urban and rural settings and natural resources;

- Impacts on environmental public health from the above issues, considering relationships between environment, both natural and built, and human populations, health and wellbeing.

The assessment will rely on the mapping of multiple direct and indirect impacts combined with a risk ranking exercise to enable planning to target priority areas with a view to recovery. This will support decision making and prioritise human health and wellbeing, economic recovery and environmental sustainability with a view to minimising and preventing the impacts of legacy issues.

Any assessment of the impacts of conflict on the environment and human health must be mindful of the socio-ecological systems that connect them, rather than simply analysing, measuring or describing them in isolation from each other. Understanding these systems linkages will be crucial for successfully addressing adverse impacts, identifying the most important leverage points in systems with a focus on providing positive socio-ecological outcomes and minimising the potential for unidentified negative impacts.

As noted, the environmental situation in Ukraine is multifaceted and complex. A comprehensive assessment may need more than one lens to assess acute risks / hazards that may need to be addressed. The literature review of the six key areas is one lens to enable planning for a detailed impact assessment, i.e. starting with a broad categorization of different types of damage (damage to critical infrastructure, debris and remnants of armed conflict, institutional and governance breakdown, impacts on agriculture and important ecosystems etc.) and describing the impacts and knock-on effects of each one.

The challenge posed by this approach is that cumulative impacts and system linkages are difficult to assess and present adequately. Another approach is to start by grouping similar pressures together, for example similar contaminants, similar types of physical or biological aspects; and assessing their impacts and the multiple sources contributing to impacts. It might also be possible to start by analysing information on impacts using data on emerging health problems and environmental monitoring showing emerging environmental issues and work backwards to establish causal pathways. These approaches may be a better way of identifying and mapping cumulative impacts from multiple pressures. However, they may require more time, and could be less suitable in situations where the risks from specific types of conflict actions are important to establish. As more data becomes available – the benefit of the various analytical approaches can be considered and rely on input from the range of government and non-government sources.

In situations where it is important to establish a systems-level understanding of the consequences of conflict, a broader approach may be possible. This would entail mapping of the main interconnections between drivers, damage, pressures, impacts, the vulnerability / resilience of environmental and human receptors, and reactions or adaptations of humans to pressures, with particular emphasis on identifying positive and negative feedback loops as well as levers for change at a systems level. As part of this exercise, the need to assess residual risks is imperative and hence the use of risk assessment as part of decision making will be helpful. As noted above this may be beneficial if the purpose is to identify the most effective leverage points for preventing or mitigating damage. In this context, it is also important to recognize that environmental protection, restoration and management can play an important role in rebuilding trust between communities and societies in the wake of conflict (Ida *et al.* 2021; UNEP 2016).

All these lenses or approaches are valid, depending on the context and purpose of an assessment. A combination of approaches would allow the most comprehensive picture to be established.

The ongoing collection and preservation of data, information and other evidentiary material in Ukraine is a massive undertaking. An unprecedented volume of environmental data is being gathered. It needs to be collated, validated, evaluated and used to build future assessments. UNEP is developing a risk matrix and framework to inform planning, including the range of methodologies that will be required.

This limited time-bound review has shown that the impacts from the conflict in Ukraine continue to have major impacts at the country and global level. The evidence is clear - conflicts are a significant source of environmental degradation, adding to the triple planetary crises we are facing. The conflict must cease and recovery must ensue.

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Annex

Annex I Environmental governance in Ukraine

The Law of Ukraine 'Basic principles (strategy) of the state ecological policy of Ukraine for the period up to 2030' (Verkhovna Rada of Ukraine 2019) identifies the root causes of Ukraine's environmental problems and the lack of environmental legislation to deal with environmental issues. The dominance of the resource and industry sectors, ineffective governance measures, limited ability to manage and regulate environmental issues including the lack of a compliance regime and insufficient funding, amongst other issues have been highlighted.

The same law defines the aim of the state ecological policy, which is to achieve good environmental conditions by introducing a ecosystems-based approach to all areas of socio-economic development of Ukraine. This again is meant to ensure the constitutional right of every citizen of Ukraine to a clean and safe environment, and to introduce sustainable use, conservation and restoration of natural habitats.

The Ministry of Environmental Protection and Natural Resources (formerly Ministry of Ecology and Natural Resources) is the special government institution responsible for the formulation and implementation of environmental policy in the country. In line with its mandate, the Ministry also supervises the work of the State Agency of Water Resources, State Agency of Forestry Resources, State Geological Survey Service and State Ecological Inspectorate of Ukraine. However, other government institutions are partly involved in the implementation of the ecological policy, for instance, the Ministry of Agrarian Policy and Food is supervising the State Service of Ukraine on Geodesy, Mapping and Cadastre as well as the State Agency of Melioration and Fisheries Resources and the Ministry of Energy of Ukraine.

At the oblast and district or municipal administrative levels, special departments exist to implement the ecological policy at the local level. The Ministry and other environmental agencies do not have law enforcement as part of their mandate and Ukraine does not have a special law enforcement agency dealing with environmental crimes. The National Police and to some extent the State Security Service of Ukraine are dealing with investigations of environmental crime. Processual supervision is handled by the special environmental prosecutor's office – a part of the Office of the General Prosecutor of Ukraine. The State Environmental Inspectorate has a responsibility only for control in the field of environmental protection, rational use, reproduction and protection of natural resources (State Environmental Inspectorate of Ukraine 2018).

The World Bank's Country Environmental Analysis of Ukraine (2016) found Ukrainian environmental policy to be first and foremost declaratory, without essential enforcement mechanisms. It describes lack of coordination and alignment between different policies, limited impact analysis and frequent changes to legislation as core issues.

Ukraine has in recent years accelerated its efforts to address environmental challenges (OECD 2022). Progress has been made when it comes to preserving nature and green, low-carbon economic development. The recently adopted 'Strategy for the State of Environmental Policy of Ukraine for the Period till 2030' and accompanying action plan are for instance increasing ambitions for reducing pollution. The results of these efforts can be seen in several areas, OECD is reporting on improved energy efficiency as well as significant increases of households connected to sewage networks and larger shares of renewables in the primary energy supply (OECD 2022).

Sustainable management of chemicals and hazardous waste has been incorporated into Ukrainian legislation, guided by the Association Agreement between Ukraine and the European Union (EU), the European Atomic Energy Community and their Member States. The Association Agreement identifies priority areas of cooperation and gradual approximation of Ukrainian legislation to the EU law, namely to EU Regulations № 1907/2006 (REACH) and № 1272/2008 (CLP). However, the country lacks a clear policy on the safe circulation of chemicals throughout their life cycle.

Several governmental agencies are involved in policy making in the field of chemicals management, including the Ministry of Economy, the Ministry of Environmental Protection and Natural Resources, the Ministry of Health, the Ministry of Development of Communities and Territories of Ukraine and the State Service on Food Safety and

Consumers' Protection. However, despite significant pressure from the Cabinet, only part of the policy and legal acts proposed by the National Security and Defence Council of Ukraine (NSDC) were adopted before the outbreak of the current conflict in February 2022.

Previous economic and environmental progress are at risk of losing momentum because of the current conflict and the subsequent damage and impacts from shelling of nature, industrial facilities and critical infrastructure is negatively impacting human health and ecosystems both in the short and long term (OECD 2022).

Annex II **Collection of data and Information from stakeholders in Ukraine**

The Operational Headquarters (OH)[3] at the State Environmental Inspectorate of Ukraine collects data on:

- emergencies, such as explosions, bombardment of fuel and lubricants warehouses, oil storage facilities, enterprises that may use hazardous and / or chemicals in production;
- damage, destruction or shutdown of sewage treatment plants before discharge into water bodies – water utilities, industrial facilities;
- destruction of dams of filtration fields and leakage of waste to the terrain; destruction of waste-water treatment or hydraulic structures;
- ignition (burning and decay) of waste disposal sites, such as landfills;
- damage to the soil, burning and deforestation, especially in protected areas.

From the first days of the current conflict, the Ukrainian government, civil society and the private sector realized the importance of the registration of incidents, damage and destruction caused by the situation with high risk of significant impact on the environment. A variety of actors are participating in data collection, record-keeping and monitoring of damage. While OH is dealing with the registration of loss and damage at the national level, the Ukrainian Association of Regional and Oblast Councils – UAROC in cooperation with the State Ecological Academy has created the Centre of the Monitoring of the Impacts of War, mainly operating at the community level, but also in preparedness to respond to possible environmental, and Chemical, Biological, Radiological and Nuclear (CBRN) disasters. Ukrainian businesses have united around the UN Global Compact in Ukraine collecting data on environmental loss and damage of the private sector.

In addition, several international non-government organisations, such as the peace organization PAX, the Zoï Environment Network, the Conflict Environment Observatory (CEOBS) and IMPACT Initiatives are dealing with verification and visualization of data available from social media. The environmental network Zoï has presented maps of environmental damage of the current conflict in Ukraine. Various think tanks, like the Kyiv School of Economics (KSE), are dealing with sectoral loss and damage assessments with a strong focus on assessing losses due to degradation of natural resources. At the same time, the Institute of the Geochemistry of the Environment of the National Academy of Sciences of Ukraine (NASU) is trying to conduct assessments of chemical pollution of soil and groundwater in various areas. The NASU Institute of the Environmental Economics and Sustainable Development is assessing the impact on the water sector.

[3] The Ecological Committee of the Ukrainian Parliament (Verkhovna Rada) initiated the creation of an Operational Headquarters (OH). Participants of the OH include representatives of the Ecological Committee of the Verkhovna Rada, the Ministry of Environmental Protection and Natural Resources, the State Environmental Inspectorate, the National Police, the State Security Service, the special environmental prosecutor's office, representatives of civil society and internationally recognized experts.

UN environment programme