

Ecocide in Ukraine – The Toxic Legacy of Russia’s War

Eugene Z. Stakhiv, PhD

July 16, 2024

[Testimony for presentation before the Commission on Security and Cooperation, Helsinki Commission, U.S. Congress]

ABSTRACT

Russia’s war against Ukraine has resulted in widespread destruction of both critical civilian infrastructure, as well as degradation of vital ecosystems and biodiversity, along with tens of thousands of battlefield casualties. Lost in the accounting is the long-term environmental damage to both ecosystems and public health from the toxic residue of millions of pieces of military ordnance scattered over a 1500km swath of the battle front. This includes the longer-term costs of ecological restoration and remediation of countless toxic and hazardous sites and demining, which are vastly understated, as are the inevitable emerging adverse chronic public health effects. It is important to have a full accounting of the war’s damage and costs of reconstruction and rehabilitation – for setting priorities and ultimately for compensation by Russia. Regardless, considering the enormous costs involved, Ukraine may have to consider designating many areas as ‘Red Zones’ or ‘Zones of Exclusion’, equivalent to the Chernobyl exclusion zone, thereby creating a 1500 km archipelago of forbidden zones.

INTRODUCTION

The relentless Russian assault against Ukraine over the past 900 days of warfare and bombardment has caused an escalating series of devastating catastrophes inflicted on its populace, not least of which is a silent victim – the environment. Whereas the human and socioeconomic toll of sacrifice and suffering is well understood and duly documented by many institutions, such as the [Kyiv School of Economics](#) and the [World Bank](#), accounting for the harmful long-term effects of ecocide, and its multiple pathways of causing deleterious human health effects, is still sketchy and deficient.

It is important to fully account for all damages inflicted by the Russians – both to set realistic priorities for scarce reconstruction funds, as well as for future compensation claims for the war crimes committed by Russia. Potentially, among the most harmful, long-lasting and widespread ecological and human health impacts are those from the toxic contamination caused by millions of artillery

shells and land mines that litter a broad 1500km crescent of destruction – from Kyiv, through Kharkiv to Kherson.

Ecocide is defined as the deliberate or negligent destruction of the natural environment by human action. In most cases, except for the Kakhovka dam demolition and many other deliberate instances of destruction of smaller dams and critical infrastructure by [Russian forces](#), the destruction of natural and managed ecosystems is largely a byproduct of indiscriminate Russian military operations and shelling.

Ecocide is considered a war crime under the Rome Statute. The International Criminal Court's (ICC) Rome Statute considers ecocide a war crime under Article 8(2)(b)(iv) if an intentional attack causes "widespread, long-term, and severe damage to the environment" that is disproportionate to the anticipated military advantage.

Work is underway to better define the legal principles under which nations can be prosecuted for ecocide war crimes. A recent [U.N. International Law Commission Report](#) on protection of the environment in relation to armed conflicts, covered many of the causes of environmental harm during a conflict. A great many directly address Russia's clear culpability in destroying Ukraine's infrastructure and its environment.

For example, Draft Principle 17 on protected zones states that "An area of major environmental and cultural importance designated by agreement as a protected zone shall be protected against any attack, as long as it does not contain a military objective." Russian forces stationed in the Black Sea Biosphere Reserve, along the southern coast near Kherson, caused fires that could be seen from space.

During the first [13 months of war](#), 36 fuel storage facilities were destroyed, including 17 oil depots, generating pollutants from the burning of over 100,000 tons of oil, oil products, and gasoline. The bombing of Ukraine's energy infrastructure has accelerated throughout 2024. Added to this were attacks on chemical complexes, fertilizer and nitric acid plants, resulting in [release of toxic substances](#), including nitric acid and ammonia – the most dramatic of which was the destruction of the iron smelting and steel plants in [Mariupol](#).

In March 2023, the [European Parliament](#) voted in support of including ecocide into EU law. The Kakhovka dam disaster prompted the EU to push ahead with its legislation on ecocide. Russia's wanton aggression against Ukraine has been

deliberate, targeting civilians, hospitals, energy infrastructure, and its agricultural, energy and industrial base.

The destruction of [Kakhovka reservoir](#) and the resultant massive destruction of aquatic ecosystems in the lower Dnipro river basin is but one example of deliberate actions by Russia, where it was shown that **ecocide** encompasses a myriad of associated adverse direct ecological effects as well as indirect human health effects, such as loss of access to health facilities and medical care, and a host of indirect chronic human health effects, including malnutrition.

The recent UN/Ukraine Kakhovka [‘Post-Disaster Needs Assessment’](#) Report estimated that there was approximately \$2.79 billion in direct damage to infrastructure and assets, with losses exceeding \$11 billion, with a particularly long-lasting environmental impact that is yet to be quantitatively estimated. For example, more than 600,000 hectares [1.5 million acres] are now without irrigation water formerly provided by Kakhovka reservoir. As a result, fields lay fallow, affecting food production, jobs, health and self-sufficiency for tens of thousands of residents dependent on farming for their livelihoods. These fields also sustained migratory birds and waterfowl, which are greatly diminished in numbers. Ukraine is a major pathway for migratory birds flying between central Asia and the Middle East. Recently, a survey of [migratory birds in Kashmir](#) showed significant declines in various species, attributing them to the war in Ukraine.

The environment has been the silent victim of war. The immediate and short-term damage to the environment has been estimated at [\\$56.4 billion](#). However, the Ukrainian government uses an estimation method that relies on foregone revenues from fees, taxes, and other regulatory charges for pollution caused by municipal and industrial discharges from destroyed wastewater treatment plants that were no longer functioning. Thus, this accounting method does not include the [long-term environmental impacts](#), such as the profoundly damaging long-term effects on human health from pollution, or damage to natural ecosystems and biodiversity, which can only be fully assessed once the war has ended.

The term ecocide encompasses many dimensions – devastation not only of the natural environment, but also of the managed human environment, including forestry, agriculture, aquaculture and water resources. The managed forests, reservoirs and agricultural fields also provide habitat for a broad ecological food chain. In addition, long-term adverse chronic human health effects and ecosystem food chain disruptions result from chemical contamination of the environment via

millions of explosive artillery shells, rockets and landmines. These impacts should be added to the rubric of ecocide as a permanent and, as yet, incompletely documented category of deleterious public health effects, and designated as a [war crime](#).

One of the ways of understanding the financial magnitude of the ecosystem restoration costs and those of toxic waste remediation is to briefly consider two ongoing projects in the U.S. : the East Palestine train derailment cleanup and the restoration of the Florida Everglades, which roughly equals the ecosystem losses in Ukraine, both in area and biological importance to Europe.

On February 3, 2023, a Norfolk Southern freight train derailed in East Palestine, Ohio. About twenty of the affected cars contained hazardous materials, including vinyl chloride, ethylene glycol, ethylhexyl acrylate, butyl acrylate and isobutylene, and several cars contained oil. Some cars spilled their loads into an adjacent ditch that feeds a stream which eventually empties into the Ohio River.

As of Jan 2024, [over \\$1billion](#) has been spent by Norfolk Southern for the cleanup, which consists of \$836 million for environmental-related clean-up expenses and \$381 million for community assistance and health programs. Ultimately, more than 176,000 tons of contaminated soil were excavated and transported out of East Palestine for appropriate disposal.

The effort to remove vast amounts of contaminated soil and water from the relatively small site has involved at least seven different [licensed](#) hazardous waste disposal facilities across four states: Ohio, Indiana, Michigan and Texas. There are hundreds of comparable contaminated sites in Ukraine. The environmental situation in the Russian-occupied part of Eastern Ukraine is far worse, however, since the conflict began there in 2014. Donbas is the industrial base of Ukraine, and its coal mines and chemical processing plants were already in disrepair before the war began in 2014 – now, it is beyond repair, according to a [UN report](#), creating major disastrous environmental degradation from acid mine drainage, old wastewater treatment plants and closed coal mines.

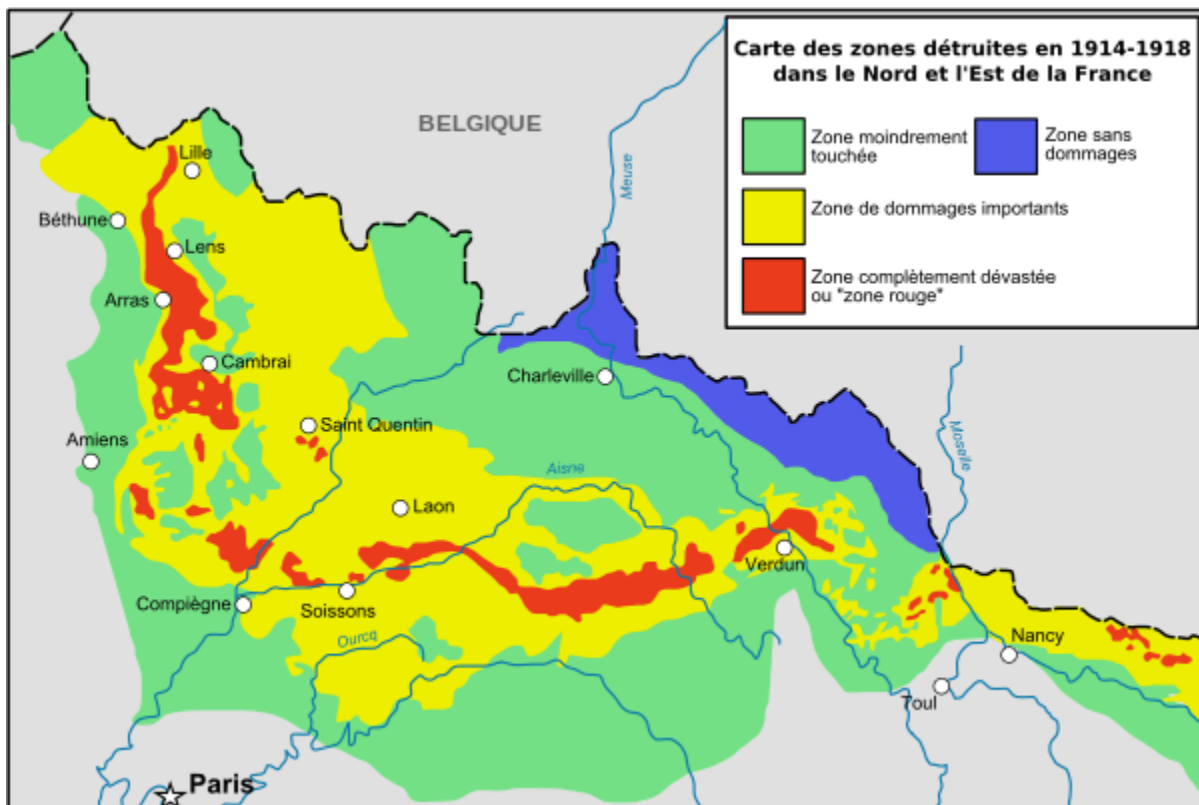
Restoration of the Florida Everglades began in 2000. The 60 or so projects funded by Congress over a period of 25 years, were primarily to restore the natural hydrologic pathways that sustained a richly diverse ecosystem, disrupted by Corps of Engineer flood control projects. The project scale, complexity and costs rival what Ukraine would probably need over the next three decades, to restore the numerous habitats and ecosystems destroyed by Russian operations. Everglades

projects costs have escalated to [\\$ 23 billion by 2023](#). Congress and the state of Florida have committed over \$1 billion towards the [costs of restoration in 2024-2025](#).

The Prospect of ‘Red Zones’ in Ukraine

The Battle of Verdun in 1916 was one of the bloodiest battles of World War I, lasting 300 days and costing over 300,000 lives, with nearly 1 million other casualties. The battles of Ypres, Somme and Verdun created a desolate barren wasteland over a distance of 250 miles [400km], from Nancy to Lille. During the year-long battles, the French and German armies fired about 10,000,000 artillery shells.

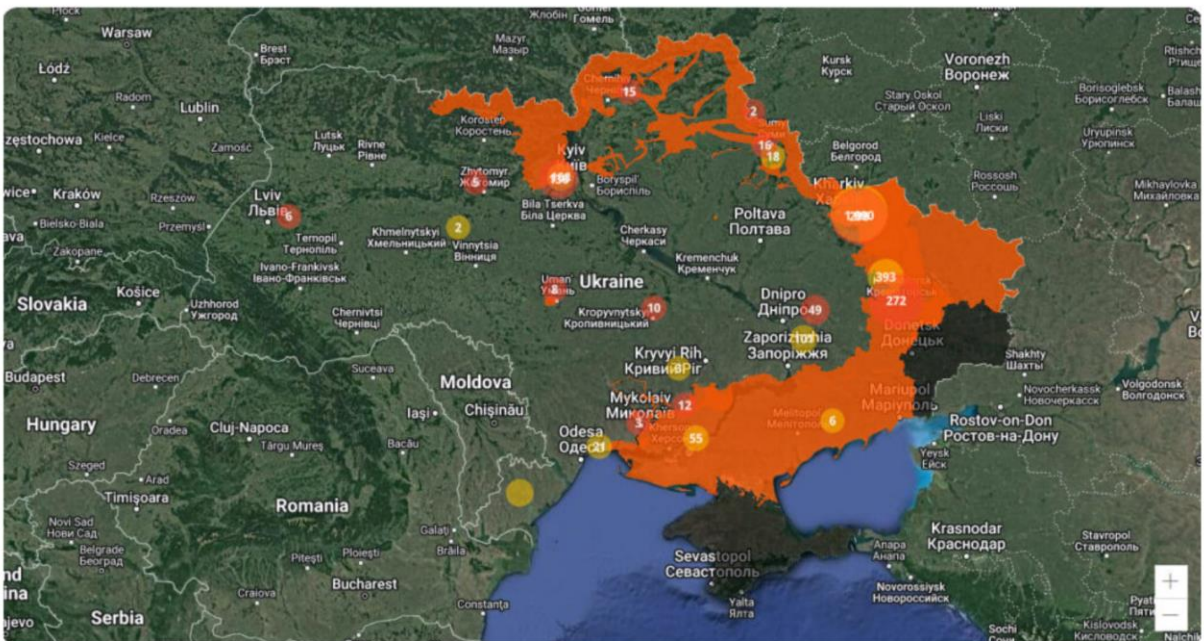
Over 100 years later, that crescent of destruction, extending over 250 miles of France’s and Belgian’s border, is still a dangerous place and is a forbidden zone for human activities – the ‘**Zone Rouge**’ - as it still hides hundreds of thousands of pieces of unexploded ordinance from the intensive shelling during those intense WWI battles. After the war, the French closed some 16 million acres northeast of Verdun due to unexploded ordnance and uninterred human remains. Much of this area is "off limits" to this day, as millions of unexploded shells still lie in the soil around Verdun.



Source: https://en.wikipedia.org/wiki/Zone_rouge

For comparison, at the peak of the Battle of Bakhmut along Ukraine's front lines, each side was firing 10,000 artillery shells daily. During the 2023 course of the Ukraine-Russia war, it is estimated that more than [10 million shells](#) have been fired by Russia alone, within Ukraine's lengthy battlefield.

During the 2 ½ years of constant shelling, death and destruction, Russia has created an archipelago of desolate contaminated wastelands stretching from Kyiv to Kharkiv to Kherson – a distance of over 1500 km [900 mi]. This crescent of destruction is littered with millions of bomb craters, mortars, rockets and mines – many of which are unexploded and dangerous to the local populace.



Map of Ukrainian territories that could potentially be contaminated by explosive objects as of April 2023. Source: State Emergency Service of Ukraine, <https://mine.dsns.gov.ua/>

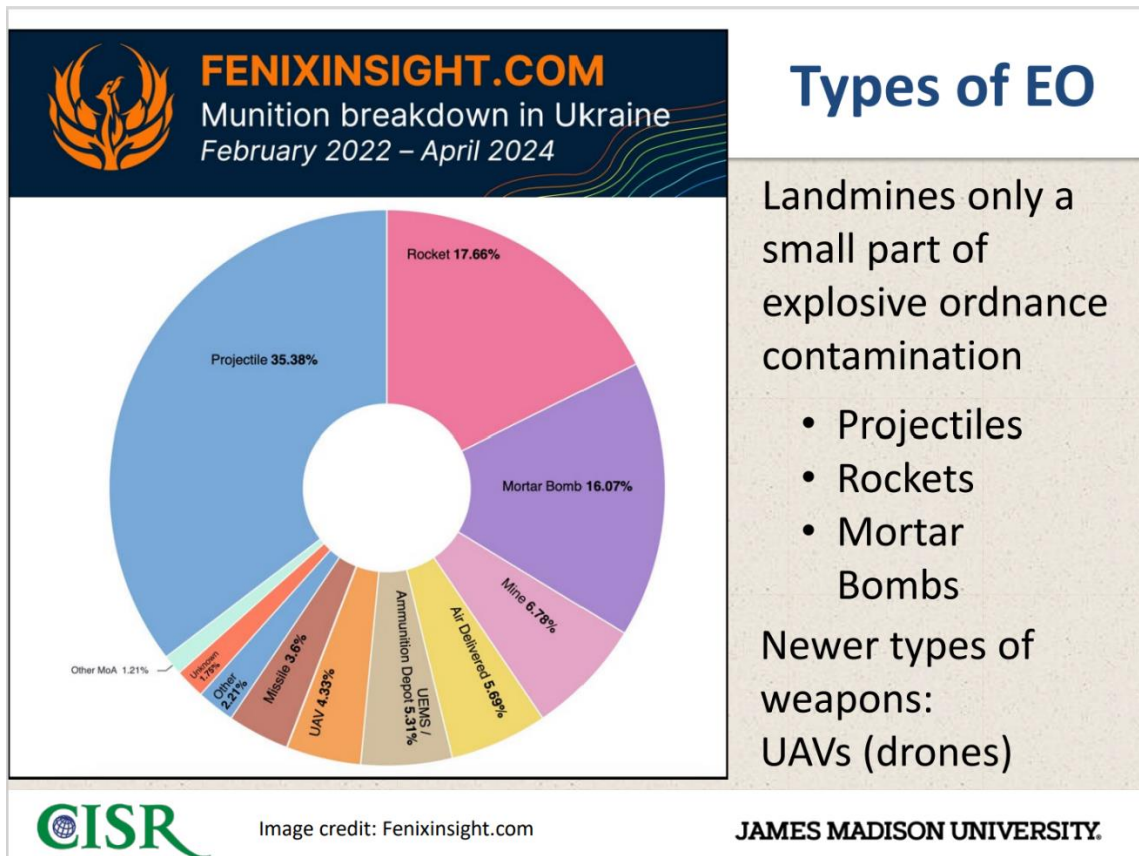
Source: <https://www.vox.com/world-politics/2023/11/30/23979758/ukraine-war-russia-land-mines-artillery-humanitarian-crisis>

The big difference, though, between France's 'Zone Rouge' and Ukraine's 'Red Zone', is land mines – millions of unexploded land mines covering tens of thousands of square kilometers. Land mines were not used much in WWI – only

beginning in WWII. It is estimated that over [2 million mines](#) have been laid by both sides, since Russia's invasion on Feb 2022. Since 2022, landmines and explosive remnants of war have contributed to more than 1,000 civilian casualties in Ukraine, both injuries and fatalities [386], [according to HALO and Ukrainian authorities](#).

So, in addition to the tens of millions of artillery shells, mortar, rockets and cluster bombs that proliferate over Ukraine's landscape, a significant percentage of which are unexploded [UXO], most of the land mines are still in place, also unexploded.

Of necessity, Ukraine will have to prioritize its land mine and UXO clearance along this long crescent of desolation. They will have to contemplate designating their own 'Red Zone' simply because of the very high costs associated with mine clearance, and the reality that much of the land is contaminated with the toxic residue of explosives. Mechanical mine clearance cannot rid the soil of those toxic contaminants – **especially if they are detonated in place.**



TNT, rapid detention explosives (RDX), and high melting explosives (HMX) are the most commonly found explosive substances in soil. All of them are popular materials used by military forces, and these substances and their derivatives have polluted environments to levels that threaten the health of humans, livestock, wildlife, and entire ecosystems. Unexploded ordnance (UXO) from military operations also pose a serious environmental threat due to the release of toxic substances from corroding metal ordnance [artillery shells and land mines], in addition to the risks associated with the potential for accidental detonations.

Depleted uranium is used routinely to harden artillery shells that can penetrate tank armor. Uranium is a very dense metal, and depleted uranium can be put on the tips of tank shells, bullets and mortar rounds to increase their ability to penetrate targets. The radioactive material could add to Ukraine's massive post-war clean-up challenge. The [U.S. military](#) has studied the impact of depleted uranium on U.S. troops in the Gulf War and to date has said it has not found higher risk of cancers or other illnesses in those servicemembers who were exposed. It has said it will continue to monitor those who were exposed.

It is [estimated](#) that as much as 2 % (by mass) of a TNT-filled 155-mm round remained as residuals on the soil surface after detonations, which translates to 140 grams of explosive residues per round. Heavy metals are among the most frequent and most persistent contaminants in war zones, including lead, antimony, chromium, arsenic, mercury, nickel, zinc, cadmium, and copper. For example, soils of the Flanders region of Belgium during World War I, still contain elevated concentrations of copper due to the intense shelling on battlefields there over 100 years ago.

In addition, according to the Ukrainian military, Russia uses old ammunition produced over 30 years ago, 40% of which either does not explode or its explosive substances do not burn out completely and pollute the air. In some cases, in liberated areas, even unexploded 500-kg bombs were found. International demining experts estimate a dud rate of Russian munitions [between 10 and 30](#) percent, with cluster munitions reaching 40%. In 2022 Russia alone fired around 11 million artillery rounds, which might amount to over 2 million UXO on the territory of Ukraine left from artillery fire alone.

While digging a rail line through the Somme battlefields in 1991-92, to connect with the "[Chunnel](#)", the French *démineurs* ("de-miners") handled an average of five tons of unexploded ordnance per day that had been unearthed during the

excavation. Throughout France, the *démineurs* collect some 900 tons of ordnance per year, with 30 tons of that being gas shells. Luckily, no one was killed during the "Chunneling" - but every year several French *démineurs* are killed and injured disposing of gas and high-explosive shells, and in 1991 alone, 36 French farmers were killed plowing up unexploded ordnance from the Great War.

Ukraine faces a similar prospect of creating its own 'Red Zone', a lengthy chain of islands contaminated by toxic chemicals, strewn with UXO's, contaminating agricultural fields and polluting groundwater. It already has a 'Forbidden Zone' – the Chernobyl Exclusion Zone - an area of approximately 2,600 sq km (1,000 sq mi) in Ukraine, north of Kyiv, immediately surrounding the Chernobyl Nuclear Power Plant, where radioactive contamination is highest and public access and habitation are restricted.

On a positive note, the Chernobyl Exclusion Zone has become a [thriving sanctuary](#) with natural flora and fauna with some of the highest biodiversity and thickest forests in all of Ukraine. This is due to the lack of human activity in the Exclusion Zone and is thriving despite the radiation.

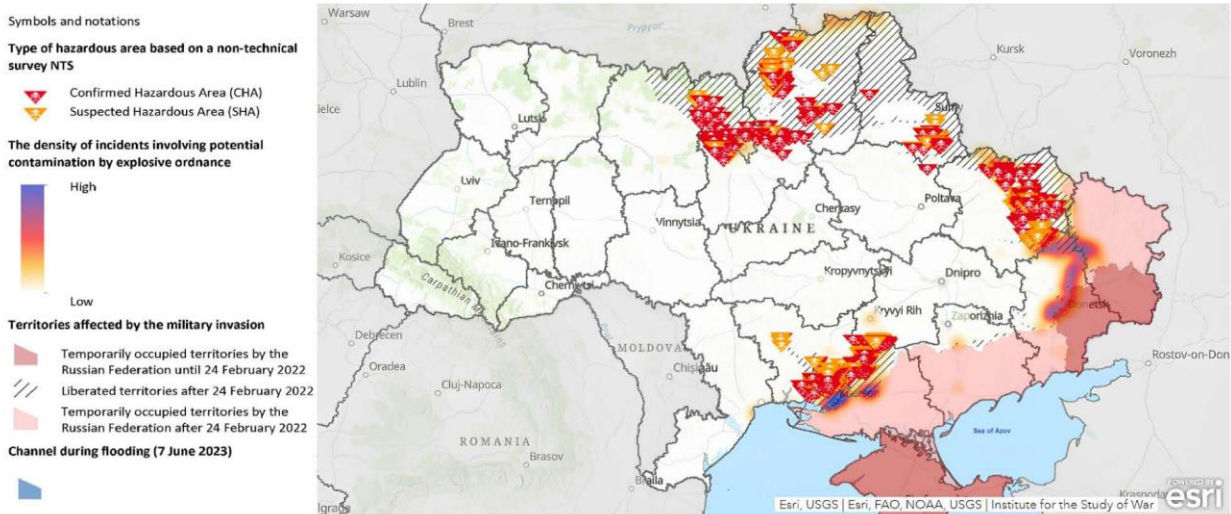
Long-term Ecological and Health Consequences of Bombing

In February, 2024, a High Level Working Group on "[The Environmental Consequences of War](#)" published their report. In that report, there were five recommendations addressing the problems associated with clearing of land mines. They wanted to ensure that demining procedures followed international standards, and that the risks of demining be properly accounted for. Also, that "Ukraine should aim to prioritize clearance programs that provide a dual benefit to communities by removing mines and facilitating environmental enhancement through land restoration and sustainable land use practices." That's a very tall order, by any measure.

Russia's bombing and mining along the front, from Kyiv to Kherson, covers roughly 160,000 square kilometers [62,000 sq mi – 40 million acres], approximately the area of Maryland, Massachusetts, South Carolina and Vermont. The bombing has created countless long-term health hazard sites, together with a myriad of potential '[Superfund sites](#)' of destroyed chemical factories, fertilizer storage sites, water and wastewater treatment plants.

The Ukrainian government estimates that only about [20 percent](#) of the total area of 160,000 sq km has suspected or confirmed contamination by land mines and other

UXO's, or about 32,000 sq km. With these calculations, the Government is preparing to clear and release 80% of the contaminated territories in the aforementioned areas in the next 10 years. Some experts confirm that this is feasible provided there will be at least 10,000 deminers, a sufficient number of machines and robotic systems, as well as surveillance, detection and extraction drones.



Source: adapted from ua.imsma.org

Thousands of lives will be lost before all the priority territories can be remediated, and the medical costs associated with treating the chronic health effects of individuals could easily amount to tens of billions of dollars in the future.

COSTS OF RESTORATION AND REMEDIATION

The term ‘restoration’ has generally been applied to restoring damaged natural ecosystems. ‘Remediation’ has usually been associated with decontamination of sites polluted by toxic chemical spills, unregulated disposal of industrial chemical wastes or nuclear wastes. There is a good database on the costs of restoring natural ecosystems, both in the U.S. and U.K., based on the work of many agencies tasked with restoring millions of acres of degraded habitat and aquatic ecosystems, such as the Army Corps of Engineers, Bureau of Reclamation, National Park Service, Fish and Wildlife Service and EPA.

Likewise, there are very good estimates of various types of remediation costs – from Superfund sites, formerly used military sites, chemically contaminated sites and nuclear waste sites [Dept of Energy]. The U.S. military has conducted

considerable [research](#) on the most cost-effective methods and technologies for remediating contamination of their firing ranges.

However, these costs must account for not only the **physical remediation** [construction, disposal, incineration, etc.] of a site, but also the costs of **ecological restoration** of adjacent lands and affected streams, and the **long-term public health consequences** via health monitoring and possible compensation for chronic and incurable conditions. The East Palestine train derailment offers a good example of these costs, amounting to over \$1 billion.

There is another important category of costs – actually loss of income, and production, called foregone farm benefits lost to farms and farmers who could not produce because equipment was damaged and lands mined and contaminated by toxic residues of bombing. As of June 2023, the Kyiv School of Economics estimated that Ukraine’s agriculture sector had incurred \$8.7 billion in direct damages to agricultural machinery, equipment, and storage facilities, as well as from stolen or damaged agricultural inputs, such as fertilizers and seeds, and outputs, such as crops and livestock. The sector’s \$40.3 billion losses represent farmers’ diminished incomes due to [foregone production](#), lower selling prices for products, and higher operational costs across all stages of the agri-food value chain. In other words, the unrealized economic benefits are four times greater than the direct physical damages to farms and equipment.

Restoration

One measure of benefits and costs of ecosystem restoration is to compare the cost of restoring one hectare versus the benefit that one hectare of habitat contributes to ecosystem maintenance of various functions. Of course, different ecosystems and habitats have different values and benefits – an estuarine wetland is worth more than a freshwater marsh, which is worth more than a hectare of forest – on average.

A comprehensive study on the valuation of ecosystem services was conducted in 2020 by the [U.K. Dept of Environment, Food and Rural Affairs](#). It covered over 25 typical services provided by habitats and ecosystems, ranging from food, genetic resources, biodiversity, climate regulation to esthetic experiences and hunting. And it covered a wide range of ecosystems, from open ocean, coral reefs to mangrove forests, marshes and freshwater wetlands. The mean value of the suite of ecosystem services for all ecosystem types was computed as \$3500/ha/yr [in

2020 dollars]. The figures ranged from a high of \$119,000/ha/yr for tropical forests to \$1600 for grasslands. Figures that more closely represent Ukraine's ecosystems were inland and coastal wetlands, \$49,000; cultivated areas, \$8,000 and rivers and lakes, \$20,700/ha/yr.

For example, the [U.S Army Corps of Engineers](#), alone, spent \$710M for aquatic restoration projects in 2022. The agency restored, improved or protected 108,000 acres [44,000 Hectares] in 2019, and 115,000 acres [46,500 ha] in 2021. This translates, on average, to approximately \$13,000/ha for restoration costs.

Ukraine's [Environment Minister Strilets](#) identified a large number of ecologically protected areas that were impaired or severely damaged by Russian forces. Ukraine is home to 35 per cent of [Europe's biodiversity](#). There is reported damage to 160 [of 271] 'Emerald network' sites, totaling 627,000 hectares. These 'Emerald' sites are part of a European system of protected conservation areas and natural habitats for endangered species. Also, 16 UNESCO Ramsar sites, totaling 2.9 million hectares, have been substantially impaired. These sites are wetlands designated to be of international importance under the [Ramsar Convention](#), an intergovernmental environmental treaty established in 1971 by UNESCO.

Remediation

There are many examples of costly toxic and hazardous waste remediation projects in the U.S. which can be readily transferred to Ukraine, adjusting for purchase power parity [PPP], wherein the costs of products and labor in Ukraine in Hryvnia or current USD would be lower than in the U.S., for example. There are approximately 11,000 'Superfund' sites in the U.S. – that is industrial hazardous waste sites that affect human health, regulated under the [CERCLA law](#) of 1980.

To date, [\\$21 billion](#) has been spent on remediating these sites, with an average cost of [\\$41 million per site](#). The cost of treatment of hazardous wastes ranges from \$50-\$130/ton, depending on whether they require simple landfill, chemical treatment or incineration. Tens of thousands of hectares of land have been contaminated in Ukraine, requiring remediation of millions of tons of soil.

By the time the Russia-Ukraine war is over, there could easily be the equivalent of hundreds of 'Superfund' sites in Ukraine – mostly in and around urban areas. One such city, Mariupol, is the site of five iron and steel processing plants, with several open slag waste disposal ponds adjacent to the Azov Sea. There was a year-long battle in Mariupol, creating one extensive Superfund site.

Another example of compensation for the adverse health effects of toxic and hazardous wastes is the recent settlement for groundwater pollution at Marine Camp Lejeune over a period of 50 years. The U.S. Congressional Budget Office estimates that \$6.1 billion will be spent to compensate thousands of victims who drank this water over a period of years of continuous pollution, which causes a wide range of nerve damage and cancers.

The recent U.S. Government settlement on the [Marine Camp LeJeune groundwater pollution case](#), is projected to cost over \$21 billion, is but one example of comparable human health effects of groundwater pollution caused by various chemical solvents and contaminants that were carelessly disposed over a 30-year period, causing a wide range of cancer-related illnesses. Much of Ukraine's prospective 'Red Zone' lies in rural agricultural areas, where the populace is dependent on untreated groundwater.

According to the [World Bank](#), in its third rapid damage assessment report [Feb 2024], **demining works alone will cost USD 37 billion**. [According to the Kyiv School of Economics](#), the cost of clearing a parcel of land can reach more than \$3,000 per hectare by manual means. As a result, small and medium-size farms cannot afford demining, while state services are directed toward demining cities and communal infrastructure projects, with limited resources allocated to farms. By one United Nations estimate, the cost to produce a landmine is between \$3 and \$75 while the cost of removing it is between \$300 and \$1000.

There are many [innovative technologies](#) being developed to detect land mines that harness drones, magnetometers and artificial intelligence to inexpensively locate mines. The much larger and vastly more costly issue is mine clearance technologies. Problem – exploding mines in place is the cheapest way – but it also contaminates the soil, leading to a suite of adverse secondary and tertiary environmental and human health consequences. Manual clearance of mines, by defusing, is a slow, dangerous, laborious and costly process.

There are many [different approaches](#) to manual demining, with most requiring more than 30 minutes per square meter, according to one comprehensive comparison and test of these methods. Hence, the average manual mine clearance rate would be about 10-20 square meters per person per day. One hectare is 10,000 sq. m. so, it would take [approximately 500 sappers](#) one day to clear one hectare.

A recent report by [GLOBSEC](#) [Jan 2024] is the most comprehensive and informative treatise on the current status and problems of landmines and demining

in Ukraine. To date, [Ukraine’s allies](#) have allocated over \$700M for landmine removal – far from the World Bank estimate that would be required. But that does not include decontamination of agricultural lands, and decontamination of groundwater sources that rural villages depend on. Understandably, [critical infrastructure](#) is Ukraine’s top priority for demining, such as roads, electricity lines, gas and water pipes, and power stations. So is civilian safety, making sure people can return to schools or hospitals safely. Then comes areas that intersect with Ukraine’s economy, specifically the grain fields that underpin the country’s agricultural sector. Full clearance — that is, removing every single mine — is not feasible with stretched resources and an ongoing conflict. Hence, the realistic prospect of an archipelago of ‘Red Zones’ across Ukraine’s Eastern provinces that will take decades, if not generations, to demine and decontaminate.

In 2021, DOD [estimated](#) that it would cost \$11.9 billion to clean up 1,700 sites in its Formerly Used Defense Sites [FUDS] program which had been contaminated by a broad mix of chemicals, including those from firing ranges. The FUDS program cleans up sites that have been contaminated with hazardous substances created by military operational uses. Table 4 [below] shows estimated per acre costs of remediation. There are many such military sites in Ukraine, that will need to be cleaned up in the future.



Table 4: High Cost Estimates to Clean Up an Acre with a High Density of Contamination, by Service

Service	Acreage	High cost estimate (dollars)	Average high cost per acre (dollars)
Air Force	2,835,579	2,140,072,819	755
Army	8,691,311	65,855,410,348	7,577
Marine Corps	1,023,623	3,719,488,388	3,634
Navy	134,459	920,669,000	6,847

Source Table 4: [GAO-04-601 DOD Operational Ranges: More Reliable Cleanup Cost Estimates and a Proactive Approach to Identifying Contamination Are Needed](#)