Strategos, 8(2), 2024.
UDK 355.425
UDK 502/504
Original scientific paper

STRATEGOS

Impact of Military Activities on the Environment

Zvonko Krajnović, LTC Andrej Smolek [1]

Abstract

Security cannot be fully understood without considering environmental factors. Due to the close relationship between military activities and the environment, military actions have a long history of causing environmental damage worldwide. With an increasing diversity of actors in the modern security landscape, their ever-growing (covert) interests, and the increasingly complex interdependence of security trends and factors, the global security environment is undergoing dynamic changes, causing significant and often unpredictable impact on the environment. Knowledge about the destructive capabilities of cutting-edge military technologies developed over the years is limited to a small number of people. Militarization can be seen as one of the most devastating human endeavors. It is particularly necessary to raise awareness about the dominance and destructiveness of unconventional military activities. The synergy between environmental protection and crisis management should aid in finding solutions and preventing the emergence of a vicious cycle linking military activities, crises, diseases, poverty, and ongoing environmental destruction.

Keywords

environment, military activities, unconventional military activities, ecological disaster

1 Zvonko Krajnović, Croatian Armed Forces Reserve Officer, zvonko.krajnovic@gmail.com
LTC Andrej Smolek, Dr. Franjo Tuđman Croatian Defence Academy, smolekus@yahoo.com

Introduction

The ongoing destruction of the environment has raised awareness about the devastating impact of human activity on nature. The environment is a dynamically balanced interactive system of abiotic factors (land, water, air, climate, noise, etc.) and biotic factors (flora and fauna), alongside the anthropogenic environment (infrastructure, systems, and products of modern times). Negative changes to the environment pose a threat to the survival of humans, flora, and fauna on Earth. By the late 20th century, scientists increasingly recognized the ecological factor as critical to understanding new security risks and the potential for armed conflict. The concept of environmental security describes threats to political stability arising from ecological problems. Everyday human activities in production processes (industry, transportation, etc.) and their associated accidental occurrences have significantly contributed to environmental degradation. These activities consume and activate substantial amounts of pollutants and energy, leading to changes in the composition of land, water, and air, disrupting the balance of environmental factors, and consequently resulting in the extinction and disappearance of many species of flora and fauna, as well as posing risks to human health. The disruption of this balance is further influenced by activities aimed at successfully implementing military and military-political interests.

Military activities include operations conducted by states and other actors for defense and security. Due to their close relationship with the environment, military activities have had a long history of causing environmental damage globally. Among human activities, military operations are a significant and enduring contributor to environmental degradation. Therefore, researchers focusing on environmental issues approach the military mindset with significant skepticism, as there are concerns that solutions conceived in a military dimension may accelerate conflict development rather than address environmental problems or promote ecological cooperation (Rogers, 1997). Numerous studies have been conducted on the impacts of military activities on the environment, showing a clear continuity of effects ranging from very negative to very positive. However, it is notable that these studies vary significantly in methodology and content, being "limited in depth

and fragmented by discipline" (Machlis & Hanson, 2008, p. 729). There are a number of positive impacts of military activities on the environment, primarily regarding the infrastructure of training military activities (due to the fragmentation and isolation of certain base or training areas). Positive contributions of military activities are also made through various projects[1] (Brochu & Thiboutot, 2019) and programs[2]. However, military activities lead to significant exploitation of global natural and energy resources, as well as degradation of the biosphere as a whole, which consequently creates pronounced ecological effects and negative impacts (hereinafter referred to as "impacts"). A paradox emerges from the primary mission of militaries: while tasked with ensuring national defense and security, military activities often cause substantial harm to the environment. This is primarily a consequence of the irrational consumption of renewable and non-renewable natural resources, the use of conventional weapons and technologies of great destructive power, and the development of unconventional military technologies. Some military activities are contextually linked to forms of civilian activities (industry-military industry), which have a significant impact on the environment. Therefore, separating the military contribution (military industry) from the environmental impacts of civilian industry poses considerable challenges. The operation, maintenance, and exploitation of military infrastructure (bases and training grounds) have recently been significantly regulated worldwide, especially in Europe. However, unregulated military training activities from the past continue to keep contaminated sites active even today[3]. While efforts are being made to prevent contamination in bases and training grounds, the "sustainable" development of unconventional military activities on the other hand increases the environmental impacts of military operations. Although the ecologically destructive nature of warfare has a long history, the potential for creating contamination continues to grow. Modern military

1 Revolutionary insensitive, green, and healthier footwear technology with reduced harmful contamination. *(Revolutionary Insensitive, Green, and Healthier Training Technology with Reduced Adverse Contamination, RIGHTTRAC).*

2 See: https://www.serdp-estcp.org/

3 Numerous cases of environmental harm are supported by the results of laboratory analyses. *ATS-DR-a (Agency for Toxic Substances and Disease Registry)*. See: https://www.atsdr.cdc.gov/

activities have moved significantly closer to densely populated areas. There is persistent use of hazardous substances in military equipment and weaponry, as well as in industry and construction materials, which consequently and potentially creates acute and chronic risks for complex biological and ecological systems, leading to a severely contaminated environment of an ecocidal nature. From the perspective of contemporary military activities, warfare plays a major, but not exclusive, role in exacerbating environmental impacts. An additional paradox associated with military activities is that, while scientific development, including environmental science, has increased our understanding of the ecological consequences of weapon use (both conventional and unconventional), it has also enabled the development of unconventional weapons explicitly aimed at environmental destruction. Therefore, the consequences of military activities are becoming increasingly visible. Although warfare itself inherently violates international legal regulations, numerous rules of war offer potentially significant environmental protection during conflicts. These include principles such as limitation, military necessity, distinction between military and civilian targets, and prohibition of causing excessive injury or unnecessary suffering, and proportionality. From the perspective of environmental protection, the principle of proportionality is particularly incompatible with modern military activities. In addition to these customary rules, which can indirectly protect the environment, there are specific regulations for certain weapons, such as chemical, biological, radiological, and nuclear weapons (CBRN weapons), as well as anti-personnel mines. However, in wartime activities, international legal protection of the environment[4] is still weak, and systems of accountability and environmental remediation are mostly non-existent (Paunović, 2017). The aim of this paper is to present, from a security perspective, the complex mechanism of the impact of military activities on the environment, the development of potential ecological disasters, and overall security. The

4 Official secrecy and the lack of independent scientific assessment of damage have hindered the measurement of warfare's impact on the environment. The conventions aimed at preventing environmental destruction during warfare lack detail, clarity, and authority to effectively limit ecological harm. The current international legal framework designed to prevent environmental destruction during military hostilities is ineffective. Moreover, since the terms of the treaties are ambiguous, they can easily be manipulated to ensure interpretations that align with one's own interests (Kelly, 1992, p. 921).

presentation begins by emphasizing training military activities as the most studied area. This is followed by an overview of the impact of past high- and low-intensity military conflicts, which have also been extensively examined. Finally, the paper highlights dominant and permanent unconventional forms of environmental threats. In this order, the levels of potential negative impacts on the environment are also outlined.

The Concept of Military Activities from the Perspective of Environmental Impact

Despite varying financial, developmental, technical, and personnel capacities and capabilities, most armed forces (hereinafter: military) of the world's countries are divided into three primary branches: ground forces, air forces and air defense, and naval forces. Additionally, modern militaries often include special forces, and, in major powers, space forces. However, modern forms of military activities also include both state and non-state military elements, known as paramilitary formations (hereinafter: paramilitaries[5]). Paramilitaries play a significant role in Fourth Generation Warfare (4GW), which represents an abstraction of war and peace, with blurred lines between military and civilian (and the vague distinction between conventional and unconventional warfare, author's note), leading to a gradual fragmentation of warfare in the contemporary period (through the lens of military activities, author's note) (Joseph, 2017, pp. 1305-1306). The transformation of the security environment, driven by the processes of globalization, impacts modern military activities, which are often tied to the interests of non-state and supranational actors, such as industrial and military-industrial complexes, as well as multinational and transnational corporations of both military and non-military nature. Given the increasing diversity of actors in the contemporary security environment, their ever-growing (covert) interests,

5 Paramilitaries (as unconventional actors, author's note) refer to irregular military forces, private armies, private security companies and mercenaries, guerrilla groups, criminal organizations, tribal warriors, armed gangs, ethnic/religious armies, militias, religious militants, rebel groups, and groups of intelligence operatives (for conducting covert and/or clandestine actions and operations, either independently or in cooperation with special forces, author's note). (Okumu & Ukelegbe, 2010; Joseph, 2017).

and the complex interdependence of security trends and factors, the global security environment is continuously undergoing dynamic changes, which significantly and unpredictably affect the environment. These characteristics fundamentally influence the resources available for environmental protection and security. Based on various operational structures, capabilities, goals, and covert and concealed strategic interests, militaries and paramilitaries collectively, through their operational activities, contribute to military actions that impact the environment.

Military activities can be categorized as conventional[6] and unconventional[7] based on their methods of operation. From both a general perspective and in terms of environmental impact, the approaches and methods used vary depending on the forces[8] involved and the weapons[9] employed in these

6 Conventional (war) military activities are those conducted using traditional weaponry and conventional (standard) methods and tactics of operation.

7 Unconventional warfare (unconventional military activities, author's note)—in a broader sense—refers to a wide range of military and paramilitary operations, typically of long duration, predominantly conducted through, with, or by domestic or surrogate forces that are organized, trained, equipped, supported, and led to varying degrees by an external source. This includes, but is not limited to, guerrilla warfare, subversion, sabotage, intelligence activities, etc. (JP 1–02, p. 562) (paramilitary dimension of unconventional military activities). In a narrower sense, unconventional warfare involves the use of weapons and technology for mass destruction, such as Chemical, Biological, Radiological, and Nuclear (CBRN) weapons and geoengineering weapons and technology (military scientific-research dimension of unconventional military activities). One of the most common (though not the only) operational manifestations of unconventional military activities is special operations (for more on special operations, see JP 1–02, 2003). According to Kilcullen (2019, p. 10), "unconventional warfare is one of the oldest, most cost-effective, and historically most successful forms of warfare."

8 Conventional forces are units and joint forces that are organized, equipped, and trained to operate under conventional conditions. Unconventional forces include Special Forces and paramilitaries (the paramilitary dimension), as well as state defense agencies (scientific-research) and those state and international agencies and actors connected to the defense sector (the military scientific-research dimension). These forces are involved in covert and clandestine operations and special operations.

9 Conventional weapons are those whose use is permitted under all international legal regulations. Unconventional weapons are those whose use (in experimental and testing phases) is prohibited by international conventions, such as CBRN weapons and technologies (Chemical, Biological, Radiological, and Nuclear), geoengineering weapons and technologies, and those used in special operations, as well as any weapons and technologies still in the research phase (experiments and testing) whose effects may be harmful to the environment from an ecological perspective. The use of unconventional weapons is often subject to plausible deniability, meaning that their use can be convincingly denied.

activities. However, in terms of environmental impact, the distinction between conventional and unconventional military activities lies in the fact that conventional military activities of high intensity can cause large-scale environmental damage, even reaching the level of disaster, through the implementation of unconventional operations. On the other hand, unconventional military activities, even on a smaller scale, can still lead to significant levels of destruction. In military operations, actors operate either independently or jointly, in a coordinated manner at tactical, operational, and strategic levels (for more details on these levels, see JP 1-02), aligned with the requirements, effects, and contributions to achieving tactical, operational, and strategic objectives. Military activities influence the environment to varying degrees through their processes, intensity, spatial dispersion, duration, scope, types, methods, and ways of applying resources, weapons, and technology. The environmental impacts of military activities manifest through direct and indirect, as well as intentional (e.g., sabotage, diversions, experiments—essentially covert operations) and unintentional (e.g., accidental/collateral destruction—not the primary goal) effects, actions, and processes.[10]

Two primary conventional military activities are military training and military exercises (hereinafter: training military activities). Conventional training military activities make up about 70% of all military activities and are conducted to develop and maintain the operational capabilities of armed forces. To ensure the effective execution of conventional military activities, they are preceded and accompanied by military development activities and military maintenance activities. Military development activities include: the construction of bases and training grounds, experimentation/testing, scientific research, the production of military equipment, weapons, technologies, and the manufacturing of explosives and explosive ordnance (hereinafter: EO). Military maintenance activities include the use (of facilities for troop accommodation, equipment for infrastructure maintenance,

Since evidence of covert and special operations is highly classified and sometimes invisible, unverifiable accusations are typically met with plausible denials.

10 Note: The terms "intentional" and "unintentional" are used in the text in such a way that when referring to unintentional actions, the term will not be explicitly stated. When intentional actions are described, the term "intentional" will be clearly emphasized to highlight the deliberate nature of those actions.

resources for maintaining infrastructure and equipment/weapons, various harmful and hazardous chemicals, fuel, etc.), transportation (of military equipment, hazardous waste, harmful and dangerous chemicals, explosives, and unexploded ordnance or UXOs), storage (of fuel, harmful and hazardous chemicals, explosives, UXOs, etc.), disposal (in land pits and in the depths of lakes, seas/oceans), destruction (by detonation and incineration) and/or dismantling of unexploded, obsolete, or damaged UXOs, and the disposal and/or destruction of military waste, written-off material, and outdated weaponry. All these activities take place within military bases, on training grounds, and in other isolated military infrastructure.[11] Although it is estimated that currently only military training grounds cover about 3% of the Earth's surface, the limited number of studies on military bases and training grounds (and therefore on the number of active, repurposed for civilian use, and inactive military bases, ranges, and other infrastructure), alongside the increasing presence of paramilitary groups globally, indicates that the total global area and distribution of bases and ranges are currently unknown. The large variations in size and operational use of military bases and ranges lead to a wide range of immediate and indirect long-term anthropogenic impacts, both in terms of type and severity, with significant consequences for the environment.

(Conventional) wartime military activities are essentially conflicts (of low and high intensity) between two or more armies in which conventional weapons are employed. However, some modern conventional military activities are taking on unconventional characteristics, involving the actions of unconventional forces and the use of unconventional weapons and methods in wartime. Therefore, in this context, this synergy is referred to simply as wartime military activities.

Unconventional military activities (of a covert and indirect nature) primarily involve the operations of unconventional forces and the use of

11 Isolated military infrastructure includes, in a broader sense, military-industrial complexes and factories/facilities whose production is tied to the development and equipping of the military and armed forces; in a narrower sense, it refers to specially designated facilities, such as warehouses and smaller or larger areas for dismantling and/or disposal, destruction, and/or demilitarization of UXOs and outdated military equipment.

unconventional weapons both in wartime (as part of conventional activities) and in "peacetime" conditions. Achieving tactical, operational, and strategic objectives (influencing decision-making), preparing for combat operations, and/or impacting the course of hostilities are the general and primary aims and operational consequences of unconventional military activities. The objectives and impacts of these activities differ when they occur as part of wartime activities versus in "peacetime" conditions. Unconventional forces often conduct their training in less familiar or undisclosed areas. These areas typically consist of covert and secretive infrastructure (laboratories, bases, and ranges), representing concealed processes whose environmental impacts remain largely unknown.

Military Activities – (Negative) Environmental Impacts

Military activities have the potential to harm the environment in multiple ways, from highly visible impacts to those whose harmful effects can only be detected through specialized detection technologies. They may cause widespread and long-term environmental disturbances, contamination, and large-scale degradation. The extent to which military activities affect the environment depends on the pre-existing environmental conditions (e.g., impacts from other sources of contamination, such as industrial activities or the general state of the environment before wartime or unconventional military activities), the nature of the disturbance (type of emergency and action or type of warfare), the sensitivity and resilience of biological and human-made systems, and the durability of the impacts. However, numerous studies have shown that the degree of impact—namely, the severity of environmental disturbance and degradation—is directly related to the intensity and scope of military activities. The fundamental fact about the environmental impacts of military activities is that they are significantly influenced by militarization (the extension of military priorities into civilian functions). Modern military activities are only feasible through extensive use of fossil fuels (oil), nuclear fuels, toxic substances, chemicals, and explosives, whether in conventional or unconventional military operations, as well as through the extensive manipulation of the environment in the case of unconventional military activities—often with minimal opportunities for control.

Military Development Activities

Contamination from heavy metals, hazardous chemicals, and explosives is among the most significant environmental issues within military infrastructure, with substantial potential to pollute surrounding areas and adjacent civilian regions. The general negative impacts associated with the construction of complex military infrastructure projects, such as bases and training grounds as part of military development activities, include habitat and soil degradation and chemical contamination. Intensive excavation processes, vegetation removal (e.g., deforestation), and soil compaction increase the likelihood of invasive species introduction (Yager et al., 2009), alter soil structure, compromise its physical integrity, and raise erosion potential. These activities also reduce water infiltration rates, increase runoff, and alter soil chemistry (Tang et al., 2005). Chemical contamination of local groundwater and surface water resources may occur due to increased wastewater runoff carrying sediments and chemicals linked to waste disposal (e.g., hazardous construction materials, paints) and accidental spills of hazardous substances (e.g., fuel and oils) during military infrastructure development, posing risks of significant environmental shifts. At test ranges (both land and water) and isolated military infrastructures (such as military-industrial sites), incidents (with high catastrophic potential), including the release of thermally polluted or wastewaters from production processes (e.g., wastewater containing high TNT explosive concentrations, known as red water) and the use and disposal of hazardous chemicals, can cause abrupt increases in water and air toxins, reduced dissolved oxygen levels, loss of biodiversity, migration of certain species, and widespread environmental contamination. Studies indicate that residues found at testing and production sites have caused serious long-term chronic contamination and environmental damage (Lewis et al., 2010). Due to hydrological connections, contamination from these sites can spread over long distances.

Military Maintenance Activities

In general, military infrastructure is subjected to mechanically, energetically, and toxically intensive activities. The environmental impacts of military maintenance activities can be divided into two main areas: operations of military infrastructure, which include the functional activities of the infrastructure itself and military exercises assigned to specific locations, and routine deployments of units at the national level, abroad, and in areas beyond national jurisdiction (Westing, 2006). Infrastructure operation and maintenance processes, as well as storage practices, result in significant quantities of various military waste, hazardous waste (e.g., medical waste, asbestos), chemicals, radioactive substances (e.g., depleted uranium used in ammunition), and explosives. Most chemicals and explosives that enter the environment accumulate in soil, plants, sediments, and water layers, migrating across soil and groundwater through both biotic and abiotic processes, entering surface waters, and spreading over large distances (Francis, 2011). Inefficient use of energy resources (e.g., the CO_2 emissions from major military forces far exceed those of many other armies combined) and chemicals, improper disposal (e.g., in land pits, deep lakes, seas, and oceans), storage, destruction (e.g., incineration), and demilitarization of UXOs (including UXOs with CBRN agents) lead to severe immediate and indirect contamination of soil, air, groundwater, and surface water. This contamination results in long-term habitat degradation for flora and fauna and long-lasting environmental impacts. Notable contamination cases in air force bases are associated with the spillage of aviation (jet) fuel and lubricating oils from aboveground and underground storage tanks (Nunes et al., 2011), and solvents like benzene; fire-fighting training involving perfluoroalkyl chemicals (PFCs), which have been used for decades in fire-fighting foams (Aqueous Film Forming Foams, AFFF), as well as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) (Arias et al., 2015); accidental chemical container leaks and spills of polychlorinated biphenyls (PCBs) from electrical substations; maintenance of green areas using herbicides and pesticides; and atmospheric deposition (and runoff of atmospheric water) of hydrocarbons, heavy metals, PCBs, and polycyclic aromatic hydrocarbons (PAHs) from jet fuel combustion around platforms and runways.

Military Training Activities

Many aspects of military training activities can have markedly different environmental impacts. The negative effects of military training on the environment can be categorized based on their level of disruption: high, medium, or low (Wang et al., 2014). High levels of environmental disruption occur with the continuous exploitation of training grounds through high-intensity training involving all branches of the military, which leads to thorough degradation and pollution of areas designated for various military functions and training activities within bases or training grounds. Some medium-level impacts from military training can become significant enough to prevent further training due to changes in the environmental characteristics necessary for effective training, such as areas heavily contaminated with unexploded ordnance (UXO), where the presence of UXOs and toxic substances within them poses significant hazards. Military training activities range in scale, from small groups of soldiers and equipment to large simulated battles involving thousands of personnel and extensive military hardware. Consequently, at many high-intensity training grounds for major armed forces, it is impractical to establish rest periods for environmental recovery (Zentelis et al., 2017), despite the average land ecosystem recovery time being around 22 years (Jones & Schmitz, 2009).

Infantry training, especially in basic military exercises and specialized drills, is widely dispersed and utilizes ammunition up to 20mm in caliber, along with explosives such as primary explosives found in ammunition, military pyrotechnics, propellants/powders, and high explosives (hand grenades, anti-tank weapons, 40 mm grenade launchers, etc.). Basic infantry training takes place in secure areas designated for live-fire exercises with infantry weapons (shooting ranges), explosive handling zones (representing the greatest environmental concern due to the large quantities produced and used), and training areas for using grenades, grenade launchers, and anti-tank weaponry. However, wherever ammunition and UXO are used, contamination inevitably occurs.

Environmental impacts in these areas manifest as direct contamination from explosives, propellants/powders, and unexploded ordnance (UXO)

(Chatterjee et al., 2017; Brochu & Thiboutot, 2019), as well as from heavy metals/inorganic contaminants (ammunition residues) (Migliorini et al., 2004). These impacts also include direct destruction of soil cover and vegetation, accidental killing or maiming of wildlife (due to the destructive, toxic, and thermal effects of ammunition, explosives, and explosive devices), and the immediate creation of noise (small arms fire, launch explosions, and target explosions) (Larkin et al., 2016). Most explosives and heavy metals are resistant to biological degradation or removal treatments, thus persisting in the biosphere as sources of contamination potentially harmful to the environment. Lead, as the main component of small arms ammunition, is the most significant and dangerous contaminant of shooting ranges. Other heavy metals that contaminate soil in the form of ammunition residues include mercury (Hg), tin (Sn), antimony (Sb), copper (Cu), chromium (Cr), nickel (Ni), zinc (Zn), cadmium (Cd), and manganese (Mn). The type of ammunition used during training, the quantities used, and the efficiency of its reactive components (heavy metals) in breaking down are the main factors contributing to shooting range contamination. Depending on environmental factors, particularly soil type (coarse sand, fine sand, loam, clay), lead (Pb) may initially remain inert. Under the influence of environmental factors (such as weather conditions or changes in soil conditions like pH, moisture, and organic matter), lead particles may oxidize (or transform into lead carbonate). When lead quantities exceed soil retention capacity, this results in long-term contamination of soil and aquatic ecosystems (Brochu & Thiboutot, 2019).

The training process in infantry tactics (infantry and mechanized infantry) can have a wide range of environmental impacts, primarily determined by the duration and intensity of training, as well as the number and size of infantry units, the weaponry used, the combat vehicles involved (including armored vehicles, infantry fighting vehicles—both wheeled and tracked—trucks, engineering vehicles, and off-road vehicles), and the specific nature of training requirements and processes. Tactical infantry training can result in immediate effects, such as soil stripping (e.g., from intense movement by infantry and combat vehicles), direct destruction of vegetation (e.g., camouflage needs; small arms fire, heavy machine guns from 12.7 mm to 20 mm, and cannons from 25 mm to 40 mm mounted on combat vehicles), immediate changes to

soil structure and destruction of plant and animal habitats (e.g., movement of combat vehicles, digging of shelters and trenches, placement of training anti-personnel and anti-armor mines, explosions of various explosive devices). Other impacts include the potential introduction of invasive species and increased soil erosion due to continuous use of certain locations on the training range, as well as the creation of spatially unpredictable noise (e.g., movement of combat vehicles, helicopter overflights and landings, small arms fire, projectile launches and explosions on target) that significantly impacts some fauna species (Larkin et al., 1996). In the long term, there are indirect effects of intensive destructive action from ammunition, explosives, and unexploded ordnance, as well as contamination from residues of heavy metals, explosives, and partially detonated ordnance and UXO.

Training for armored-mechanized units is designed to simulate real combat scenarios. Maneuvers by these units (tanks and combat vehicles) exert the greatest mechanical impact on soil and vegetation at training ranges. The effects of these activities manifest as mild soil compaction and minimal vegetation damage, severe soil compaction, fragmentation and displacement of surface particles, crushing and/or uprooting of vegetation, complete loss of vegetation, destruction of habitats for certain flora and fauna species (Wang et al., 2014), and the spread of invasive species. During wet periods, additional impacts include deepening of ruts, disruption of local water flows, flooding, extensive vegetation destruction, and threats to the survival of some plant species (Perkins et al., 2007). Frequent and intensive use of tanks and combat vehicles results in indirect long-term effects such as reduced plant species richness and diversity, a decrease in vegetation cover, increased soil erosion rates, changes in soil chemistry, and greater instability in groundwater and surface water systems (Quist et al., 2003). Additional impacts include the appearance of invasive foreign species and the formation of complex successional patterns due to interaction with other land use activities. Live-fire exercises (both stationary and on the move) increase direct and indirect environmental impacts. Immediate effects include more spatially pervasive and less predictable noise (from tank movement, projectile launches, and explosions on target), significant vegetation destruction, and accidental killing or maiming of wildlife. Indirect impacts include contamination from

heavy metal and explosive residues from large-caliber projectiles in soil, groundwater, and surface waters.

Some of the immediate impacts (noise from projectile launches and target explosions) and all indirect impacts of armored-mechanized units are also part of artillery training activities (weapon systems: multiple rocket launchers, cannons, howitzers, mortars, etc.). Artillery ranges typically cover vast areas with significant natural value, including sources of groundwater and surface water. When projectiles are fired from weapon systems, propellants/powders are left behind, either as a by product of firing or as residual/disposed propellant. These residues contain energetic compounds such as dinitrotoluene (DNT), nitroglycerin (NG), nitrocellulose (NC), nitroguanidine (NQ), and sometimes aluminum (Al) and lead (Pb), as well as ammonium perchlorate (AP) in rocket propellants. Residues consist of discrete solid fibers or fragments of partially burned grains or flakes of propellant. Combustion of propellant fuel leaves large amounts of unburned and carbonized particles. The concentration of these residues depends on the specific weapon system used. The destructive impact of projectiles from these weapon systems is capable of removing large quantities of soil, creating substantial habitat damage in the form of craters and initiating succession within the affected area ("bombturbation"). These highly disturbed areas may experience soil structure and quality degradation, leading to ecosystems dominated by disturbance-resistant flora and fauna species (Warren et al., 2007) or the introduction of invasive foreign species. Soil within craters is compacted and contaminated with residues of deposited explosives and fine heavy metal particles. The heavy metal content in artillery ammunition differs slightly from that of small arms ammunition, including iron (Fe), aluminum (Al), copper (Cu), chromium (Cr), tungsten (W), beryllium (Be), zinc (Zn), arsenic (As), uranium (U), and depleted uranium (DU). The ability of these heavy metals to transform into other compounds increases contamination levels, introducing contaminants that were not originally present in the ammunition. Transformation occurs during detonation or due to weathering of deposited heavy metal particles. In detonation, temperatures and pressures reach extremely high levels, often exceeding the melting points of some heavy metal compounds. This creates molten substances that readily react with other compounds to form new metal

complexes, alloys, or salts (Brochu & Thiboutot, 2019). Dispersed across the soil surface, these particles undergo chemical and physical weathering. The level of contamination in artillery ranges depends on the intensity of area usage, the efficiency of weapon systems and ammunition, and environmental factors (pH, organic matter, weather conditions, etc.). Through various mechanisms, soil contaminated with explosives contains substances in soil, sediment, and surface and/or groundwater in a wide range of concentrations. Surface explosions impact the environment by causing physical degradation (destruction of structure and loss of fertile soil), thermal degradation (heat from explosions depletes the organic soil layer), and chemical degradation (soil contamination from explosive and heavy metal residues). Indirect impacts are created by unexploded ordnance (UXO), which acts as a potential long-term, localized source of soil and/or water contamination. Meanwhile, deflagration and partial detonation (low-order detonation) release significant amounts of explosives (up to 3 kg of particles over 1 mm in size), resulting in immediate environmental impacts (Taylor et al., 2015; Brochu & Thiboutot, 2019). As much as 2% of explosive residues (by weight) from 155 mm ordnance loaded with TNT remain on the soil surface after full detonation (high-order detonation), translating to 140 g of explosive residue per round. However, studies on low-intensity artillery training in several countries have consistently shown that mortar and howitzer projectiles with high-explosive fillings (Comp. B and TNT) that fully detonate do not contaminate the impacted areas (Pichtel, 2012).

Environmental impacts associated with air force training and exercises (air combat tactics, aerial interceptions, aerobatics, low-altitude tactics, bombing and rocketing, and targeting aerial targets) include: bird strikes and fatalities during flights; bombturbation, contamination of training grounds and surrounding areas, as well as groundwater and surface water with metals, explosives, and aircraft UXO, which indirectly affects population dynamics, has long-term negative effects on terrestrial ecosystem communities, and disrupts the physical-chemical integrity of soil (Davis et al., 2007; Sanatana, 2009). Additionally, spatially predictable and unpredictable noise generation occurs (during aircraft and helicopter takeoffs/flights/landings and pre-flight preparations) from aircraft jet engines, helicopter rotor pulses, and

sonic booms (Larkin et al., 1996; Rodriguez-Seijo et al., 2019); contamination from heat and jet fuel combustion particles (including polycyclic aromatic hydrocarbons, ammonium perchlorate, etc.). The environmental consequences of air defense training and exercises can be compared to those of ground forces in the domain of live-fire exercises.

Environmental impacts associated with naval training and exercises (including river forces) manifest as follows: the use of sonar directly disrupts the signaling abilities of marine mammals, leading to interference with their predator detection, communication, foraging, reproductive activities, and sometimes resulting in stranding, with long-term indirect impacts. Sonar, propellers, the loading/firing/unloading of naval weapon systems, and UXO explosions create unpredictable spatial noise pollution (Sarić & Radonja, 2014). UXO detonations, whether direct (detonation) or indirect (shockwaves), can kill, cause serious internal injuries, or disrupt the abilities of marine, river, and lake fauna (Govoni et al., 2008). Direct contamination of marine environments with vessel wastewater, heavy metals, and explosives is also a significant concern. Furthermore, international military exercises can indirectly introduce invasive foreign species (through ballast water and hull fouling), which can substantially impact local biodiversity.

The potential environmental impacts of military training activities are also evident in the use of military pyrotechnics, which are employed by all branches of the armed forces. Pyrotechnics are used in various forms, including incendiary devices (such as toxic white phosphorus), sound and smoke generators (e.g., chemical and nuclear attack simulators, smoke bombs), and light producers (such as tracers in ammunition and illumination devices). These contain various heavy metals and oxidizers. Many pyrotechnic devices include perchlorate, which poses a significant contamination risk if pyrotechnics are not disposed of properly. Depending on their composition, pyrotechnic smokes may contain hexachloroethane (HC), anthracene, metals, and pyrophoric substances (such as white and red phosphorus). The quantity of metals released by pyrotechnics is typically low enough to be indistinguishable from naturally occurring levels unless training is particularly intense within a confined area.

Military maintenance activities, training exercises, and warfare are mobile systems with an international scope, driven by global military cooperation, crisis zones, and high-intensity militarization (the expansion of military priorities into civilian areas). This global scale makes contamination of military training grounds a significant international concern. High-intensity militarization, which essentially serves as preparation for warfare, escalates the environmental impact of military activities. This is reflected through increased defense industry production, the construction of new military infrastructure and maintenance of existing facilities (domestically, in other countries, and in areas outside national jurisdiction), intensified training activities, the rise of paramilitary operations (e.g., illegal logging for war purposes or chemical, biological, radiological, and nuclear (CBRN) weapon deployment), unsustainable exploitation of flora and fauna by local populations for war preparedness, and the abandonment of productive land (leading to land degradation). Consequently, these cumulative activities drive significantly higher consumption of renewable energy resources (oil and gas) and non-renewable natural resources (such as aluminum, lead, copper, nickel, iron, tungsten, and zinc), primarily within military industry production processes.

Wartime Military Activities

Wartime military activities are inherently noticeable, immediate, and extremely destructive. The impacts of such activities can lead to a range of ecologically complex or catastrophic consequences due to the (potential) large-scale use of conventional weapons or catastrophic effects of an unconventional nature. This could result from the use of conventional weapons against critical industrial infrastructure containing hazardous substances or from exploiting environmental vulnerabilities as a means of threat. Wartime military activities take place in natural and urban areas, across geographically dispersed locations that may be more or less isolated from each other. In terms of their overall environmental impact, these activities have the potential to affect large spatial areas, often linked by natural features (lakes, rivers, seas/oceans) and sensitive infrastructure (industrial sites with hazardous materials

or secret laboratories for CBRN research) worldwide. The use of natural and synthetic contaminants in wartime activities can lead to severe environmental degradation and contamination on a catastrophic scale, typically associated exclusively with unconventional military activities. Unlike conventional training exercises or military development and maintenance activities, environmental damage is inevitable in wartime. Wartime military activities are not (in practice) subject to regulations, oversight, or process management aimed at environmental protection.

The primary concern of those engaged in wartime military activities is the unconditional achievement of tactical, operational, and/or strategic goals, often at the expense of the environment. The environmental impact of conventional military training activities, depending on their intensity and scope, represents a minimal baseline for the environmental impact of actual wartime military activities. The manifestation of wartime activities through potentially high-intensity and large-scale conflicts across vast areas affected by war, with potentially unrestricted use of both conventional and unconventional (CBRN) weapons, significantly increases the risk of destroying critical industrial infrastructure. Additionally, this can lead to extensive degradation and contamination of large land and water areas, and a considerably longer duration of environmental impact, potentially resulting in far greater degradation, contamination, and multidimensional indirect and long-term impacts on the environment compared to conventional training exercises and standard military development and maintenance activities. The potentially greater intensity and scope of environmental impact from wartime military activities is further intensified by:

- the direct increase in the number of affected biological hotspots containing endemic and endangered plant and animal species, including national parks as cultural heritage;
- the direct introduction of invasive foreign species through combat vehicles;
- the consumption of vast quantities of fuel (oil), leading to high CO_2 emissions;
- unintentional and intentional direct environmental destruction, such

as flooding land, triggering landslides, causing massive fires, and indirect effects, such as the construction of makeshift shelters and refugee camps due to sieges or displacement, as well as the urgent search for food and water sources;

- direct land degradation, destruction of flora and fauna, and contamination of groundwater and surface water due to the placement and detonation of anti-tank and anti-personnel mines, improvised explosive devices (IEDs), and intensive bombing, rocketing, and shelling (indirect effects on biodiversity due to contamination from explosives, land rendered unusable for agriculture, and disrupted integrity from demining efforts);
- direct destruction of cultural heritage;
- the direct sinking of ships containing hazardous substances (and CBRN weapons), resulting in oil spills and long-term decomposition impacts of hazardous materials.
- direct destruction of military equipment (such as tanks and combat vehicles) due to intense conflicts, generating military waste (releasing a range of harmful and hazardous chemicals, heavy metals, and hazardous substances into soil, water, and air);
- direct destruction of residential areas, large (and smaller private) industrial facilities, storage sites, power installations, and illegal improvised factories for IEDs and CBRN weapons due to intense urban conflicts. The resulting waste (e.g., toxic dust, asbestos, PVC, household and medical waste, various harmful and hazardous chemicals) can ignite, creating a large toxic cloud that spreads contamination. The disposal of this waste during wartime poses both a short-term and long-term environmental challenge;
- as unconventional tactics (using "scorched earth" methods to achieve tactical, operational, and strategic objectives and influence decision-making and the course of the conflict), intentional contamination of land, air, and water through the use of known and improvised (unknown) chemical, biological, and radiological agents is employed

to modify the environment for tactical purposes[12] (chemical modification) and incapacitate enemy forces (chemical and biological) as well as for covert experimentation (chemical, biological, and radiological). Environmental Modification in Wartime Activities involves large-scale, disruptive techniques aimed at depriving the adversary of any conditions that provide shelter, cover, food, etc. (e.g., deforestation, destruction of vegetation and land using herbicides and pesticides, physical alteration of the natural landscape) (Westing, 2006). Disruptive actions may also trigger large-scale "natural" forces (e.g., inducing heavy rainfall). A further long-term issue associated with the use of pesticides and herbicides is bioaccumulation and the prolonged persistence of these chemical agents in the environment, resulting in chronic impacts on ecosystems. Agents like mustard gas (HD) and lewisite (L) (blister agents), as well as VX, tabun (GA), soman (GD), and sarin (GB) (nerve agents), are generally not highly persistent, but their degradation products remain significantly stable in the environment, with some retaining high toxicity. Sarin (GB) is one of the most dangerous nerve agents, as it is difficult to detect; being soluble, it poses a significant threat to the environment, especially to water resources, while nerve agents in general are expected to have lethal impacts on soil biota. Biological weapons, used either for covert experimentation or to achieve tactical-operational advantages, can be applied in various ways: as a broad operation, seemingly overt (with concealed intentions), deployed strategically over large areas of the attacked country; as an open action for tactical purposes (e.g., targeting tactical strongholds); as a covert operation, poisoning food or destroying food resources in a small, confined area (e.g., a city, island, or closed facility). Artificial Cobweb is one substance suspected of being linked to covert chemical-biological experiments during wartime. Studies suggest that due to its properties, artificial

12 "Environmental Modification Techniques" refer to any technique used to alter, through the intentional manipulation of natural processes, the dynamics, composition, or structure of Earth (Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, 1976, ENMOD Convention). The ENMOD Convention prohibits only the use of such techniques in warfare, but not the research behind them. Therefore, the continuous development of methods for environmental modification remains permitted.

cobwebs could be considered a military-tactical combat system capable of carrying various pathogenic microorganisms or chemical agents (Furić & Orehovec, 2001; Vučemilović, 2010). However, its environmental impact remains unknown.

- by paramilitary forces, the deliberate destruction of fields, forests, crops, water supplies, fauna, residential and healthcare infrastructure, etc., and forced displacement of populations, to deny the opponent the environmental advantages or for criminal purposes. This often occurs when corporate actors engage paramilitary forces in wartime activities. In many cases, humanitarian crises are intentionally orchestrated to achieve the deliberate destruction of environmental resources;
- direct environmental contamination (of soil, water, air, flora, and fauna) resulting from artillery and air strikes targeting critical industrial infrastructure (such as petrochemical plants, oil facilities, pharmaceutical factories, warehouses, and wastewater treatment systems) containing harmful and hazardous chemicals and substances (e.g., ammonia, sulfur dioxide, sulfuric acid) with residual environmental impacts. These activities pose local, national, and regional environmental risks, and frequently have an ecocidal impact (Eifried, 1998; Orehovec et al., 2004). Often, the immediate effects of contaminants are relatively short-term (e.g., mass die-off of aquatic life), while long-term contamination is expected in areas like ponds, lakes, and coastal zones, primarily through heavy metal pollution. Burning oil and chemicals results in significant air contamination (e.g., polycyclic aromatic hydrocarbons, dioxins, sulfur dioxide). Depending on the extent and nature of air contamination and the prevailing topographic and atmospheric conditions in the area, this can lead to contamination spreading via acid rain and deposition, with serious environmental impacts as a consequence.
- direct contamination from the heat generated by explosions (producing nitric acid), military pyrotechnics, fires in damaged structures and critical industrial infrastructure, and from the intense operations of military aircraft. These activities release large amounts of heat into the already warm air, along with toxic byproducts from

explosions and fires, significantly affecting air quality, natural air currents, and local flora and fauna (Protopsaltis, 2012).

The overall indirect and long-term consequences of warfare activities (including a significant proportion of unconventional paramilitary and military scientific-research actions) on the environment can vary in scale. The cumulative indirect effects of warfare that contribute to total wartime damage and environmental security changes can be observed through: displacement of populations (due to mines, unexploded ordnance, CBRN weapons, and physically and chemically contaminated and degraded environments), which leads to an accumulation of refugees in areas previously unburdened by human presence, creating an added strain on the environment; increased illegal hunting by paramilitary groups (impacting protected animal species); unsustainable exploitation of natural resources to sustain wartime economies; additional contamination and costs in post-war recovery processes, demilitarization, and demining; and, with or without occupation, the disruption and reduction of infrastructural and institutional capacities (healthcare, social, economic, and administrative) for environmental management (particularly regarding waste management). In the context of potential long-term ecocidal impacts (unconventional activities), warfare may lead to altered natural conditions, impact extreme weather patterns, and contribute to species extinction and/or biodiversity loss. A significant period is required for the partial recovery of damaged ecosystems, while some habitats may be permanently destroyed.

Alongside environmental contamination caused by conventional military activities, extreme weather changes are an inevitable aspect of contemporary military operations. Most findings to date indicate that the amount of energy produced by humans (i.e., human activities, including military activities) by burning various organic fuels would lead to minor changes in Earth's thermal balance, thus causing only very limited climate change (Stajić & Vujić, 2012). However, unconventional military activities, weapons, and technologies are considered to have a significant impact on increasing environmental contamination (to a greater extent than conventional military activities as a whole) and on climate change. The role of military activities in climate change is substantial, yet they are excluded from discussions and concerns regarding climate change. Thus, climate change discussions are not geared toward

climate and environmental protection, but rather toward military activities and strategic-defense objectives.

Unconventional Military Activities

Unconventional military activities (the paramilitary and scientific-research dimensions) conducted during "peacetime" involve unexpected possibilities for the organized, covert, and highly aggressive use of unconventional weaponry aimed at concealing it (secret disposal), achieving strategic goals (terrorist actions), deterrence, preparation for warfare, and various covert military experiments (e.g., chemical and biological experiments) and operations. These activities often have transnational and global implications.

Known cases of chemical weapon disposal in seas and oceans have typically taken place decades ago, conferring upon them a status of long-term (potential) contamination of catastrophic proportions (Albright, 2012). Due to the larger-scale, covert nature of these disposals, the exact locations and quantities of the chemical weapons remain practically unknown. Although research is underway to assess the environmental impacts of these chemical disposals, their inherent properties regarding physical, chemical, and long-term toxicity for humans and the environment remain unclear, though risks are evident. Long-term environmental impacts of incidents at nuclear facilities and of sunken (nuclear-powered) submarines are fundamentally unknown or insufficiently studied. Similarly, ecological issues tied to the illegal disposal of radioactive materials and waste resulting from global nuclear weapons and energy development programs cannot be resolved with the current level of technology, to which unconventional military activities significantly contribute.

Compared to the use and secret experimentation with chemical, and particularly biological, weapons (e.g., so-called "ethnic weapons"), unconventional activities involving the development (testing) and deployment of nuclear bombs and warheads are better known. However, although the effects of nuclear warhead testing and use are still felt in some parts of the world today, precise data on their long-term environmental impacts remain insufficiently researched. Nuclear explosions leave a substantial environmental impact

through the release of heat, kinetic, and radioactive energy (Prãvãlie, 2014). Ultimately, a significant environmental impact of nuclear explosions lies in their potential to activate and expand existing fault lines, which can consequently lead to major earthquakes.

Around the world, numerous accidents at critical infrastructure sites have occurred, resulting in catastrophic environmental impacts. The circumstances and timing of these disasters have often raised suspicions about intentional causes, potentially aimed at conducting or concealing military experiments and/or destabilizing a state or region. Such suspicions regarding unconventional military activities are further supported by the widespread use of radioactive materials in energy production and the excessive use of pesticides and fertilizers in agriculture, which lead to significant levels of "natural" or "unintentional" environmental contamination. Distinguishing between an accident and intentional action can be challenging. Among potential CBRN (chemical, biological, radiological, and nuclear) agents intended for unconventional military activities, significant effects are anticipated, as these agents can be effectively weaponized to meet numerous operational and strategic requirements. Compared to conventional weapons and CBRN weapons that are overtly or covertly used in military operations, these agents offer substantial advantages in effectiveness and in the ability to "erase" traces of their use. Consequently, due to these advantages and insufficiently researched cases, their environmental impact remains largely unknown. During past wars (particularly the Vietnam War), it became evident that climate and weather conditions, as well as the state of water bodies and soil, significantly influence combat operations. Likewise, natural disasters often result in high casualty rates. Both of these factors spurred efforts, which later led to successful attempts, to exploit these phenomena for unconventional warfare purposes, essentially turning the environment into a tool of warfare (Environmental Warfare). This "weapon" is especially suitable for covert or secret operations under ostensibly "peacetime" conditions. Unconventional military activities using geoengineering weaponry involve the intentional application of tools and methods for military and intelligence purposes, as well as for experimentation (military-scientific research), which can induce harmful effects and changes in the biosphere (House et al., 1996).

These small-scale changes to Earth's systems may have profound global impacts. Military geoengineering includes the application of a range of interrelated technologies and activities. Although research and development in these technologies, often initially intended for military use (and only later for civilian applications), have long reached massive proportions, two "fundamental" methods from the unconventional geoengineering arsenal affecting the environment are HAARP (High Frequency Active Auroral Research Program), either alone or in combination with chemical trails (chemtrails) produced by aerosol releases from civilian and military aircraft and drones. Originally military projects, their use is formally intended for strategic military objectives, including climate control, and scientific research. Although this application alone is sufficient to degrade the environment significantly, their use for any purposes beyond these stated ones is consistently denied. Unconventional military activities are designed to make the intentional actions appear as natural weather disasters, using plausible deniability to mask their effects within the broader ecological chaos. The results become noticeable only after some time, making it challenging to trace them back to geoengineering activities. Analysis of chemical trails, conducted by both institutional and independent scientists worldwide, reveals that they contain a combination of polymer nanoparticles resembling spider webs, metallic aerosol nanoparticles (arsenic, lead, cadmium, beryllium, barium, manganese, zinc, iron, etc.), various compounds (methylmercury, iron oxides and hydroxides), and agents from the arsenal of biological and chemical weaponry. The impacts of unconventional geoengineering weaponry (within the military scientific-research dimension) on the environment, as studied so far, manifest in the following ways: frequent occurrences of "natural" disasters (floods, hurricanes, tornadoes, earthquakes); disruptions in atmospheric circulation; disturbances in stable weather patterns (precipitation inhibition) and habitats; damage to the ozone layer, which protects the biosphere from lethal ultraviolet solar radiation; severe harm to agricultural crops and flora due to extreme weather (untimely rainfalls, acid rain, decreased or increased humidity, prolonged droughts or severe floods, elevated nighttime and winter temperatures), etc. While geoengineering technologies and weapons of mass destruction (CBRN) differ in many ways, both serve as instruments

of power that lack precise targeting capability. Moreover, geoengineering, which relies on shared global resources, is unlikely to be effective unless tested or deployed on a global scale, adding another layer of ecological uncertainty to each attempt to minimize collateral damage (Chalecki & Ferrari, 2018). The potential benefits of geoengineering for civilian purposes, ostensibly aimed at mitigating climate change, are often outweighed by negative impacts on different regions and societies. In reality, its application often serves military objectives (House et al., 1996). In this context, geoengineering exacerbates several core issues related to climate change, as described above, all of which are potential sources of conflict.

Military Activities as a Potential Environmental Disaster (Crisis)

Modern military activities have left, and continue to leave, a substantial negative legacy with a multidimensional impact on the environment. The distinctions between the environmental impacts of conventional and unconventional military activities are increasingly blurred, with almost complete overlap, as illustrated in Figure 1.

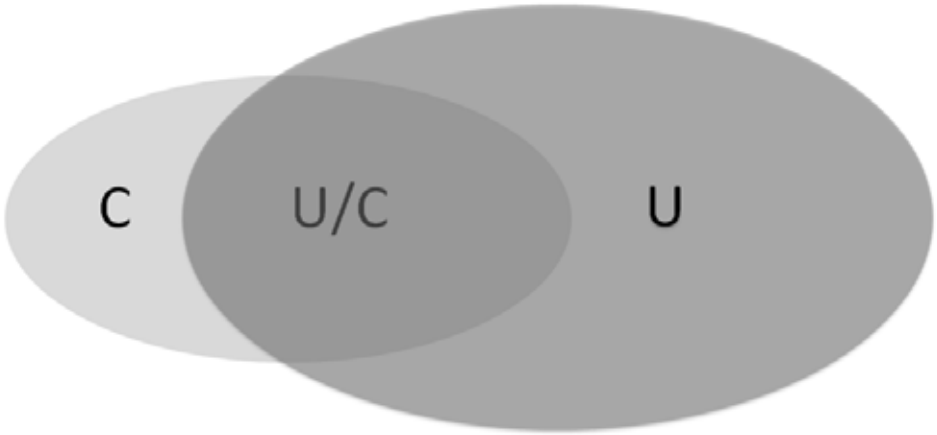

Figure 1. **Relationship and Scale of Environmental Impact from Conventional (C), Unconventional as Part of Conventional (U/C), and Unconventional Military Activities (U)**

The entirety of military activities with a high potential for ecological disaster is presented in Table 1, which provides a summarized overview of the preceding text. The table complements Figure 1, reinforcing the dominance and potential for ecological catastrophe with an emphasis on the unconventional dimension of military activities.

MILITARY ACTIVITIES			POTENTIALS FOR ENVIRONMENTAL CATASTROPHE	
MILITARY DEVELOPMENT ACTIVITIES	Production; Testing; Experiments	C	UNINTENTIONALLY	ACCIDENTS IN PRODUCTION PLANTS
		U	UNINTENTIONALLY	ACCIDENTS IN THE PRODUCTION OF CBRN WEAPONS IN LABORATORIES
			INTENTIONAL	EXPERIMENTS AND TESTING OF CBRN WEAPONS; GEO ENGINEERING
MILITARY MAINTENANCE ACTIVITIES	Storage; Disposal; Transport	C	UNINTENTIONALLY	ACCIDENTS IN WAREHOUSES; ACCIDENTS IN TRANSPORT
		U	INTENTIONAL	DISPOSAL OF HAZARDOUS NUCLEAR WASTE, AMMUNITION; CHEMICAL WEAPONS DISPOSED IN SEAS/OCEANS AND ABANDONED IN MILITARY STORAGE; TERRORIST ACTS AND SABOTAGE (STORAGE AND TRANSPORT)
TRAINING MILITARY ACTIVITIES	Training	C	UNINTENTIONALLY	HIGH INTENSITY TRAINING
WAR ACTIVITIES	Conflicts	U/C	(UN)INTENTIONALLY	HIGH INTENSITY OF CONFLICT AND USE OF A LARGE QUANTITY OF EO
		C	(UN)INTENTIONALLY	DESTRUCTION OF INDUSTRIAL CRITICAL INFRASTRUCTURE WITH DANGEROUS CHEMICALS; GEOENGINEERING
		U	INTENTIONAL	
UNCONVENTIONAL MILITARY ACTIVITIES	Preparation for war; Terrorist activities ("peace"); Open secret and covert actions	U	INTENTIONAL	DESTRUCTION OF CRITICAL INDUSTRIAL INFRASTRUCTURE; USE OF CBRN WEAPONS; GEOENGINEERING

***Table 1*. Potential Environmental Disaster Risks**

Despite the specific characteristics of unconventional military activities (such as indirectness, secrecy, and plausible deniability), military operations as a whole, in terms of environmental impact, display both predictable and unpredictable aspects of disasters akin to visible technological and natural hazards. To a large extent, they are part of peacetime and can make a difference, influencing the reduction of the military footprint on the environment, primarily through an understanding of military activities as a crisis in their entirety. Conventional military development activities (e.g., the military industry) and maintenance activities (such as global military infrastructure) are among the leading factors impacting the environment, especially when compared to civilian sectors (e.g., industrial or transportation). Predictability in these activities relates to preventive measures (during the potential crisis phase) in implementation (acceptable risks, protective measures, safety measures, standard operating procedures). Disruptions resulting from training exercises (often intensive) are predictable and thus amenable to management, minimizing and mitigating impacts. Consequently, military training range managers, acting as crisis managers, often face conflicting demands in balancing the primary military mission with legal requirements to protect soil quality, water resources, and endangered species.

Unpredictability, with an aspect of partial predictability, in military activities is primarily associated with warfare and unconventional military activities (such as the development of new military technologies and/or technologies with potential military applications, e.g., biotechnology; covert paramilitary operations). Predictability and/or the determination that disruptions are directly or indirectly caused by warfare can be challenging due to the multiple interactions between conventional and unconventional activities, particularly considering the hidden impacts of unconventional military activities that may arise. Predictability and/or environmental impact assessments, which typically focus on a limited set of indicators, cannot encompass the full range of concealed and "enigmatic impacts" on the environment from unconventional military activities. This challenge is compounded by the inherently unpredictable nature of ecological systems. Like other dimensions (social, political, economic) that influence warfare and unconventional military activities, ecological impacts often exhibit nonlinear

behavior, where minor changes can lead to amplified reactions that are nearly (if not entirely) impossible to predict. In such cases, the characteristics of modern military activities as crises and their environmental impacts reflect the synergy of certain features of contemporary (and future) crises. This synergy manifests as phenomenologically new, long-lasting occurrences (various types of hazards) that introduce novel, generative problems with significant consequences and unconventional impacts on vital resources, rendering traditional crisis management systems ineffective. It is evident that crises associated with military activities require preparation through strategies based on anticipation.

Conclusion

From a military perspective, a true peacetime period for the environment hardly exists. Military development, maintenance, and training activities (excluding the unconventional dimension of these activities) can often be monitored, with potential for minimizing and mitigating environmental impacts. However, since military forces focus on maintaining operational capability rather than environmental protection, these "opportunities" are frequently underutilized, particularly in the militaries of less-developed countries and in paramilitary groups. On a global scale, the intervals between wars tend to last longer than individual conflicts, leading to a significant impact on the environment from ongoing military development, maintenance, and training activities during these extended peacetime periods, particularly among major powers and large armies, but also from unconventional military activities. Secrecy, a fundamental aspect of all military operations, suggests that in the context of military development and maintenance, the diversity and volume of waste generated, along with practices surrounding the handling, storage, and use of hazardous chemicals and explosives, as well as disposal and destruction practices, may have substantial environmental impacts that remain largely unknown and insufficiently researched. Due to the highly classified nature of developmental, wartime, and unconventional military activities, only a small group of individuals possesses knowledge of the destructive capacities of the most advanced war technologies developed

over many years. Militarization can therefore be viewed as the single most ecologically destructive human endeavor. Often depicted as a casualty of military conflict, the environment can nonetheless become a catalyst for unconventional military actions when sufficiently exploited. Environmental protection, the assessment of the environmental impacts of military activities, and the capability to foresee destructive military operations with potential for catastrophic outcomes deserve greater and more genuine international attention. In addition to integrating all known "peacetime" conventional military activities into research processes, it is essential to include—and particularly to foster awareness of—the dominance and destructiveness of unconventional military activities. It is clear that military intelligence will not invent a 'weapon for environmental protection.' The synergy between environmental protection and crisis management should aid in developing solutions and in preventing the formation of a vicious cycle linking military activities, crises, diseases, poverty, and ongoing environmental destruction. The failure to grasp the environmental harms of military activities may, in fact, pose one of the greatest threats to international stability.

References

Albright, R.D. (2012) *Cleanup of chemical and explosive munitions: Locating, identifying contaminants, and planning for environmental remediation of land and sea military ranges and ordnance dumpsite*. Elsevier: Oxford.

Arias, E.V., Mallavarapu, M., Naidu, R. (2015) Identification of the source of PFOS and PFOA contamination at a military air base site. *Environ Monit Assess*, 187.

Brochu, S. & Thiboutot, S. (2019) Greener munitions. In: Cumming, A.S. & Johnson, M.C. *Energetic Materials and Munitions - Life Cycle Management, Environmental Impact and Demilitarization*. 75-102.

Chalecki, E.L., Ferrari, L.L. (2018) A New Security Framework for Geoengineering. *Strategic Studies Quarterly*.

Chatterjee, S., Deb, U., Datta, S., Walther, C., Gupta, D.K. (2017) Common explosives (TNT, RDX, HMX) and their fate in the environment: Emphasizing bioremediation. *Chemosphere*, 184, 438-451.

Davis, J. S., Hayes-Conroy, J.S., Jones, V.M. (2007) Military pollution and natural purity: seeing nature and knowing contamination in Vieques. *Puerto Rico Geo Journal*, 69,165-179.

Eifried, G. (1998) Terrorism Against Chemical Plants: Hazards and Risks. *Proceedings of the CBMTS Industry I, Eco-Terrorism Chemical and Biological Warfare without Chemical and Biological Weapons*, 25-31 October, Zagreb-Dubrovnik, Croatia. 84-88.

Francis, R. A. (2011) The impacts of modern warfare on freshwater ecosystems. Environment Management, 48, 985-999.

Furić, K. & Orehovec, Z. (2001) Artifical Cobweb: Chemical and Physical Analysis. Proceedings of the CBMTS *Industry II, The First World Congress on Chemical and Biological Terrorism*, 21-27 April, Dubrovnik, Croatia. 140-143.

Govoni, J.J., West, M.A., Settle, L.R., Lynch, R.T., Greene, M.D. (2008) Effects of underwater explosions on larval fish: implications for a coastal engineering project. *Journal of Coastal Research*, 24 (2B), 228-233.

House, T.J., Near, J.B., William, B. i sur. (1996) *Weather as a Force Multiplier: Owning the Weather in 2025. A Research Paper*. US Air Force.

Jones, H.P. & Schmitz, O.J. (2009) Rapid recovery of damaged ecosystems. *PLoS One*, 4 (5).

Joseph, P. (2017) *The SAGE Encyclopedia of War: Social Science Perspectives*. SAGE Publications, Inc.:Thousand Oaks.

JP 1 – 02 (2001) *Department of Defense Dictionary of Military and Associated Terms*. Joint Chief of Staff.

Kelly, K.M. (1992) Declaring War on the Environment: The Failure ofInternational Environmental Treaties During the Persian Gulf War. *American University International Law Review*,Vol.7, 921-950.

Kilcullen, D. (2019) The Evolution of Unconventional Warfare. *Scandinavian Journal of Military Studies*, 2(1), 61-71.

Larkin, R.P., Pater, L.L., Tazik, D.J. (1996) Effects of military noise on wildlife. A literature review. *Construction Engineering Research Lab (Army),* Champaign, IL, USA. No. USACERL-TR-96/21.

Lewis, J., Sjöström, J., Skyllberg, U., Hägglund, L. (2010) Distribution, chemical speciation, and mobility of lead and antimony originating from small arms ammunition in a coarse-grained unsaturated surface sand. *J Environ Qual.*, 39,-70.

Machlis, G.E. & Hanson, T. (2008) Warfare ecology. *BioScience*, 58, 729-736.

Migliorini, M., Pigino, G., Caruso, T.P., i sur. (2004) The effects of heavy metal contamination on the soil arthropod community of a shooting range. *Environ Pollut*, 129, 331-40.

Nunes, L. M., Nunes, Y-G. Zhu, T.Y. Stigter, i sur. (2011) Environmental impacts on soil and groundwater at airports: origin, contaminants of concern and environmental risks. *J. Environ. Monit*., 13, 3026-3039.

Okumu, W. & Ukelegbe, A. (2010) (eds.) *Militia, Rebels and Islamic Militants: Human Insecurity and State Crises in Africa*, Pretoria, Institute of Security Studies.

Orehovec, Z. et al. (2004) Chemical Warfare without Chemical Weapons – Response. *Proceedings of NATO Summit Forum on Business and Security*, Berlin 10-15 March.

Paunović, N. (2017) Zaštita životne sredine u oružanim sukobima: Od progresa do regresa. *Međunarodno pravo* 1, 103-125.

Perkins, D.B., Haws, N.W., Jawitz, J.W., Das, B.S., Rao, P.S.C. (2007) Soil hydraulic properties as *ecological indicators* in forested watersheds impacted by mechanized military training. Ecological Indicators, 7, 589-597.

Pichtel, J. (2012) Distribution and fate of military explosives and propellants in soil: A review. *Applied and Environmental Soil Science*, Article ID 617236.

Prãvãlie, R. (2014) Nuclear Weapons Tests and Environmental Consequences: A Global Perspective, AMBIO, 43, 729-774.

Protopsaltis, C. (2012) Air pollution caused by war activity. Greece WIT Transactions on Ecology and The Environment, Vol. 157. WIT Press https://www.witpress.com/Secure/elibrary/papers/AIR12/AIR12009FU1.pdf

Quist, M.C., Fay, P.A., Guy, C.S., Rubenstein, B.N., Knapp, A.K. (2003) Military training effects on terrestrial and aquatic communities on a grassland military installation. *Ecological Applications*, 13 (2), 432-442.

Rodríguez-Seijo, A., Perez-Zabaleta, A., Labeaga-Azcona, J.M. (2019) Effects of noise Emitted by Military Aircraft on Housing Close to an Air Base: The Case of Gando Air Base (Spain). *Rev. Int. Contam. Ambie.*, 35,207-221.

Rogers, K.S. (1997) Pre-empting violent Conflict: Learning from environmental cooperation. U: Gleditsch, N.P. (ed.) *Conflict and the Environment*. Dordrecht, Kluwer Academic Press.

Sanatana, D.B (2009) Resisting toxic militarism: Vieques versus the U.S. Navy. In: White, R. (ed.) *Environmental Crime. A reader*. Willan Publishing: Devon. 350-359.

Sarić, I. & Radonja, R. (2014) Noise as a source of marine pollution. Scientific Journal of Maritime Research, 28, 31-39.

Stajić, Lj. i Vujić, D. (2012) Uticaj geofizičkog oružja na ugrožavanje životne

sredine za potrebe rata, *Zbornik radova Pravnog fakulteta u Novom Sadu*, br. 2., 121-141.

Tang, Z., Engel, B.A., Pijanowski, B.C., Lim, K.J. (2005) Forecasting land use change and its environmental impact at a watershed scale. *J. Environ. Manage.*, 76, 35-45.

Taylor, S., Bigl, S., Packer, B. (2015) Condition of in situ unexploded ordnance. Sci. Total Environ, 505, 762-769.

Vučemilović, A. (2010) Toksikološke posljedice oružja za masovno uništavanje i noksa u suvremenom ratovanju i terorizmu. *Arh Hig Rada Tokskol*, 61, 247-256.

Wang, G., Murphy, D., Oller, A., Howard, H., Anderson, A., Rijal, S., Myers, N., Woodford, P. (2014) Spatial and temporal assessment of cumulative disturbance impacts due to military training, burning, haying, and their interactions on land condition of fort riley. *Environ. Manag.*, 54 (1), 51-66.

Warren, S.D., Holbrook, S.W., Dale, D.A., Whelan, N.L., i sur. (2007) Biodiversity and the heterogeneous disturbance regime on military training lands. *Restor. Ecol*. 15 (4), 606-612.

Westing, A.H. (2006) Environmental and ecological consequences of war. U: Geeraerts, G. *et al. Dimensions of Peace and Security*. 83-95.

Yager, L.Y., Jones, J., Miller, D.L. (2009) Military training and road effects on Imperata cylindrica (L.) Beauv. (Cogongrass). *Southeastern Naturalist*, 8, 695-708.

Zentelis,R., Banks, S., Dale, R.J., Dovers, S., Lindenmayer, D. (2017) Managing military training-related environmental disturbance. *Journal of Environmental Management* 204, 486-493.

Utjecaj vojnih djelovanja na okoliš

Sažetak

Sigurnost se ne može u potpunosti razumjeti bez uzimanja u obzir čimbenika vezanih uz okoliš. Zbog bliske povezanosti vojnih djelovanja i okoliša, vojne akcije imaju dugu povijest uzrokovanja štete na okoliš diljem svijeta. S obzirom na sve veću raznolikost aktera u suvremenom sigurnosnom okružju, njihove sve veće (prikrivene) interese te sve složeniju međuovisnost sigurnosnih trendova i čimbenika, globalno sigurnosno okružje prolazi kroz dinamične promjene koje dovode do znatnih i nepredvidivih utjecaja na okoliš. Znanje o razornim sposobnostima najmodernijih vojnih tehnologija razvijenih tijekom godina ograničeno je na mali broj ljudi. Militarizacija se može smatrati jednim od najrazornijih ljudskih pothvata. Posebno je potrebno podići svijest o dominaciji i destruktivnosti nekonvencionalnih vojnih djelovanja. Sinergija zaštite okoliša i upravljanja krizama trebala bi pomoći u pronalaženju rješenja i sprječavanju nastanka začaranog kruga koji povezuje vojna djelovanja, krize, bolesti, siromaštvo i trenutačno uništavanje okoliša.

Ključne riječi

okoliš, vojne aktivnosti, nekonvencionalne vojne aktivnosti, ekološka katastrofa