The Use of Depleted uranium weapons in the world: impacts, controversies and implications.

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Memory / The Use of Depleted Uranium Weapons in the World: Impacts, Controversies and Implications

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This work does not constitute an official academic dissertation.
This is independent research carried out with the aim of informing and raising awareness of the issues related to the use of "depleted" uranium weapons around the world.
Any possible resemblance to an academic format is intended solely to promote clarity and rigor in the presentation.

Introduction

Armed conflicts, beyond their immediate human and material tolls, cause deep and lasting environmental degradation. Military strategy has always instrumentalized the environment, seeking to exploit or transform it to gain a tactical advantage, without consideration for the long-term ecological consequences (Boulanger, 2011, p. 1). Contemporary wars, through their technological intensity, have amplified this phenomenon. The hostilities leave behind a legacy of long-lasting destruction : oil well fires polluting the atmosphere, massive oil spills into the seas, bombing of industrial sites releasing toxic substances, and contamination of soil and water by unexploded ordnance. Often relegated to the background during hostilities, these attacks manifest themselves long after the fighting has ceased, affecting the health of populations and the viability of their territories for generations to come (Massa-2023, p. 3). Among the toxic legacies of recent wars, the use of depleted uranium (DU) weapons represents a particularly complex and controversial issue, embodying the encounter between ballistic sophistication and an insidious form of persistent pollution.

Depleted uranium is a by-product of the uranium enrichment process, which aims to increase the concentration of the fissile isotope U-235 for the nuclear industry, both civilian and military. This process generates large quantities of this residue, which is mainly composed of the isotope U-238 (Lesna-2004, p. 5). Because of its very high density (about 19 g/cm³, or 1.7 times that of lead), this heavy metal is valued for its exceptional ballistic properties. Integrated into arrow shells, it gives them a superior penetration capacity, capable of piercing the most resistant armor (Lesna-2004, p. 5). However, its military effectiveness comes at a high environmental and health cost. On impact, the DU munition does not just puncture its target ; it fragments and ignites spontaneously, generating an aerosol of uranium oxide microparticles, ranging in size from two to ten microns (Lesna-2004, p. 5). These particles can be dispersed by winds over large areas, settle on soil, contaminate water sources, and be inhaled or ingested by humans and animals. Once in the body, they pose a long-term threat, raising the question of long-term contamination of ecosystems and food chains (Leistner, 2023, p. 59).

The controversy surrounding these weapons is based on their dual toxicity, a duality that fuels uncertainty and controversy. On the one hand, uranium is a heavy metal with a well-documented chemical toxicity. Like lead or mercury, it has deleterious effects on the body, with nephrotoxicity (kidney damage) being the predominant symptom. Uranium, once in the blood, preferentially binds to the proximal circumvented tubules of the kidney, which can lead to nephritis and impaired glomerular function (Gueguen Rouas, 2012, p. 2, Gueguen Rouas, 2012, p. 1). On the other hand, although its radioactivity is 40% lower than that of natural uranium, DU remains a radioactive substance emitting mainly alpha particles. The controversy is less about the existence of this radioactivity than about the degree of its toxicity, particularly in the case of internal contamination by inhalation or ingestion (Lesna-2004, p. 5). Scientific debates on the effects of low doses of ionizing radiation, in particular the relevance of the linear no-threshold model (RLSS) for carcinogenic risk assessment, add a layer of complexity and uncertainty (Tubiana et al., 2007, p. 2, Bourguignon-2022, p. 1).

This complexity is amplified by the insidious nature of the risk, described as an invisible threat (Lesna-2004, p. 75). Unlike conventional battlefield hazards, DU contamination is imperceptible to the human senses. It is lurking in the formulas of physicists and chemists, making populations and even soldiers dependent on scientific expertise that is far from unanimous (Lesna-2004, p. 75). This creates fertile ground for fear and mistrust, especially as accusations of disinformation have emerged. It has been suggested that the term depleted was deliberately used to minimize the perception of danger and semantically dissociate these munitions from the nuclear domain among policymakers and the public (Barrillot-2001, p. 8). The contrast between the often reassuring official discourses on the harmlessness of these weapons and the rigorous precautions taken by the military during the testing and handling of these same munitions only accentuates skepticism and fuels controversy (Barrillot-2001, p. 8).

It is in this context of health, environmental, ethical and geopolitical tensions that this work is inscribed. Its ambition is to go beyond the simple description of the controversy to analyze its technical, scientific, legal and strategic foundations. The aim will be to examine in depth the use of depleted uranium weapons, analysing their properties, the actual and potential impacts of their use, the controversies they generate, as well as the international legal framework whose effectiveness is being debated. The aim is to provide a comprehensive and nuanced analysis of the reasons for their continued deployment, the short- and long-term consequences for people and the environment, and the prospects for more responsible management, including possible alternatives. To do so, the analysis will be based on a review of the scientific literature and on emblematic case studies, such as the Gulf and Balkan wars. This introductory chapter aims to lay the foundations of this approach : it will present the objectives and methodology of the research (1.1), delineate in detail the context and the problem (1.2), and then present the complete structure of the thesis (1.3).

1.1 Objectives and Methodology

In order to respond in a systematic way to the complex issue raised by the use of depleted uranium (DU) weapons, this thesis engages in an exhaustive and multidimensional analysis of this phenomenon. The aim is to shed light on its technical foundations, its multiple consequences and the lively controversies it generates. To do so, our research is structured around several specific objectives and is based on a rigorous methodology, designed to navigate a subject where scientific, legal and political issues are intertwined.

Research objectives

This general objective is divided into several interrelated lines of research : 1. Describe and contextualize : The aim is to establish a factual knowledge base by describing the physical, chemical and ballistic properties of depleted uranium, as well as the history of its development and use in modern armed conflicts. 2. Assess impacts : The analysis will systematically focus on the environmental and health consequences of the use of these weapons. This includes the study of long-term contamination of ecosystems, as well as the in-depth examination of toxicological risks (chemical and radiological) for military and civilian populations. Particular attention will be paid to the nature of scientific controversies and the methodological limitations of existing epidemiological studies. 3. Analysing normative frameworks : The thesis will critically examine ethical debates and the applicable international legal framework. This will assess whether international humanitarian law and environmental law provide adequate and effective protection against the risks posed by weapons to the AU (Massa-2023, p. 8). 4. Deciphering the strategic and political issues : Another objective is to understand the geopolitical and strategic rationalities that motivate the continued use of these weapons despite the controversies, as well as to analyze the reactions of states, international institutions and the crucial role of non-governmental organizations in publicizing the issue. 5. Proposing avenues for regulation : Finally, this thesis aims to go beyond the observation by proposing avenues for reflection for a more responsible management of this toxic heritage, by exploring regulatory efforts, technological alternatives and concrete policy recommendations.

Methodological approach

To achieve these objectives, this research adopts a qualitative and interdisciplinary approach, drawing on tools from political science, law, sociology of science and environmental studies. It combines a critical examination of the theoretical and legal framework with an in-depth analysis of practical cases, intended to highlight possible flaws in the existing protection regime on the ground (Massa-2023, p. 9).

The methodology is based on two main pillars :

1. A literature review and a critical review of the literature : this approach consists of synthesizing and analyzing a diverse corpus of sources. This includes scientific publications specializing in toxicology and environmental sciences (Leistner, 2023, p. 14), reports from international organizations such as the United Nations Environment Programme (UNEP), international legal texts, military policy documents, veterans' testimonies, as well as social science works on risk management and socio-technical controversies. The analysis of media productions will also be mobilized to understand how the controversy has been constructed and brought to the public square (Lesna-2004, p. 6).

2. The multiple case study : Adopted as the main research method, the case study allows the theoretical analysis to be anchored in specific conflictual contexts, each of which marked a stage in the awareness of the problem (Tranquillo-2023, p. 6). The conflicts of the Gulf War (1991), the Balkans (1994-1999) and the Iraq War (2003) will be examined in detail. This approach has a dual purpose : it is descriptive, by providing facts on the extent of use and its documented consequences, and exploratory, by serving to identify gaps in legal and policy frameworks in the face of real-life situations (Tranquillo-2023, p. 6).

However, such an approach is not without methodological challenges. Consequence assessment is often hampered by the opacity of military data, difficulties in accessing post-conflict terrain, and delays in the implementation of impact assessments (Leistner, 2023, p. 56). Warring states frequently adopt temporal or legal « distancing strategies » to distance themselves from their responsibilities (Leistner, 2023, p. 57). Moreover, controversy is structured by a dependence on science as the sole method of validating risks, a posture that can be instrumentalized to maintain an « uncertainty that is beneficial » to political and economic interests (Petriccione-2004, p. 15). This thesis integrates these constraints not only as limits, but also as an object of analysis in its own right, striving to navigate these complexities with the required rigor. This recognition of barriers is an integral part of the scientific approach adopted.

1.2 Context and issues

Modern armed conflicts, by their intensity and technological sophistication, generate repercussions that largely transcend the duration of hostilities. Historically, environmental concerns have been relegated to the background in the face of strategic imperatives. As military strategy theorists point out, the environment has often been perceived not as a heritage to be protected, but as a theatre of operations to be exploited or altered in order to gain a tactical advantage. The wars of the twentieth and twenty-first centuries are abundant examples of this reality, from the massive defoliation in Vietnam to the oil well fires of the Gulf War. These actions, often deliberate, are not content with triggering pollution; they agglomerate, reveal and exacerbate them, acting as a catalyst on already fragile ecosystems.

Armed conflicts, for example, leave behind deep and lasting scars, transforming landscapes, contaminating resources and compromising people's health for decades.

Within this broader issue of the environmental impacts of conflicts, the use of depleted uranium (DU) weapons is a particularly complex and controversial case study. Depleted uranium is a by-product of the uranium enrichment process, consisting mainly of the non-fissile isotope U-238 (about 99.8%) and a very small proportion of U-235 (about 0.2%). It is a heavy metal with an exceptionally high density (18.95 g/cm³), which gives ammunition a higher puncture capacity, especially for anti-tank arrow shells. Its pyrophoric property, which causes it to ignite spontaneously on impact, further increases its destructive effectiveness by generating extreme temperatures inside the target. This ballistic advantage explains its adoption by several armies since the end of the twentieth century.

The central problem of these armaments lies in their dual nature. On impact, part of the DU munition sprays into an aerosol of fine uranium oxide particles, on the order of a few microns, which can be dispersed by the wind over several kilometres before being deposited. This dispersion generates a « toxic environmental legacy », carrying both a chemical and a radiological risk. While the chemical toxicity of uranium as a heavy metal is proven and well documented, mainly causing kidney pathologies (nephrotoxicity), its radiotoxicity, although low, is the subject of lively scientific and public controversy. Uranium, filtered by the kidneys, is deposited on tubular cells and can cause irreversible cell damage. The most intense debate, however, concerns the risks associated with chronic internal exposure following the inhalation of these particles. Once lodged in the lungs or other organs, they can irradiate the surrounding tissues over very long periods of time, raising fears about the development of serious pathologies, such as leukemia and other cancers.

This controversy emerged forcefully in the public space following the 1991 Gulf War. Veterans, first American and then European, have reported a set of chronic and disabling pathologies grouped under the name of « Gulf War syndrome », questioning their potential exposure to depleted uranium among other toxic agents. Civil society, through veterans' associations that are particularly active in the United States, has been instrumental in publicizing this issue. In Europe, and particularly in France, the controversy gained momentum later, during the military operations in Kosovo at the end of the 1990s. This mobilization has structured the public debate around an opposition between civil society, demanding transparency and recognition, and state institutions, in particular the ministries of defense, which have long tended to minimize the risks.

Since then, the issue has gone beyond the scientific framework to become a major ethical, legal and political issue. From an ethical point of view, it raises a fundamental question : « can the military institution undermine the health security of its own members by using the technologies it implements or tests ? » This question naturally extends to civilian populations in conflict zones, who are exposed to long-term contamination in spite of themselves. On the legal front, scientific uncertainty has led to calls for the application of the « precautionary principle ». This principle, which originated in environmental law, stipulates that « the lack of certainty, taking into account the scientific and technical knowledge of the moment, must not delay the adoption of effective and proportionate measures aimed at preventing a risk of serious and irreversible damage ». It is particularly relevant for technological risks with delayed effects, such as those of asbestos or nuclear irradiation, where the cause-and-effect link is long and difficult to establish. The rejection of moratoriums on the use of weapons at the AU has thus been denounced as a violation of this principle.

Politically, the debate is often characterised by the opacity of user states and the instrumentalisation of uncertainty. Critics accuse the authorities of a cover-up, motivated by the fear of acknowledging an unacceptable mistake (exposing troops without adequate protection) or by unspeakable economic and political issues, such as the low-cost management of waste from the nuclear industry or the desire to avoid expensive compensation and complex clean-up operations. The « invisible » nature of the threat, which « escapes our perceptions » and remains « lurking in the formulas of physicists and chemists », only exacerbates the apprehension and complexity of the controversy, making the public dependent on the often contradictory discourses of experts. The absence of closure of the scientific debate thus allows its political reactivation with each new conflict where the use of these weapons is suspected or proven.

Recent events, including speculation about the supply and use of these munitions in the conflict in Ukraine, demonstrate that this issue remains relevant. This thesis is at the heart of this fundamental tension : it aims to analyze the precarious balance between the claimed military utility of weapons to the AU and the environmental, health and social consequences, proven or suspected, that they entail. It will be a question of untangling a complex web of tactical considerations, scientific uncertainties, ethical controversies and a flawed international legal framework, in order to answer the central question of the responsible management of this toxic legacy of contemporary wars.

1.3 Structure of the thesis

In order to respond systematically to the issue raised, this thesis is structured according to an analytical progression aimed at elucidating the different dimensions of the use of depleted uranium (DU) weapons, from their technical foundations to their geopolitical implications.

The second chapter will lay the technical and historical foundations of the study. It will detail the physical and chemical properties of depleted uranium, which determine both its ballistic effectiveness and its potential toxicity. This chapter will also retrace the genesis of these armaments and their history of use in conflicts, providing an essential context for understanding the issues that arise from them.

Building on this basis, the third chapter will examine the direct environmental and health consequences. The analysis will focus on the long-term contamination of ecosystems and the toxicological, chemical and radiological risks for combatants and civilian populations. Particular attention will be paid to scientific controversies and the methodological limitations of existing studies, which structure the public debate.

The fourth chapter will broaden the analysis to the normative and societal dimensions. It will explore ethical debates, including with regard to the precautionary principle, and assess the adequacy of the current international legal framework. The role of civil society actors, in particular non-governmental organizations (NGOs), in publicizing this issue and shaping international responses will also be analyzed.

The fifth chapter will take a geopolitical and strategic perspective to elucidate the reasons for their continued use. It will endeavour to decipher the military rationalities underlying their use, the opacity maintained by user states and the possible links with the management of nuclear industry waste.

To anchor the analysis in concrete contexts, the sixth chapter will mobilize the multiple case study, a central methodological approach of this research (Tranquillo-2023, p. 6). The conflicts of the Gulf War (1991), the Balkan War (1994-1999) and the Iraq War (2003) will illustrate the dynamics described. Recent speculations relating to the conflict in Ukraine will also be discussed to underline the contemporary relevance of the topic.

Going beyond the observation, the seventh chapter will move towards a prospective approach. It will assess international regulatory efforts aimed at a moratorium or ban, make recommendations for a more responsible management of this toxic legacy, and explore technological alternatives.

Finally, the eighth chapter will be the conclusion of this work. It will offer a synthesis of the main results, demonstrating how they respond to the initial problem. This conclusion will also open up perspectives on the future evolution of the controversy and identify complementary lines of research.

The Properties and Applications of Depleted Uranium Weapons

The controversy surrounding depleted uranium (DU) weapons, outlined in the introduction, is rooted in their fundamental duality : a tactical asset claimed by the general staff and a potential toxic legacy whose long-term consequences fuel concerns. To understand the complexity of the health, ethical and legal debates that will be addressed later, it is imperative to first analyze the very nature of this material, the foundations of its adoption by the armed forces and the context of its deployment. Military discourse focuses almost exclusively on ballistic performance, evaluating the material in terms

of its destructive effectiveness. Conversely, critical discourse focuses on the chemical and radiological properties that manifest themselves after the impact, generating a threat described as « invisible » (Lesna-2004, p. 75) for combatants and civilian populations. The aim of this chapter is to establish the technical basis for understanding this dichotomy. It propose to deconstruct the technical object in order to better understand the political object, by exploring the characteristics of the AU that justify its use in the field of armaments.

The military interest in DU is based on the combination of two exceptional physical properties : extreme density and pyrophoric character. On the one hand, its very high density (18.95 g/cm³), about 70% higher than that of lead, makes it one of the densest metals available in large quantities (Lesna-2004, p. 5). This characteristic is crucial for so-called kinetic energy ammunition (or arrow shells), whose effectiveness does not depend on an explosive charge but on the mass and speed of the projectile. By concentrating maximum mass in a minimum volume, DU indenters maximize kinetic energy at impact, giving them a perforation capacity that few materials can match. This allows them to pierce the toughest armor, such as that of modern battle tanks. For example, the French 120 mm OFL 120 F2 ammunition, intended for the Leclerc tank, can penetrate 640 mm of armor at a distance of two thousand meters (Barrillot-2001, p. 49). On the other hand, its pyrophoric character, i.e. its ability to ignite spontaneously on contact with the air under the effect of the very high temperatures generated by the impact, adds a devastating side effect (Barrillot-2001, p. 30). Once the armor is breached, the fragmented penetrator ignites inside the target vehicle, causing a sudden increase in temperature and pressure, which can incinerate the crew and detonate the on-board ammunition. This unique combination makes the AU, from a purely tactical point of view, an "ideal anti-tank weapon" (Barrillot-2001, p. 30).

However, it is this same pyrophoric property that is at the root of the main health and environmental concern. During its combustion, a significant part of the indenter – estimated by some experts to be up to 60% – is sprayed into an aerosol of fine particles of uranium oxides (UO2, U3O8), the size of which can be as small as a few microns (Barrillot-2001, p. 115).These particles can be dispersed by the wind over large areas, contaminating soil, water and air, before potentially being inhaled or ingested by humans. It should be remembered that depleted uranium is a by-product of the enrichment process of natural uranium. The latter is composed of several isotopes, mainly U-238 (about 99.3%) and U-235 (about 0.7%), the only fissile isotope. For nuclear applications (power plants and weapons), the concentration of U-235 must be increased. The enrichment process removes some of the U-235, leaving behind large amounts of « depleted" uranium, which is therefore more than 99.7% U-238 » (Lesna-2004, p. 5). This state of affairs has a major political and economic consequence : the global nuclear industry has generated huge stocks of this waste, which is expensive to manage. Its use in armaments thus represents an economically advantageous solution to "dispose of the enormous stock of nuclear waste" (Lesna-2004, p. 59), transforming an environmental liability into a strategic asset.

Although its properties, including its density, have found civilian applications – as a ballast and counterweight element in aeronautics, or as a radiation shield (Massa-2023, p. 65) – the conditions of use and the associated risks are radically different. The 1992 crash of El Al's Boeing 747 in Amsterdam, which was carrying 390 kg of AU as a counterweight, tragically illustrated this danger : it is estimated that more than 150 kg were consumed in the fire, dispersing uranium oxides over a residential area and raising health issues similar to those of veterans (Barrillot-2001, p. 26, Lesna-2004, p. 62). While the chemical toxicity of uranium as a heavy metal is well established, causing kidney damage (Lesna-2004, p. 5), its radiotoxicity (about 60% of that of natural uranium (Massa-2023, p. 65), remains the subject of intense controversy, particularly in the case of chronic internal exposure through inhalation of particles. In addition, the composition of DU can vary : if it comes from the reprocessing of spent nuclear fuel, it can contain traces of isotopes that are much more radiotoxic, such as plutonium or uranium-236, making it more dangerous than DU from the enrichment of raw ore (Massa-2023, p. 65).

In order to build a solid and nuanced knowledge base, this chapter will be divided into three parts. The analysis will begin with a detailed examination of the physical and chemical properties of the AU, delving into the metallurgical and radiological aspects that determine its dual face as a military asset and a potential contaminant. Its main military applications will then be described, reviewing the different types of ammunition (20, 25, 30, 105 and 120 mm projectiles) and the weapon systems that use them, such as the A-10 aircraft or the Abrams tank (Barrillot-2001, p. 34). Finally, a history of its use will trace the genesis of this technology and its deployment in armed conflicts, from the Gulf War to the Balkans, via Iraq. This section will remind us that the idea of using uranium for its ballistic properties is not new, since its beginnings date back to 1943, when Nazi Germany used it to replace tungsten, which had become scarce (Barrillot-2001, p. 30). This technical and factual analysis is an essential prerequisite for a rigorous assessment, in the following chapters, of the environmental and health impacts as well as the geopolitical and legal implications raised by the use of these munitions. Understanding the war machine in its material workings is the sine qua non condition for being able to analyze its human and environmental consequences.

2.1 Military Applications

The unique physical and chemical properties of depleted uranium (DU), analysed above, are being used for specific military applications, transforming this by-product of the nuclear industry into a strategic component of modern arsenals. The combination of its extreme density and pyrophoric character has made it a material of choice for high-intensity conflicts, although its use is not a recent innovation. As early as 1943, the Minister of Armaments of the Third Reich, Albert Speer, had used natural uranium to manufacture shells to replace tungsten, the supply of which had become impossible (Barrillot-2001, p. 30). However, it was during the second half of the twentieth century that research, particularly in the United States, systematized the use of UA, establishing it as a reference material for both offensive and defensive applications.

The Offensive Application : The Kinetic Energy Piercing Ammunition

The most widespread and decisive offensive application of DU is the manufacture of armor-piercing ammunition with kinetic energy, and more specifically *Armor-Piercing Fin-Stabilized Discarding Sabot* (APFSDS). The fundamental principle of these weapons is based on the maximization of kinetic energy ($Ec = 1/2mv^2$) delivered over a minimum impact surface. The exceptional density of DU (18.95 g/cm^3), often combined with a small proportion of titanium to increase its hardness (Barrillot-2001, p. 30), makes it possible to design long, thin and extremely heavy indenterators. Fired at very high speed, these metal « rungs » concentrate a colossal force, giving them a penetration capacity greater than that of most other materials. It is this characteristic that justifies its use by the French Ministry of Defence, because of the « unique physical properties of this metal that give it the ability to penetrate deeply into the strongest armour » (Barrillot-2001, p. 55). DU even outperforms its main competitor, tungsten, thanks to an adiabatic shear phenomenon known as « self-sharpening, » which allows it to maintain a sharp shape when penetrating where tungsten tends to blunt.

However, the performance of these munitions is not limited to perforation alone. The pyrophoric nature of uranium adds a devastating side effect, referred to as the « piercing-incendiary » effect. During the impact at very high speeds, extreme friction and compression generate intense heat, bringing the temperature of the projectile beyond 600°C (Massa-2023, p. 65). At this temperature, uranium ignites spontaneously on contact with oxygen. The fragments of the penetrator that pass through the armor disperse inside the target vehicle as an aerosol of glowing uranium oxide particles. This flaming aerosol causes a sudden increase in temperature and pressure inside the passenger compartment, triggering fires, the explosion of stored ammunition and fuel, and thus neutralizing the crew (Barrillot-2001, p. 30, Massa-2023, p. 65).

This synergy between an extreme armor-piercing effect and a major incendiary and pyrotechnic effect is what makes DU ammunition, from the point of view of its users, « the ideal anti-tank weapon » (Barrillot-2001, p. 30).

The reported performance on the battlefield is significant. The speed of an DU projectile can be around Mach 5 (about 1500 m/s) with an effective range exceeding 3000 meters, nearly 1000 meters more than conventional tungsten shells. Military experts have even suggested that during the Gulf War, some shots could pierce a tank from one side to the other and hit a second one located behind (Barrillot-2001, p. 72).

This tactical effectiveness has led to the development and integration of these technologies by several military powers. * The United States : Pioneers and main users, the United States has a complete panoply of armaments at the AU. The most emblematic example is the weapon system of the A-10 « Warthog" ground attack aircraft. Designed in the 1970s under the direction of the engineer Pierre Sprey, this aircraft was articulated around its main weapon : a six-metre-long Gatling cannon GAU-8A weighing 1800 kg » (Barrillot-2001, p. 32). « This gun is fed by up to 1350 PGU-14 30 mm DU rounds, which it can fire at a rate of 4200 rounds per minute » (Barrillot-2001, p. 32). The U.S. arsenal is not limited to the U.S. Air Force. The U.S. Army has also adopted DU for a wide range of calibers, ranging from 7.62 mm ammunition in the form of « darts" for assault rifles, to 25 mm ammunition (M919) for infantry fighting vehicles, to 105 mm and 120 mm tank shells » (Barrillot-2001, p. 33, Barrillot-2001, p. 34). Production is carried out by a military-industrial complex including companies such as Aerojet, Olin Ordnance, and Primex Technologies. In 2000, these companies had already manufactured more than a hundred million cartridges for the GAU-8A gun alone (Barrillot-2001, p. 33). It should be noted that the DU penetrators of the decommissioned PGU-14 munitions were recovered and reused to manufacture 25 mm M919 ammunition, illustrating the management of DU as a strategic resource (Barrillot-2001, p. 35).

- France : French production of DU munitions began around 1995, when the French Atomic Energy Commission (CEA) announced the construction of a new building at the SICN in Annecy for the mass production of « kinetic ammunition bars » on behalf of Giat Industries (Barrillot-2001, p. 48). Giat Industries (now KNDS) produced two main models : the OFL 105 F2 arrow shell for the AMX-30 B2 tank, capable of piercing 540 mm of armor at 2000 meters, and the OFL 120 F2 for the Leclerc tank, whose production began in 1996 and which can pierce 640 mm of armor at the same distance (Barrillot-2001, p. 49). Notably, the growing media coverage of the controversies over the AU has led to a great deal of opacity on the part of French industrialists. DU ammunition, although presented in defence catalogues such as that of GICAT in 1998, has disappeared from subsequent editions, such as that of 2000 (Barrillot-2001, p. 41).

- The United Kingdom : British forces have also adopted these technologies, including to arm their main battle tank, the Challenger 2. The latter uses 120 mm APFSDS ammunition, such as the L27A1 version that entered service in 1999 (Barrillot-2001, p. 41). The manufacture of these munitions is not without risk, as evidenced by a major fire of depleted uranium at a Royal Ordnance plant in February 1999, which put the site out of service (Barrillot-2001, p. 41).

- Russia and other actors : Russia has also developed DU ammunition, including for the 125 mm guns of its T-64 and T-72 tanks. These are not only arrow shells but also hollow charge shells (HEAT-FS) such as the 3BK21M model, whose casing is jacketed with DU to increase the effectiveness of the explosive charge during penetration (Barrillot-2001, p. 51). Beyond these four main producers, the proliferation of these weapons is a major concern. According to the Campaign Against Depleted Uranium (CADU), some fifteen countries are believed to hold AU munitions in their arsenals, including Greece, Turkey, Israel, Saudi Arabia, Kuwait, Pakistan and Taiwan (Barrillot-2001, p. 79). France, although it claims not to have exported this ammunition, has designed its 105 mm shells to be compatible with foreign tanks such as the Leopard or the M60, leaving the door open to potential markets (Barrillot-2001, p. 83).

Beyond their predominant anti-tank role, the properties of the DU are being leveraged for other offensive applications. It is used in particular in the design of warheads intended for the destruction of hardened targets (« bunker busters »). The strategic objective is to be able to annihilate command and communication centers buried under meters of reinforced concrete, offering considerable destructive power without resorting to nuclear weapons and the political stigma associated with them (Parsons-2002, p. 5). In addition, a trend towards the generalization of DU is emerging with the development by European consortia, such as CTAI, of medium-caliber (40 mm) ammunition, presented with slogans such as "lethal, compact, cheap, available" (Barrillot-2001, p. 54).

The Defensive Application : Reinforced Armor

The second major military application of depleted uranium is defensive. Its exceptional density makes it a component of choice for composite shielding. This innovation was motivated by the strategic context of the Cold War. Faced with the quantitative superiority of Warsaw Pact armored forces in Europe, the United States sought to achieve qualitative technological superiority. It was in this context that they announced, at the end of the 1980s, a program aimed at equipping three thousand of their main battle tanks, the M1 Abrams, with new composite armor incorporating depleted uranium plates (Barrillot-2001, p. 35).

Developed by companies such as the Manufacturing Science Corp. and Nuclear Metals Inc., this armor gave the M1A1 tanks unparalleled protection against most known anti-tank weapons, giving the U.S. military what the Pentagon estimated to be a « decade-long technological advance » over its Soviet adversary (Barrillot-2001, p. 35). The principle is to intersperse layers of metallic DU within a steel matrix. When an enemy projectile hits the armor, the DU plate, by its density and hardness, helps to fragment or deflect the penetrator, dissipating its kinetic energy and protecting the crew.

While this technology significantly increases the survivability of the vehicle and its crew on the battlefield, it has some notable drawbacks. The main one is the very significant increase in the weight of the tank, which limits its speed, increases its fuel consumption and imposes severe logistical constraints in terms of transport (bridges, ships, planes). Therefore, it is likely that only certain tank models or elite units are equipped with this type of heavy armor (Barrillot-2001, p. 35). This defensive application also creates a paradox : a tank protected by DU armor, if hit and destroyed by enemy ammunition (whether DU or not), becomes a major source of contamination itself. Burning the vehicle can disperse the DU particles contained in its armor, turning a wreckage into a site of long-lasting radioactive and chemical contamination.

Ultimately, the versatility of depleted uranium, used for both offensive and defensive applications, explains its adoption as a strategic material by many of the world's leading militaries. From small-caliber ammunition to heavy tank shells to armor, DU has established itself as a key component for conflicts where material superiority is a decisive factor. Its integration is sometimes referred to by technical terms such as « staballoy » (Barrillot-2001, p. 80), which testifies to its status as a military material in its own right, normalized within military-industrial complexes. This tactical and strategic effectiveness, undisputed by its users, is nevertheless inseparable from the serious health, environmental and legal questions that its use on the battlefield raises. Every impact of an DU munition, every destruction of armor containing it, transforms a combat zone into a potentially contaminated site in the long term, thus shifting the cost of war to future generations and ecosystems. It is these consequences that form the core of the following chapters.

2.2 History of use

The history of the use of depleted uranium (DU) weapons is inseparable from the conflicts of the late twentieth and early twenty-first centuries. It traces a clear trajectory : from a technological innovation developed in the context of the Cold War, the AU has become a standardized component of the arsenals of several military powers, whose tactical effectiveness is matched only by the persistence of the controversies that accompany each of its uses. The analysis of this history is fundamental to understanding how a by-product of the nuclear industry could become a major weapon and a source of enduring international concern, illustrating the ongoing tension between short-term military advantage and long-term health and environmental consequences.

The concept of exploiting the physical properties of uranium for ballistic purposes is an old one. As early as 1943, faced with a shortage of tungsten, the Ministry of Armaments of the Third Reich, headed by Albert Speer, used natural uranium to manufacture shells (Barrillot-2001, p. 30). However, the systematic development of DU munitions is a direct consequence of the technological race of the Cold War. Faced with the overwhelming numerical superiority of Warsaw Pact armored forces in Europe, the United States sought to gain a decisive qualitative advantage. The rearmament program initiated under President Ronald Reagan thus stimulated the search for armaments capable of destroying hardened targets, such as buried command centers and new-generation battle tanks (Parsons-2002, p. 5). UA, with its extreme density, self-sharpening phenomenon and pyrophoric properties, then proved to be a material of choice, superior even to tungsten. Alongside these technical advances, an early awareness of the dangers emerged ; as early as 1948, the United Nations Conventional Armaments Commission warned against « radiological weapons », defined as « weapons operating by means of radioactive material », going so far as to classify them as weapons of mass destruction. This commission anticipated that by-products from nuclear reactors could be used to contaminate entire areas, causing widespread damage to people and the environment (Barrillot-2001, p. 104). This early warning stands in stark contrast to the later classification of weapons at the AU as purely conventional by user states.

The first documented mass use of weapons by the AU occurred during the Gulf War in 1991. This operation was a real large-scale « baptism of fire » for this technology. During Operation Desert Storm, coalition forces, and mainly US forces, made extensive use of these munitions to counter Iraq's large fleet of armored vehicles. Available estimates, although fragmentary, indicate more than 940,000 30 mm projectiles fired by A-10 « Warthog" ground attack aircraft and more than 14,000 larger caliber shells (105 mm and 120 mm) fired by Abrams tanks, dispersing a total mass of about 40 tons of DU into the environment, particularly in the border region between Iraq and Kuwait » (Mathieu Matieu, 2001, p. 2). British forces also acknowledged firing about eighty rounds of this type (Barrillot-2001, p. 71). Although the French authorities have stated that their forces have not used DU ammunition, as it is not yet in domestic production, questions remain as to whether American ammunition could be tested by AMX-30 B2 tank units (Barrillot-2001, p. 71).

It was in the immediate aftermath of this conflict that the controversy over the « Gulf War Syndrome » appeared. Veterans from the United States, the United Kingdom, and other coalition countries began to report a range of chronic and unexplained conditions, including neurological disorders, chronic pain, respiratory problems, and cancers, including leukemia (Lesna-2004, p. 5). Exposure to DU was quickly cited as one of the potential causes, ushering in a public and scientific debate that has continued to intensify (Lesna-2004, p. 5). Initially, this debate was marked by a silence on the part of the military authorities and a media treatment that some observers described as a « blackout », the issue being considered politically sensitive in the context of a war perceived as a military success (Lesna-2004, p. 50). It was not until the late 1990s and early 2000s that the subject gained visibility, in particular thanks to investigative reports such as that of « The Secret Radioactive War », a subject broadcast in February 2000 (Lesna-2004, p. 17).

Despite the emerging controversies, the use of these weapons continued and became systematic in the Balkan conflicts, where they were used by NATO forces. Between 1994 and 1995, during the Bosnian war, the American air force fired 10,800 projectiles at the DU. This crucial information was only revealed late, at the end of 2000, following the revelations of the Italian Minister of Defence.The latter expressed his « bitterness" at the fact that NATO had only belatedly provided information essential for the security of the military and local populations, underlining a breakdown of trust within the alliance » (Barrillot-2001, p. 73). The use of these munitions culminated in the 1999 NATO air campaign in Kosovo, an all-air operation in which 31,000 shots were fired by U.S. A-10 aircraft. NATO officially confirmed this practice in a letter addressed to the UN Secretary-General, Kofi Annan, in March 2000, transforming the rumours into a proven fact (Lesna-2004, p. 17, Massa-2023, p. 66).

This confirmation, combined with increased media attention in Europe, crystallized the controversy. At the end of 2000, the Italian, then Spanish, Belgian, Portuguese and French press began to report cases of leukaemia and other cancers in soldiers who had served as peacekeepers in the Balkans, popularising the expression « Balkan syndrome » (Lesna-2004, p. 21). This new « syndrome » has had a major resonance effect : it has not only triggered a political and health crisis in Europe, but it has also given new legitimacy to the demands of Gulf War veterans. Unlike the « Gulf syndrome », where the etiology remained multifactorial and debated (exposure to pesticides, vaccines, oil well fumes), the public debate on the Balkan syndrome has focused almost exclusively on DU as the sole causative agent. This shift has established a direct and powerful link, in public perception, between the weapon and its presumed health consequences. The controversy intensified, involving national parliaments, the European Parliament and many scientific institutions, which were pressed to express their opinion on the dangerousness of the material (Mathieu Matieu, 2001, p. 3).

The entry into the twenty-first century has not marked the end of the use of weapons in the AU. These were again widely used in Afghanistan after 2001 and, above all, during the invasion of Iraq in 2003, where their effectiveness against armoured and fortified targets was once again exploited, this time in often urban environments, potentially increasing the exposure of civilian populations (Parsons-2002, p. 5). Beyond these proven uses, there are persistent allegations of their deployment in more recent conflicts, notably during Operation Cast Lead in Gaza (2008-2009) and during the international intervention in Libya (2011) (Massa-2023, p. 64). Although often difficult to verify due to the opacity surrounding military operations, these reports keep the AU issue at the forefront of the concerns of disarmament organizations and non-governmental organizations. This opacity is a structural feature of the dossier : manufacturers tend to be discreet, sometimes using code names such as « staballoy » to designate the material (Barrillot-2001, p. 80) or simply removing these munitions from their public defence catalogues when the media controversy intensifies, as was the case in France after 1998 (Barrillot-22001, p.41).

In short, the history of the use of depleted uranium weapons reveals the path of a military technology whose undisputed tactical effectiveness is systematically followed by a wake of health and political crises. From the Gulf War to the Balkans and beyond, each deployment has reinforced a recurring cycle of military power demonstrations, followed by official silence, the emergence of pathologies in veterans and civilians, intense media controversy, and finally official denials and sustained scientific uncertainty. This evolution from a military secret to a global public health issue and a complex international legal problem demonstrates that the consequences of the use of these weapons go far beyond the temporal and geographical framework of the battlefield. The impacts and implications of this cycle are at the heart of this thesis.

2.3 Physical and chemical properties

Depleted uranium (DU) is a metal whose singular physicochemical properties explain its adoption in the military field as well as the intense controversies surrounding its use. An in-depth analysis of these properties is essential to grasp the fundamental duality of this material : on the one hand, a remarkable ballistic efficiency that makes it a weapon of choice for high-intensity conflicts ; on the other hand, a long-lasting toxic legacy that raises complex health, environmental and ethical issues. To do this, it is necessary to examine successively its isotopic composition, its physical characteristics which justify its military use, and finally its chemical and radiological properties, which are at the origin of major concerns.

Isotopic composition and origin of depleted uranium

Depleted uranium is a direct by-product of the enrichment process of natural uranium. The latter, as extracted from the ore, is a mixture of three main isotopes : uranium-238 (U-238), which constitutes the overwhelming majority with about 99.27% of the mass, uranium-235 (U-235), the fissile isotope essential for nuclear chain reactions, present at 0.72%, and finally uranium-234 (U-234), a product of the decay of U-238, in a very small proportion (about 0.0055%) (THE OXIDE STORAGE SCANDAL-2023, p. 7, Camarasa Chalabreysse, 1980, p. 3). The enrichment process consists of artificially increasing the proportion of U-235 (generally between 3% and 5% for civilian reactors, and well beyond for military applications) by separating it from the heavier U-238. This operation generates two flows : a small amount of enriched uranium and a very large amount of uranium « depleted » in U-235 and U-234 (Lesna-2004, p. 5).

The isotopic composition of DU used for military purposes is therefore significantly different from that of natural uranium. It is composed almost exclusively of U-238 (about 99.8%), with a residual U-235 content reduced to about 0.2%, and an even smaller proportion of U-234 (about 0.0008%) (THE OXIDE STORAGE SCANDAL-2023, p. 7). This change in composition has a direct consequence on the radioactivity of the material, which will be detailed below. Due to the colossal quantities of DU stocks generated by the global nuclear industry, this material, initially considered as a waste, has found a low-cost application in various sectors, including civil (counterweights in aeronautics, radiation protection screens) and especially military (Lesna-2004, p. 5).

Physical properties : a decisive ballistic advantage

The reasons for the adoption of DU in armaments lie mainly in two of its exceptional physical properties: its density and its pyrophoricity.

The first, and most decisive from a ballistic point of view, is its extremely high density of 18.95 g/cm³ (Lesna-2004, p. 5). For comparison, it is nearly 1.7 times higher than that of lead (11.3 g/cm³) and is very close to that of tungsten (19.3 g/cm³), the main competing material for armor-piercing munitions. By virtue of the principle of kinetic energy ($Ec = 1/2mv^2$), this exceptional density makes it possible to concentrate a maximum amount of energy in a projectile of reduced caliber, giving it a formidable perforation capacity. The French Ministry of Defence has explicitly justified its use by the "unique physical properties of this metal which give it the ability to penetrate deep into the strongest armour" (Barrillot-2001, p. 55). DU is thus the main component of *Armor-Piercing Fin-Stabilized Discarding Sabots* (APFSDS), long, thin penetrators capable of piercing several hundred millimeters of armored steel at a distance of several kilometers (Massa-2023, p. 69).

DU even surpasses tungsten not only in density, but also in a phenomenon known as « self-sharpening » (or adiabatic shear) on impact, which allows it to retain its tip shape during penetration, where tungsten tends to blunt.

In addition to this density, there is a second militarily advantageous property : its pyrophoric character. During a very high-speed impact against armor, extreme friction and compression convert part of the kinetic energy into intense heat, raising the temperature of the projectile to about 500°C or more (Mathieu Matieu, 2001, p. 1, Barrillot-2001, p. 26). At this temperature, uranium ignites spontaneously on contact with oxygen in the air. Fragments of the penetrator that pass through the armor disperse inside the target vehicle as glowing particles, starting fires and detonating stored ammunition and fuel. This secondary incendiary effect greatly increases the lethality of the weapon, incapacitating not only the vehicle but also its crew. It is the synergistic combination of this extreme penetration capability and devastating incendiary effect that has made DU a material of choice for modern anti-tank munitions, considered ideal by its users (Barrillot-2001, p. 30). To optimize these properties, DU is often used in an alloy with a low proportion of titanium, which increases its hardness (Barrillot-2001, p. 30), and suspicions exist as to the use of beryllium sheaths to prevent premature inflammation, adding another potential source of toxicity.

Chemical and radiological properties : the source of controversy

While the physical properties of DU explain its effectiveness, its chemical and radiological properties, exacerbated by impact conditions, are at the heart of health and environmental concerns.

Chemically, uranium is a heavy metal whose toxicity is proven and comparable to that of other metals such as lead or mercury (Mathieu Matieu, 2001, p. 1, Gueguen Rouas, 2012, p. 14). This chemotoxicity, which is not disputed, mainly affects the kidneys. After absorption into the body, uranium circulates in the blood and is filtered by the kidney glomeruli. It preferentially accumulates in the cells of the proximal bypassed tubules, where it can induce oxidative stress and cell damage leading to cell death (apoptosis) and, in case of high exposure, to acute tubular nephritis (Gueguen Rouas, 2012, p. 1, Gueguen Rouas, 2012, p. 15). This nephrotoxicity is the main health effect documented during uranium poisoning, whether acute or chronic (Gueguen Rouas, 2012, p. 1).

The health risk is considerably amplified by the physical transformation of the projectile on impact. A significant fraction of the mass of the indenter (some experts estimate up to 60%) is not simply melted or fragmented, but is sprayed into an aerosol of very fine particles of uranium oxides (UO_2, U_3O_8) (Barrillot-2001, p. 115). These particles, with a diameter of a few microns, are small enough to be inhaled and lodge deep in the pulmonary alveoli (Lesna-2004, p. 5). Once lodged in the lungs, these oxide particles, which belong to the class of least soluble uranium compounds (class Y), can remain there for years, with a biological purification period of more than 500 days (Camarasa Chalabreysse, 1980, p. 4). This persistence creates chronic double exposure : local chemical exposure to lung tissue and a slow, continuous release of uranium into the bloodstream, which then attaches to target organs such as kidneys and bones. This transformation of the solid metal into a respirable aerosol is the key mechanism that makes the toxicity of DU relevant not only to wounded shrapnel, but also to any person, military or civilian, in the vicinity of the point of impact and exposed to contaminated dust and fumes (Mathieu Matieu, 2001, p. 1).

Finally, the radiological properties of DU are the most controversial aspect of the debate. Being depleted of the isotopes U-235 and U-234 (the latter being a powerful alpha emitter despite its low mass), DU is about 40% less radioactive than its natural equivalent, with a specific alpha activity of about 14,400 Bq/g compared to 25,200 Bq/g for natural uranium (THE OXIDE STORAGE SCANDAL-2023, p. 7, Massa-2023, p. 65). DU is primarily an emitter of alpha particles. This type of radiation, made up of helium nuclei, is not very penetrating and is stopped by a simple sheet of paper or the outer layer of the skin. It therefore presents almost no risk of external irradiation. On the other hand, the danger becomes significant in the event of internal contamination. When an alpha particle is emitted inside the body, for example by a uranium oxide particle lodged in the lung, it deposits all its energy over a very short distance, seriously damaging the few cells it passes through and potentially inducing cancer-causing genetic mutations (Barrillot-2001, p. 115). Moreover, it is reductive to consider only alpha activity. The U-238 decay chain produces short-lived offspring, such as thorium-234 and protactinium-234, which are beta and gamma emitters (THE OXIDE STORAGE SCANDAL-2023, p. 4). The total activity (alpha, beta, gamma) of AU is therefore higher than its alpha activity alone, a point often overlooked in official communications that tend to minimize the radiological risk (THE OXIDE STORAGE SCANDAL-2023, p. 4).

The most heated controversy, however, is not about this intrinsic radioactivity, but about the purity and origin of the raw material. The isotopic composition mentioned above is that of an AU resulting from the beneficiation of virgin ore. However, DU can also come from the reprocessing of spent nuclear fuel from reactors. In this case, the uranium was contaminated in the reactor with fission products and transuranic elements (such as neptunium, americium and especially plutonium), as well as a higher concentration of U-236, an isotope that does not exist in nature (Massa-2023, p. 65). The presence, even in trace amounts, of these highly radiotoxic contaminants, particularly plutonium, which is a potent carcinogen, would radically change the weapon's risk profile, making it significantly more dangerous than its mere designation as "depleted uranium" would suggest (Lesna-2004, p. 23). The persistent opacity of user states in disclosing the precise isotopic composition of their munitions fuels the suspicion of hidden contamination and makes independent health risk assessments extremely difficult, thus fuelling a long-lasting scientific and political controversy.

Environmental and health impacts

After analysing the technical foundations and properties that make depleted uranium (DU) a formidable anti-tank weapon, it is now necessary to examine the flip side of this ballistic performance : its environmental and health legacy. The transition from the technical object, designed for immediate and targeted destruction, to the object of controversy, whose effects unfold in space and time, takes place at the moment of impact. When the combustion of the indenter releases an aerosol of toxic particles, the tactical asset is transformed into a long-lasting and diffuse threat, described as an « invisible threat » (Lesna-2004, p. 75). This threat escapes the circumscribed temporality of the armed conflict to be part of the long term of post-conflict contamination. It challenges the traditional distinction between the moment of hostilities and the return to peace, demonstrating that pollution does not fade with the cessation of fighting, but leaves a lasting imprint that sustainably reconfigures territories and the relationship that societies have with their environment (Leistner, 2023, p. 8). This chapter aims to analyze these impacts in depth, shifting the analysis from the immediate battlefield to the insidious consequences that affect ecosystems and future generations, long after the guns have fallen silent.

The major concern stems from the dispersion of fine particles of uranium oxides which, once released, can contaminate large areas. Often micrometric in size, these particles are easily transported by wind and water, allowing them to cross borders and settle far from their point of emission. They then become integrated into soils, river sediments and groundwater, thus contaminating the entire food chain (Leistner, 2023, p. 52). This environmental contamination is not a mere temporary alteration; it represents a profound and potentially irreversible change in environments.

Humans mark their passage through the sedimentation of their activities, which is actualized in the geological stratification of the radiochemical substances released during the war (Leistner, 2023, p. 91). The post-conflict ecosystem is « radically different from the pre-conflict one » (Leistner, 2023, p. 17), characterized by biodiversity loss and latent toxicity. Uranium, as a heavy metal, can be absorbed by plants, ingested by animals, and concentrated in organisms, turning environmental pollution into a direct health risk for human populations who depend on these resources for their livelihoods (Massa-2023, p. 64). The issue is all the more critical as the precise location of contaminated sites is rarely communicated by the military forces, leaving local populations in the dark about the dangers to which they are exposed. This lack of transparency creates areas of risk where agricultural activities, water harvesting or even children's play become potential vectors of exposure, disproportionately affecting the poorest communities, who are also « the least likely to be the subject of scientific investigation » (Leistner, 2023, p. 59).

In terms of health, the risks associated with depleted uranium are manifested through a double toxicity, one proven and the other hotly debated. On the one hand, its chemical toxicity as a heavy metal is a well-established toxicological fact. Regardless of its radioactivity, uranium, once in the body, preferentially targets the kidneys where it can accumulate and cause dysfunction, or even acute renal failure in the event of high exposure (nephrotoxicity) (Gueguen Rouas, 2012, p. 1). On the other hand, its low radiotoxicity is at the heart of intense controversy, particularly in the case of chronic internal exposure through inhalation of insoluble particles. Unlike external irradiation, these particles can become permanently lodged in the lungs, lymph nodes or skeleton, emitting short-range but high-energy alpha radiation that can damage the DNA of nearby cells. It is this last route of exposure that raises the greatest concern, as it is associated by many researchers, veterans and victims' associations with the emergence of serious pathologies. In fact, among military personnel and civilians in conflict zones (Iraq, Balkans), there is an abnormally high incidence of leukemia, various cancers, neurodegenerative diseases, kidney failure and congenital malformations (Leistner, 2023, p. 100). These complex syndromes, often grouped under the umbrella term « Gulf War Syndrome », have fueled a scientific and media controversy that remains unresolved, in part because of the difficulty of establishing a direct and unique causal link in a multifactorial context (Lesna-2004, p. 5).

In the face of persistent scientific uncertainty about the long-term health effects of exposure to low doses of DU, the debate has gone far beyond the academic framework to become eminently political. This lack of consensus is exacerbated by the methodological challenges inherent in studies in a post-conflict context : the presence of multiple confounding factors (exposure to other toxic agents, post-traumatic stress), the absence of baseline health data for local populations, the difficulty of reconstructing individual exposure doses, and the long latency times of certain pathologies such as cancers. This uncertainty is often instrumentalized. Arms-using states at the AU tend to downplay risks based on the absence of irrefutable scientific evidence, while non-governmental organizations and affected countries invoke testimonies and preliminary studies to demand a moratorium or ban (Lesna-2004, p. 70). In this context of polarization, the « precautionary principle » emerges as a relevant framework for analysis and action. Enshrined in international environmental law, it stipulates that « the lack of certainty, taking into account the scientific and technical knowledge of the moment, must not delay the adoption of effective and proportionate measures aimed at preventing a risk of serious and irreversible damage » (Lesna-2004, p. 54). The application of this principle to the case of AU would imply a reversal of the burden of proof : it would no longer be up to the victims to prove the harmfulness of the AU, but to the users to demonstrate its harmlessness.

This principle is becoming an essential conceptual tool for assessing the responsibility of States and questioning the ethical and legal legitimacy of the use of such weapons.

In order to methodically analyze these complex and multidimensional issues, this chapter will be divided into three interrelated parts. It will first examine environmental contamination in detail, describing the physico-chemical mechanisms of DU dispersion and assessing its long-term consequences on soil, water and the biosphere. This will be followed by an in-depth discussion of the health risks to combatants and civilian populations, making a crucial distinction between proven chemical toxicity, the mechanisms of which are well understood, and controversial radiotoxicity, which is the source of most concerns. Finally, a third section will be devoted to the critical analysis of scientific controversies and the limitations of epidemiological and toxicological studies, in order to understand the structural and political reasons why, decades after their first mass use, these weapons continue to give rise to so much debate and uncertainty. This factual and nuanced analysis of the physical consequences is an essential prerequisite for addressing, in the following chapters, the ethical, legal and geopolitical dimensions of their use.

3.1 Environmental Contamination

Environmental contamination is one of the most insidious and long-lasting legacies of the use of depleted uranium (DU) weapons. Far beyond the temporal and geographical framework of the battlefield, it transforms conflict zones into long-term sources of pollution, the consequences of which extend to all ecosystems, permanently affecting the biosphere and the human populations that depend on it. This phenomenon, which is part of a larger history of the contamination of the world in the industrial age, is radicalized by the practice of war (Leistner, 2023, p. 23). Far from being a simple collateral damage, the spread of DU is a direct and predictable consequence of the physicochemical properties of the material, which, during its military use, metamorphoses from a dense and solid metal into a volatile, persistent and biologically accessible contaminant. The analysis of this contamination requires an understanding of its mechanism of genesis, its multiple vectors of dispersal, and finally, the almost eternal nature of its footprint on the environment.

The central mechanism of contamination lies in the transformation of the DU on impact. As detailed in Chapter 2.2, the pyrophoric nature of the projectile, combined with the extreme kinetic energy released when striking an armored target, causes a meteoric rise in temperature, estimated at about 500°C or more (Mathieu Matieu, 2001, p. 1). This intense heat leads to partial vaporization, oxidation and spontaneous ignition of the uranium. A significant fraction of the mass of the indenter, up to 60%, is thus sprayed into an aerosol composed of micro and nanoparticles of uranium oxides (mainly UO_2 and U_3O_8). This metamorphosis is the fundamental tipping point : a kinetic weapon, designed for a localized armor-piercing and incendiary effect, simultaneously becomes a radiological and chemical dispersal weapon. The dangerousness of these particles is increased by their volatility, which allows them to spread well beyond the points of impact (Mathieu Matieu, 2001, p. 1). Thus, the act of war is not limited to visible and immediate destruction. It sediments an invisible and perennial pollutant footprint within the affected environments, durably changing the relationship between societies and their environment (Leistner, 2023, p. 8). War acts as a catalyst here, revealing and aggravating environmental vulnerabilities, while introducing new forms of pollution whose long-term management is a major challenge (Leistner, 2023, p. 13).

Once the uranium oxide aerosol has been generated, it is disseminated by multiple vectors, ensuring widespread and multifaceted contamination of environmental compartments : air, soil and water. The first and fastest vector is atmospheric dispersion. The particles, which are micrometric in size, are light enough to remain suspended in the air and be carried by the winds over very long distances. This phenomenon is particularly critical in desert regions such as Iraq and Kuwait, where strong and frequent winds can move these clouds of contaminated dust hundreds of kilometres (Mathieu Matieu, 2001, p. 1).

Studies point out that these particles, which are finer than talcum powder, can aggregate into tiny grains of sand. This process of fixation and resuspension by sandstorms creates a continuous cycle of contamination, giving the aerosol fallout a « virtually unlimited » scope.

Airborne contamination is therefore not a single post-impact event, but a dynamic process that can expose populations and ecosystems away from the initial combat zones, long after hostilities have ended.

The second compartment affected is the soil, which becomes the final receptacle of atmospheric fallout and the source of long-term contamination. Beyond this diffuse deposit, more concentrated contamination comes from projectiles that did not reach their target, or fragments of those that broke on impact. In the Balkans, for example, it has been documented that a large number of DU munitions have never been recovered and remain buried in the ground, acting as point sources of chronic pollution (Leistner, 2023, p. 61). Exposed to environmental conditions (humidity, oxygen, microbial activity), these uranium metal fragments oxidize and corrode slowly. This gradual dissolution process releases uranium in more mobile chemical forms, which can then migrate vertically into the soil profile. This slow but continuous migration poses a direct threat to the underlying water systems.

Indeed, the third vector of contamination is water, both underground and surface. Uranium dissolved in the soil solution can percolate until it reaches groundwater, contaminating drinking water supplies that are essential for local populations (Leistner, 2023, p. 94). Similarly, surface water runoff on contaminated soils can transport uranium particles to rivers, lakes and reservoirs. Once in aquatic ecosystems, uranium can become part of the food chain : it is absorbed by aquatic plants, consumed by benthic organisms, and bioaccumulates in fish. The use of this contaminated water for irrigating crops or watering livestock is another major route into the human food chain. The contamination of the AU thus establishes a « delayed destruction » (Leistner, 2023, p. 149), the effects of which may not appear until years or even decades after the conflict, affecting all living things and mortgaging health and environmental security for future generations. This dispersion follows a « chain along which pollution spreads », affecting not only the place of the impact but also all the ecological and social systems that depend on it (Leistner, 2023, p. 91).

What fundamentally distinguishes depleted uranium contamination from other war pollution is its exceptional persistence, which borders on permanence. Uranium-238, the main isotope of DU, has a radioactive half-life of 4.51 billions years, an order of magnitude comparable to the age of the Earth itself. This geological time scale is beyond human comprehension. Therefore, « when it enters the environment, the AU does so for almost eternity, with consequences that we are incompetent to judge » (Leistner, 2023, p. 99). Once disseminated in the form of fine particles over vast territories, the contamination is technically and economically impossible to decontaminate. It is « virtually ubiquitous, definitive as soon as it is emitted, irreversible in its effects and ineffaceable in the environment » (Leistner, 2023, p. 93). The use of these weapons constitutes an act with irreversible consequences, a permanent change in the chemical and radiological composition of the affected ecosystems.

This persistence creates an overwhelming transgenerational responsibility. Military decisions made today impose a health and environmental burden on future generations who had no part in the conflict (Leistner, 2023, p. 150). This phenomenon is reminiscent of the spread of other long-lasting military pollutants, such as Strontium-90 from atmospheric nuclear tests, which falls with rainfall, integrates into the soil, passes into plants, and permanently attaches itself to human bones (Leistner, 2023, p. 93). DU contamination is part of this line of military pollution that insinuates itself into bodies and ecosystems, creating an invisible and lasting form of occupation. Anxiety arises from this durability, but also from the lack of precise knowledge about the extent of the very long-term consequences (Leistner, 2023, p. 150). Human action then finds itself « under occupation » of the environmental consequences of war, forced to evolve in a contaminated context from which it seems impossible to extricate oneself physically or psychologically (Leistner, 2023, p. 8).

In conclusion, environmental contamination by DU is a complex and multidimensional phenomenon, characterized by large-scale dissemination via air, water and soil, and almost eternal persistence. This scientific reality, based on the intrinsic properties of the material, nevertheless comes up against official discourses that tend to minimize its impact. Reports, such as those concerning analyses carried out at French test sites, claim to have found no trace of uranium other than that naturally present in the environment (Lesna-2004, p. 38). Similarly, belligerents such as NATO have been able to argue that the use of sophisticated weapons is aimed at minimizing environmental damage (Leistner, 2023, p. 71), creating a profound disconnect between the rhetoric of "clean war" and the reality of long-term pollution.

In addition, the accurate assessment of the extent and severity of this contamination is significantly hampered by practical and methodological difficulties. Teams of experts, including those from the United Nations Environment Programme (UNEP), face a flagrant lack of resources that forces them to limit their studies to « site-specific snapshots », making it impossible to accurately represent all the alterations (Leistner, 2023, p. 60). Post-conflict assessments are often late, sometimes beginning years or even decades after the end of hostilities, when data on the initial environmental status has disappeared and local governance is weak (Leistner, 2023, p. 56). Finally, it is extremely difficult on the ground to formally distinguish the share of contamination due to DU from that from other sources of pollution, whether industrial, pre-existing to the conflict, or linked to other military activities (Leistner, 2023, p. 61, Leistner, 2023, p. 61). This set of uncertainties, difficulties of evaluation and divergences of interpretation, exacerbated by a « discursive shield » erected by users (Leistner, 2023, p. 71), constitutes the fertile ground for scientific controversies and the limitations of studies that will be addressed in the next section.

3.2 Scientific controversies and limitations of studies

The yawning disjunction between, on the one hand, the tangible reality of environmental contamination and the seriousness of the pathologies reported by veterans and civilian populations, and on the other hand, the persistent absence of a definitive scientific consensus on the effects of depleted uranium (DU), constitutes an arena of scientific and political controversy. This gap is not simply the result of a lack of data ; It is the product of a complex and systemic interplay between methodological challenges inherent in post-conflict research, the profound politicization of scientific expertise, and the selective amplification of uncertainty by the media. The analysis of these controversies reveals that science, far from functioning as a neutral and objective arbiter, is here a contested space where divergent interpretations, institutional interests and epistemological paradigms clash.

The first and most fundamental limitations are of an epistemological and methodological nature. Establishing an irrefutable causal link between exposure to DU and a long-latency pathology, such as cancer, represents a considerable scientific obstacle. The modern battlefield is a multi-toxic environment, a complex « cocktail » where soldiers have been exposed to a multitude of potential risk factors. In the case of the Gulf War, these factors include the preventive administration of pyridostigmine bromide, multiple vaccination programs, exposure to toxic fumes from burning oil wells, intensive use of pesticides, potential contact with Iraqi chemical agents, and the intense psychological stress of combat (Lesna-2004, p. 62). In this context, isolating the specific contribution of the AU is an almost insurmountable epidemiological challenge, especially since the synergistic effects between these different agents are largely unknown. Moreover, the burden of proof comes up against the principle of « impossible refutatio », as formulated by Professor Salamon : a statistician may prove that a phenomenon exists, but he can never prove that it does not exist; he can only conclude that he did not observe it (Lesna-2004, p. 36). This fundamental uncertainty, inherent in the scientific method, fuels persistent doubt and shifts the debate from the scientific field to that of politics, where the precautionary principle becomes a central argument (Lesna-2004, p. 54).

At the heart of the controversy is also a fundamental debate in radiation protection on the validity of the « linear without threshold » (LSS) model. This model, which postulates a direct proportional relationship between the radiation dose received and the risk of cancer, even for the lowest doses, is widely used by regulatory bodies. However, it is criticized by part of the scientific community for its tendency to overestimate the risks at low exposures (Tubiana, 1996, p. 27). Critics argue that biological mechanisms of DNA repair, effective at low doses, can be saturated at high doses, rendering linear extrapolation invalid. Some major epidemiological studies, often cited to justify this model, have even been accused of using « circular » reasoning. As a critical analysis points out, these studies postulate the validity of the LSS model to justify the pooling of low- and high-dose data ; This clustering then leads to a statistically significant risk, which is presented as a « demonstration » of the effect of low doses. However, if we do not adopt this postulate and analyze in isolation the cohorts that received less than 100 mSv, says the pro-nuclear community, « we do not find any significant carcinogenic effect » (Tubiana et al., 2007, p. 20). This fundamental controversy, which goes far beyond the case of the AU, undermines the possibility of calmly assessing its radiological risk. Finally, many field studies suffer from glaring methodological problems : lack of resources, assessments conducted years after conflicts making initial data collection impossible, and difficulty in distinguishing DU contamination from other pre-existing sources of pollution, whether industrial or related to other military activities (Leistner, 2023, p. 61).

In addition to these intrinsic difficulties, there is a profound politicization of expertise, which transforms the scientific debate into a public and mediatized « battle of experts ». The discourse is polarized between, on the one hand, state institutions, including defense ministries, which tend to minimize risks, and independent organizations and critical scientists. The official discourse oscillates between categorical statements and ambiguous formulations. For example, the French Ministry of Defence was able to affirm that DU « does not constitute radioactive material », a statement described as « inaccurate » by independent experts, before other official bodies such as the Office for Protection against Ionizing Radiation (OPRI) declared that its radioactivity is « significant » and that the material is « anything but innocuous » (Lesna-2004, p. 23). This contradictory communication fuels suspicion. The authorities' strategy sometimes seems to be to maintain vagueness, or even to overwhelm criticism with a deluge of unusable information. When a French MP asked the Minister of Defence for the scientific dossier on the health impact of the AU, he received seven binders weighing nearly ten kilograms, a volume that « not just any MP has the availability or the competence to analyse » (Barrillot-2001, p. 98).

This approach, which is akin to a façade of transparency, reinforces the idea that the official position is based on a starting hypothesis, that of harmlessness, rather than on an open investigation (Barrillot-2001, p. 98).

This politicization is exacerbated by obvious institutional biases. The World Health Organization (WHO), for example, has been heavily criticized for its inaction. Under pressure from the International Atomic Energy Agency (IAEA), whose mandate includes the promotion of the peaceful uses of nuclear energy, the WHO is said to have limited its work to a simple « monograph » that was only a « scan of a selection of existing literature ». Worse, this selection was largely biased,

Focusing almost exclusively on chemical toxicity and relying on sources directly from the Pentagon or the Rand Corporation, an affiliated think tank (Parsons-2002, p. 4). This climate of suspicion is the ideal breeding ground for whistleblowers like Thierry Lamireau and dissident experts. The case of Dr. Asaf Durakovic, colonel, veteran and nuclear medicine specialist, is emblematic. He claims that his research on the pathologies of Gulf soldiers was actively hindered, his requests for analyses « supposedly lost » and that he was finally « fired for disobedience » (Lesna-2004, p. 45). Although the reliability of his analyses, which claimed to find traces of DU in the urine of veterans ten years after the conflict, was subsequently « contested » by part of the scientific community (Lesna-2004, p. 19), his testimony had a considerable media impact. He embodies the figure of the dissident expert whose speech is perceived as « free from any duty to respect secrecy » but also « enlightened » by his internal experience, giving him a particular legitimacy in the face of official discourse (Lesna-2004, p. 46).

This climate of scientific controversy and institutional suspicion is then amplified, simplified and framed by its media staging. The media play a crucial role, not so much in creating controversy, but in structuring it for the general public. The analysis of media coverage shows that « media inflation focuses on the period of doubt, suspicion about the reality and the future of the danger ». The media peak is during the period of uncertainty » (Lesna-2004, p. 70). Once the first scientific results, often nuanced and complex, are published, media interest tends to fade, leaving the public with an impression of unresolved uncertainty (Lesna-2004, p. 70). The problem is then « reactivated in a punctual and superficial way » during new conflicts, without the substance of the debate having really advanced in the public sphere (Lesna-2004, p. 70). In this process, complex issues are inevitably simplified (Lesna-2004, p. 72). The example of the semantic and conceptual transition from the « Gulf War Syndrome » to the « Balkan Syndrome » is particularly eloquent. While in the first case, which emerged in the United States, AU was only one of the many potential causes invoked for a constellation of various pathologies (Lesna-2004, p. 5), in the European controversy over the Balkans it became « the only claimed causality » (Lesna-2004, p. 25). The media have thus crystallized the debate around a direct and unique link : AU → Leukemia (Lesna-2004, p. 62).

This media focus also offered a platform for alternative hypotheses which, although scientifically unproven, responded to a quest for meaning in the face of unexplained pathologies. The « contamination of manufacturing lines » by transuranics such as plutonium is a good example. Relayed by investigative journalists, this theory suggests that the DU used, resulting not only from the enrichment but also from the reprocessing of spent nuclear fuel, could contain traces of plutonium, a « dangerous and highly carcinogenic nuclear toxicant ». This presence, even if slight, « sheds light on the onset of diseases » and could explain the rapid appearance of serious pathologies, something that is difficult to attribute solely to the radiotoxicity of uranium-238 (Lesna-2004, p. 23). It is crucial to note that it is civil society actors, first and foremost veterans' associations such as Avigolfe in France, who « bring the debate to the surface in the media » (Lesna-2004, p. 7). Driven by the need to obtain recognition and compensation for their suffering, these associations play a leading role in alerting public opinion and forcing the authorities to react. Let us also recall again the actions and articles of the blogger and director of the film « Uranium en Limousin », Thierry Lamireau.

Ultimately, the scientific controversies surrounding depleted uranium are not the result of a simple lack of knowledge, but of a confluence of factors : the objective limits of epidemiology in conflict zones, the fundamental debate about the effects of low doses, the influence of political and military agendas on research, and media coverage that privileges the dramaturgy of controversy over the complexity of science.

This situation has a major societal consequence : it leads to an erosion of public trust in the ability of science to « tell the truth » and to offer unequivocal solutions.

The public finds itself faced with a « science incapable of offering a solution that wins the support of all ; therefore of a science surpassed by the own tools it has produced » (Lesna-2004, p. 68). The lack of scientific closure leaves veterans, local people, and policymakers in a vacuum where anxiety and suspicion thrive. The controversy over the AU then itself becomes an « argumentative tool » in broader political debates, such as criticism of NATO interventions (Lesna-2004, p. 70). Thus, a public and environmental health issue is transformed into a major ethical, legal and geopolitical issue, the ramifications of which will be explored in the following chapters.

3.3 Health risks

As a direct extension of the long-term contamination of ecosystems described in the previous chapter, the health risks associated with depleted uranium (DU) constitute the most visceral and alarming dimension of its use. The release of AU into the environment is not an ecological abstraction ; It translate into concrete and multifaceted human exposure, transforming conflict zones into sources of potential pathologies for decades to come. Once dispersed, DU enters the body through several distinct routes of exposure. The most immediate and critical route on the battlefield is the inhalation of aerosols of micro and nanoparticles of uranium oxides, generated by the pyrophoric combustion of the penetrators during impact. These particles, which are fine enough to reach the pulmonary alveoli, pose an acute risk to combatants and civilians in the vicinity of the strikes. However, the danger does not end with the end of hostilities. The resuspension of these particles by winds, particularly in arid environments such as Iraq, creates a chronic inhalation threat for local populations. In the longer term, the contamination of soil and groundwater opens up a second, more insidious route of exposure : the ingestion of contaminated water or food, integrating uranium into the human food chain (Leistner, 2023, p. 94). A third way, mainly concerning soldiers and deminers, is the contamination of open wounds with fragments of ammunition or contaminated soil.

Faced with these multiple routes of exposure, the toxicity of depleted uranium manifests itself according to a fundamental duality that structures the entire scientific and medical controversy. On the one hand, DU acts as a heavy metal, whose chemical toxicity is proven, documented and scientifically little disputed. On the other hand, it behaves as a radioactive substance emitting alpha particles, whose long-term stochastic effects, including its carcinogenic and genotoxic potential, are the subject of intense controversy, deep uncertainty and serious public concern. This dual nature, chemical and radiological, is the key to understanding the complexity of health risks and the apparent contradiction between the reassuring speeches of certain military authorities and the alarming testimonies of veterans and affected populations.

The chemical toxicity of uranium is the best characterized and constitutes the basis of proven health risks. As a heavy metal, DU exerts pronounced nephrotoxicity, with the kidney universally recognized as its primary target organ (Gueguen Rouas, 2012, p. 2). The pathophysiological process is well understood. After absorption into the bloodstream, whether pulmonary or digestive, uranium is transported and rapidly filtered by the kidney glomeruli. It is at the level of the proximal convoluted tubules (TCP) that its toxicity is most acute. The epithelial cells of these tubules, which are responsible for the reabsorption of essential elements, preferentially accumulate uranium (Gueguen Rouas, 2012, p. 1). This intracellular accumulation disrupts multiple metabolic functions and leads, in particular through oxidative stress, to cell death (apoptosis or necrosis) (Gueguen Rouas, 2012, p.1).

The clinical consequences of this cell attack depend on the dose and duration of exposure. Acute exposure to a high dose of uranium can cause acute tubular nephritis, a serious condition manifested by proteinuria (abnormal presence of proteins in the urine), glycosuria and a significant decrease in glomerular filtration rate, which can progress to severe renal failure (Gueguen Rouas, 2012, p.1). In the post-conflict context, chronic exposure to low doses is of particular concern. These exposures, although insufficient to trigger an acute attack, are suspected of inducing mild but progressive renal alterations. The development of more specific and sensitive urinary biomarkers, such as beta-2-microglobulin or the Kim-1 protein (Kidney injury molecule-1), has made it possible to detect such subclinical impairment in experimental studies, well before the onset of overt symptoms (Gueguen Rouas, 2012, p.1, Gueguen Rouas, 2012, p. 1). This renal toxicity, solidly established by decades of toxicological research, constitutes an undeniable basis for health risk. It proves that even if its radioactivity is disregarded, depleted uranium is in no way a « harmless » material (Lesna-2004, p. 23). Although the kidney is the most sensitive organ, other tissues may be affected by the chemical toxicity of UA, which can accumulate in the liver and bone system, where it can potentially interfere with calcium metabolism (Leistner, 2023, p. 94, Mathieu Matieu, 2001, p.1).

If the chemotoxicity of DU is a scientific fact, its radiotoxicity is the area of uncertainty and the most virulent controversy (Lesna-2004, p. 5). It is here that the deepest fears crystallize, because the risks evoked are no longer organic dysfunctions, but formidable pathologies such as cancer, leukemia and congenital malformations. The controversy arises from the very nature of the AU's influence. Composed mainly of uranium-238, it is an emitter of alpha particles. These particles, heavy and charged, are very energetic but have a very low penetrating power ; they are stopped by a simple sheet of paper or the stratum corneum of the skin. The radiological risk of DU is therefore lower in the event of external exposure. The danger arises when DU particles are internalized, by inhalation or ingestion. Once fixed in an organ, for example an insoluble uranium oxide particle lodged in lung tissue, they deliver their alpha energy in a very small volume, chronically irradiating the surrounding cells in high doses. It is this localized and persistent irradiation that is suspected of inducing DNA damage, which can potentially lead to mutations and the development of cancer.

The most important and high-profile fears concern the carcinogenic potential of UA, and more specifically the induction of leukemias and lymphomas. The issue emerged publicly in the United States shortly after the 1991 Gulf War, when veterans, grouped in associations, began to report an abnormally high incidence of various pathologies, including cancers (Lesna-2004, p. 5, Lesna-2004, p. 5). The debate then spread across the Atlantic and exploded in Europe in the late 1990s and early 2000s, following NATO operations in the Balkans. Cases of leukaemia in Italian, Portuguese, Belgian and French soldiers who served in Bosnia and Kosovo triggered a real political and media crisis, placing the AU at the centre of the accusations (Lesna-2004, p. 21, Mathieu Matieu, 2001, p. 3). At the same time, reports from Iraqi doctors and researchers pointed to a dramatic increase in the incidence of cancer and leukaemia, particularly in the south of the country, a region massively bombed with DU munitions in 1991 and 2003. A study conducted by Professor Mona Kamma of the University of Baghdad concluded that there was an « almost five-fold increase in cancer cases » in a group of people exposed to fighting (Mathieu Matieu, 2001, p. 2). These converging observations, emanating from sources as diverse as Western veterans and the Iraqi civilian population, have constituted a sufficiently troubling body of evidence to anchor the suspected link between AU and cancer in the public debate (Lesna-2004, p.14).

To further complicate the picture, a sub-controversy has emerged concerning the very composition of so-called « depleted » uranium. Investigative journalists and independent scientists have put forward the hypothesis that the DU used in munitions, from uranium enrichment but also from the reprocessing of spent nuclear fuel, could be contaminated by traces of much more radiotoxic transuranic elements, such as plutonium-239 (Lesna-2004, p. 23).

The presence, even the slightest one, of plutonium, a powerful carcinogen, would radically change the assessment of radiological risk. This « possibility of contamination of manufacturing lines » has been mentioned to explain why such serious pathologies could occur so quickly, arguing that plutonium is a « dangerous and highly carcinogenic nuclear toxicant » (Lesna-2004, p. 23).

Beyond the carcinogenic risk, another major source of anxiety, perhaps the deepest, is related to the potential reprotoxic and genotoxic effects of uranium. This fear affects the sustainability of life and raises the spectre of a pathological heritage being passed on to future generations. The same sources that warned of the rise in cancers in Iraq also reported a « more than three-fold increase in spontaneous abortions and an almost three-fold increase in congenital anomalies » in populations exposed to fighting (Mathieu Matieu, 2001, p. 2). Poignant testimonies from American and British veterans have corroborated this macabre picture, reporting the birth of children with « monstrous » malformations and rare pathologies after their return from the Gulf (Mathieu Matieu, 2001, p. 1). These syndromes, which have been observed repeatedly in the various conflict zones where the AU has been used (Kuwait, Serbia, Bosnia, Kosovo), have led observers such as the writer Rob Nixon to speak of « slow violence », a delayed destruction that permanently contaminates water, food chains and, ultimately, bodies and their descendants (Leistner, 2023, p. 100). The weapon's impact is no longer only physical and immediate, it acquires a « geo-temporal » dimension, compromising the health of future generations and establishing a contamination that continues to spread long after the cannons have silenced.

Finally, these specific pathologies (kidney failure, leukaemia, malformations) are often part of a much broader, diffuse and confusing clinical picture, frequently referred to by the controversial term « Gulf War syndrome » or, later, « Balkan syndrome ». This term does not refer to a single, well-defined disease, but rather to a constellation of heterogeneous, chronic and often disabling symptoms and pathologies, reported by a significant number of veterans. The list of conditions grouped under this banner is long and varied : irreversible damage to the lungs, liver and bones, immunodeficiency, extreme chronic fatigue, muscle and joint pain, neurological disorders (memory loss, difficulty concentrating, vision disorders), hematological, respiratory, digestive and skin disorders (Mathieu Matieu, 2001, p. 1, Lesna-2004, p. 13).

The etiology of this syndrome is one of the greatest mysteries of contemporary military medicine. It is crucial to emphasize that exposure to depleted uranium, although often highlighted in the media, is only one of the many potential causes cited. The modern battlefield is a multi-toxic environment, and coalition soldiers during the Gulf War were exposed to a complex cocktail of potential dangers. Other suspected etiological factors include: the preventive administration of pyridostigmine bromide as an antidote against nerve gases, multiple vaccination programmes (particularly against anthrax and botulinum toxin), exposure to toxic fumes from hundreds of Kuwaiti oil wells set on fire by the Iraqi army, exposure to pesticides and insecticides used massively in the camps, potential contact with low-level Iraqi chemical agents following the destruction of ammunition depots, and finally, the intense psychological stress of combat (post-traumatic stress disorder) (Lesna-2004, p. 62, Lesna-2004, p. 13).

In the face of this extraordinarily complex « causal web », isolating the specific contribution of the AU is a scientifically daunting task. It is also likely that the syndrome is not the result of a single cause, but rather of synergistic effects between several of these factors, which leads all international authorities and the armed forces to say that « depleted uranium weapons are without proven danger » ! An organism whose immune system is already stressed by multiple vaccinations and stress, and exposed to a wide range of chemical pollutants, could thus develop an increased sensitivity to the toxic effects, both chemical and radiological, of depleted uranium. The very history of the controversy illustrates this complexity : while in the debate on the Gulf War Syndrome, the AU was only one cause among others, the controversy over the « Balkan syndrome » that erupted a few years later focused almost exclusively on uranium, which became « the sole object of debate » (Lesna-2004, p. 10).

In short, the analysis of the health risks associated with depleted uranium reveals a contrasting and deeply problematic landscape. It ranges from toxicological certainty, with chemically induced and scientifically demonstrated nephrotoxicity, to the greatest epidemiological uncertainty regarding its long-term radiological effects. The striking juxtaposition between, on the one hand, serious pathologies, complex syndromes and recurrent testimonies from veterans and civilian populations on several continents, and on the other, the extreme difficulty in establishing a formal and irrefutable scientific causal link, constitutes the fertile ground for scientific controversies, methodological limitations of studies and battles between experts that will be explored in detail in the next section.

Ethical and legal controversies

Extending the analysis of the physical impacts and toxic legacy of depleted uranium (DU) weapons, this chapter shifts the questioning from the factual terrain to the normative field of their legitimacy. The previous chapter established a fundamental tension : the ballistic effectiveness of the AU is opposed by an « invisible threat » (Lesna-2004, p. 75) whose long-term effects are marked by profound scientific uncertainties. It is precisely this uncertainty that constitutes the pivot of the controversy, transforming a technical issue into a profound ethical and legal dilemma. Far from justifying inaction, the lack of scientific certainty about the seriousness of the risks makes it necessary to question the moral and legal responsibility of states that deploy a technology with potentially serious and irreversible consequences for populations and ecosystems (Lesna-2004, p. 56). This situation leads to a characteristic polarization : user states tend to minimize the risks by arguing the lack of irrefutable evidence, while non-governmental organizations and affected countries invoke testimonies and preliminary studies to demand strict regulation.

Uncertainty thus becomes a semantic and political battlefield where the acceptability of a weapon whose pollution does not fade with the cessation of fighting, but leaves a lasting imprint that reconfigures territories in the long term.

The aim of this chapter is to examine the principles used to regulate a technology of war whose effects go beyond the spatio-temporal framework of the battlefield. The ethical debate, which constitutes the first layer, transcends the traditional question of armed violence to question the very nature of the damage inflicted. It brings into play the responsibility towards future generations, condemned to cohabit with a toxic heritage, and raises the emblematic figure of the innocent victim, embodied by the child exposed to the risk of congenital malformations (Lesna-2004 p. 74). At the same time, it raises an ethical question internal to the armed forces : can an institution legitimately jeopardize the health of its own members through the technologies it deploys (Lesna-2004, p. 81) ? Faced with these dilemmas, the « precautionary principle » emerges as a central analytical framework. He proposes a reversal of the burden of proof : in the event of a risk of serious and irreversible damage, the lack of scientific certainty should not delay the adoption of preventive measures (Lesna-2004, p. 55). Applied to the AU, it suggests that the responsibility no longer lies with the victims to prove the causal link, but with the users to demonstrate the safety of their weapons. This approach, although contested for its paralyzing potential, is defended as the only rational response to a paradox : it encourages us to « modify causes that we admit may not be the right ones, to prevent effects that we do not know how to decide whether they are harmful or not » (Lesna-2004, p. 56). This logic finds an echo in broader philosophical frameworks, notably the "ethics of fear" and the « principle of responsibility » developed by Hans Jonas.

Faced with humanity's disproportionate technical capacities, Jonas postulates that the anticipation of the worst-case scenario, even if unlikely, must become a guide for moral action (Leistner, 2023, p. 155). Fear, far from being paralyzing, becomes a heuristic, a cognitive tool that reveals the fragility of life and forces us to act cautiously and preventively (Leistner, 2023, p. 156).

From a legal point of view, weapons in the AU occupy a grey area. As they are not explicitly proscribed by any specific treaty, their legality is challenged in the light of the fundamental principles of international humanitarian law (IHL). The first principle to be tested is that of distinction, which requires that attacks differentiate between combatants and civilians. However, the DU aerosol released on impact disperses uncontrollably, contaminating the environment indiscriminately and potentially affecting civilians years after the conflict. The second is the principle of proportionality, which prohibits attacks whose collateral damage would be excessive in relation to the concrete and direct military advantage expected. Assessing this proportionality becomes almost impossible when the damage includes latent, unquantifiable health and environmental risks that span decades. Finally, the prohibition of weapons causing superfluous harm or unnecessary suffering is invoked. If the toxicity of DU is not its primary mode of action, its long-term radiological and chemical effects could be considered a form of additional suffering not justified by military necessity, placing DU in a category similar to that of incendiary weapons or anti-personnel mines, the effects of which strike « indiscriminately » (Lesna-2004, p. 53). The most direct attempt at regulation is found in Additional Protocol I of 1977 to the Geneva Conventions, which prohibits the use of methods or means of warfare « designed to cause or may be expected to cause widespread, long-lasting and serious damage to the natural environment » (Tranquillo-2023, p. 10). However, the effectiveness of this provision is severely limited. On the one hand, the cumulative threshold for the three conditions (« widespread, long-lasting and severe ») is extremely high and difficult to prove. On the other hand, several military powers have not ratified this protocol or have expressed reservations, which, combined with the general weakness of IHL sanction mechanisms, makes its application almost illusory (Tranquillo-2023, p. 11, Massa-2023, p. 20). In the face of these shortcomings, some legal scholars and activists propose bolder conceptual frameworks, such as the recognition of the crime of « ecocide, » which would aim to protect not only humans, but the « habitability of the world » as a whole, by recognizing the deep interdependencies between ecosystems and human life (Leistner, 2023, p. 162).

This legal vacuuming has catalyzed an intense mobilization of civil society and international organizations, which are working to politicize the issue and build a customary norm against the use of the AU. Building on the success of the international campaign to ban anti-personnel mines that culminated in the Ottawa Treaty, coalitions of NGOs are actively campaigning for an international moratorium on the production, transfer and use of weapons at the AU. Their strategy is to circumvent the deadlock in traditional disarmament forums by raising public awareness, documenting the consequences on the ground and exerting political pressure on state. This dynamic has led to several resolutions in the European Parliament and the United Nations General Assembly, calling for caution and greater transparency on the part of users (Lesna-2004, p. 26). These international reactions, although not binding, contribute to stigmatizing the weapon and strengthening the argument in favor of its regulation, illustrating how, in the absence of a formal ban, the battle is being played out as much on the ground of law as on that of political and moral legitimacy.

In order to methodically analyze these multidimensional issues, this chapter will be structured in three parts. We will first address the ethical debates that structure the controversy, exploring in depth the moral arguments and philosophical frameworks, such as the precautionary principle and the ethics of responsibility, that are mobilized to challenge the acceptability of these weapons. We will then examine the applicable international legal framework, critically analysing the principles of IHL and existing treaties in order to highlight their ambiguities, limitations and challenges related to their implementation.

Finally, a third section will be devoted to the study of international reactions and the role of NGOs, illustrating how political pressures, civil society campaigns and diplomatic initiatives seek to fill legal gaps and influence state practices towards a de facto, if not de jure, ban.

4.1 International legal framework

The status of depleted uranium (DU) weapons under international law is characterized by a notable normative indeterminacy. In the absence of an international treaty specifically prohibiting their production, stockpiling or use, their legality must be examined in the light of the principles and rules of International Humanitarian Law (IHL), the purpose of which is to limit the effects of armed conflicts by protecting non-combatants and restricting the means and methods of warfare (Tranquillo-2023, p. 10). The first concerns about the environmental damage caused by conflict emerged only late in the international legal corpus, mainly in reaction to the massive destruction observed during the Vietnam War (Massa-2023, p. 15). This development has led to the adoption of instruments which, while not explicitly aimed at the AU, provide the main framework for its evaluation. This situation places these armaments in a legal limbo, where their conformity with the law is fiercely contested, not on the basis of a direct prohibition, but through a complex process of interpretation, analogy and application of general principles.

The most relevant treaty instruments for this analysis are those dealing with the protection of the environment in times of armed conflict. Additional Protocol I of 1977 to the Geneva Conventions is central to this. Drawing on lessons learned from Vietnam, where the use of herbicides such as Agent Orange highlighted the vulnerability of the environment as a victim of war (Massa-2023, p. 17, Massa-2023, p. 17), this protocol introduced explicit environmental protections. Its Article 35(3) prohibits « the use of methods or means of warfare that are designed to cause, or may be expected to cause, widespread, long-lasting and serious damage to the natural environment » (Massa-2023, p. 17). This prohibition is reinforced by Article 55, which protects the natural environment from such damage and prohibits attacks against it as retaliation (Tranquillo-2023, p. 10). At the same time, the 1976 Convention on the Prohibition of the Use of Environmental Modification Techniques for Military or Any Other Hostile Purposes (ENMOD) prohibits the use of the environment as a weapon, for example by causing earthquakes or modifying the climate (Massa-2023, p. 21).

However, its scope, focused on the deliberate manipulation of the forces of nature, differs from that of Protocol I, creating potential ambiguities and distinct thresholds for application (Tranquillo-2023, p. 10, Leistner, 2023, p. 68).

However, the application of these provisions to weapons at the AU faces a major obstacle : the particularly high threshold for application and the vagueness of the widespread, long-lasting and serious cumulative criteria. As these terms are not defined in any treaty, they leave a wide margin of interpretation, which constitutes a significant legal loophole (Massa-2023, p. 75). - Extended : This criterion raises the question of scale. DU contamination is diffuse, concentrated around the points of impact but can be dispersed by winds in the form of aerosols. User states argue that this contamination does not cover large enough areas – often interpreted as several hundred square kilometres – to be considered « widespread ». - Sustainable : This is the criterion most easily met by the DU, whose radiological half-life is in billions of years. However, the interpretation of « sustainability » itself varies between treaties. For the ENMOD Convention, it can mean a few months or seasons, while for Protocol I, it is generally understood to span several decades (Tranquillo-2023, p. 10). The persistence of the AU far exceeds these two interpretations. - Serious : This criterion is the most subjective and the most contested. Should the severity be assessed in terms of immediate ecological disturbance or long-term health risks to human populations ?

In the absence of a definitive scientific consensus on the effects of chronic exposure to low doses of DU, it is difficult to prove harm of sufficient « severity » to satisfy this legal test.

This semantic ambiguity gives these protections a « relative effectiveness » (Massa-2023, p. 20) and is aggravated by practical obstacles. Key state, such as the United States or France, have not ratified Protocol I or have made reservations, thus limiting its binding scope (Massa-2023, p. 20). In addition, the general weakness of IHL enforcement mechanisms contributes to low state compliance (Tranquillo-2023, p. 11).

Faced with the obvious limitations of treaty law, the analysis must shift to the customary principles of IHL, which are binding on all States, regardless of their treaty ratifications. The first is the prohibition of causing « superfluous evil » or unnecessary suffering, codified in Article 35(2) of Protocol I (Massa-2023, p. 17). The International Court of Justice has defined these evils as « suffering greater than the inevitable evils involved in the achievement of legitimate military objectives » (Massa-2023, p. 71). In the case of the AU, the legitimate military advantage is its kinetic ability to pierce armor. Opponents argue that the resulting effects – long-term radiological and chemical contamination, kidney disease, potential carcinogenic hazards and alleged birth defects – constitute suffering that far exceeds this initial military objective. They add no military value to the neutralization of the target and inflict lasting harm on surviving combatants and civilian populations.

The second principle is that of distinction, a cornerstone of IHL, which requires that attacks be directed only against military objectives. While the use of munitions by the AU respects this principle a priori by targeting specific military targets (tanks, armoured vehicles), their effects *a posteriori* prove to be indiscriminate. Once the projectile is pulverized on impact, the uranium oxide aerosol is deposited on soil and water sources, entering the food chain and contaminating the environment without distinction between military and civilian areas. This toxic persistence has led to a recurrent analogy with anti-personnel mines, which also continue to "strike indiscriminately" long after the end of hostilities, constituting a deadly legacy that hinders the reconstruction and security of civilians (Lesna-2004, p. 53).

The third principle is that of proportionality, which prohibits attacks that can be expected to cause incidental loss of civilian life, injury to civilians or damage to civilian objects, which would be excessive in relation to the concrete and direct military advantage expected (Tranquillo-2023, p. 10). The application of this principle to the AU is particularly complex. The military advantage is clear and immediate : the destruction of an armored target. Incidental damage, however, is diffuse, uncertain,

and deferred in time. It includes the costs of remediation, long-term health risks for generations, and the loss of agricultural land. Weighing a quantifiable military advantage against qualitative and long-term environmental and human harm is a formidable challenge that makes the proportionality test difficult to apply conclusively.

Finally, the intense scientific controversy on health impacts, documented in the previous chapter, places the precautionary principle at the heart of the legal debate. Stemming from international environmental law, this principle is gaining relevance in IHL. It postulates that in the event of a risk of serious or irreversible damage, the lack of absolute scientific certainty should not be used as a pretext for postponing the adoption of effective measures (Lesna-2004, p. 56). Legal experts, NGOs and international institutions argue that, in the face of continuing uncertainties and potentially catastrophic risks, the use of the AU should be suspended under this principle. The argument is that it « recommends precisely not waiting for complete evidence to counteract potentially serious risks » (Lesna-2004, p. 55).

As positive law currently stands, weapons at the AU are not covered by existing classifications. They are not considered nuclear weapons, as they do not cause an explosion by fission or fusion and are not designed to kill by radiation (Massa-2023, p. 70). Nor are they chemical weapons within the meaning of the Chemical Weapons Convention, as depleted uranium is not listed as a prohibited toxic agent and its primary function is kinetic, not chemical (Massa-2023, p. 70). However, this normative vacuum has provoked significant political reactions. The UN General Assembly has adopted several non-binding resolutions that express "serious concerns" about the health and environmental effects of the AU and call on user states to be transparent about strike zones (Massa-2023, p. 80). Similarly, the European Parliament has called for a global ban (Massa-2023, p. 80).

Faced with the inadequacy of the current framework, several avenues *of lege ferenda* (the law as it should be) are being explored. The first is the development of a specific ban treaty, along the lines of the Ottawa Convention on anti-personnel mines or the Oslo Convention on cluster munitions (Massa-2023, p. 80). Such an approach would have the advantage of creating a clear and unambiguous standard, circumventing the difficulties of interpreting existing treaties and stigmatizing the weapon at the international level. A second, more ambitious proposal is that of a « Fifth Geneva Convention » devoted exclusively to the protection of the environment in times of war (Massa-2023, p. 81). This initiative, although not having found sufficient political support to date, responds to the observation that IHL remains fundamentally anthropocentric and struggles to protect the environment as such. Finally, a third way is that of criminalization through the recognition of the crime of « ecocide » in international criminal law (Massa-2023, p. 78). This concept, which aims to punish massive and deliberate destruction of the environment, could create individual criminal liability for decision-makers ordering the use of weapons with devastating environmental consequences. Such an approach would represent an ontological shift, protecting not only the human but also the « habitability of the world » as a whole (Leistner, 2023, p. 162). These debates, although forward-looking, reflect a growing awareness of the inadequacy of positive law in the face of the challenges posed by the toxic legacies of modern warfare.

4.2 Ethical debates

The use of depleted uranium (DU) weapons largely transcends purely military, technical or even health frameworks of analysis, to plunge into the heart of fundamental moral dilemmas. The latter question the responsibility of states, the nature of modern warfare and the legacy imposed on future generations. The impacts documented in the previous chapters – almost eternal environmental contamination and serious health risks, proven for some, strongly suspected for others – constitute the breeding ground on which a deep ethical controversy has developed. This puts in tension the logic of short-term tactical effectiveness and that of indiscriminate, irreversible and deferred consequences. These weapons, referred to by some critics as "such unconventional weapons," blur the traditional lines between conventional, chemical, and radiological weaponry, precisely because their effects are not limited

to immediate kinetic destruction, but create a slow and insidious form of violence. The ethical controversy feeds on this fundamental ambiguity, pitting an official discourse valuing surgical precision against the reality of long-lasting and uncontrollable pollution, hidden behind a « discursive shield » erected by users (Leistner, 2023, p. 71).

At the centre of this debate is the question of responsibility for a technology whose long-term effects cannot be fully known or controlled. This situation echoes the work of the philosopher Hans Jonas and his Principle of Responsibility.

Faced with the disproportionate technical capacity of humans, Jonas proposes a « heuristic of fear » not a paralyzing fear, but a mobilizing anxiety that must constrain action in the face of the unveiling of the fragility of the world (Leistner, 2023, p. 156). This anxiety, born of the « indeterminate » (Leistner, 2023, p. 154), becomes an essential ethical driving force.

DU is a textbook case for this ethic : the release of a pollutant whose half-life is measured in billions of years and whose health consequences are the subject of intense controversy embodies this situation where technology threatens the ontological conditions of life (Leistner, 2023, p. 155). Jonassian ethics thus argues for an « ethics of conservation, preservation and prevention, rather than an ethics of progress and improvement » (Leistner, 2023, p. 155), colliding head-on with the military rhetoric of permanent technological progress.

This philosophical approach finds a more concrete and political translation in the Precautionary Principle. This principle stipulates that the lack of full scientific certainty should not be used as a pretext for postponing the adoption of measures to prevent a risk of serious and irreversible harm to the environment or human health (Lesna-2004, p. 56). For many civil society actors, experts and NGOs, the health risks and long-term contamination associated with the AU fully justify the application of this principle. They argue that reasonable doubt about the long-term effects should lead to a total ban on the production, possession and use of this type of weaponry, arguing that it is imperative « not to wait for complete evidence to counteract potentially serious risks » (Lesna-2004, p. 55, Lesna-2004, p. 55). The question is no longer to prove the danger with absolute certainty, but to decide whether society can accept to take such a risk, the positive counterpart of which, a military advantage, is neither directly perceptible nor shared by the populations who suffer the long-term consequences (Lesna-2004, p. 82). However, the application of this principle is not without complexity, as underlined by the paradox noted by Philippe Mongin : precaution « encourages us to modify causes that we admit may not be the right ones, in order to prevent effects that we do not know how to decide whether they are harmful or not » (Lesna-2004, p. 56). This aporia is illustrated by the dilemma of the military authorities themselves : the preventive administration of pyridostigmine to soldiers during the Gulf War, suspected of being one of the causes of the eponymous syndrome, was justified as an application of the precautionary principle against a potential chemical attack (Lesna-2004, p. 57). The ethical question then becomes : where should the precaution be located when the preventive measure itself generates a risk of another nature ? In the case of the AU, proponents of its ban believe that the nature of the potential harm – serious pathologies, irreversible contamination – is of such magnitude that it settles the debate in favor of a total ban.

The ethical debate is broadening well beyond the immediate victims of the conflict. It involves an overwhelming transgenerational responsibility. By permanently contaminating soil and water, the use of DU imposes a health and ecological burden on future generations, calling into question the « habitability of the world » for those who had no part in war decisions (Leistner, 2023, p. 18, Leistner, 2023, p. 162). This toxic legacy is not an abstraction ; It results in a lasting change in living conditions, where cultivated soil, drinking water and breathing air become potential risk vectors for decades or even centuries. This perspective transforms the act of war into a potential « crime against habitability », a form of ecocide that affects the complex relationships between humans and the rest of the living world (Leistner, 2023, p. 162). This vision, which promotes an « ontology of connectivity » that recognizes the deep interdependencies between all living things and their environment (Leistner, 2023, p. 162), is radically opposed to the technoscientific approach of modern warfare that tends to reduce the

environment to a « vast neutral field to be exploited » or to « phusiomorphize » natural entities, depriving them of any intrinsic value (Leistner, 2023, p. 166). This dissemination of a toxic burden also raises an acute question of environmental justice.

The use of the AU is akin to a form of toxic colonialism, where the most powerful nations export their nuclear waste and the associated health risks to the territories and bodies of more vulnerable populations, often in states weakened by conflict. This dynamic, where the environmental burden is unevenly distributed, is a flagrant violation of the principles of fair treatment.

It is reminiscent of the injustice suffered by indigenous communities such as the Navajo, whose land and health were sacrificed for uranium mining, placing them in a position of « high-risk population » (Berthier-Foglar, 2011, p. 8). The use of the AU on international battlefields reproduces this injustice on a geopolitical scale, imposing a lasting burden on populations who have neither the means to protect themselves nor the means to decontaminate their environment.

Finally, the ethical dilemma takes on a poignant human face and is declined on two fronts. First, it calls into question the moral contract between the state and its own armed forces. A fundamental question arises : « can the military institution undermine the health security of its own members by using the technologies it implements or tests ? » (Lesna-2004, p. 81). The development of the « Gulf War Syndrome » and then the « Balkan Syndrome » has placed this issue at the centre of public debate. Thousands of veterans reported disabling chronic conditions, while military institutions were accused of downplaying risks, denying causal links, and in some cases concealing or destroying compromising medical documents (DU KOSOVO, 2024, p. 4). The state asks its soldiers to risk their lives in the face of the enemy, a risk inherent in the military function. However, the ethical line is crossed when these same soldiers are exposed, without fully informed consent, to insidious toxic threats whose effects manifest themselves years later, and their suffering is then met with institutional denial. Even more strikingly, the controversy is carried by the figure of the innocent victim par excellence : the child. As one analyst points out, in any conflict, the child « embodies the inconceivable innocent victim, and it is through his image that the horror of an event is authoritatively imposed » (Lesna-2004, p. 74). The recurrent testimonies and reports of an increase in congenital malformations in the heavily bombed areas – « in Iraq babies are born without heads », « Iraqi soldiers have given birth to babies with monstrous malformations » – mobilize a moral condemnation that transcends expert debates (Lesna-2004, p. 74). This symbolic imagery, which evokes a corrupt future and a « monstrous » and « unviable » humanity (Lesna-2004, p. 74), is in direct opposition to the rational and scientific discourse deployed by the defence institutions. It is a direct confrontation between two modes of argumentation : on the one hand, the « rational tool » of the managers of the polemic, and on the other, the « manipulation of symbolic images » which addresses the emotional to convince of the moral unacceptability of the situation (Lesna-2004, p. 44).

Ultimately, the ethical debates on depleted uranium highlight an irreconcilable conflict of values. On the one hand, there is a pragmatic and cynical logic, supported by the military-industrial complex (Barrillot-2001, p. 8), which values military efficiency and economic interests. In this perspective, AU weapons are presented as a « cheap » and strategically effective solution, offering moreover « a good outlet » for bulky nuclear waste stockpiles (Lesna-2004, p. 15, Lesna-2004, p. 64). On the other hand, an ethic of precaution and responsibility that places the preservation of life, the health of ecosystems and the future of future generations above any strategic imperative. This fundamental tension is often exacerbated by deliberate « misinformation » and a discursive strategy aimed at downplaying the nuclear nature of the material – the term « depleted » serving to « virtually obscure the fact that it is indeed uranium » (Barrillot-2001, p. 8) – and to promote the myth of a « clean war » (DU KOSOVO, 2024, p. 4) to reassure policymakers and public opinion. It is at the intersection of these contradictory moral imperatives that international law struggles to find its place, struggling to qualify and regulate a weapon whose effects unfold on a temporal and biological scale that defies its traditional categories.

4.3 International reactions and the role of NGOs

Faced with the legal vacuum and the profound ethical dilemmas raised by the use of depleted uranium (AU) weapons, the inaction and ambiguity of states have catalyzed the emergence of a transnational front of protest. This normative and political vacancy is not fortuitous ; it is the product of a deliberate strategy on the part of the military-industrial complex to declassify the AU from its membership in nuclear materials and to minimize its effects, including through scrupulously orchestrated disinformation for policymakers (Barrillot-2001, p. 8). By obscuring the radiological nature of the material behind the reassuring adjective of « impoverished », users have created a « discursive shield » that has long paralyzed any attempt at regulation. It is precisely this space, left vacant by state institutions reluctant to question military technology deemed efficient and economical, that has been taken over by a heterogeneous coalition of civil society actors. Supported by non-governmental organizations (NGOs), victims' associations and the media, this mobilization transformed an issue initially confined to the technical and ballistic spheres into a major socio-political issue, articulated around public health, environmental justice and the transparency of military action. This dynamic was all the more pronounced because it was part of a societal context of widespread loss of confidence in official information and in the ability of public authorities to manage health risks, a mistrust exacerbated in France by crises such as that of contaminated blood (Lesna-2004, p. 8).

The initial impetus and moral force for this mobilization emanate from its most direct and legitimate victims : the veterans. Following the 1991 Gulf War, then the conflicts in the Balkans, associations such as Avigolfe in France were formed to defend soldiers suffering from chronic and unexplained pathologies, described as « Gulf War syndrome ». Their fight was not only a request for compensation, but a quest for recognition of their suffering in the face of institutional denial. The status of the victim, and in particular of the loyal soldier who is potentially betrayed by his own hierarchy, has given a powerful symbolic and emotional charge to the public debate, shifting the issue from the technical terrain to that of the moral responsibility of the state towards its own forces (Lesna-2004, p. 75). Individual legal actions, such as that of veteran Hervé Desplat in France, have been widely publicized, embodying the struggle of thousands of others and forcing the opening of judicial investigations for « manslaughter and involuntary injuries » (Lesna-2004, p. 17, Lesna-2004, p. 59). These pioneering groups, whose expertise was based on lived experience, were quickly joined by a coalition of actors with converging motivations. Environmental organizations, alerted by long-term environmental contamination, anti-nuclear movements, seeing the AU as a form of insidious reintroduction of nuclear power on conventional battlefields, and human rights NGOs, concerned about the effects on civilian populations, have joined forces (Lesna-2004, p. 8). The strategic objective of this organized civil society has crystallized around a proven model : the international campaign that led to the Ottawa Treaty on anti-personnel mines. The ambition was to replicate this success by obtaining first a moratorium, then a complete ban on the production, trade and use of arms at the AU (Lesna-2004, p. 16). This approach aimed to circumvent the impasse of positive law by creating a new international norm through the political and moral stigmatization of the weapon, by reclassifying it as a weapon with indiscriminate effects, like the mines that continue to strike long after the end of hostilities.

The rise of this movement and its political impact are inseparable from the role of amplifier played by the media. The controversy, initially confined to American veterans' circles, found an explosive resonance on the European public scene during the media coverage of the « Balkan syndrome » between 2000 and 2001 (Lesna-2004, p. 22). This event acted as a catalyst, creating a domino effect where the media of each European country that participated in NATO operations (Italy, Portugal, Belgium, etc.) began to investigate the health of their own soldiers, creating a continental-wide crisis (Lesna-2004, p. 21). The press then played a crucial function, going far beyond the simple dissemination of information. It has actively constructed a counter-narrative, opposed to the official version of the general staff.

By giving a platform to dissident experts – physicists, doctors, or even former officers such as a Pentagon expert or a US Navy officer quoted in the press – the media legitimized the controversy and elevated it to the rank of a credible scientific debate in the eyes of the public (Lesna-2004, p. 15). Above all, they framed the debate around the question of institutional credibility. Accusatory headlines have flourished, claiming that « the highest military authorities lied for years » and that the Pentagon has accumulated negligence and « multiplied evasions » (Lesna-2004, p. 22). By frontally accusing NATO and its General Staff of having « withheld information » on the use and dangers of these munitions (Lesna-2004, p. 15), the press forged a powerful narrative of concealment and contempt, which found a deep echo in a public opinion already shaken by other health scandals and increasingly critical of official discourses on « clean war » (Dorsouma Bouchard, 2006, p. 11, DU KOSOVO, 2024, p. 3).

This combined pressure from civil society and the media has provoked a chain reaction, albeit often disorderly and fragmented, at the level of intergovernmental organizations, revealing fault lines within Western alliances themselves. Within the European Union, the controversy moved from the health field to the political field when, in early January 2001, the Italian Prime Minister, Giuliano Amato, publicly called on NATO to demand the truth, a step quickly followed by Belgium and Portugal (Lesna-2004, p. 21). This protest by Allied member countries marked a decisive stage, transforming the crisis into an internal political problem within NATO. Soon after, the European Parliament, acting as the political conscience of the continent, took a prominent stance by passing a resolution that called for a moratorium on the use of weapons in the AU. This act, although not binding, had considerable symbolic weight, as it aligned a major European institution with the main demand of NGOs and increased the pressure on the European Commission, whose President, Romano Prodi, had already mentioned a ban if the risks were proven (Lesna-2004, p. 26). Targeted and challenged from within, NATO found itself on the defensive, forced to multiply communiqués and set up committees of experts in an attempt to regain credibility seriously damaged by accusations of lack of transparency towards its own allies (Lesna-2004, p. 22).

At the same time, the United Nations system was universally called upon to assume the role of arbiter, both scientific and diplomatic, in a controversy in which each party availed itself of its own expertise (Lesna-2004, p. 11). Specialized agencies such as the United Nations Environment Programme (UNEP) and the World Health Organization (WHO) have been mandated to conduct post-conflict assessments in Kosovo, Bosnia and Herzegovina and later Iraq. Their reports, often methodologically prudent and scientifically nuanced, did not, however, put an end to the controversy ; on the contrary, they have become a new interpretive battlefield. On the one hand, proponents of the use of the AU, such as the Pentagon, have seized on the lack of definitive scientific evidence of a direct causal link with serious pathologies to conclude that it is relatively harmless (Parsons-2002, p. 3). On the other hand, NGOs and critical countries stressed that these same reports confirmed the long-term contamination of the environment, identified risks for certain population groups and recommended decontamination and monitoring measures, thus advocating for a strict application of the precautionary principle. This « battle of interpretations » demonstrated the extent to which science itself had become a political issue. On the diplomatic front, continued pressure from civil society and a growing number of non-user states culminated in the adoption, starting in 2007, of several resolutions by the UN General Assembly. Although non-binding, these resolutions, by expressing « serious concerns » about the health and environmental effects of the AU and calling on user states for greater transparency on strike zones, enshrined official recognition of the problem at the highest international level.

Ultimately, international reactions to the use of weapons in the AU exemplify the dynamics of a transnational advocacy network. A mobilization initiated « from below » carried by the moral legitimacy of the victims and the tenacity of a network of NGOs, then relayed and amplified by the media sphere, succeeded in cracking the « discursive shield » erected by the military institutions.

This campaign has forced intergovernmental organisations, from NATO to the UN to the European Union, to break their silence and take a position, revealing the irreducible tensions between the strategic and economic logics of user states and the ethical and precautionary imperatives defended by a growing part of the international community.

Even in the absence of a formal ban treaty, this mobilization has durably increased the political and reputational cost associated with the use of these weapons. It has thus put the issue of depleted uranium on the global political agenda, no longer as a mere technical issue, but as a powerful and disturbing symbol of the toxic legacies of modern warfare and the resulting responsibility for present and future generations.

Geopolitical and strategic analysis

Extending the analysis of the material impacts and normative controversies raised by depleted uranium (DU) weapons, this chapter addresses the geopolitical and strategic dimension that underlies the sustainability of their use. It has been established that the tactical effectiveness of these munitions is counterbalanced by an « invisible threat » and persistent scientific uncertainty, creating a legal grey area. Far from constituting a simple normative vacuum, this space of ambiguity is actively instrumentalized : it becomes the theater where the logics of power, economic interests and discursive strategies of states are deployed. This chapter therefore proposes to decipher the power dynamics that explain the maintenance of these weapons in contemporary arsenals, despite growing normative pressures. It is a question of going beyond the examination of the consequences to question the root causes of these « techno-political choices » (Lesna-2004, p. 3), by analysing how international political considerations and economic imperatives take precedence over health and environmental issues. The issue of the AU thus illustrates in an emblematic way the tension, inherent in modern wars, between the search for immediate military effectiveness and the management of a toxic legacy whose effects are spread over the long term, sustainably reconfiguring territories and the lives of civilian populations long after the cessation of hostilities. The debate on the AU highlights the difficulty for contemporary societies to accept a military risk whose strategic interest is difficult to perceive for the citizen, who derives no direct benefit from it and is therefore inclined to retain only the disadvantages (Lesna-2004, p. 82).

The persistence of the use of these weapons is explained by a complex intertwining of interests in which strategic advantages, economic imperatives and political calculations are mixed. On the military level, DU munitions meet a central requirement of post-Cold War asymmetric conflicts : the ability to destroy hardened targets, including enemy command centers buried in reinforced bunkers. The use of an DU warhead thus appears to be a tactically « clean » solution : it offers a penetrating power almost equivalent to a tactical nuclear strike, but without generating the political and media opprobrium associated with the image of the mushroom cloud (Parsons-2002, p. 5). In addition to this strategic efficiency, there is a decisive economic advantage. The « economic and strategic interests that would have presided over the production and use of depleted uranium weapons » (Lesna-2004, p. 63) are at the heart of the controversy. Indeed, the manufacture of these weapons makes it possible to dispose of massive stocks of depleted uranium, a waste product of the uranium enrichment industry, at low cost, thus transforming an expensive and cumbersome liability into a high-value military asset (Lesna-2004, p. 59). This dual rationality, both military and economic, constitutes a powerful incentive for states with a nuclear industry, especially since the development of such high-performance technological alternatives would imply extremely high substitution costs (Lesna-2004, p. 59).

In order to preserve these advantages in the face of growing contestation, user states have developed a discursive and political strategy based on opacity and systematic risk minimization. A central tactic has been to « downgrade depleted uranium from its belonging to the category of nuclear materials », a semantic manoeuvre in which the qualifier « depleted » opportunely obscures « the fact that it is indeed uranium » (Barrillot-2001, p. 8). This disinformation, scrupulously maintained for the benefit of political decision-makers and the public, aims to dissociate these weapons from the imaginary of nuclear war and its radioactivity (Lesna-2004, p. 63).

This culture of secrecy is reinforced by institutional mechanisms such as « Secret Defense », which has been « fully applied to depleted uranium weapons in France » (Lesna-2004, p. 16). This opacity was blatantly manifested by the lack of transparency of the military authorities, in particular the Pentagon and NATO, accused of having « lied for years » (Lesna-2004, p. 22) and of having deliberately concealed information on the use of these munitions and the associated risks, including from their own allies (Lesna-2004, p. 22, Lesna-2004, p. 15). The denial of risks can also be explained by the desire to avoid the potentially colossal financial consequences that would be involved in the recognition of a causal link : the costs of decontaminating the sites, but also compensation for veterans and the civilian populations affected (Lesna-2004, p. 59).

This fundamental dissonance between, on the one hand, an official discourse that is intended to be reassuring and, on the other hand, the health and environmental concerns expressed by veterans, local populations, NGOs and certain states, has generated strong geopolitical tensions. The use of these weapons has become a major point of friction, including within the Atlantic Alliance during the conflicts in the Balkans. The controversy, initially confined to activist circles, took a European turn when countries such as Italy, Belgium and Portugal publicly called NATO to account after the discovery of cases of leukaemia in their soldiers (Lesna-2004, p. 21). This crisis revealed a deep fracture of trust, as U.S. allies realized that they had not been informed of the risks to which their troops were exposed (Lesna-2004, p. 22). In addition, the controversy over the toxicity of the AU has been transformed into a political « argumentation tool », regularly reactivated on the occasion of new conflicts such as in Afghanistan or Iraq (2003) to challenge the legitimacy of Western military interventions (Lesna-2004, p. 70). Persistent scientific doubt thus becomes the fuel of a political contestation that cannot be definitively extinguished, illustrating a mutation in which citizens' trust is shifting from vertical institutions (governing) to horizontal groupings from civil society, which act as counter-powers (Lesna-2004, p. 83).

In order to methodically examine these complex dynamics, this chapter will be divided into four parts. It will first analyse geopolitical tensions and the reactions of affected countries, demonstrating how the use of the AU has generated diplomatic friction and exposed cracks within traditional military alliances. The reasons for the continued use of these weapons will then be studied in depth, deconstructing the official argument to highlight the decisive weight of economic and industrial motivations. A third section will focus on the recent speculations and systemic opacity that characterize this issue, illustrating the strategies of control of information and management of controversy by States. Finally, the chapter will deal specifically with the management of nuclear waste as a major explanatory factor, although often obscured, of the durability of this military technology, thus revealing the deep interweaving between the civil and military issues of nuclear power.

5.1 Reasons for continued use

Despite ethical, legal and health controversies, and pressure from civil society for a moratorium (Lesna-2004, p. 26), the majority of military powers persist in producing and using depleted uranium (DU) weapons. This continuity is not a matter of mere stubbornness, but of a convergence of strategic justifications, economic logics and institutional risk management strategies that together constitute a powerful obstacle to calls for prohibition. The analysis of these reasons reveals a clear hierarchy where immediate military effectiveness and economic interests take precedence over long-term health and environmental uncertainties. To understand this persistence, it is necessary to deconstruct the three interdependent pillars that support it: the primacy of tactical superiority, economic and industrial imperatives, and finally, the discursive and institutional strategy of managing controversy.

The first pillar, and the one most ostensibly invoked by the general staff, is the tactical and strategic superiority of the AU. In contemporary military doctrine, technological advantage is a decisive factor. The weapons at the AU embody this quest for material superiority. As detailed in Chapter 2.1, their unique physical properties, in particular extreme density combined with a self-sharpening phenomenon (adiabatic shear) during impact, give them a higher penetration capacity of the strongest armor than their main competitor, tungsten. This ballistic efficiency is not a marginal advantage ;

It is seen as a determining factor on modern battlefields, where the rapid and definitive neutralization of enemy armored vehicles is crucial. This position is explicitly assumed by the users. The French Ministry of Defence, for example, declared in 2001 that « any other technological choice would imply a significant loss of the operational capabilities of our forces » and that it therefore did not envisage putting an end to the production of this type of ammunition (Barrillot-2001, p. 56).

This operational logic, centred on immediate performance, is often presented as a pragmatic evidence, as illustrated by this rhetorical question formulated in the media during the conflict in Afghanistan : « If it is a formidable weapon, why would the military deprive themselves of it ? » (Lesna-2004, p. 61). This perspective tends to dismiss long-term considerations, which are considered secondary to the imperative of military victory and the protection of the forces involved.

Beyond its anti-tank role, the AU offers a solution to a major strategic dilemma that emerged at the end of the Cold War : the destruction of hardened targets, such as bunkers and underground command centers. The U.S. rearmament program launched under the Reagan administration was based on the belief that victory in future conflicts would depend on the ability to effectively neutralize such infrastructure (Parsons-2002, p. 5). While a tactical nuclear strike could achieve this goal, its use is politically and diplomatically unthinkable because of the stigma associated with it and its devastating consequences, described as « dreadful for public relations » (Parsons-2002, p. 5). Conventional weapons, on the other hand, often lack the necessary penetrating power. DU warheads are then presented as an ideal intermediate solution, capable of piercing meters of reinforced concrete and causing devastating incendiary effects inside the target, without crossing the nuclear threshold. They make it possible to achieve a maximum strategic objective with a minimum political cost, offering the appearance of a « clean » strike from the point of view of international public opinion (Parsons-2002, p. 5). This capability was seen as a decisive advantage in the conflicts in Iraq and the Balkans, and it continues to justify keeping these weapons in arsenals for future conflicts against adversaries with fortified infrastructure. Moreover, the trend observed towards the generalization of the AU, with the development by European consortia of medium-caliber (40 mm) ammunition, shows that this logic of superiority is no longer confined to heavy tank shells, but extends to the entire « arsenal of artillerymen », thus normalizing its use at different levels of combat (Barrillot-2001, p. 54).

The second pillar justifying the continued use of the AU is economic and industrial. It is based on a particularly advantageous symbiosis between two strategic sectors of the state : the nuclear industry and the military-industrial complex. Depleted uranium is, by definition, a by-product of the process of enriching uranium for nuclear reactors and atomic weapons. This process generates massive quantities of AU, whose global stocks amount to several hundred thousand tons. This material, far from being rare, is an abundant waste whose management (secure storage in the very long term) represents an environmental constraint and a considerable financial burden for States with a nuclear programme. The use of the AU in armaments brings about an almost alchemical transformation : it converts a costly responsibility into a military and economic asset. This logic is at the heart of the accusations made by critics, who argue that the manufacture of weapons at the AU makes it possible above all to « dispose of the enormous stockpile of nuclear waste » (Lesna-2004, p. 59). For the defence industry, DU is an almost free raw material, which makes the production of armour-piercing munitions particularly profitable. This economic advantage is a strong marketing argument, as evidenced by the slogan of a European consortium for its new ammunition : « Lethal, compact, cheap, available » (Barrillot-2001, p. 54).

This convergence of interests has created a powerful « technological lock-in ». The entire production chain, from research and development to mass production by companies such as Giat Industries (now Nexter and then KNDS France) in France or Starmet in the United States, is optimized for UA. The substitution of this material by alternatives with equivalent performance, such as tungsten alloys that are more efficient but also much rarer and more expensive, would be « extremely costly » (Lesna-2004, p. 59). Such a change would imply not only higher production costs, but also an overhaul of supply chains, training programs, and potentially employment doctrines. The inertia of this military-industrial system is therefore immense. War, as a driver of intense production and mobilization, durably shapes economic structures and resource supply networks deemed crucial (Leistner, 2023, p. 22, Leistner, 2023, p. 48).

In the case of the AU, this logic paradoxically applies to waste, but the result is the same : an economic and industrial ecosystem has been built around this technology, making any transition difficult and costly. This system also benefited from the interruption in the early 1990s — coinciding with the first mass use of the AU during the Gulf War — of negotiations at the UN to ban radiological weapons, a category in which AU weapons could have been classified.

This interruption allowed the military-industrial complex to massively adopt these weapons before a preventive ban could be put in place (Barrillot-2001, p. 107).

The third pillar, finally, is institutional and discursive. Faced with increasing pressure from public opinion, the media and NGOs, user states have developed a sophisticated argumentative strategy to manage controversy and justify the status quo. The central axis of this strategy is the notion of « unproven risk » (Lesna-2004, p. 54). In the absence of a scientific consensus establishing an irrefutable and universally accepted causal link between exposure to DU and the pathologies observed in veterans and civilians, the authorities believe that the conditions for a ban are not met. This epistemological posture is crucial : it requires a level of evidence that is almost impossible to achieve in complex and multifactorial post-conflict environments, where many other toxic agents are present. As a result, the burden of proof is reversed : it is no longer up to the user to demonstrate the harmlessness of his weapon, but to the victims to prove the causality of their ailments. This approach constitutes a de facto rejection of the precautionary principle, which would precisely require the adoption of preventive measures in the event of a risk of serious and irreversible damage, even in the absence of complete scientific certainty (Lesna-2004, p. 54).

This strategy of doubt is reinforced by an active policy of opacity and concealment. Recurring accusations (cf. the whistleblower Thierry Lamireau) point to a desire on the part of institutions, in particular NATO and the Pentagon, to « hide information » and minimize the scope of the risks (Lesna-2004, p. 15). The media reported that NATO staffs were aware of the risks but « accumulated negligence », « multiplied evasions and incomplete statements » (Lesna-2004, p. 22). The use of technical terms or code names such as « staballoy » (Barrillot-2001, p. 80) or the sudden disappearance of AU ammunition from French arms catalogues after increased media coverage bear witness to this desire to control information. This reluctance to be transparent is also fuelled by the fear of the financial and legal consequences of official recognition of the danger. The potential cost of systematic decontamination of the vast affected territories in Iraq and the Balkans, combined with the cost of compensating the thousands of veterans and civilians affected, would be astronomical (Lesna-2004, p. 59). Legal proceedings have also been initiated in several countries, such as in Italy, where a causal link has been recognized for certain soldiers, or in France with the opening of a judicial investigation for « manslaughter and involuntary injuries » (Lesna-2004, p. 59). Risk minimization thus becomes a strategy for limiting the legal and financial liability of the State.

This institutional stance is reinforced by the fact that political decision-makers rely mainly on the expertise provided by the military-industrial complex itself, which has every interest in downgrading the AU from its category of nuclear material and emphasizing its relative harmlessness in order to sustain its use (Barrillot-2001, p. 8). Dissenting voices within the military and scientific apparatus, such as that of Dr. Asaf Durakovic, a former colonel and nuclear medicine specialist whose research on Gulf veterans has been hampered, suggest a willingness to filter out discordant information (Lesna-2004, p. 45). Finally, this strategy of denial is sometimes part of broader political logics. It has been argued that during the Balkan conflict, any criticism of NATO's use of the AU was perceived as implicit support for the Serbian regime, which helped to stifle debate in the name of Western political unity. Conversely, the controversy over the AU is sometimes revived by NATO's detractors, which encourages the organisation to adopt a defensive and non-transparent posture, thus maintaining a cycle of mistrust.

In conclusion, the continued use of depleted uranium weapons cannot be attributed to a single cause. It is the product of a robust and interdependent system where the tactical rationality of military superiority, the powerful economic incentives of an integrated military-nuclear pipeline, and a sophisticated institutional strategy of risk management and information control converge and reinforce each other. This triple logic creates a formidable barrier to change, systematically marginalizing health, environmental and ethical concerns in favor of short-term imperatives considered superior by user states.

5.2 Recent Speculations and Opacity

The geopolitical analysis of depleted uranium (DU) is inseparable from one of its structural and permanent characteristics : opacity. Far from being a mere consequence of the secrecy inherent in military operations, the lack of transparency on the production, stockpiling and use of these weapons is akin to a deliberate and multidimensional strategy. This culture of secrecy, maintained by military authorities, political spheres and industrial actors, has not only hindered the scientific and historical understanding of past conflicts ; it constitutes the fertile ground on which speculation thrives with each new armed intervention. Opacity is therefore not a simple obstacle to analysis, it is an object of analysis in itself. It functions as an active policy tool, aimed at managing the perception of risks, perpetuating scientific and legal uncertainty, and preventing any form of accountability. This phenomenon is all the more salient in that it collides head-on with the imperative of transparency that permeates contemporary democratic societies, where citizens demand that institutions have the right to scrutinize the risks they generate (Lesna-2004, p. 49).

The mechanisms of this opacity are complex and are articulated at different levels. At the heart of this strategy is an institutional culture of secrecy, which is particularly prevalent in the field of defence. In France, the invocation of « Secret Defense » is « totally applied to depleted uranium weapons, » a practice that is part of a broader « religion of secrecy » within military research, where innovation is rarely subject to control by experts outside the defense (Barrillot-2001, p. 94). This informational endogamy creates a closed circuit where information is produced, validated and controlled by the same actors, preventing any form of independent counter-expertise. Information is thus « scrupulously misguided », particularly for the benefit of political decision-makers who, for questions deemed « technical », depend almost exclusively on experts from the military-industrial complex (Barrillot-2001, p. 8). Semantic manipulation is one of the preferred tools of this strategy. The use of the term « impoverished », for example, came « opportunely to the rescue, almost obscuring the fact that it is indeed uranium » (Barrillot-2001, p. 8). In doing so, it operates a form of linguistic decontamination, minimizing the perception of risk and downgrading matter from its nuclear category in the collective imagination.

The practice is so entrenched that it has led to ostracization of experts such as Dr. Asaf Durakovic, a former colonel and nuclear medicine specialist in the U.S. Army. When he suspected a link between DU and the pathologies of Gulf veterans, his research was actively sabotaged—from supposedly « lost » urine samples, to cease work, to his dismissal for « disobedience »—illustrating how the system not only withholds information, but actively silences internal dissenting voices (Lesna-2004, p. 45).

This institutional opacity is coupled with an equally calculated industrial discretion. Faced with the increasing media coverage of controversies, arms producers have adopted a strategy of active concealment. The use of more innocuous code names, such as « staballoy » — a possible contraction of « stabilized alloy » or, more cynically, « stable killing alloy » (Barrillot, 2001, p. 80) — makes it possible to hide the real nature of the material from the uninitiated. In addition, companies do not hesitate to erase all traces of this ammunition from their public documents when the media pressure becomes too strong. The case of the catalogues of the GICAT (Groupement des industries françaises de défense et de sécurité terrestres et aéroterrestres) is emblematic in this respect : while the 1998 edition openly presented models of munitions to the AU, these had entirely disappeared from the 2000 edition, demonstrating that « the media coverage of depleted uranium leads to opacity » (Barrillot-2001, p. 41). Political and military communication espouses this logic of avoidance and denial. The official discourse is characterized by « evasions and incomplete statements » (Lesna-2004, p. 22). This stance caused a breach of trust with the media, which quickly adopted a vocabulary reflecting a perception of duplicity on the part of the authorities : « lies », « semi-truths », « concealments », or even « organised blackouts » (Lesna, 2004, p. 50). The reply of the French Minister of Defence, Alain Richard, asserting confidently at the height of the Balkan crisis that « in three days we will talk about it more », was seen as a symbol of institutional contempt and was strongly criticised.

The history of this controversy is thus punctuated by late and partial admissions, in which institutions such as NATO were only « forced to admit » the use of the AU in the Balkans following « revelations in the press » (Lesna-2004, p. 15).

The underlying motivations behind this strategy of concealment are legal, economic and political. The analysis of media critics suggests that this silence is a response to a « triple causality ». Firstly, it would be a question of avoiding the recognition of « unacceptable errors », i.e. of admitting that the potential dangerousness of the product was known without adequate protection measures having been put in place for the military and the civilian population. Admitting such negligence would expose states to massive legal proceedings. In France, the opening of a judicial investigation for « manslaughter and unintentional injuries » following complaints from veterans (Lesna-2004, p. 59) materializes this legal risk, transforming the health debate into a criminal issue for the State.

Secondly, this opacity protects against « unmentionable economic and political issues ». The interests at stake are considerable. Depleted uranium represents a very low-cost solution for disposing of the huge stocks of waste from the civil and military nuclear industry, transforming an expensive liability into a strategic asset (Lesna-2004, p. 59). Its military effectiveness, especially against modern armor, is considered so high that any alternative would be extremely expensive to develop to achieve equivalent performance. CTA International's advertising slogan for a new 40 mm munition at the AU, « Lethal, compact, cheap, available » (Barrillot-2001, p. 54), perfectly sums up this pragmatic logic that prevails internally, far from reassuring public speeches. Finally, the potential cost of decontaminating the affected sites and compensating the victims, whether military or civilian, would be astronomical and would set a precedent with serious consequences (Lesna-2004, p. 59).

Third, silence can serve short-term international policy objectives. The media and political blackout observed during the Balkan war has been analysed by some observers as a desire to preserve NATO's unity and the legitimacy of its intervention. In a context of « single thinking » and « demonization of Serbs, » any information that might complicate the narrative of a just war was perceived as inappropriate. Thus, « denouncing the use of depleted uranium munitions (...) meant « supporting the Serbs » and risked « influencing » public opinion » against the intervention. The silence was therefore not only a cover-up of technical facts, but a political act aimed at maintaining the cohesion of a coalition and the support of public opinion.

The most direct and lasting consequence of this culture of secrecy is to fuel a recurrent and self-perpetuating cycle of speculation. The systematic refusal to provide clear, precise and verifiable data on past practices has durably eroded the credibility of the official word. Every denial of more recent conflicts is now interpreted through the lens of previous cover-ups. As a result, persistent allegations about the deployment of these weapons in Afghanistan, again in Iraq in 2003, Gaza (2008 to 2025) or Libya (2011) find fertile ground in this widespread mistrust. Doubt remains structurally, and the issue of the toxicity of the AU is « reactivated, but in a punctual and superficial way, when an international conflict is established ». The announcement by the United Kingdom, the United States and then many NATO countries such as France, of the supply of ammunition to the AU to Ukraine in 2023 immediately revived the global debate, perfectly illustrating this mechanism. In this context, the absence of evidence is no longer interpreted as proof of absence, but as an indication of a successful concealment. The burden of proof is de facto reversed : user states are presumed guilty of hiding the truth, and only radical transparency, incompatible with the current military culture, could begin to restore trust.

In conclusion, opacity and concealment are indeed the nerve centre of the geopolitical problem of depleted uranium. They are not a communication defect, but a risk governance strategy, a defense mechanism protecting considerable legal, financial and strategic interests. By creating and maintaining lasting uncertainty, this strategy not only prevents an exhaustive scientific and health assessment of the consequences of these weapons, but it also paralyses any significant progress towards binding international regulation. The lack of information, actively produced and maintained, thus becomes the main instrument for the perpetuation of their use and the impunity that surrounds it.

The controversy over depleted uranium is therefore, fundamentally, a struggle for access to information and for the right of people to know the exact nature of the wars waged in their name.

5.3 Geopolitical tensions and reactions of affected countries

The shock wave caused by the use of depleted uranium (DU) weapons goes far beyond the perimeter of the battlefield and the temporality of hostilities. By leaving a lasting toxic footprint, the health and environmental implications of which were detailed in the previous chapter, these munitions transform territories, bodies and collective memories into political issues of the first order. They thus become the catalyst for complex and persistent geopolitical tensions, reconfiguring relations between states long after the fighting has ceased. The very notion of « affected country » is multidimensional : it is not limited to nations whose soil has been directly contaminated, but extends to military allies kept in the dark about the risks incurred by their own troops, as well as to the user countries themselves, which find themselves confronted with virulent internal contestation undermining the legitimacy of their action. The analysis of these chain reactions, which unfold at distinct but interconnected scales—intra-alliance, international, and domestic—reveals how a perceived short-term tactical advantage can turn into a major diplomatic, political, and strategic liability in the long run.

Depleted uranium, by its very nature, acts as a revealer of the fault lines, power asymmetries and contradictions that structure contemporary international relations.

A first fault line, and undoubtedly the most unexpected for its promoters, has emerged within the Atlantic Alliance itself, an organisation based on mutual trust and information sharing. The « Balkan syndrome » controversy, which erupted publicly in late 2000, acted as a powerful detonator, revealing a deep crisis of confidence between the United States, the main user of these weapons, and several of its European allies. The scheme was not new ; it echoed the « Gulf War syndrome » that had already sown doubt a decade earlier, but the Balkan crisis brought the controversy to the political heart of Europe. While the Italian, then Spanish, Portuguese and Belgian media began to relay with increasing intensity the cases of leukaemia and other cancers among soldiers who had served as peacekeepers in Kosovo and Bosnia (Lesna-2004, p. 21), the controversy quickly left the health field to invade the political sphere. The tipping point came in early January 2001, when the then Italian Prime Minister, Giuliano Amato, closely followed by the Belgian and Portuguese governments, publicly called on NATO to demand that « the truth be told » about the use and real risks of depleted uranium (Lesna-2004, p. 21).

This frontal questioning, coming from the founding members of the Alliance, highlighted a structural flaw : NATO, and particularly the Pentagon, had not clearly informed its partners in advance of the exact nature of the munitions used, nor of the basic precautions to be taken for the thousands of European soldiers deployed in potentially contaminated areas (Lesna-2004, p. 22). This withholding of information was perceived not as simple negligence, but as the manifestation of a « accomplished fact » policy led by Washington, accused of treating its allies as subordinates rather than as equal partners (Lesna-2004, p. 60). The European press has seized on this narrative, denouncing an organisation that has « lied for years » and a Pentagon that has « accumulated negligence » and « multiplied evasions » (Lesna-2004, p. 22). The crisis thus transcended the simple criticism of failing health management to become an open challenge to the hegemonic structure of the Alliance where the imperatives of American military doctrine — in particular the search for a « zero death » war for its own forces through overwhelming air supremacy (Lesna-2004, p. 60) — took precedence over the security and informational sovereignty of its allies. The controversy has revealed that solidarity within NATO has its limits, crumbling in the face of the imperatives of a dominant power reluctant to share information on military technology deemed strategic but politically sensitive.

For the nations directly targeted by the strikes, such as Iraq, Serbia, Bosnia and Herzegovina or Kosovo, the reactions revolve around a very different dynamic, that of domination suffered and lasting post-conflict resentment. In these contexts, environmental contamination is not understood as a simple « collateral damage », but as the tangible and permanent stigma of external aggression and a violation of their sovereignty.

War, by potentially irreversibly modifying the local ecosystem, also reconfigures political imaginaries. It attacks what can be perceived as the « natural cradle » of the nation, desecrating the territory and establishing a lasting mistrust of populations towards their own environment (Leistner, 2023, p. 37).

In the case of Iraq, the massive use of the AU during the 1991 and 2003 wars is part of the broader American desire to « annihilate » a recalcitrant regional actor and to « establish its long-term strategic dominance » over a region crucial to its oil resources (DU KOSOVO, 2024, p. 2). Long-term radioactive and chemical pollution then becomes the material and symbolic legacy of this domination, a form of war continued by other means.

This situation is exacerbated by a radical informational asymmetry : coalition forces have long refused to communicate the precise coordinates of strike zones, leaving local authorities and international organizations helpless in the face of an invisible threat, impossible to map and therefore extremely costly and complex to manage. This withholding of information is a political act in itself, which prolongs the state of vulnerability of the targeted country and hinders any prospect of reconstruction and decontamination. This dynamic is reminiscent of that of the neocolonial exploitation of resources, where strategic or economic benefits are externalized and privatized by intervening powers, while environmental, health, and social costs are internalized and borne indefinitely by local populations, leaving them impoverished and trapped in a toxic legacy (ETOGA, p. 7). The AU thus became a powerful political symbol, crystallizing the grievances linked to the military intervention and feeding a discourse of victimization that durably complicated any attempt to normalize diplomatic relations.

Finally, a third layer of tensions, just as destabilizing, is manifesting itself within the user countries themselves. The military front abroad is coupled with a domestic political front that weakens their international posture and national cohesion. The concept of « friendly fire », traditionally used to describe accidental friendly fire, has acquired a new, deeper and more insidious symbolic dimension. The weapon no longer only mistakenly harms an ally on the battlefield; it turns against its own side in a delayed and « surreptitious » way, affecting the health of its own soldiers years after their exposure (Lesna-2004, p. 81). This awareness, driven by veterans' associations such as Avigolfe in France (Barrillot-2001, p. 10), has fuelled a growing mistrust of citizens towards their military and political institutions. The latter are accused of sacrificing the health of their troops on the altar of tactical efficiency and for unspeakable economic interests, such as the cheap solution offered by the AU to dispose of the enormous stocks of waste from the nuclear industry (Lesna-2004, p. 59).

This breach of the contract of trust between the state and its citizen-soldiers has materialized in an intense legal and political battle. In France as in Italy, the opening of judicial investigations for « manslaughter and involuntary injuries » following complaints filed by the military (Lesna-2004, p. 59) testifies to this judicialization of politics.

The state finds itself in an untenable position : to officially recognize the dangerousness of the AU would be to admit its responsibility, paving the way for massive claims for compensation and a questioning of military technology considered to be highly efficient and economical. This dilemma explains the authorities' strategy of denial and « incomplete statements » (Lesna-2004, p. 22), a stance that only amplifies mistrust. More broadly, this controversy is part of a societal change in which vertical trust in governing institutions is eroded in favor of horizontal ties embodied by the countervailing powers of civil society (Lesna-2004, p. 83). The army can no longer operate in an isolated sphere ; its technological and strategic choices are now subject to public scrutiny and to the imperatives of justification that go beyond the sole framework of military effectiveness (Lesna-2004, p. 82).

In conclusion, depleted uranium functions as a powerful analyzer of the power dynamics and latent tensions of the post-Cold War international system. Its residual toxicity, both physical and political, generates fractures on multiple scales. At the intra-alliance level, it cracks solidarity and reveals power asymmetries within NATO. At the international level, it feeds lasting resentment in the targeted countries, which perceive its presence on their soil as a continuation of the aggression by environmental and health means, complicating any true reconciliation. Finally, at the national level, it sows division at the very heart of user democracies, pitting the state against its own veterans and eroding citizens' trust.

Far from being a simple ballistic component, the AU has become a total geopolitical object, whose management of the toxic legacy constitutes a major diplomatic and societal issue.

It demonstrates with particular acuity that the consequences of a war never end with the last shot but are inscribed in the earth and in the bodies for generations.

5.4 Nuclear Waste Management

The geopolitical analysis of depleted uranium (DU) armament would be incomplete without examining its fundamental link with the problem, both technical and political, of nuclear waste management. As established in Chapter 2.2, DU is a direct by-product of the uranium enrichment process, generated in massive quantities by the civilian and military nuclear industries. Global stocks, estimated at more than 1.5 million tonnes, continue to grow, posing a considerable logistical and financial challenge. This material has a paradoxical and highly problematic status : it is both radioactive and chemotoxic waste, whose secure storage in the very long term is technically complex and financially expensive, and at the same time a strategic resource with valued ballistic properties. The management of these colossal stocks is therefore a triple political, economic and regulatory challenge (Lesna-2004, p. 65), and appears to be a determining factor, although often unacknowledged, in the decision of some States to integrate it into their arsenals. This dynamic of « valorization » of waste constitutes an « exemplary » case study of the symbioses between the military-industrial complex and the nuclear industry.

At the heart of the controversies that have surrounded the AU for decades is the argument, made by many analysts, journalists and non-governmental organizations, that its military valorization represents a solution of formidable pragmatic efficiency to manage the surpluses of the nuclear industry. This critical perspective argues that the use of DU in munitions makes it possible to « solve the unavoidable problem of storage » of waste from the nuclear industry (Lesna-2004, p. 16). The transformation of a costly liability into a military asset is thus perceived as one of the « unspeakable economic and political issues » that underlie the opacity and denial of the authorities in the face of proven health and environmental risks (Lesna-2004, p. 50). According to this logic, « the radioactive and highly toxic nature of these weapons was then, and since, intentionally neglected » (Lesna-2004, p. 16) in favor of economic and strategic rationality. This approach offers good value for money (Lesna-2004, p. 64) by avoiding a cascade of exorbitant costs. The construction and maintenance of long-term storage facilities, environmental monitoring over centuries, insurance premiums to cover accident risks, and potentially, compensation for populations and veterans. For its detractors, the use of AU in armaments is therefore an « unacceptable » way of getting rid of long-lived radioactive waste (Lesna-2004, p. 9) by outsourcing the problem to foreign theatres of operations.

The appeal of this alternative solution is fully illuminated in the light of the technical, financial and societal obstacles inherent in conventional nuclear waste management. The nuclear fuel cycle, from mining to the dismantling of power plants and armaments, generates colossal volumes of residues of various kinds. For example, Canada, a historical producer of uranium, manages more than 200 million tonnes of radioactive mine tailings, which still contain 80% of the original radioactivity of the ore and very long-lived radionuclides such as thorium-230 (75,000 years), making their secure containment necessary for millennia (ETOGA, p. 8). In France, the waste from the military nuclear program alone represents a volume of 130,000 m³, to which will be added the reactor cores of the dismantled nuclear submarines, posing a management challenge that will extend over several generations (Quilès, Collin, Drain, 2018, p. 68).

The management of these materials is governed by increasingly strict national and international regulations, which require sophisticated technical solutions. Organizations such as the French Nuclear Safety Authority (ASN) in France oversee research programs aimed at ensuring long-term safety, in particular through advanced conditioning, long-term storage and, for the most hazardous waste, deep geological disposal (Fraternité, Liberté Égalité-2021, p. 2). These solutions involve decades of research, tens of billions of euros in investments, and institutional stability on timescales that defy imagination. However, these projects systematically meet with strong public opposition. Surveys show that a large majority of the population would refuse to live near a chemical or radioactive waste storage site (Lesna-2004, p. 85).

This opposition is not only the result of the "NIMBY" syndrome (« Not In My Backyard »); it is rooted in a deep mistrust of institutions. Only 12% of those questioned believe that the authorities are telling the truth about these issues (Lesna-2004, p. 84). This fear is exacerbated by well-identified factors : the risk is perceived as imposed, artificial, irreversible, poorly understood by science and particularly threatening for future generations (Lesna-2004, p. 86).

In this socio-political context, the possibility of « solving » part of the nuclear waste problem by silently exporting it via munitions becomes a strategically tempting option for decision-makers.

The opacity and regulatory arrangements surrounding the effective management of DU stockpiles are particularly well illustrated by several cases in France, which testify to the tensions between the imperatives of environmental protection and the interests of national defence. The controversy over the Bessines-sur-Gartempe site (Haute-Vienne / France) is emblematic. In 1995, COGEMA (which became AREVA, then ORANO) obtained authorization to store nearly 200,000 tons of depleted uranium oxide (U_3O_8). Crucially, the facility has been classified as a simple Classified Facility for the Protection of the Environment (ICPE), and not as a Basic Nuclear Facility (BNI). This regulatory choice, justified by activity calculations that have been the subject of strong criticism, made it possible to evade the obligation to carry out an in-depth safety study under the aegis of the nuclear safety authority, as would have been required by the status of INB (LE SCANDALE DU STOCKAGE D'OXIDE-2023, p. 1). This manœuvre led the public inquiry commission, an extremely rare occurrence, to issue a unanimously unfavourable opinion on the project, an opinion that was nevertheless ignored by the prefectural authorities (THE OXIDE STORAGE SCANDAL-2023, p. 1). Critics have also pointed to the inadequacy of the radiological impact assessment method, designed for mine tailings and not concentrated depleted uranium oxide, whose isotopic composition may include traces of U-236, an indicator of the provenance of reprocessed spent fuel (THE OXIDE STORAGE SCANDAL-2023, p. 5).

Another striking example is that of the military test site in Bourges, where DU waste from test firings is stored. Its administrative regime has undergone successive and significant changes, illustrating a desire to remove it from public scrutiny. Initially classified as a de facto INB in an ANDRA inventory in 1994, it was then reclassified as a « Nuclear Facility of Interest to Defence » (INID), a previously unknown name, before becoming an ICPE under the Ministry of Defence. This final status, governed by a specific decree, exempts him from the obligations of ordinary regulations, in particular with regard to public declarations and civil environmental inspections (Barrillot-2001, p. 66). These examples demonstrate a clear tendency to use defense secrecy and regulatory tricks to minimize the constraints and public exposure associated with the management of military nuclear materials.

In short, the management of nuclear waste largely transcends the simple technical dimension to become a powerful lever in the geopolitical and strategic calculation of nuclear states. The transformation of an environmental, financial, and politically explosive liability into a high-performance, cost-effective military asset constitutes a major structural incentive for the production and continued use of depleted uranium weapons. This strategy is a form of multi-layered risk and cost externalization. It transfers the environmental and health burden of managing radioactive waste to foreign territories, often weakened by conflicts, which have neither the technical means nor the financial resources to assess the contamination and even less to treat it. This dispersion constitutes definitive and irreversible pollution, transforming battlefields into uncontained nuclear waste sites (Leistner, 2023, p. 93). This issue is part of a broader framework, that of the legacy of military nuclear power, as already underlined in 1997 by the deputy Christian Bataille when he warned of the need for those responsible to explain the management of the waste resulting from the French military nuclear program (Quilès, Collin, Drain, 2018, p. 68). Thus, depleted uranium is not just a weapon ; It is the symptom of a system which, faced with the management of a toxic legacy on quasi-geological time scales, finds in war a short-term escape from its long-term responsibilities.

Case Studies

Following the analysis of the geopolitical, economic and discursive drivers that perpetuate the use of depleted uranium (DU) weapons, this chapter transposes the study to the empirical field of conflicts. While the previous sections have deconstructed the technical properties, potential impacts, and normative controversies associated with these weapons, their full understanding requires an examination of their use in real-world situations. The theoretical analysis of the « invisible threat » and the « legal grey zone » cannot grasp the full complexity of the phenomenon without being confronted with the realities of the battlefields, where technological choices materialize into toxic legacies. It is through the study of concrete cases that it becomes possible to assess the adequacy, or inadequacy, between theoretical legal frameworks and the practical dynamics of armed conflict (Massa-2023, p. 8). This approach aims not only to illustrate the previous arguments but also to test them by observing how the logics of power, economic imperatives and concealment strategies identified in Chapter 5 unfold and interact in specific operational contexts. Each conflict studied thus acts as a laboratory revealing a distinct facet of the problem : surprise and initial denial, the political crisis within a military alliance, the trivialization of use despite controversy, and finally, the reactivation of the issue in the most recent geopolitical configurations.

The analysis will focus on four emblematic theatres of operations, the selection of which makes it possible to trace the historical and political evolution of the controversy. The Gulf War (1991) was the founding conflict. For the first time, DU munitions were used on a large scale, marking a technological turning point in armor-piercing warfare. This conflict crystallized the controversy of Gulf syndrome, a set of chronic and unexplained pathologies reported by tens of thousands of American and British veterans (Mathieu Matieu, 2001, p. 1). Depleted uranium was quickly suspected of being one of the potential causes, along with exposure to fumes from burning oil wells or chemical agents (Lesna-2004, p. 36). This inaugural episode served above all as a textbook case in terms of crisis communication and military disinformation. Faced with growing concerns, the authorities, in particular the Pentagon, have implemented a rhetoric of « clean war » or « precision surgery », concealing the health consequences and the ecological disaster caused by the conflict (DU KOSOVO, 2024, p. 3, Lesna-2004, p. 51). Information manipulation, initial denial and systematic risk minimization have become markers of user states' handling of this issue (DU KOSOVO, 2024, p. 4), setting a precedent that will have a lasting influence on public perception and future controversies.

The Balkan conflict (1994-1999) then transposed the controversy to the European level, moving it from an issue perceived as essentially Anglo-Saxon to a continental crisis. The use of DU munitions by US A-10 aircraft in Bosnia (1994-1995) and then in Kosovo (1999) sparked serious concern when cases of leukaemia and other cancers were reported in Italian, Belgian, Portuguese and French military personnel who served in the region (Lesna-2004, p. 21). The media coverage of the « Balkan syndrome », a term coined in direct analogy with that of the Gulf (Lesna-2004, p. 25), has transformed a scientific controversy into a major political crisis.

This episode revealed deep fissures within NATO, with several European governments accusing the organization and the Pentagon of deliberately withholding crucial information about the risks faced by their own troops (Barrillot-2001, p. 73). NATO's belated admissions, constrained by press revelations, fuelled suspicions of a lack of systemic transparency (Lesna-2004, p. 15) and demonstrated that the AU had become a political « argumentative tool » capable of weakening military alliances.

The war in Iraq (2003), the third case study, demonstrates the persistence of the use of these weapons and a form of trivialization, despite a decade of intense debates and increased international awareness. The use of the AU during this conflict confirms the importance of the strategic and economic logics, analysed above, on normative and health concerns. A major difference, however, lies in the context of use : unlike the desert battles of 1991, DU munitions were used on a massive scale in urban areas, multiplying the risks of contamination for civilian populations and posing unprecedented decontamination challenges. This development has revived fears about the long-term consequences, including the increase in birth defects and cancers among the Iraqi population, allegations supported by numerous testimonies but difficult to prove scientifically due to the country's instability and the destruction of its health infrastructure (Lesna-2004, p. 74). This case is a prime example of the systemic difficulty in conducting rigorous environmental and epidemiological assessments in a chaotic post-conflict context (Leistner, 2023, p. 56).

Finally, the examination of the information relating to Ukraine (under the multiple communications of the whistleblower Thierry Lamireau) anchors the issue in the most contemporary geopolitical context. The announcement by the United Kingdom, and then by the United States and many other NATO countries such as France, of the supply of ammunition to the DU to the Ukrainian army to counter Russian armor instantly reactivated the global controversy. This situation makes it possible to analyse in real time how the AU is instrumentalised in the information war, with Russia accusing the West of introducing weapons with a « nuclear component » and threatening an escalation. The irony is that Russia also uses depleted uranium weapons ! This case highlights the eminently political and symbolic dimension of these weapons, far beyond their tactical effectiveness alone. It also raises, in a preventive manner, the crucial question of the environmental legacy of a high-intensity conflict in Europe, where the AU is added to a long list of war pollutants that will leave a lasting imprint on ecosystems and the health of populations (Leistner, 2023, p. 8) and there, at the very least, of the whole of Europe. The radioactive contamination of these weapons can also be seen on a daily basis by consulting the European Commission's guidelines.

The comparative analysis of these conflicts will highlight recurrent patterns, while highlighting their specificities. It will trace the evolution of state communication strategies, moving from pure denial to calculated risk minimization, and will show how civil society, through veterans' associations such as Avigolfe (Lesna-2004, p. 19), has organized itself to challenge the official discourse and demand accountability. By tracing the chronology and particularities of each context, this chapter aims to demonstrate how a military technological choice has gradually evolved into a societal, ethical and political issue of global scope, the implications of which continue to unfold.

6.1 Gulf War (1991)

The 1991 Gulf War, led by an international coalition under the aegis of the United Nations to liberate Kuwait, represented the first massive and documented use of depleted uranium (DU) weapons. This conflict set a major precedent, not only tactically, but more importantly by giving rise to the enduring controversy surrounding this technology. Presented to public opinion as a post-modern war, defined by technological mastery, « surgical strikes » and the ambition of a « zero death » conflict (Lesna-2004, p. 48), Operation *Desert Storm* left in its wake a toxic legacy that transformed environmental protection in the event of armed conflict into a major international concern (Dorsouma Bouchard, 2006, p. 16, Massa-2023, p. 9). This conflict was indeed a veritable « war of communication » (Lesna-2004, p. 51), in which information, tightly controlled by the military authorities via a system of pools, served to project the image of a clean and controlled intervention.

However, this official narrative has been profoundly shaken by the gradual emergence of long-term health and environmental consequences, revealing a yawning gap between the strategic discourse and the reality experienced by combatants and civilian populations. This case study is therefore foundational, as it crystallizes the transition from a military advantage into a public health crisis and a complex political issue, the ramifications of which continue to unfold decades later.

Operationally, the conflict functioned as an « experimental battl » for this new generation of munitions. Faced with the numerical superiority of the Iraqi armored divisions, a legacy of Soviet doctrine, the coalition forces, mainly American and British, made massive use of the DU for its exceptional piercing capabilities. Estimates suggest the dispersion of about 40 tons of DU in the theater of operations, via more than 940,000 30 mm projectiles fired by A-10 ground attack aircraft and 14,000 larger caliber shells (105 mm and 120 mm) fired by Abrams tanks (Mathieu Matieu, 2001, p. 2). The effectiveness of these weapons has exceeded all expectations. Their superiority over conventional tungsten munitions was overwhelming : their speed, around Mach 5 (about 1500 m/s), and their useful range, reaching 3200 meters, gave them a decisive advantage. The testimonies of soldiers on the ground report such a formidable efficiency that some shots could pierce a tank from one side to the other to hit a second one located behind it. For many soldiers, these munitions were perceived above all as a technological asset guaranteeing their survival and superiority over Iraqi T-72 armoured vehicles (Barrillot-2001, p. 93). However, this power proved so unprecedented that it led to tragic incidents of « friendly fire ». On February 27, 1991, an American M1A1 tank opened fire on other friendly armored units, killing six and wounding twenty-five. These « accidents » starkly illustrate how the raw performance of this technology sometimes exceeded the capacity for discernment and control on a fluid and chaotic battlefield.

However, this tactical superiority was quickly overshadowed by health and environmental concerns. Early awareness of the risks existed in some scientific and military circles, long before the controversy erupted publicly. As early as November 1991, only a few months after the end of hostilities, a report by the British Atomic Energy Authority, based on an in situ study, put forward the alarming estimate that DU residues left on the ground could cause up to 500,000 potential deaths in the long term. This early and spectacular warning, although debated, demonstrates that the potential dangerousness of the contamination was not an a posteriori discovery, but a risk identified from the outset. Despite this, the post-conflict management of this contamination has revealed blatant institutional negligence. A report by the U.S. General Accounting Office (GAO), published in January 1993, bore an unequivocal title : « The Army Was Not Prepared to Deal with Depleted Uranium Contamination » (Barrillot-2001, p. 93). The official document harshly criticized the lack of training, protocols, and protective equipment for soldiers who were required to operate in contaminated areas, inspect or clear vehicles destroyed by AU munitions. This finding is all the more striking in contrast to the subsequent deployment of specialized decontamination teams, dressed in full-body protective suits, to « clean » tank carcasses (Barrillot-2001, p. 93).

This paradox highlights a recognition of the danger at the level of the hierarchy, but a deficient or even non-existent application of preventive measures for the vast majority of troops exposed in the field.

It is in this context of uncontrolled contamination and institutional silence that the controversy over the « Gulf War Syndrome » has emerged. The controversy first took root in the United States, shortly after the conflict, before spreading to Europe and France later, towards the end of the 1990s (Lesna-2004, p. 5, Lesna-2004, p. 12). Veterans of the coalition have begun to report a heterogeneous and confusing set of chronic pathologies : neurological disorders (memory loss, lack of concentration), persistent headaches, chronic fatigue, muscle pain, breathing problems, kidney disease, as well as an abnormal incidence of cancer and leukemia (Lesna-2004, p. 5, Lesna-2004, p. 18). The complexity of this controversy lies from the outset in its multifactorial etiology. Indeed, exposure to DU is only one of the many suspected risk factors, alongside exposure to toxic fumes from hundreds of burned oil wells, to pesticides and insecticides massively used, to a cocktail of vaccines administered in emergency (notably against anthrax and botulism), to the preventive intake of pyridostigmine bromide against nerve agents, and the intense psychological and physiological stress inherent in any armed conflict (Lesna-2004, p. 18, Lesna-2004, p. 36).

This multiplicity of potential causes has made it extremely difficult to establish a direct and irrefutable scientific causal link, creating a situation of uncertainty that Professor Roger Salamon, mandated by the French government to study the subject, has described as « impossible refutation ». He explained that a statistician can prove that a phenomenon exists, but can never prove that it does not exist, which places the debate in the complex field of the precautionary principle (Lesna-2004, p. 36). This scientific uncertainty has been exacerbated by the authorities' opaque management of information. The strict control of communication during the conflict was prolonged by an official silence on its health consequences, an attitude that journalists and associations have described as a media « blackout » (Lesna-2004, p. 17). The press itself oscillated between warning, evoking "damning testimonies", and caution, headlined « Syndrome or psychosis ? » (Lesna-2004, p. 20).

It took the determined action of veterans' associations, such as Avigolfe in France, for the subject to impose itself in the public space. These organizations have collected testimonies, alerted the media and initiated legal proceedings to obtain recognition of the pathologies of their members (Lesna-2004, p. 19). Their efforts have been relayed and scientifically supported by the work of dissident researchers, including Dr. Asaf Durakovic, a former colonel in the US Army and a specialist in nuclear medicine. Having become a real whistleblower, he claimed to have been dismissed from his post after insisting on conducting research on the AU, his requests for analysis having been « allegedly lost » and his work deemed disturbing by his superiors. His research, presented at scientific conferences, has had a considerable impact. They revealed the significant presence not only of depleted uranium, but also of uranium-236 in the urine and tissues of veterans, nearly ten years after the end of the conflict (Barrillot-2001, p. 95). The detection of U-236, an artificial isotope that does not exist in nature and is a byproduct of used nuclear fuel, suggested that the DU used in the munitions came from reprocessed uranium. This discovery was crucial, as it involved a potentially more complex and radiotoxic contamination than that admitted by official sources, shifting the risk from the field of chemical toxicity alone to the more controversial field of long-term internal radiotoxicity (Barrillot-2001, p. 95). Although his analyses were disputed by part of the scientific community (Lesna-2004, p. 19), they provided tangible arguments to veterans and forced governments to be more transparent, leading to the creation of parliamentary fact-finding missions and epidemiological investigations (Lesna-2004, p. 20).

Ultimately, the Gulf War not only demonstrated the military effectiveness of depleted uranium weapons, but more importantly it established the paradigm of controversy that would define their future use. This conflict set up a recurring cycle : a demonstration of technological superiority on the battlefield, followed by the emergence of unexplained pathologies in combatants and civilians, a period of denial or minimization by the political and military authorities, an intense scientific battle marked by uncertainty and the politicization of research, and finally a slow and painful quest for recognition and reparation for the victims, carried by associations and the media. This seminal case has permanently inscribed in the collective consciousness a powerful, although scientifically debated, link between the use of these weapons and serious health consequences, transforming an initially technical and military issue into a global public health problem and an ethical and legal issue of the first order.

6.2 Iraq War (2003)

Twelve years after the first Gulf War, Iraq was once again the scene of a massive use of depleted uranium (DU) weapons during the invasion led by the international coalition in 2003. This conflict does not represent the emergence of a new phenomenon, but rather a dramatic intensification and the reactivation of an already lively controversy in a heavily affected territory (Lesna-2004, p. 70). The operation, initially presented as a surgical intervention aimed at neutralizing weapons of mass destruction that the Iraqi regime was accused of possessing, paradoxically led to the dissemination of radiological and chemical contamination on an unprecedented scale. As soon as the offensive was announced, the question of the use of these munitions immediately resurfaced in the international public debate, fuelled by the precedents of the Balkans and the still debated health consequences of the 1991 conflict (Lesna-2004, p. 61).

The case of 2003 is therefore fundamental in that it illustrates an escalation of use on an environment and a population already weakened by more than a decade of economic sanctions and sporadic bombings. Iraq, already considered a disaster zone in terms of health, has thus become a tragic laboratory of the long-term consequences of this military technology, offering an emblematic case study that condenses all the issues raised by this thesis. The analysis of this conflict makes it possible to go beyond a simple military chronicle to question the foundations of a strategy which, under the guise of tactical effectiveness, mortgages the health and environmental future of entire regions.

The scale of use in 2003 significantly exceeds that of all previous conflicts. While post-1991 assessments were based on estimates of several tens of tons, it is now accepted that about three hundred tons of DU were dispersed on Iraqi territory during the second intervention (Barrillot-2001, p. 72). This spectacular quantitative increase, nearly ten times greater than that of 1991, testifies to a systematization of the use of these munitions in the arsenal of the coalition, mainly American and British. This quantitative escalation has been accompanied by qualitative and tactical developments with far-reaching consequences. Unlike 1991, when the use was mostly concentrated in desert areas against military objectives clearly identified as armored columns, the 2003 invasion was characterized by strikes in mixed environments, significantly including densely populated urban and peri-urban areas. This use, in line with the American doctrine of destroying hardened targets and buried command centers (Parsons-2002, p. 5), transformed the DU from an anti-tank weapon to a weapon for penetrating and destroying infrastructure. A-10 Warthog planes and Abrams tanks fired DU shells into cities such as Baghdad, Basra and Fallujah, pulverizing vehicles but also buildings, bridges and other civilian structures. This new doctrine of use has radically changed the nature of exposure. The dispersion of uranium oxide aerosols no longer takes place in desert areas, but in the heart of living spaces, contaminating the air, homes, markets, schools and playgrounds. The destructive efficiency, touted by the Pentagon, has thus resulted in an insidious and lasting contamination of the daily spaces of the civilian population.

The consequences of this new wave of contamination have exacerbated an already critical health and environmental situation. As early as the late 1990s, a convergence of testimonies from Iraqi doctors and preliminary epidemiological studies, although methodologically disputed by the Western powers, reported an alarming increase in serious pathologies. Local research reported a fivefold increase in cancers and a tripling of congenital anomalies in the regions of southern Iraq, the most affected by the 1991 conflict (Mathieu Matieu, 2001, p. 2, Mathieu Matieu, 2001, p. 2). The figure of the child victim, particularly through the unbearable images of « monstrous congenital malformations », became a powerful media and political symbol of the suffering of the Iraqi population, although the direct causal link with the AU still remained scientifically debated (Lesna-2004, p. 74). It is on this disastrous health soil that the contamination of 2003 has been superimposed. United Nations Environment Programme (UNEP) reports have corroborated these concerns, confirming that the risks of inhalation of DU dust are high in the vicinity of impact sites, creating areas of long-term danger where mere breathing or ingestion of dust can lead to chronic internal exposure (Leistner, 2023, p. 59).

The post-conflict chaos has multiplied the routes of exposure : the destruction of infrastructure has encouraged the resuspension of contaminated particles, while the savage dismantling of the carcasses of military vehicles hit by DU shells, practiced by civilians to recover metal, has become a source of direct poisoning. In addition, the uncontrolled destruction of unexploded ordnance, through open burning or detonation, has contributed to the release of more toxic substances into the environment, worsening an already out-of-control situation (Leistner, 2023, p. 63).

This health and environmental crisis is aggravated by a persistent and systemic opacity on the part of the coalition forces. This withholding of information is not mere negligence, but appears to be part of a deliberate strategy to minimize the scope of the consequences and evade responsibility. In its post-conflict assessments, UNEP explicitly lamented the lack of crucial information, noting that no independent data was available on chemical and nuclear agents potentially released by bombing of industrial facilities and military sites, the full list of which has never been released (Leistner, 2023, p. 63). Specifically concerning the AU, the communication of the precise geographical coordinates of firing shots (« firing coordinates ») has remained fragmented, late, and often incomplete.

This lack of accurate data makes it almost impossible to conduct a comprehensive and rigorous risk assessment. It prevents scientists from geographically correlating the areas of contamination with the outbreaks of observed pathologies, thus creating scientific uncertainty that is then instrumentalized by the user states to deny any causal link.

This withholding of information significantly hinders independent scientific research and, even more seriously, it paralyses any remedial and public health policy. Without knowing where the contamination « hot spots » are, it is impossible to decontaminate sites, secure risk areas or inform local populations of the dangers to which they are exposed. Communities, often the poorest, continue to live, cultivate and draw water from polluted land, in ignorance maintained by military secrecy (Leistner, 2023, p. 59).

In short, the Iraq war of 2003 constitutes a paradigmatic case study and the culmination of the problem of depleted uranium weapons. It symbolises a form of « double punishment » inflicted on a country, contaminating a second time an environment and a population already bruised by a previous conflict and a decade of embargo. This conflict demonstrates an unprecedented escalation in the scale of contamination, a doctrinal shift towards urban application that maximizes civilian exposure, and a policy of opacity that perpetuates scientific uncertainty and constitutes a major obstacle to the recognition of damage and the implementation of protective measures. The Iraqi case thus condenses, in a particularly acute way, all the health impacts, legal controversies and geopolitical implications that constitute the subject of this thesis. It highlights the stark contradiction between the discourse of « clean wars » and the reality of long-lasting radioactive and chemical pollution, the effects of which will continue to be felt for generations. This tragedy illustrates the urgent need for strict international regulation of these armaments, otherwise other territories could suffer the same fate in the future, such as the Gaza Strip, the West Bank, Lebanon, etc.

6.3 Speculation about Ukraine

The conflict in Ukraine, initiated by the Russian invasion in February 2022, has reactivated the controversy over depleted uranium (DU) weapons with unprecedented acuity and global scope. Unlike the speculations that have surrounded more recent conflicts where their use remained in the realm of allegation, the Ukrainian case marked a decisive break. He shifted the debate from hypothesis to factual certainty, following the successive official announcements by the United Kingdom in March 2023, and then by the United States in September 2023, relating to the delivery of ammunition of this type to the Ukrainian armed forces. This formalization transformed the conflict into an emblematic contemporary case study, illustrating in real time the entire cycle of the AU problem : from strategic justification to media controversy and health concerns.

More fundamentally, this situation unfolds on a terrain of structural mistrust, a direct legacy of decades of opacity and concealment on the part of the military authorities, as analysed in depth in Chapter 5.3.

Thus, the revival of the controversy in Ukraine is not simply « one-off and superficial », as often observed during the outbreak of a new conflict ; it is profound and lasting, because it is based on state confirmations that directly engage the responsibility of the supplying nations and that definitively anchor the AU in the material and psychological landscape of war.

The introduction of these specific munitions is part of an already catastrophic environmental context, which multiplies the potential risks. As early as July 2022, well before the DU deliveries, the United Nations Environment Programme (UNEP) warned of the creation of a « toxic environmental legacy for Ukraine and its region » (Leistner, 2023, p. 7). UNEP's preliminary assessments painted an alarming picture, showing considerable damage to critical infrastructure : nuclear power plants, energy facilities, refineries, mines, and many industrial and agro-industrial sites. The report detailed the release of hazardous substances, « ranging from solvents to ammonia and plastics, » following bombings of factories and warehouses. Explosions at « fertilizer and nitric acid plants » as well as the destruction of large livestock farms, whose carcasses pose an additional health risk, further aggravated the situation (Leistner, 2023, p. 7). This massive destruction has caused « multiple incidents of air pollution and potentially serious contamination of groundwater and surface water » (Leistner, 2023, p. 7). The introduction of depleted uranium therefore superimposes a new layer of pollution, of a radioactive and chemotoxic nature, on this already heavily contaminated substrate.

Uranium oxide microparticles, generated during the impact of munitions, can take the same dispersion pathways – atmospheric, water, and soil – as chemical pollutants already present, creating a complex toxic cocktail and exacerbating the potential for « gradual penetration of pollutants into organisms and ecosystems » (Leistner, 2023, p. 8). This new pollution is intended to leave a « lasting imprint » that « sediments within the environments » (Leistner, 2023, p. 8). As a result, long after the cessation of hostilities, reconstruction and daily life will be durably conditioned by this imperative to move within a « contaminated context » (Leistner, 2023, p. 8). This conflict confirms in the most tragic way that « war is literally toxic » (Leistner, 2023, p. 7) and that the clean-up of Ukrainian territory will be a monumental challenge. The presence of depleted uranium exponentially complicates future decontamination operations, requiring specific radiological protocols, skills and equipment that go far beyond conventional post-conflict environmental remediation. Ukraine will therefore need « enormous international support to assess, mitigate and repair the damage » (Leistner, 2023, p. 7), a task made even more difficult and costly by this specific contamination.

The decision to supply these weapons responds, from the Western point of view, to a strategic and pragmatic logic. The primary objective is to give Ukrainian forces a decisive tactical advantage against Russian tanks and armored vehicles, whose composite and reactive armor is particularly vulnerable to the piercing performance of DU arrow shells. This approach is in line with a military doctrine which, since the Vietnam War and the unfortunate experiences in Somalia, has favoured technological supremacy and ranged strikes to « strike fast and hard » while minimizing human losses within its own ranks (Lesna-2004, p. 60). By providing these munitions, Ukraine's allies are transferring not only a material capability, but also an element of this doctrine focused on lethal effectiveness. This purely military rationality is perfectly encapsulated by CTA International's advertising slogan for an AU munition : « lethal, compact, cheap, available ». This argument highlights the « unspeakable economic and political issues » that underlie the persistence of these weapons : they represent a low-cost solution for recovering the waste of the nuclear industry, transforming an expensive liability into a strategic asset.

However, the geopolitical analysis would be profoundly incomplete if it omitted Russia's posture and capabilities. The Russian military industry has long developed and produced its own anti-tank ammunition with depleted uranium, including the 115 mm 3UBM-13 shells for the T-62 tank gun and the 125 mm 3BM32 shells (Barrillot-2001, p. 51). The secrecy that « is the rule in military matters » in Russia makes the evaluation of their stock and their effective deployment in the Ukrainian theater particularly difficult (Barrillot-2001, p. 51). Nevertheless, this proven capability establishes a potential symmetry on the battlefield and exposes the hypocrisy of Russian rhetoric, which has vehemently condemned Western deliveries as a near-nuclear escalation. The DU thus becomes not only a kinetic weapon, but also a powerful instrument in information warfare.

The controversy cannot therefore be reduced to a unilateral criticism of the Western bloc ; It must take into account the fact that the two main belligerents potentially have this technology, which further complicates ethical debates and the prospects of binding international regulation.

The delivery announcements have inevitably reactivated the mechanisms of crisis communication and risk minimization already observed during past controversies. The official discourse of supplier countries, relayed by certain institutions, has focused on highlighting military efficiency while trying to temper health and environmental concerns. To do so, he relied on well-established rhetoric : the low radioactivity of uranium, the insistence on the modes of exposure necessary to present a danger, and above all, the semantic use of the qualifier « impoverished ». As the critical literature has noted, this term « has opportunely come to the rescue, almost obscuring the fact that it is indeed uranium » and downgrading matter from its nuclear category in public perception (Barrillot-2001, p. 8). However, the effectiveness of this communication is now almost nil due to the heavy history of the Gulf and Balkan wars.

The history of this controversy is punctuated by belated admissions and denials contradicted by the facts, where institutions like NATO were only « forced to admit » to the use of the AU as a result of « press revelations. » This history, marked by accusations of lies, « half-truth », « concealment » and organised blackouts, has durably undermined the credibility of the official word.

As a result, every new insurance is now filtered through a lens of structural skepticism. The burden of proof is de facto reversed : as the analysis of systemic opacity concludes, « the absence of evidence is no longer interpreted as proof of absence, but as an indication of a successful concealment" »(cf. 5.3). In this context, the counter-discourses put forward by non-governmental organizations, independent scientists and veterans' associations find a considerable echo, playing the role of « counter-powers » in the face of a state discourse deemed biased (Lesna-2004, p. 83).

In short, the Ukrainian case is a striking and tragic synthesis of the multidimensional issues related to depleted uranium. It is not just another case study; it is the real-time manifestation of all the dynamics analyzed in this thesis.

It highlights in a stark way the irreducible tension between the search for short-term tactical effectiveness and responsibility for the health and ecological consequences in the very long term. It forcefully demonstrates how an institutionalized culture of secrecy and past cover-ups fuel a lasting mistrust that hinders any serene and enlightened public debate.

As the conflict drags on, Ukraine has become the theatre of application and observation of these complex dynamics, where military confrontations are superimposed on crucial informational issues and, above all, the question of the future management of a toxic legacy that has now been proven.

The battle for truth and accountability for the impact of depleted uranium in Ukraine has only just begun ; it promises to be as long and arduous as the one still being waged, thirty years later, by the veterans and civilian populations of Iraq and the Balkans.

6.4 Balkan conflict (1994–1999)

If the Gulf War was the « baptism of fire » of depleted uranium (AU) weapons, the Balkan conflict represents the decisive turning point where the controversy over their use imposed itself with unprecedented force on the European political and media scene. This new phase has transformed a concern initially confined to veterans' circles and a few non-governmental organizations into a crisis of international scope, directly involving European governments and NATO command structures. The intervention in the former Yugoslavia, carried out in two distinct stages – first in Bosnia-Herzegovina and then in Kosovo – not only attested to the systematized use of the AU by the American air force, but also highlighted a culture of opacity and withholding of information within the Atlantic Alliance itself. This context has catalyzed the emergence of the « Balkan syndrome » in the media, forging a direct causal link in public opinion between these munitions and the appearance of serious pathologies, and has thus imposed an inevitable public debate on the health and environmental consequences of these weapons (Lesna-2004, p. 6). The geographical proximity of the theatre of operations and the European nationality of the peacekeepers potentially exposed made this conflict a paradigmatic case study, demonstrating how a tactical choice can have profound and lasting political, social and legal repercussions.

The use of DU by NATO forces occurred in the first place during the Bosnian war, an intervention that took place in relative secrecy as to the nature of the weaponry used. Between 1994 and 1995, and more particularly during the intensive strikes of Operation Deliberate Force in August and September 1995, the U.S. air force fired 10,800 projectiles at the DU, mainly from its A-10 « Warthog » ground attack aircraft (Barrillot-2001, p. 73). However, this usage remained undisclosed to the public and, more problematically, to some of the NATO allies whose troops were deployed on the ground. The information was not revealed until five years later, at the end of 2000, when the Italian Minister of Defense at the time, Sergio Mattarella, made it public. He then expressed his « bitterness » at NATO's failure to provide « information important for the security of the Bosnian community and that of the military in a timely manner » (Barrillot-2001, p. 73).

This statement highlighted a major gap in communication and trust within the Alliance. For European troop-contributing countries, the revelation came as a shock : their soldiers had been operating, patrolling and living for years on potentially contaminated sites without knowledge and, therefore, without any specific protective measures.

This withholding of information has materialized the concept of « invisible threat » analyzed in Chapter 3. The lack of data on the location of impacts has turned post-conflict areas into a field of chronic and unintentional exposure. Uranium oxides, which were dispersed during the impacts, were able to contaminate soil, surface water and groundwater, insidiously integrating themselves into the local food chain. For SFOR (Stabilization Force) soldiers and civilians returning to their villages, everyday gestures – cultivating a vegetable garden, drinking water from a well, or simply breathing in the dust raised by the winds – have become potential vectors of exposure to a toxic, low-level radioactive contaminant. NATO's opacity thus deprived the actors on the ground of the possibility of applying the slightest precautionary principle, feeding a feeling of betrayal among the allies and laying the foundations for the political crisis to come (Lesna-2004, p. 22).

The use of these munitions then escalated significantly during the NATO-only air campaign in Kosovo in 1999, as part of Operation Allied Force. During these 78 days of bombing, about 31,000 DU projectiles were fired by American A-10 aircraft (Lesna-2004, p. 17). Unlike the Bosnian episode, this use was officially confirmed by NATO in a communication addressed to the Secretary General of the United Nations, Kofi Annan, in March 2000 (Lesna-2004, p. 17). This recognition, although belated and formulated in technical terms, was a turning point : it transformed allegations and suspicions into proven and documented facts, providing a tangible basis for criticism and requests for clarification. The debate was no longer *whether* AU weapons had been used, but *what the consequences were*.

This use was also part of a broader context of environmental degradation, described by some observers as « ecocide ». NATO bombings have targeted industrial complexes, refineries and chemical warehouses, causing highly toxic substances to be released into the environment. The Danube River, one of the most important biodiversity corridors in Europe, was polluted by hydrocarbons and chemicals, affecting ecosystems and the quality of drinking water for millions of people downstream (Leistner, 2023, p. 52). DU contamination has therefore been added to a cocktail of war pollution, considerably complicating post-conflict health impact assessments and the possibility of isolating a single causal agent for the pathologies observed, a structural methodological challenge in such contexts (Leistner, 2023, p. 64).

The inflection point of the controversy came explosively in late 2000 and early 2001. The European press, initiated by Italian newspapers such as *La Repubblica*, which headlined « Kosovo : the uranium that kills », began to report on a series of cases of leukaemia and other forms of cancer affecting Italian soldiers returning from the Balkans (Lesna-2004, p. 21). The phenomenon quickly spread to other European countries, with Spain, Portugal, Belgium, Greece and France reporting similar cases. The media then coined the expression « Balkan syndrome », in direct analogy with the « Gulf War syndrome » that had hit the headlines a few years earlier (Lesna-2004, p. 25).

However, a fundamental and far-reaching distinction has been made in media treatment and public perception. While for the Gulf, the etiology of the syndrome remained multifactorial and debated (exposure to pesticides, vaccines, oil well fumes, post-traumatic stress, and DU among others) (Lesna-2004, p. 13), the debate on the Balkans focused almost exclusively on depleted uranium. This has imposed itself as « the only claimed causality » (Lesna-2004, p. 25). This narrative simplification created a direct and powerful causal link in public opinion, turning DU into the main, if not the only, pathogen responsible for soldiers' illnesses. This focus has given the controversy an unprecedented political intensity, making it evolve into a major diplomatic and health crisis. Heads of government, such as Italian Prime Minister Giuliano Amato, have publicly called on NATO to « tell the truth » (Lesna-2004, p. 21). The debate was brought to the national parliaments, which launched committees of inquiry (Lesna-2004, p. 31), and to the European Parliament, which called for a moratorium on the use of these weapons (Mathieu Matieu, 2001, p. 3). The issue has also moved from the political to the judicial field, with the filing of complaints by veterans' associations aimed at having the service link for their pathologies recognized and obtaining compensation (Lesna-2004, p. 59).

On the health and environmental front, the controversy has been fuelled by a series of evaluations with often divergent conclusions, illustrating a real « battle of expertise ». The United Nations Environment Programme (UNEP) has conducted field missions, first in Kosovo in 2000 and then in Bosnia and Herzegovina in 2002 (Massa-2023, p. 66). The Kosovo report, published in January 2001, confirmed localized but significant radioactive contamination at eight of the eleven sites studied, with the presence of DU particles in soil, water and lichens (Barrillot-2001, p. 76). At the same time, testimonies and preliminary studies carried out on the spot reported a worrying increase in serious pathologies among local populations, including leukaemia and congenital malformations, conditions similar to those observed in Iraq after 1991 (Mathieu Matieu, 2001, p. 3, DU KOSOVO, 2024, p. 4).

Faced with these alarming data, the military authorities (including the Pentagon) and organizations such as the World Health Organization (WHO) have published reports aimed at reassuring. Their main argument was to compare the radioactivity of DU with the natural radioactivity present in the environment. The official conclusions stated that the health risk was « negligible compared to the normal risks of life » and that the levels of contamination detected could often not be « differentiated from the natural concentration of uranium » (Leistner, 2023, p. 76). However, this argument has been strongly criticized for its methodological flaws. It failed to consider the specific nature of the exposure : it is not a weak and homogeneous external irradiation, but internal contamination by insoluble uranium oxide particles which, once inhaled or ingested, can become permanently lodged in the lungs or bones, causing high-energy alpha irradiation of the surrounding tissues. Moreover, these same official reports contained important nuances, acknowledging that WHO health standards for drinking water could be exceeded locally and that only military use of DU was likely to significantly alter environmental concentrations (Leistner, 2023, p. 76). The controversy has been complicated by journalistic investigations suggesting that the DU used was not pure, but potentially contaminated with more radiotoxic minor actinides, such as plutonium, from the reprocessing of spent nuclear fuel (Lesna-2004, p. 23). This confrontation of expert opinions, combined with the persistence of tens of thousands of unrecovered projectiles buried in the ground, constitutes a latent threat whose long-term effects remain poorly assessed, maintaining a climate of scientific uncertainty and political mistrust (Leistner, 2023, p. 61).

In short, the Balkan conflict acted as a powerful and painful revelation. Not only did he confirm the integration of AU weapons into the conventional arsenal of the NATO powers, but above all he exposed the controversy to a wide audience, shifting it from the technical and military arena to the political, social and legal arena. This case study vividly demonstrates how an armament, justified by a tactical advantage on the battlefield, has generated lasting and systemic consequences that go far beyond this framework: a deep and persistent crisis of confidence within one of the world's most powerful military alliances, a lasting health concern for veterans and civilian populations in the affected areas, and an unresolved scientific and ethical debate about the responsibility of States for the delayed and diffuse consequences of their military choices. The legacy of the Balkans has thus left a lasting mark on the perception of these weapons, positioning them on the ambiguous border between conventional and non-conventional, and has fuelled international efforts to regulate or even ban them.

Towards regulation and alternatives

After analysing the technical properties of depleted uranium weapons, their health and environmental impacts, the normative controversies they generate, and their concrete deployment through various case studies, the analysis conducted so far has highlighted a complex and persistent problem. The previous chapters have shown how, despite decades of debate and a growing awareness of the risks, the use of these munitions continues, legitimized by an argument combining strategic imperatives, military opacity and the instrumentalization of scientific uncertainties.

The use of deliberately reassuring rhetoric, downgrading depleted uranium from its status as a nuclear material to a conventional technology, has made it possible to mask the nature of its long-term effects (Barrillot-2001, p. 8). The result is a toxic legacy on the battlefields, persistent contamination of soil and water that poses an intergenerational threat, and a legal « grey area » that hinders the emergence of a clear normative response.

The fundamental principles of international humanitarian law, such as the distinction between combatants and civilians or the prohibition of superfluous evil, are put to the test by a weapon whose toxic and radiological effects diffuse uncontrollably long after the impact, affecting belligerents and non-belligerents alike (Massa-2023, p. 72).

This chapter now looks resolutely to the future, moving from diagnostic analysis to exploring solutions for the regulation of this controversial technology and proposing viable alternatives.

The shortcomings of positive international law are the main obstacle to a formal ban, which struggles to unambiguously qualify these armaments (Massa-2023, p. 73). Instruments such as the Convention on Certain Conventional Weapons (CCW) or Additional Protocol I to the Geneva Conventions recall the prohibition of causing « widespread, lasting and serious » damage to the environment, but their cumulative thresholds of application make it difficult to invoke them in the case of depleted uranium (Massa-2023, p. 27). This situation is exacerbated by the recurrent demand for « irrefutable scientific evidence » of their dangerousness, a condition set by some state actors to consider a binding international treaty (Massa-2023, p. 80). Faced with this institutional inertia, civil society, NGOs and certain political bodies have sought to reverse the burden of proof by mobilizing the precautionary principle (Barrillot-2001, p. 10). This principle, which stems from environmental law in the 1970s and is enshrined in the Barnier Law of 1995 in France, postulates that « the lack of certainty, taking into account the scientific and technical knowledge of the moment, must not delay the adoption of effective and proportionate measures aimed at preventing a risk of serious and irreversible damage » (Lesna-2004, p. 54). Its application to the military field, although debated (Lesna-2004, p. 55), offers a powerful ethical and legal lever for challenging the status quo. It is a question of substituting a preventive logic for a curative one, basing a ban on the assessment of potential risks rather than waiting for post-factum certainties that could only note already irreversible damage (Lesna-2004, p. 55). This approach is part of an ethics of responsibility, as theorized by Hans Jonas, which advocates conservation and preservation in the face of a technology whose long-term effects are unknown (Leistner, 2023, p. 155). The « fear heuristic » then becomes an intellectual tool to anticipate worst-case scenarios and act before they materialize, thus fighting against excessively optimistic technophile discourses (Leistner, 2023, p. 156). However, the precautionary principle itself faces paradoxes, including the difficulty of assessing the seriousness and irreversibility of damage before it has manifested itself (Lesna-2004, p. 56).

This chapter therefore proposes to explore these avenues in a systematic way in order to overcome these obstacles. It will first examine the regulatory efforts and calls for a moratorium that have emerged on the international scene, notably within the United Nations and the European Parliament (Lesna-2004, p. 26). The moratorium is analysed here not as an end in itself, but as an indispensable precautionary measure, a political and strategic pause aimed at freezing the use and proliferation of these weapons until a legal consensus can be forged (Lesna-2004, p. 53). This section will highlight the crucial role of non-state actors, such as veterans' associations (such as Avigolfe), in putting this issue on the political agenda (Barrillot-2001, p. 10). Secondly, it will make a set of recommendations for more responsible management of existing arsenals and contaminated areas. Beyond a simple call for transparency, it will be a question of proposing concrete frameworks for action : the obligation to inform local populations of the risks incurred (ETOGA, p. 13), the implementation of systematic decontamination protocols financed by users, the creation of long-term health monitoring registers for civilians and soldiers exposed, and finally, the establishment of liability and redress mechanisms for environmental and human damage. Aware that any disarmament approach must respond to the security imperatives claimed by States, the chapter will finally analyse the technological alternatives available or under development. This approach aims to deconstruct the argument of military necessity by demonstrating that there are other materials and designs of ammunition, particularly tungsten-based, capable of performing the same tactical anti-armor functions.

The existence of such alternatives considerably weakens the justification for the use of a weapon whose collateral damage is so controversial, making the suffering it causes difficult to justify and potentially « superfluous » within the meaning of humanitarian law (Massa-2023, p. 72).

The aim is to draw realistic prospects for a future in which military effectiveness is no longer achieved at the cost of lasting environmental contamination and a threat to the health of future generations.

7.1 Recommendations

Following an analysis of the technical properties, health and environmental impacts, normative controversies and regulatory impasse surrounding depleted uranium (DU) weapons, this chapter makes a series of pragmatic recommendations. These proposals do not claim a single, immediate solution, but constitute a systemic and multidimensional approach to overcoming the status quo, characterized by epistemological controversy and political paralysis. Faced with a problem that intertwines ballistic, health, environmental, ethical and legal issues, a fragmented response would be ineffective. The recommendations that follow therefore focus on three interrelated and complementary axes : strengthening transparency and independent research, establishing a robust legal and normative framework, and promoting full accountability and alternatives.

Axis 1 : Strengthening Transparency and Independent Research

Informational opacity, coupled with an institutional discourse of risk minimization, is the fundamental obstacle to any responsible management of the AU's toxic legacy. The first series of recommendations therefore aims to establish the conditions for objective, shared and usable knowledge, by replacing the logic of military secrecy with a logic of health and environmental responsibility.

1 Establish an obligation of transparency on strike zones : The introduction of a legal obligation, and no longer a mere incentive, for user states to systematically communicate the precise data of their strikes (exact geographical coordinates, quantity and type of ammunition) is a fundamental measure. This communication should be addressed not only to the governments of the affected states, but also to the relevant international agencies, first and foremost the United Nations Environment Programme (UNEP) and the World Health Organization (WHO). This transparency is the *sine qua non* condition for any effective post-conflict action : it is the only way to map risks, to target environmental monitoring programs (water and soil sampling), to protect civilian populations by marking and prohibiting access to the most contaminated areas, and to rationally organize complex and costly decontamination operations (Dorsouma Bouchard, 2006, p. 11, ETOGA, p. 13). Without this data, local populations and demining personnel are exposed to an invisible threat, and remediation efforts are doomed to be partial and ineffective. Already encouraged by several non-binding resolutions of the UN General Assembly, this measure must evolve into a binding norm of the law of armed conflict, integrated, for example, in a new protocol to the Convention on Certain Conventional Weapons (CCW).

2 Create an independent international observatory : Inspired by the proposals made at the national level, particularly in France where the parliamentary fact-finding mission had recommended the « creation of a permanent observatory for the monitoring of military personnel and former soldiers » (Lesna-2004, p. 36), the establishment of a permanent and independent international structure is recommended. Financed by international contributions outside the direct control of the user States, this observatory would have a threefold mandate. First, it would be responsible for conducting and centralizing longitudinal epidemiological studies on the health of veterans and exposed civilian populations, applying standardized protocols to ensure comparability of data across different theatres of operations.

3 Second, it would oversee long-term environmental monitoring programs. Third, it would serve as a platform for validating and disseminating scientific information, in order to counter disinformation. Such a structure, by guaranteeing the independence of expertise vis-à-vis military institutions and industrial complexes, would make it possible to overcome the sterile polarization between official expertise, often accused of partiality, and militant counter-expertise, sometimes criticized for their lack of rigor. It would be an essential guarantee of credibility to restore the confidence of the affected populations (Lesna-2004, p. 40).

4 Fund multidisciplinary research on combined effects : It is imperative that scientific research move away from the monofactorial paradigm that has characterized the debate so far. The focus on proving a direct and unique causal link between DU exposure and a specific pathology has come up against what Professor Salamon has called « impossible refutation » : a statistician can never prove the non-existence of a phenomenon, only his inability to observe it. This requirement of absolute proof, in the context of a « poly-contaminating war » such as the one in the Gulf, is a methodological dead end that objectively serves a strategy of inaction. It is therefore recommended to fund research that takes a holistic approach to the war exposome, i.e. the study of the synergistic and cumulative effects of exposure to DU with other toxic agents present on the battlefield (oil well fumes, heavy metals from other munitions, chemical residues). Understanding how DU interacts with other environmental and physiological stressors is more scientifically relevant and will allow for better assessment of overall health risks to ecosystems and people.

Axis 2 : Establishing a Robust Legal and Normative Framework

In the face of the « legal grey area » and the inadequacy of existing international law (Massa-2023, p. 73), the development of clear and binding norms is essential to frame the potential use of weapons at the AU and the management of their consequences.

5 Reverse the burden of proof through the systematic application of the precautionary principle : The most structuring recommendation is a fundamental reorientation of the legal paradigm. We must stop demanding from victims « irrefutable scientific evidence of the dangerousness » of these weapons, as paradoxically formulated in a resolution of the European Parliament which thus empties its own call for a ban on its substance (Massa-2023, p. 80). This requirement is a rhetorical maneuver that makes any regulation impossible. It should be replaced by a rigorous application of the precautionary principle. As enshrined in French law by the Barnier Law of 1995, this principle stipulates that « the lack of certainty, taking into account the scientific and technical knowledge of the moment, must not delay the adoption of effective and proportionate measures aimed at preventing a risk of serious and irreversible damage » (Lesna-2004, p. 54). Applied to the military field, it implies a reversal of the burden of proof (Lesna-2004, p. 55): it would be up to the user states to provide robust guarantees on the long-term safety of these weapons before deploying them. In the absence of such guarantees, the precautionary measure requires, at a minimum, a moratorium and the implementation of preventive risk management measures. This approach recognizes the complexity of causality and the paradox underlined by Philippe Mongin, according to which precaution « encourages the modification of causes that we admit may not be the right ones, in order to prevent effects that we do not know how to decide whether they are harmful or not » (Lesna-2004, p. 56). It is an ethical and political choice that prioritizes the protection of human health and the environment in the face of persistent scientific uncertainty.

6 Define international standards for decontamination and public health : To make remediation obligations operational, it is imperative to establish, under the aegis of organizations such as the WHO and the International Atomic Energy Agency (IAEA), clear, quantified and legally binding contamination thresholds. These standards should cover both chemical and radiological toxicity. For drinking water quality, a binding limit value for uranium by weight, based for example on the WHO's interim guide value of 30 µg/L (Caamaño et al., 2012, p. 13), should be adopted internationally. For radiation protection, annual effective dose limits for the public (e.g. 1 mSv/year in addition to background radiation (THE OXIDE STORAGE SCANDAL-2023, p. 3) and stricter dose constraints by source or site (e.g. 0.3 mSv/year per « practice" » as recommended by the UK NRPB (THE OXIDE STORAGE SCANDAL-2023, p. 6) should be defined for post-conflict areas.

7 The existence of such standards would provide an objective and non-negotiable framework for initiating and evaluating decontamination operations (marking, removal of penetrators, containment of sites (Barrillot-2001, p. 102) and to put an end to the arbitrariness that currently prevails, where each situation is managed on a case-by-case basis and often in a deficient manner (None-2022, p. 242).

8 Recognize AU contamination as war damage : International law must evolve to explicitly recognize widespread and long-lasting environmental contamination caused by DU munitions as war damage for which the user state is responsible. This qualification would be based on the already existing but under-applied principles of Additional Protocol I to the Geneva Conventions and the ENMOD Convention, which prohibit methods of warfare causing "widespread, lasting and serious" damage to the environment (Dorsouma Bouchard, 2006, p. 7). Such recognition would have a double scope. Legally, it would create a solid legal basis for demanding reparations to fully fund clean-up operations and public health programs, applying the « polluter pays » principle to the battlefield. Strategically, it would constitute a powerful deterrent, by internalizing the environmental and health costs in the strategic calculation of States before any use of these weapons.

Axis 3 : Promoting Responsibility and Alternatives

Finally, a proactive approach is essential to encourage the phasing out of these weapons, not only through legal constraint, but also through economic incentives and technological innovation.

9 Integrate life-cycle costs into the choice of armaments : The perceived advantage of the AU lies in its almost zero acquisition cost, since it is a recovered waste product of the nuclear industry. This economic calculation is profoundly fallacious because it ignores all the negative externalities deferred over time. It is therefore recommended that military procurement processes should include a full life-cycle cost analysis. This analysis must include a rigorous estimate of future expenditures : very long-term environmental monitoring, complex decontamination of soil and infrastructure (particularly in urban areas), treatment and safe storage of contaminated waste (soil, scrap metal), and funding of health systems for the management of pathologies potentially linked to exposure. By internalizing these exorbitant costs, the so-called « savings » made on purchase disappear, revealing the AU for what it is : a major financial, health and ecological liability. This full accounting would drastically reduce its attractiveness and make technological alternatives more competitive.

10 Actively support technological and doctrinal alternatives : The « technological lock-in » in favor of the AU can only be overcome with strong political will. It is recommended that States, especially those that have already spoken out in favour of a moratorium or ban, establish an international fund or redirect their research and development budgets to accelerate the development of alternatives. This includes perfecting tungsten alloys to improve their terminal performance, but also, and perhaps most importantly, promoting doctrinal changes that make absolute perforation capacity less central. Investing in stealth technologies, battlefield networking, and situational intelligence, as exemplified by the development of hybrid armor, represents a strategic path to make DU obsolete, not through substitution but through paradigm shift.

11 Strengthening democratic oversight and the role of civil society : The persistence of the AU in arsenals is largely due to the fact that debate has been hijacked by the « military-industrial complex » and confined to a sphere of experts who present the issue as purely « technical » in order to evade political debate (Barrillot-2001, p. 8). To counter this depoliticization, it is essential to strengthen the mechanisms of democratic control. National parliaments should systematically set up bodies for evaluating technological and scientific choices, on the model of the French Parliamentary Office (OPECST), to enable elected representatives to make an informed judgement on the global implications of these military choices (Barrillot-2001, p. 10). At the same time, the role of NGOs, veterans' associations such as Avigolfe, investigative journalists or whistleblowers such as Thierry Lamireau, must be protected and supported, because their mobilization is a crucial driver for maintaining pressure on governments and bringing the demand for a moratorium or a ban to the political scene, as shown by the "Balkan syndrome" crisis (Lesna-2004, p. 26).

In short, this set of interrelated recommendations aims to initiate a transition. It is about moving from a paradigm of tolerated uncertainty and diluted liability to a risk management framework based on precaution, transparency and accountability. By acting simultaneously on the levers of knowledge, law and technology, the international community can gradually build a robust standard of non-use and move towards solutions that ensure safety without compromising the health of future generations and the viability of their environment (Leistner, 2023, p. 144).

7.2 Technological Alternatives

In the face of the persistent and growing controversies surrounding depleted uranium (DU), the search for technological alternatives is a fundamental path towards more responsible arms management. This quest, however, is not a simple technical substitution ; it comes up against deep structural obstacles, at once tactical, economic and doctrinal, which explain the persistence of the AU in modern arsenals. As analysed in detail in chapters 2.1 and 5.2, the use of these munitions was imposed thanks to a singular combination that is difficult to replicate : on the one hand, an undeniable ballistic superiority, materialised by the phenomenon of adiabatic shear which gives the projectile a unique self-sharpening capacity during penetration; on the other hand, an exceptionally low production cost, which transforms radioactive and toxic waste, which is expensive to store, into a strategic asset. Any alternative solution must therefore compete on both fronts to be considered viable, a challenge that has led to a veritable « technological lock-in » within the military-industrial complexes. Technology, which through its development has produced this risk of a new nature where it « infiltrates the body to destroy it » (Lesna-2004, p. 66), is thus called upon to remedy it, which requires a reflection that goes beyond the reductive framework of material substitution.

Historically, the most studied alternative is the use of tungsten-based alloys. This metal, with a density close to that of uranium, is the main and almost only competitor for the manufacture of kinetic energy penetrators. However, it has ballistic performance that the general staffs consider to be inferior. Unlike UA, which retains a pointed shape by losing material by « chips » on impact, tungsten tends to deform plastically and become blunt, forming a « mushroom » head. This behavior decreases its terminal effectiveness, reducing the depth of penetration in modern composite armor. Although there is ongoing research aimed at improving tungsten alloys to overcome this shortcoming, the tactical advantage of DU remains, in the minds of military planners, a decisive argument. In addition, the economic obstacle is considerable. Tungsten is a relatively rare metal, whose extraction, purification and shaping are energy-intensive and expensive processes. Its cost is out of all proportion to that of depleted uranium, which is available in abundance and almost free for the arms industry. This financial gap directly contradicts the economic logic underlying the use of the AU, promoted by industrialists with profitability arguments such as « lethal, compact, cheap, available ». Consequently, the debate focused on tungsten, although technically relevant, keeps the reflection within a restricted framework of material substitution, without calling into question the doctrine of use that justifies the need for such perforation capacities.

A more innovative, and potentially more transformative, approach is to make a doctrinal paradigm shift. Rather than locking itself into an ever-widening race for punctures, this new perspective shifts the axis of military superiority from raw firepower to situational intelligence, networking, and stealth. The objective is no longer to guarantee the destruction of an enemy armored vehicle after having engaged it, but to avoid the engagement itself by not being detected. It is in this context that recent developments in hybrid propulsion for combat vehicles are taking place. Emblematic programmes such as that of the Griffon multi-role armoured vehicle (VBMR) in France, or the conclusive tests carried out by the manufacturer Arquus on its VAB Mk3 Electer demonstrator, illustrate this underlying trend (Nicolas-2023, p. 67).

This technology redefines the conditions of ground combat by offering major tactical advantages. The ability to travel several kilometres in « all-electric" mode gives the vehicle a considerably reduced sound discretion and heat signature. This stealth allows for maneuvers that were previously impossible, such as à final approach to the target in stealth mode » (Nicolas-2023, p. 67), surveillance phases (« silent watch ») without thermal or noise emission from the main engine, or silent infiltrations into enemy areas. In this configuration, survival on the battlefield no longer depends solely on the thickness and composition of the armor, but on the ability to control information and evade detection by enemy systems. Hybridization also brings substantial secondary benefits : an instantaneous power surplus, increased resilience thanks to the redundancy of propulsion systems, and a significant reduction in energy consumption, thus reducing the heavy logistical footprint of armored forces (Nicolas-2023, p. 67). This strategic evolution, if it is generalized to all armored fleets, could eventually relativize the importance of the absolute perforation capacity of ammunition. If the target cannot be acquired, the nature of the penetrator becomes a secondary issue. Dependence on such extreme and controversial materials as depleted uranium could thus be reduced not by substitution, but by doctrinal obsolescence.

However, such a doctrinal and technological transition faces considerable systemic resistance. First of all, it comes up against the inertia of the military-industrial complex. Decades of investment have created an entire ecosystem – supply chains, specialized factories, research centers, human skills – entirely dedicated to the AU sector. As the analysis of disinformation practices points out, « political decision-makers rely on experts from the military-industrial complex » (Barrillot-2001, p. 8), who have every interest in perpetuating this technology by minimizing its dangers. A second major obstacle is the official position of many user states, which demand « irrefutable scientific evidence » of the dangerousness of these weapons before considering a moratorium or ban (Massa-2023, p. 80). This requirement for absolute certainty is a rhetorical strategy that reverses the burden of proof and deliberately ignores the complexity of post-conflict environments, where establishing a direct causal link is almost impossible. This position, as expressed by General Pierre-Marie Gallois, maintains a « scandalous ambiguity » about the real nature of these weapons and their effects (Barrillot-2001, p. 108). Finally, the financial obstacle is immense.

The transition to new technologies represents a colossal cost, not only in research and development, but also in the dismantling of existing sectors and the conversion of infrastructure. The rhetorical question then arises : « Why invest in an area where any risk of pollution and therefore any need for recovery have been excluded ? » (None-2022, p. 244). As long as the risk associated with the AU is officially minimized, the incentive to invest heavily in alternatives remains low.

In the face of these forces of inertia, the main driver of change lies in the rigorous application of the precautionary principle. Born in the 1970s in response to emerging environmental risks, this principle stipulates that « the lack of certainty, taking into account current scientific and technical knowledge, must not delay the adoption of effective and proportionate measures aimed at preventing a risk of serious and irreversible damage to the environment » (Lesna-2004, p. 54).

It imposes a reversal of the logic of expectation and denial, by requiring preventive action in the face of a plausible threat, even if it is not scientifically quantified with certainty. This principle is increasingly supported by an awareness, even within military institutions, of the strategic impacts of environmental degradation.

The experience of past conflicts, such as the Vietnam War, where massive defoliation had a lasting effect on international public opinion, has shown that the environment is no longer a simple theatre of operations, but a political and strategic issue in its own right (Boulanger, 2011, p. 1). Finally, this evolution is part of a broader ethical framework, which questions the very purpose of technological progress.

In the face of techniques whose destructive potential can have irreversible consequences for ecosystems and future generations, thinkers such as Hans Jonas argue for an « ethic of conservation, preservation and impediment, rather than an ethic of progress and improvement » (Leistner, 2023, p. 155). It is not a question of rejecting technology, but of redirecting it towards purposes that take into account the vulnerability of man and his environment.

Ultimately, while technological alternatives to depleted uranium exist and are under development, their effective deployment is conditioned less by an imminent material breakthrough than by a political and strategic will to redefine the criteria of military effectiveness.

The transition from a logic of perforating overpower to a doctrine of stealth and informational intelligence represents the most promising way to make obsolete a technology whose long-term health and environmental costs appear increasingly unsustainable.

Such a development requires moving beyond short-term industrial interests and the rhetoric of scientific doubt to embrace a vision of security that fully integrates intergenerational responsibility and the preservation of living conditions in conflict-affected territories.

7.3 Regulatory efforts and moratorium

Faced with the legal impasse over a formal ban on depleted uranium (AU) weapons and the absence of a specific treaty governing them, the mobilization of civil society and some states has converged towards a more pragmatic and politically achievable goal in the short term : the establishment of a moratorium on their production, transfer and use. This strategy, largely inspired by the success of the international campaign that led to the Ottawa Treaty on anti-personnel mines, aimed to circumvent the complex technical and legal debate on the classification of these weapons as non-conventional (Lesna-2004, p. 53, Lesna-2004, p. 53). Indeed, attempts to bring them within the scope of the 1980 Convention on Certain Conventional Weapons (CCW) or Additional Protocol I of 1977 were met with obstacles of interpretation and the reluctance of the military powers (Massa-2023, p. 27). The moratorium therefore represented a strategic waiting solution, designed to freeze the deployment of these weapons pending a comprehensive and independent assessment of their long-term health and environmental consequences. The aim was to move a controversy initially confined to the scientific and military spheres to the diplomatic field, by creating a political norm of non-use even before the existence of a binding legal prohibition.

In the early 2000s, Europe became the main arena for this debate, catalyzed by the media and political shockwave of the « Balkan syndrome ». In contrast to the « Gulf War syndrome », which had remained relatively circumscribed, the Balkan controversy caused a domino effect on a continental scale, with each NATO member country participating in the operations beginning to worry about the health of its own soldiers. Italy, whose contingents included many potential casualties, assumed a leading role in bringing the issue to the highest institutional level. At the beginning of January 2001, the Italian government officially called on NATO to demand the truth and brought the request for a moratorium to the European authorities (Lesna-2004, p. 26). This approach has created a political fissure within the Atlantic Alliance itself, transforming a health crisis into an issue of trust and transparency between allies.

The then President of the European Commission, Romano Prodi, supported this approach by referring to a formal ban if the risks were proven and by convening a committee of experts to assess the situation (Lesna-2004, p. 26).

The most significant action, however, came from the European Parliament which, acting as the political conscience of the continent, quickly adopted a resolution calling for a moratorium. Although non-binding, this act had considerable symbolic weight, as it aligned a major democratic institution with the main demand of NGOs and increased pressure on national executives and NATO bodies (Lesna-2004, p. 26).

The argument in favour of a moratorium has largely and almost exclusively revolved around the precautionary principle. This principle, which originated in environmental law in the 1970s and was enshrined in France by the Barnier Law of 1995, stipulates that « the lack of certainty, taking into account the scientific and technical knowledge of the moment, must not delay the adoption of effective and proportionate measures aimed at preventing a risk of serious and irreversible damage » (Lesna-2004, p. 54, Lesna-2004, p. 54). In the face of continued scientific uncertainty about the low-dose genotoxic and radiological effects of AU, proponents of a suspension argued that inaction was not an option. According to this logic, the mere suspicion of serious and irreversible damage to the health of civilians and soldiers, as well as to the environment, justified the cessation of the use of these weapons (Lesna-2004, p. 55). Political figures, such as MEP Paul Lannoye, have explicitly described NATO's rejection of the Italian proposal as a decision « contrary to the precautionary principle » (Lesna-2004, p. 55, Lesna-2004, p. 55). The invocation of this principle was a radical conceptual maneuver, as it aimed to apply it to the military domain, a field traditionally governed by the calculation of risk and operational necessity rather than by the anticipation of deferred and uncertain damage.

This amounted to reversing the burden of proof : it was no longer up to the victims to irrefutably demonstrate the harmfulness of the weapon, but to its users to guarantee its long-term harmlessness, a requirement that was almost impossible to meet. However, the approach raised the paradoxes inherent in this principle, which, as Philippe Mongin points out, « encourages us to modify causes that we admit may not be the right ones, in order to prevent effects that we do not know how to decide whether they are harmful or not » (Lesna-2004, p. 56, Lesna-2004, p. 56).

This political and ethical dynamic, however, was met with strong resistance from military powers and defence institutions, determined to preserve what they saw as a major technological advantage. NATO, although forced by political pressure to set up a special study committee to regain damaged credibility, firmly rejected Italy's request for a moratorium (Lesna-2004, p. 26). To justify its refusal, the Alliance put forward the argument of a « de facto moratorium », arguing that a formal ban was unnecessary since these munitions were not being used at the time of the debate. This rhetorical maneuver made it possible to dodge the substantive issue and avoid creating a binding precedent that would limit the future freedom of action of its members. Similarly, possessor states such as France have adopted an ambiguous but revealing position. While affirming that they did not use their stockpiles of weapons at the AU, the French authorities declared themselves « hostile to a moratorium on their use » (Lesna-2004, p. 26). This posture illustrates the strategic desire not to give up a military capability considered effective and economical, despite the controversies. The resistance of these actors was part of a broader communication strategy, described as « disinformation » by its critics, aimed at declassifying the AU from the category of nuclear materials and minimizing its risks by insisting on the reassuring qualifier of « impoverished » (Barrillot-2001, p. 8). The rejection of the moratorium was therefore an essential political act to maintain the « discursive shield » protecting the weapon of any regulation. The refusal of the main military powers thus paralysed any concrete progress within the Atlantic Alliance and the Council of the European Union, which postponed its decision pending the results of the work of the various international organisations (Lesna-2004, p. 26).

The relative failure at the European level and within NATO helped shift the centre of gravity of the debate to the United Nations, providing a global platform where the voices of non-users and affected countries could be heard with greater weight. Beginning in 2007, a coalition of States, led by the Non-Aligned Movement, succeeded in having several successive resolutions adopted by the First Committee (Disarmament and International Security) and the United Nations General Assembly. Resolution A/RES/62/30 of 2007 was the first of many, adopted by a large majority despite the opposition of the main user States (the United States, the United Kingdom, France, Israel). Although not legally binding, these resolutions have considerable political and normative significance. They formally acknowledge the « serious concerns » of the international community regarding the potential health and environmental impacts of the AU (Massa-2023, p. 80). In addition, they call on States that have used these weapons to provide the Governments of the affected countries with detailed information on strike zones, in order to facilitate risk assessments and decontamination operations. By institutionalizing the debate at the highest multilateral level, these resolutions have permanently placed the issue on the international disarmament agenda, increasing the reputational and political cost associated with the use of these weapons and contributing to the progressive construction of a non-use norm (Massa-2023, p. 63).

Despite these significant diplomatic advances, regulatory efforts are coming up against a fundamental contradiction that maintains a precarious status quo. On the one hand, the precautionary principle is invoked to justify preventive action in the face of scientific uncertainty. On the other hand, opponents of any form of binding regulation continue to demand « irrefutable scientific evidence » of the dangerousness of these weapons, a probationary threshold that is particularly difficult, if not impossible, to reach in the chaotic conditions of post-conflict contexts.

This requirement is implicitly present at the very heart of the institutions that have been the most critical. A 2008 European Parliament resolution, for example, while declaring itself in favour of a ban, conditions the development of an international treaty on the assumption « where there is irrefutable scientific evidence of the dangerousness of these weapons » (Massa-2023, p. 80). This restrictive clause, which echoes the arguments of the user states, partly empties the resolution of its political significance and illustrates the lame compromise between the pressure of public opinion and strategic imperatives. The result is an epistemological and political impasse : science, instead of being a neutral arbiter, has become a battlefield where the absence of certainty is instrumentalized to justify inaction. In conclusion, although the international mobilization has succeeded in imposing a lasting political stigmatization of weapons on the AU and in making the moratorium a central objective of the disarmament debate, its translation into a binding legal norm remains paralyzed by this « battle of expertise » and by the inflexible resistance of states that intend to keep this technology in their arsenals.

Conclusion

At the end of this study, this concluding chapter synthesizes the results of this thesis and provides a substantiated response to the central issue : the examination of the use of depleted uranium (DU) weapons in global conflicts, their multidimensional impacts and the controversies they generate, with a view to formulating recommendations for responsible management. This approach required an interdisciplinary approach, combining technical, environmental, legal and geopolitical analysis to grasp the object in all its complexity and understand the mechanisms that perpetuate its deployment despite a growing awareness of the risks.

The analysis demonstrated that the persistent use of such munitions is the result of a dialectical tension between the tactical effectiveness claimed by the user States and the toxic and lasting legacy they impose on territories and populations. This persistence is fostered by a rhetoric of declassification which, by presenting DU as a conventional technology, has served to mask the scope of its long-term effects (Barrillot-2001, p. 8). This maintained opacity, coupled with the recurrent demand for "irrefutable scientific evidence" of their dangerousness, has created a normative grey area. This results in an ambiguity that undermines the fundamental principles of international humanitarian law, including the

prohibition of superfluous harm and the distinction between combatants and civilians. Indeed, the thresholds of « widespread, lasting and serious » damage provided for in instruments such as Additional Protocol I are proving difficult to invoke conclusively, leaving these weapons in a situation of disputed but unresolved legality.

To articulate the final answer to our problem, this conclusion is organized into two interdependent parts. The first section, « Synthesis of findings », consolidates the main findings relating to the properties of the AU, the severity of the environmental contamination that transforms battlefields into post-conflict sacrifice zones, the scientific uncertainties fuelling a lasting controversy over the preponderance of chemical or radiological risks, the complexity of the ethical-legal debates, and the geopolitical dynamics that explain the continuity of their use, in particular the strategic and industrial interests of the producing States (Lesna-2004, p. 82). This synthesis draws up an exhaustive assessment of the short- and long-term consequences of these armaments.

Based on this diagnosis, the second section, « Future Perspectives », adopts a forward-looking approach. It explores the levers of action to overcome institutional inertia, by assessing the potential of regulatory efforts, the relevance of the precautionary principle (Barrillot-2001, p. 10) as an ethical and legal tool to reverse the burden of proof, and the viability of technological alternatives that challenge the argument of military necessity. Recalling that the environment is not an abstraction but the living space on which the health of present and future generations depends (Massa-2023, p. 3), this final part completes the analytical approach of this thesis by outlining realistic courses of action and highlighting the responsibilities incumbent on the international community in the face of this toxic legacy of modern warfare.

8.1 Future Prospects

Far from being a technological fate or a mere footnote in military history, the future of depleted uranium (DU) weapons acts as a revealing test for the international community's ability to manage the complex and delayed risks of its own innovations. Based on the synthesis of the systemic blockages and the recommendations made, it is possible to outline three prospective and interdependent trajectories that will structure the future of this controversy : a normative and ethical maturation, a potential technological obsolescence, and a societal battle for memory and transparency.

The first perspective, undoubtedly the most fundamental, concerns the evolution of the normative and ethical framework. Faced with the « legal grey area » that allowed the use of these weapons, one of the most likely, albeit slow, developments lies in the shift in the paradigm of evidence. It will be a question of moving beyond the requirement of irrefutable scientific proof of danger – a methodological impasse that, as the analysis has shown, is instrumentalized to promote inaction – to robustly integrate the precautionary principle into the law of armed conflict. This transition, which implies a reversal of the burden of proof, is rooted in an ethical maturation for which Hans Jonas' « heuristic of fear » provides a philosophical framework : not a paralyzing fear, but a rational cognitive tool that requires anticipating the worst-case scenario in the face of a technology with potentially serious and irreversible effects (Leistner, 2023, pp. 155 and 156). This trajectory finds a powerful echo in the recognition that « the environment is not an abstraction, but the space on which human beings live and on which the quality of their lives and their health depend, including for generations to come » (Massa-2023, p. 3). This statement by the International Court of Justice is not only declaratory ; it foreshadows a legal and moral obligation that challenges the primacy of short-term military necessity over long-term environmental viability. The issue of the AU could thus catalyze a convergence between international humanitarian law and environmental law, by enshrining the responsibility of States not only towards contemporary populations, but also towards those who will inherit land that has been durably contaminated.

The second trajectory is that of technological and strategic obsolescence. Beyond the normative framework alone, the gradual abandonment of the AU will depend on its loss of relevance on the battlefield. This development could follow two complementary paths : on the one hand, the research and development of direct alternatives, such as tungsten alloys ; on the other hand, and in a more structural way, an evolution of military doctrines themselves. Investment in stealth, networked warfare, artificial intelligence, and precision munitions capabilities could make the raw confrontation between armor increasingly anachronistic. If tomorrow's war relies less on the ability to pierce at all costs and more on information and the avoidance of direct contact, the AU's tactical advantage will naturally erode. This perspective, however, represents a direct challenge to the economic rationality and inertia of the military-industrial complex, which has transformed nuclear waste into a strategic resource (Barrillot-2001, p. 8). « Technology lock-in » is reinforced by established supply chains, entrenched doctrines, and an economic symbiosis between the civilian and military nuclear industries. The future will therefore depend on a clear political choice : to maintain this advantageous status quo in the short term or to actively invest in a paradigm shift that would render the AU obsolete, both technically and doctrinally.

The third perspective, finally, is societal and informational. The AU leaves a toxic legacy, turning conflict zones into « ecological time bombs » (None-2022, p. 244). The major challenge of the coming decades will be to fight against societal and institutional « forgetting » (None-2022, p. 249), once the media controversy, which is often cyclical and superficial, has dissipated (Lesna-2004, p. 70). This forgetfulness is all the more likely because the danger, after the conflict, becomes an « invisible threat » (Lesna-2004, p. 75) that spreads silently in the soil, water and food chain. Continued attention and action will depend on the vitality of civil society, veterans' associations, investigative journalism and democratic parliamentary oversight.

Their role is essential in countering the depoliticization of the debate, where the question is deliberately presented as purely « technical » in order to exclude the citizen (Barrillot-2001, p. 8). The future will require the establishment of sustainable structures, such as the recommended independent international observatory, capable of maintaining long-term monitoring and building institutional memory. This battle for transparency and against amnesia is crucial, as it conditions the implementation of any remedial policy and ensures that the perennial imprint (Leistner, 2023, p. 8) left by these weapons on the environment and bodies is not erased from the collective consciousness.

Ultimately, the prospects for depleted uranium transcend the question of a simple munition to question our model of society. They raise the fundamental question of the justification of the military risk when its consequences are dispersed over civilian populations and future generations who derive no direct benefit from it and for whom the military interest is difficult to accept (Lesna-2004, p. 82). The history of the AU is one of a technological choice whose implications go beyond its designers, blurring the boundaries between the time of war and that of peace, and confirming the feeling that today, war « is no longer possible by any means » (Lesna-2004, p. 82). The trade-off between short-term tactical effectiveness and long-term ethical, health and environmental responsibility remains open ; The responses to these will determine not only the fate of these weapons, but also the contours of a more just and sustainable international security.

8.2 Synthesis of Findings

At the end of this multidimensional analysis, it appears that depleted uranium (DU) weapons go far beyond the status of a simple technological innovation in the anti-armour arsenal. They embody a paradigmatic issue of contemporary conflicts, crystallizing the fundamental tensions between short-term military effectiveness and long-term environmental and health responsibility. Far from being a purely technical subject confined to expert circles, the AU has proven to be a powerful analyzer of the limits of our scientific, legal and ethical frameworks in the face of the diffuse, perennial and uncertain consequences of modern warfare.

The synthesis of the results of this research is based on three interdependent and hierarchical conclusions : first, it highlights the intrinsically paradoxical nature of the weapon, whose performance is the very source of its harmfulness ; it then analyzes the central role of scientific uncertainty as a political battlefield and a power issue; and it finally demonstrates the existence of a robust and self-sustaining system that ensures its continued use despite decades of controversy.

The analysis first highlighted the fundamental duality of the AU, whose tactical assets are inseparable from its toxic legacy. This is not an unfortunate side effect, but a direct and inevitable consequence of his physical makeup. The two properties that give it a greater penetration capacity than its main competitor, tungsten, are precisely those that generate its long-term threat. Its very high density, which concentrates maximum kinetic energy on a point of minimal impact, and its adiabatic shear behavior, which allows it to self-sharpen by passing through the shield, are also the mechanisms that cause the indenter to fragment into an aerosol of microscopic particles. Its pyrophoric character, which adds a devastating incendiary effect inside the target, simultaneously ensures the oxidation of these particles, making them more easily breathable and biologically assimilable. This contamination, as case studies from the Balkans to Iraq have demonstrated, is not limited to the intended military objective, nor to the battlefield, nor even to the duration of hostilities (Leistner, 2023, p. 12). The aerosol is deposited over large areas, infiltrates the soil and groundwater, and leaves a « lasting imprint » (Leistner, 2023, p. 8) that permanently contaminates the food chain. This results in a chronic health risk for civilian populations and peacekeeping forces, including proven nephrotoxicity due to its chemical toxicity of heavy metal (Gueguen Rouas, 2012, p. 2, Gueguen Rouas, 2012, p. 11).

Thus, the AU is transforming post-conflict territories into « ecological time bombs » (None-2022, p. 244), profoundly altering the relationship of societies to their environment, no longer perceived as a living space, but as a potential and invisible source of danger (Leistner, 2023, p. 180). As a result, this weapon blurs the cardinal distinctions of humanitarian law : between military objective and civilian good, between combatant and non-combatant, and above all between the time of war and that of peace, the conflict protracted in chemical and radiological form for decades.

Second, this research has shown that the heart of the controversy lies not so much in stabilized scientific knowledge as in the management and strategic instrumentalization of uncertainty. The debate on the dangerousness of the AU has become a political battlefield where doubt is not a gap to be filled but a resource to be exploited. On the one hand, user states and military institutions have systematized a rhetoric of « unproven risk. » They rely on the lack of irrefutable epidemiological evidence causally linking DU exposure to specific pathologies, a posture favored by the methodological complexity inherent in multi-toxic post-conflict environments, where it is almost impossible to isolate a single causal factor. This strategy comes up against the principle of « impossible refutation »: a statistician can never prove the non-existence of a risk, only his inability to observe it under the conditions of the study, an epistemological limit that is politically transformed into proof of harmlessness. This position is reinforced by obvious institutional biases, as illustrated by the inaction of the World Health Organization, whose work has been criticized for its bias, relying on a selection of literature from sources affiliated with the Pentagon while minimizing the radiological dimension under the influence of the IAEA (Parsons-2002, p. 4). On the other hand, civil society, veterans' associations and local populations are mobilizing testimonies, bundles of presumptions and preliminary studies to demand the application of the precautionary principle.

This polarization, amplified by media that focus on the dramaturgy of the controversy before losing interest in the scientific results, which are often nuanced and complex (Lesna-2004, p. 70), leads to an erosion of public trust in a science perceived as « incapable of offering a solution that wins the support of all ». Faced with this emptiness, this thesis underlined the relevance of ethical frameworks, such as Hans Jonas' « heuristic of fear », which does not advocate a paralyzing fear but a rational cognitive tool : the anticipation of the worst-case scenario, even if uncertain, must become a guide for moral and preventive action in the face of a technology with potentially serious and irreversible effects (Leistner, 20233, pp. 155 and 156).

Finally, the continued use of weapons in the AU is neither the result of chance nor of mere inertia, but the result of an interdependent, powerful and remarkably resilient system. The analysis revealed a « lock-in » based on three mutually reinforcing pillars. The first is military rationality, which values immediate tactical superiority and the protection of forces on the battlefield to the detriment of deferred environmental and health considerations. The second pillar, and undoubtedly the most structuring, is an implacable economic logic that operates an almost alchemical transformation : it converts abundant nuclear waste, the long-term management of which represents an environmental constraint and a colossal financial burden, into a strategic and almost free raw material for the military-industrial complex.

This symbiosis between the civil and military nuclear industry is supported by a communication strategy that aims to semantically downgrade AU from the category of nuclear materials among political decision-makers, by insisting on the term « impoverished » to conceal its uranic nature (Barrillot-2001, p. 8). This convergence of interests makes any truly independent research on the subject extremely difficult, caught between the armaments and nuclear lobbies (Mathieu Matieu, 2001, p. 2).

The third pillar is a « legal grey area » where the fundamental principles of international humanitarian law are found to be inadequate or unenforceable. The principle of proportionality becomes inoperative when it is impossible to assess collateral damage that will manifest itself decades after the conflict. The ban on weapons causing « superfluous harm » is circumvented by arguing that toxicity is not the main mode of action of the weapon.

As for specific environmental protections, such as Additional Protocol I, their trigger threshold (« extensive, long-lasting AND serious » damage) is so high that it makes their application almost illusory, creating a normative vacuum that benefits user states (Massa-2023, p. 8).

The case studies, from the Gulf War to Ukraine, have illustrated the solidity and adaptability of this system, which is evolving from a strategy of initial denial in the face of the « Gulf syndrome » to a trivialization of its use in Iraq and its recent instrumentalization in the information war.

In short, this brief has demonstrated that the issue of depleted uranium reveals a profound dissonance between the strategic logic of States and the right of populations, including future generations, to live in a healthy environment, as the International Court of Justice reminds us (Massa-2023, p. 3). The debate, falsely presented as a technique in order to exclude the citizen, is eminently political.

It questions the very justification of a risk whose tactical benefits are concentrated in the hands of the armed forces, while the health and ecological disadvantages are dispersed over territories and populations that have not consented to them and for whom this military interest is difficult to perceive or accept (Lesna-2004, p. 82).

The history of the AU is that of a technological choice whose consequences go far beyond its designers, raising the fundamental question of how to take into account military risks within democratic societies and the possibility of a war that is no longer waged « by all means » (Lesna-2004, p. 82).

It is, in short, a warning against the illusion of a « clean » technological war whose real costs can be externalized in time and space, on the bodies and lands of others...

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May this work remain a humble testimony, a modest contribution to information and reflection.

"Let us be wary of those who *today* present themselves as rigorous managers for *tomorrow* when we have to face their catastrophic lack of foresight yesterday."
Thierry LAMIREAU / press conference in Limoges
(Haute-Vienne / France) in 1993.

Completed on August 26, 2025.
Original text in French
Memory translated by artificial intelligence.

Work carried out by Thierry LAMIREAU
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