HERBIDICAL WARFARE AND ITS EFFECT ON HUMAN HEALTH: A STUDY IN THE LIGHT OF THE VIETNAM WAR

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ABSTRACT

Operation Ranch Hand. A large-scale operation that took place for nearly 10 years by the US Military during the Vietnam War. 20 million gallons of herbicides were sprayed over the vegetation of South Vietnam in order to deprive off the people residing in this part of Vietnam. Nearly 500,000 acres of crops were damaged by this Herbicide spraying, which in turn affected the health of the people who came in contact with the herbicide. While it did kill a huge amount of people, it left the remaining survivors of that region with numerous health issues and major ecological damages. The question that was debated here was whether this use of such herbicides, specifically Agent Orange, a violation of Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases, and of Bacteriological Methods of Warfare also known as Geneva Protocol. Later on, few more Treaties were signed, like the Environmental Modification Convention, which prohibits the usage of any techniques that modifies the environment. Through this paper, the author aims to analyse the effect of these herbicides on the health of the people residing in those areas, while also analysing the various Treaties enforced after this Operation and their effectiveness in prohibiting Chemical Warfare.

Keywords: Operation Ranch Hand, Agent Orange, Vietnam War, Treaties, Geneva Protocol, Environmental Modification Convention, Environmental Effect.

1. Introduction

In simple terms, War is a fight fought between the leader of the "Great Powers" to determine who is the greater power, while completely disregarding the consequences of this fight. At the end, it is the civilians who end up comprising the majority number of victims, with the soldiers coming down to a close second. At the end of the war, most casualties are the civilians *who did not* participate in the war, and the soldiers *who had to* participate in the war. Not only does a war wipe out human life in general, but it also wipes out other forms of life and necessities and every other infrastructure that facilitates quick access to these necessities. At the end of a war, one may find a tremendous damage to healthcare facilities, food manufacturing units, water systems, sanitation system, property, and agriculture. Damage to agriculture can be one of the cruellest consequences of the war, if we were to put aside the crimes committed directly against human beings, example the human experiments conducted by the Japanese and German military forces at China and Nazi Germany respectively.

Before we delve into herbicidal warfare and its impact, we need to understand the different types of weapons that exist now. Earlier, we only had those physical weapons, ammunitions, if we were to use a better term. But now, over the years of scientific development, we now have biological weapons, as well as, chemical weapons. According to the Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapon can be any chemical compound intended as a weapon "or its precursor that can cause death, injury, temporary incapacitation or sensory irritation through its chemical action". Chemical weapons are classified as weapons of mass destruction (WMD). This is so because the distinction between conventional weapons and weapons of mass destruction (WMD) lies primarily in the mechanics of their lethality and their inherent lack of precision. Conventional weapons, such as bullets, missiles, and bombs, rely on kinetic energy such as the physical impact of a projectile, explosive, or incendiary effects to neutralize a specific target. Because these forces are physical and generally localized, their damage is relatively predictable. In contrast, according to the United Nations Office for Disarmament Affairs (UNODA), weapons of mass destruction are defined by their ability to cause "indiscriminate" harm on a massive scale. Their impact is not measured by the precision of the strike, but by the widespread biological or environmental contamination they leave behind, which often makes it impossible to distinguish between combatants and

civilians[1].

Chemical weapons are a particularly volatile subset of WMDs because they utilize the toxic properties of chemical substances to incapacitate or kill, rather than relying on an explosion. As highlighted by the Organisation for the Prohibition of Chemical Weapons (OPCW), these agents are exceptionally dangerous because they can be dispersed as gases, liquid droplets, or solid aerosols. This fluidity allows them to bypass traditional physical defense; a gas cloud can drift with the wind into bunkers, ventilation systems, or civilian housing miles away from the initial impact zone. Because many agents like Sarin or VX are colourless and odourless, they can be inhaled or absorbed through the skin before the victim is even aware of the threat.

Now, let us try to understand what is Herbicidal Warfare. Herbicidal warfare is the military use of plant-killing chemicals (herbicides/defoliants) to destroy enemy crops or vegetation for cover, famously exemplified by the U.S. Operation Ranch Hand in the Vietnam War using Agent Orange to defoliate forests and deny food. It is now internationally banned by the Environmental Modification Convention (ENMOD) for its severe, long-term ecological damage, health effects from contaminants like dioxins, and disruption of food security. Normally, the opponent nation deploys the use of herbicides or any other chemical substance in order to cease the agricultural production in the nation or, to destroy every other plant that might aid the soldiers in creating a hide out. But what they missed was how harmful this herbicide is or how they have a long-term negative impact on, not only the environment but also the people. While the nations that have till date used the herbicide have claimed that their intention was to – 1) stop agricultural production, or 2) destroy plants so that the soldiers couldn't hide – and, not create a harmful, toxic environment for the civilians. These herbicides have caused multiple health issues in the civilians, which have then passed down generation to generation, or may have even caused death. The civilians either consume the whatever salvageable food crops that are laced with the toxic herbicide and fall ill, or the herbicide percolates down the soil, into the ground water hence poisoning the ground water.

While the research for creating such herbicide began during the second world war, it was not until the Malayan Emergency that Great Britain put into use this herbicide. Their goal

[1] Disarmament. United Nations. https://www.un.org/en/global-issues/disarmament

was to target the food crops, which was a part of their starvation campaign. Great Britain became the first nation to use an herbicide in a war, hence the herbicide that they used- 'Agent Orange' became a popular name amongst the world of herbicidal warfare and since been used a few times in various wars, like the Vietnam War.

The 1925 Geneva Protocol and the subsequent Chemical Weapons Convention were established specifically to address this horror, recognizing that the invisible, drifting, and lingering nature of chemical toxicity makes these weapons fundamentally different and far more unpredictable than any conventional tool of war.

1.1 Agent Orange

The nomenclature "Agent Orange" was derived solely from the identifying stripe painted on the 55-gallon drums used for storage. Chemically, Agent Orange was a mixture composed of approximately equal parts of two phenoxy herbicides: 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). While these base herbicides have relatively short half-lives, breaking down within hours or days when exposed to sunlight if not chemically bound to biological surfaces, the devastating long-term impact was caused by an unwanted contaminant.

1.2 Vietnam War

While wars in general are long, tedious, and painful, Vietnam war in itself continued for nearly 20 years with a direct involvement from United States of America, traces of whose involvement can be found in every conflict that exists till date. In the Vietnam war, Vietnam was divided into two parts – North Vietnam and South Vietnam. North Vietnam was supported by the communist nations, while South Vietnam was supported by United States of America, South Korea, Australia, and every other non-communist nation. It was during this Vietnam war that the United States of America deployed the usage of Agent Orange and other emollients in South Vietnam. According to the United States Defence Department, the herbicide was used to destroy the vegetation that was providing a hiding space for the Viet Cong, and also to destroy the agriculture that was providing food to the Viet Cong. What they missed out was the ever-lasting effect it is going to leave on the areas and the uninvolved civilians of South Vietnam. Vietnam claims that 3 million Vietnamese people were affected by this Agent Orange, which has left them with birth

defects or other health related illnesses[2]. The herbicide Agent Orange was laced with Dioxin, specifically the compound 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). TCDD is a known human carcinogen and a persistent organic pollutant linked to various severe health issues, including cancers and birth defects.

2. Research Questions

1. Whether the use of herbicides in warfare, a violation of Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases, and of Bacteriological Methods of Warfare?

2. Whether a complete ban was imposed on the usage of herbicides in Warfare by the Environmental Modification Convention?

3. Effect of Agent Orange on the people

2.1 Health Effects in U.S. Veterans

U.S. Department of Veterans Affairs regulations recognise numerous presumptive conditions for veterans exposed to Agent Orange, so that service connection is legally presumed without requiring individual causation proof. These include AL amyloidosis, ischemic heart disease, type 2 diabetes mellitus, Parkinson's disease, early-onset peripheral neuropathy, and dermatological conditions such as chloracne or similar acneiform disease.

In addition, VA's Agent Orange list encompasses multiple haematological and solid-organ malignancies, such as chronic B-cell leukaemia, Hodgkin's disease, non-Hodgkin's lymphoma, multiple myeloma, prostate cancer, and respiratory cancers of the lung, bronchus, larynx and trachea. The presumptive framework thus converts contested toxicological and epidemiological evidence into enforceable entitlements within veterans' benefits law.

Honoring our Promise to Address Comprehensive Toxics (PACT) Act 2022 substantially expanded VA healthcare eligibility and disability benefits for veterans exposed to toxic substances, explicitly including Agent Orange. Section 404 of the Act added hypertension (high blood pressure) and monoclonal gammopathy of undetermined significance (MGUS) to

[2]Agent Orange still haunts Vietnam, US. (2007, June 14). https://www.washingtonpost.com/wp-dyn/content/article/2007/06/14/AR2007061401077_4.html

the statutory list of diseases associated with herbicide exposure.

2.2 Impact on the People of Vietnam

The human toll in Vietnam vastly exceeds that experienced by U.S. personnel, given the nature of civilian environmental exposure. The Vietnamese government estimates that up to 4 million people were exposed to the defoliant, with as many as 3 million suffering illness or disability, including congenital disabilities[3].

Red Cross of Vietnam claimed that 1 million people in Vietnam have disabilities due to these toxins[4]. After the War, a study was conducted to understand how the herbicide affected the citizens. The study found high levels of dioxin in the blood samples of all citizens residing in that particular area of Bien Hoa[5]. These blood samples were collected in 1999, that is nearly 30 years after the War. Studies have also found that this exposure to dioxin has been related to cases of Spina bifida in new-born children. Many civilians residing in South Vietnam immigrated to Cambodia and Laos after the war. These immigrated Vietnamese citizens suffered the side effects of Dioxin too. They suffered miscarriages, fatigue, monstrous births, eye and skin reactions, gastrointestinal ailments.

While U.S. studies often focus on acute, paternal exposure experienced by male veterans, the Vietnamese civilian population, especially women and children living near hotspots, face chronic environmental and maternal exposure[6]. Studies show that high levels of dioxin persist in the serum of men and the breast milk of women in sprayed regions decades after the war, sometimes several times higher than in non-sprayed areas[7].

[3] Agent Orange Still Killing in Vietnam. Vietnam Women's Union. (n.d.). https://vwu.vn/tin-chi-tiet/-/chi-tiet/agent-orange-still-killing-in-vietnam-10436-601.html
[4] King, J. U.S. in first effort to clean up Agent Orange in Vietnam. CNN World. https://edition.cnn.com/2012/08/10/world/asia/vietnam-us-agent-orange/
[5]Schecter, Arnold MD, MPH; Cao Dai, Le MD; Päpke, Olaf MS; Prange, Joelle MS; Constable, John D. MD; Matsuda, Muneaki PhD; Duc Thao, Vu PhD; Piskac, Amanda L. MPH. Recent Dioxin Contamination From Agent Orange in Residents of a Southern Vietnam City. Journal of Occupational and Environmental Medicine 43(5):p 435-443, May 2001.
[6] Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides (Ninth Biennial Update); Board on the Health of Select Populations; Institute of Medicine. Veterans and Agent Orange: Update 2012. Washington (DC): National Academies Press (US); 2014 Mar 6. 6, Epidemiologic Studies: Background on Multiply Referenced Populations.
[7] Nishijo, M., Vu, H. T., Pham-The, T., Pham, T. N., Tran, N. N., Nakagawa, H., & Nishijo, H. (2022). Dioxin Congener Patterns in Breast Milk Samples from Areas Sprayed with Herbicide during the Vietnam War 40 Years after the War Ended. Toxics, 10(6), 323. https://doi.org/10.3390/toxics10060323

One may question as to has the United States of America accepted their fault, or who is to be blamed for this situation the people of Vietnam are in. One may also question as to how the civilians come in contact with the herbicide and the toxin dioxin. It is simple – No one is to be blamed, specially not the "Developed" nations. US military sprayed it as a way of affecting the visibility, the civilians inhaled it. And the rest of the herbicide sprayed on land was absorbed by the soil which then mixed with the river, hence polluting the river. Fishes and other organisms like ducks consume this water hence consuming the toxins, who are then consumed by the civilians.

One of the bigger problems posed by Agent Orange is how long its most toxic ingredient—TCDD—remains in the environment. The two main herbicide chemicals used to make Agent Orange (2,4-D and 2,4,5-T) break down quickly, but TCDD does not. Its chemical structure allows it to stay locked into soil for decades, sometimes even centuries. This problem is worse in areas with wet or waterlogged soils, such as rice fields and wetlands, because TCDD breaks down much more slowly under these conditions.

At former U.S. military bases in Vietnam, contamination levels remain extremely high. For example, soil samples from Bien Hoa Air Base in 1999 contained TCDD levels as high as 1,164,699 picograms per gram of soil—an extraordinarily dangerous concentration[8]. Even samples collected outside the base in 2004 showed contamination up to 46 times above normal soil levels.[9] These are far beyond any safe limits and require active cleanup and environmental restoration. Although some bacteria can naturally break down dioxins through certain enzymes, natural processes alone are far too slow to deal with the massive scale of pollution caused by Agent Orange.

4. Treaties and Conventions Regarding Ecological Warfare and Conservation of the Environment

The use of chemical weapons in international armed conflicts is prohibited under international humanitarian law by the 1925 Geneva Protocol and the Hague Conventions of 1899 and 1907.

[8] Morton, L. and Culbertson, C. (2022) Persistence of Dioxin TCDD in Southern Vietnam Soil and Water Environments and Maternal Exposure Pathways with Potential Consequences on Congenital Heart Disease Prevalence in Vietnam. Open Journal of Soil Science, 12, 119-150. doi: 10.4236/ojss.2022.124005.
[9] Mai, Tuan & Doan, Thanh & Tarradellas, Joseph & de Alencastro, Luiz & Grandjean, Dominique. (2007). Dioxin contamination in soils of Southern Vietnam. Chemosphere. 67. 1802-7. 10.1016/j.chemosphere.2006.05.086.

We have multiple treaties that put a bar on the usage of gases or any other substances that is harmful, but time and again, Nations have ignored this.

We have the **Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases, and of Bacteriological Methods of Warfare (Geneva Protocol)**[10], which is a general provision on chemical and biological weapons, but it is completely silent on transfer, production and storage of these weapons. A number of countries submitted reservations when becoming parties to the Geneva Protocol, declaring that they only regarded the non-use obligations as applying to other parties and that these obligations would cease to apply if the prohibited weapons were used against them. This Protocol is now considered an important part of the International Customary Law.

Later on, the **Biological Weapon Convention**[11] was signed which prohibited the development, production, acquisition, transfer, stockpiling and use of biological and toxic weapons. While this Convention is one of the strongest arms control treaties, its effectiveness has been limited due to insufficient support and the absence of any formal verification regime to monitor the compliance of the States to the norms of the Convention.

Environmental Modification Convention (ENMOD) [12]was also signed to prohibit the military or other hostile use of environmental modification techniques having widespread, long-lasting, or severe effects. This Convention was brought up in order to prohibit geophysical alteration of the environment. Currently, this Convention focuses on prohibiting the usage of any form of substance that would alter the climate the geological or environmental aspects of the land. But, this Convention is practically a Toothless Tiger, for it requires UN Security Council enforcement, which the permanent members can always veto.

A complete ban on the usage of herbicides was not implemented by the Environmental Modification Convention (ENMOD). According to ENMOD Convention, "Each State Party to this convention undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of

[10] Protocol for the Prohibition of the Use of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare. Geneva, 17 June 1925
[11] Biological Weapons Convention (BWC), or Biological and Toxin Weapons Convention (BTWC), 1975
[12] Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, 1977

destruction, damage or injury to any other State Party."[13] Article II of the 1976 ENMOD Convention provides that As used in article I, the term "environmental modification techniques" refers to any technique for changing – through the deliberate manipulation of natural processes – the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space.[14] This Convention does not implement a complete ban for if we go through the document, we can find that many State parties stand by the fact that the Geneva Protocol or the Chemical Weapons Convention do not explicitly prohibit the Military from using herbicides, what it prohibits is the usage of asphyxiating and poisonous gases. If we were to go through Article 1 and 2, we find that the Convention prohibits the usage of any substance that alters the weather of that particular area but no where mentions that the military cannot use herbicides in war. While the USA has renounced the first-hand use of Herbicides in war, it still stands by the fact that they can use herbicides in war if the usage is authorized by the President of USA or their delegate.[15]

We also have the **Convention on Biological Diversity**[16], that has three main goals: the conservation of biological diversity (or biodiversity); the sustainable use of its components; and the fair and equitable sharing of benefits arising from genetic resources. Now, one may question as to how this particular Convention is related to the matter at present. Environment, the organisms, all constitute the biodiversity of an area. If the environment in itself is suffering from the aftermath of two decades long war and its remnants left behind as ailments, biodiversity is affected in large. The protection of biodiversity is related to the prohibition of use and production and storage of these herbicides and other toxins. Hence, unless a complete ban is implemented on the nations regarding the usage of these herbicides as a form of weapon, the biodiversity is in danger. Environmental Modification Convention came into existence after the 31/72 United Nations General assembly resolution was passed. The Convention aims to prohibit the military or other hostile use of environmental modification techniques that have widespread, long-lasting, or severe effects.

We also have **The International Union for Conservation of Nature**, an international organisation working in the field of nature conservation. According to this organisation, the

[13] Article I(1) of the 1976 ENMOD Convention
[14] https://ihl-databases.icrc.org/customary-ihl/eng/docs/v2_rul_rule76
[15] The US Operational Law Handbook (1993); The US Naval Handbook (1995)
[16] Convention on Biological Diversity (CBD), 1993

ecological damage to Vietnam is something that cannot be repaired or salvaged.

Chemical Weapons Convention or, also known as the **Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction**, is an arms treaty Convention and address the production, storage and usage of chemical substances as weapons, which the Geneva Protocol had initially missed out on. This Treaty prohibits the large-scale use, development, production, stockpiling and transfer of chemical weapons and their precursors, except for very limited purposes (research, medical, pharmaceutical or protective). The main obligation of member states under the convention is to affect this prohibition, as well as the destruction of all current chemical weapons. All destruction activities must take place under OPCW verification. OPCW, or the Organisation for the Prohibition of Chemical Weapons, with 193 member states, is the body that implements the Chemical Weapons Convention. The OPCW conducts routine inspections of declared chemical facilities, challenge inspections when violations are suspected (requiring a 3/4 majority vote), and investigations into alleged chemical weapon use. Importantly, the OPCW has verification power but not enforcement power—it reports findings to member states, but cannot impose penalties.

For example, In September 2013, Syria acceded to the convention as part of an agreement for the destruction of Syria's chemical weapons. There are some chemicals which have been used extensively in warfare but have numerous large-scale industrial uses are highly regulated; however, certain exceptions do exist. Chlorine gas is highly toxic but being a pure element and extremely widely used for peaceful purposes, is not officially listed as a chemical weapon. Certain state-powers such as the Assad regime of Syria continue to regularly manufacture and implement such chemicals in combat munitions. Although these chemicals are not specifically listed as controlled by the CWC, the use of any toxic chemical as a weapon (when used to produce fatalities solely or mainly through its toxic action) is in-and-of itself forbidden by the treaty. Other chemicals, such as white phosphorus, are highly toxic but are legal under the CWC when they are used by military forces for reasons other than their toxicity.

UN Security Council Resolution 1540 (2004), adopted unanimously under Chapter VII of the UN Charter, UNSCR 1540 is binding on all UN member states, regardless of whether they've signed arms control treaties. It requires every country to prevent proliferation of weapons of mass destruction—including chemical weapons—to non-state actors. The resolution mandates

that states establish domestic controls on chemical weapons materials and enforce regulations through national legislation. This resolution fills an important gap by making WMD control obligations universal, even for countries that haven't ratified the Chemical Weapons Convention.

5. Analysis

While military planners during the Vietnam War justified herbicide use as a tactical method to remove forest cover and destroy crops—thereby ostensibly targeting military advantage rather than civilian populations. Military strategists assumed that herbicides deployed during Operation Ranch Hand would function like conventional weapons: cause intended damage and dissipate. The primary herbicide compounds in Agent Orange, specifically 2,4-D and 2,4,5-T, do indeed break down relatively quickly within months. However, the manufacturing process produced an unintended contaminant: TCDD dioxin, one of the most toxic human-made substances. Unlike the parent herbicides, TCDD persists in soil and water sediments for decades, sometimes even centuries. Soil samples collected from Bien Hoa Air Base in 1999—nearly thirty years after spraying ceased—showed contamination levels reaching 1,164,699 picograms per gram, representing concentrations far exceeding safe limits. This persistence fundamentally changed the nature of the damage from a temporary tactical effect into a chronic environmental hazard. What was intended as a time-limited operation became an ongoing source of contamination, suggesting that military planners either lacked knowledge of TCDD's properties or deliberately overlooked them.

The Vietnamese government estimates that approximately 4 million people were exposed to the herbicide, with 3 million suffering illness or disability, including congenital conditions. Studies from the National Institute of Health databases document that exposed populations experience elevated rates of specific conditions including cardiovascular disease, diabetes, neurological degeneration, and cancer, but these are documented primarily through veteran populations with access to medical surveillance. Vietnamese civilians, particularly women and children living near contamination hotspots, experienced chronic environmental exposure through contaminated food, water, and breast milk, yet received minimal medical monitoring or compensation. This asymmetry in health monitoring and support reveals how the consequences of herbicidal warfare concentrated harm among the civilian population least equipped to manage or document it.

The 1925 Geneva Protocol explicitly prohibits the use of poisonous gases and harmful substances in warfare, and subsequent treaties including the Environmental Modification Convention (ENMOD) added restrictions on techniques causing widespread environmental damage. Yet despite these legal prohibitions, the subsequent decades witnessed minimal accountability mechanisms. The Vietnamese government has pursued compensation claims against Monsanto (now owned by Bayer), arguing the company bears responsibility as the manufacturer, but legal remedies have proven limited. More recently, remediation efforts have begun through joint US-Vietnam initiatives, with USAID supporting the cleanup of contaminated sites. Since 2019, over 107,000 cubic meters of dioxin-contaminated soil have been excavated and treated around Bien Hoa Air Base, with plans for thermal treatment systems approved in 2024. However, the pace remains slow relative to the scale of contamination, and funding uncertainties have repeatedly jeopardized ongoing work. This pattern suggests that international legal frameworks, while important statements of principle, lack enforcement mechanisms robust enough to compel rapid remediation proportional to the damage inflicted.

6. Conclusion

Operation Ranch Hand sprayed 20 million gallons of herbicides across South Vietnam, achieving stated military objectives while creating consequences extending far beyond the conflict. The core contradiction lies between tactical intent and environmental reality: while military planners justified herbicide use as destroying enemy resources, they underestimated the persistence of contamination, and how the nature can be at times. Moreover, International legal frameworks proved insufficient to prevent or address this harm adequately. The Geneva Protocol, Environmental Modification Convention, and Chemical Weapons Convention all contained gaps that led to such an event happening in the history. Fifty years after the war, contamination persists in soil, groundwater, and human tissue, with health effects continuing through generations. The case demonstrates that international law must evolve beyond prohibiting weapons to include enforcement mechanisms and sustained accountability for environmental damage with delayed consequences extending across decades.