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Agent Orange Environmental and Human Health Impacts of Herbicide Use During and After the Vietnam War (A Conversation with Kenneth R. Olson)

Editorial board[1]

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Abstract

This interview presents Professor Kenneth R. Olson's scientific perspective on the environmental and human health consequences of Agent Orange use during and after the Vietnam War. Rather than treating Agent Orange solely as a historical military issue, the discussion reframes it as a long-term environmental process involving the persistence of dioxin TCDD in soils, sediments, wetlands, aquatic systems, food webs, and human populations. The interview examines the transformation of agricultural herbicides into environmental chemical weapons, the ecological mechanisms responsible for long-term contamination, and the continuing impacts on ecosystems, agriculture, and public health. Particular attention is devoted to environmental persistence, exposure pathways, maternal and occupational risks, and the need for integrated environmental monitoring and remediation. The editorial commentary further expands the discussion by proposing a broader scientific framework in which wartime contamination is investigated as a dynamic interaction between contaminants, environmental systems, food production, and population health. The interview also highlights the methodological importance of conducting environmental research during armed conflicts rather than relying exclusively on post-war investigations. Collectively, the work positions the Vietnam War as a scientifically documented model for understanding persistent military-related environmental contamination and for developing future approaches to environmental health, remediation, and ecological risk assessment.

[1] Corresponding author contact@pollution-diseases.org

Keywords: Agent Orange; dioxin TCDD; environmental chemical weapons; Vietnam War; environmental contamination; persistent pollutants; soil contamination; wetlands; food webs; exposure pathways; environmental health; maternal exposure; ecological processes; remediation; wartime environmental research.

Key Points

1. The interview reframes Agent Orange from a historical military event to a long-term environmental health problem driven by persistent contamination.
2. Environmental persistence of dioxin TCDD is controlled by soil, sediment, wetland, and hydrological processes that determine long-term exposure pathways.
3. Military application of agricultural herbicides transformed civilian technology into environmental chemical weapons affecting ecosystems and human populations for decades.
4. Long-term ecological processes, including contaminant migration, bioaccumulation, and biomagnification, represent the central scientific challenge rather than the original spraying events.
5. Protection of public health requires integrated investigation of contaminated soils, food-production systems, vulnerable populations, and ecological exposure pathways.
6. The Vietnam experience demonstrates the scientific value of conducting environmental investigations during armed conflicts while environmental evidence remains available.
7. The conceptual framework presented in the interview is applicable beyond Vietnam and provides a methodological basis for studying military-related environmental contamination worldwide.

Introduction

Interview conducted on July 12, 2026.

Prepared for the journal "Pollution and Diseases."

Interview conducted for the journal Pollution and Diseases. This text is part of the Kenneth R. Olson book-interview series. The purpose of the series is to make Professor Olson's long-term research on soils, rivers, floodplains, deltas, freshwater systems, environmental change and public policy accessible to a wider interdisciplinary audience.

Professor Kenneth R. Olson is an American soil scientist, environmental researcher and author whose work connects field-based soil science with geomorphology, environmental history, hydrology, agriculture, public policy and landscape management.

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Why This Book Matters Now

This interview extends the significance of Agent Orange research beyond historical documentation by presenting a systems-based perspective on persistent environmental contamination. It demonstrates how military technologies continue to influence ecosystems and human health through long-term interactions among soils, sediments, wetlands, food-production systems, and exposure pathways. The work argues that environmental consequences of war should be investigated as dynamic ecological processes rather than isolated historical events. It also highlights the importance of integrating environmental monitoring into ongoing armed conflicts, thereby contributing to the development of wartime environmental science as an emerging methodological field. The scientific concepts discussed are relevant not only to the Vietnam War but also to contemporary military conflicts where persistent environmental contamination poses long-term risks to ecosystems, food security, and public health.

INTERVIEW

Q: What is this book about?

A: It is difficult to imagine a scientific investigation becoming an epic story. But all the elements are there in Fate of Agent Orange [1]. This was a quest to uncover the environmental truth: what were the environmental consequences of chemical use? The story became entangled with political ideology, economic interests, and the all-too-human failure to understand the risks of introducing new and complex technologies into the environment. Political paranoia shaped the slide into the intractable quagmire of the conflicts in Southeast Asia. When weed and soil scientists began experimenting with chemicals to control plant growth, military leaders believed they had found a quick and inexpensive solution for clearing the jungle. Lacking toxicity information—some of which had been withheld for economic reasons—chemical manufacturers proceeded without fully understanding the consequences [2]. Rather than serving humanity through scientific progress, Agent Orange became an American icon associated with one of the most enduring toxic legacies of modern warfare.

The eleven chapters, developed over more than a decade with contributions from numerous reviewers, were initially intended to understand why the dioxin contaminant continued to affect non-combatants in Vietnam. The investigation eventually extended from high-level policy decisions to contaminated landscapes and finally to the chemical manufacturers themselves. It documents the legacy of shortened lives among soldiers who crossed rice paddies, aircrews who conducted the spraying missions, workers who loaded herbicide barrels at manufacturing plants, and transport personnel who guided shiploads through the Panama Canal [3,4]. When scientists finally persuaded political leaders that continued spraying represented a dangerous misuse of these chemicals, the aerial application program was terminated. Mountains of surplus barrels marked with distinctive orange bands were later incinerated at sea [5]. Meanwhile, thousands of barrels of contaminated production residues remained at chemical manufacturing facilities in the United States. Some were sold, others were incinerated at remote locations, often with additional environmental incidents during the

following decade. Only by understanding the past can future misuse of powerful technologies be prevented.

Q: Why did you decide to write this book specifically?

A: When I visited the Cu Chi Vietnam Memorial Park, northeast of Ho Chi Minh City, in 2016—more than 40 years after the spraying of Agent Orange and Agent Blue had ended—I noticed that the vegetation was dwarfed and stunted, with very few large trees remaining. I wondered why. Apparently, in an effort to locate the Cu Chi tunnel system, the U.S. Air Force, during Operation Ranch Hand, had sprayed vast areas to defoliate the jungle and expose tunnel entrances so they could be destroyed by bombing. Two of the areas most heavily affected—the Cu Chi and Iron Triangle regions—had once been considered the Garden Spot of Vietnam. It appeared that the herbicide spraying had produced long-lasting effects on the South Vietnamese landscape, its vegetation, and human health.

After completing my research on the Cu Chi soil tunnel system in 2017, I decided to investigate the use of Agent Orange as a defoliant and Agent Blue as a crop-destruction herbicide during the Vietnam War and the Second Indochina War. I assessed the environmental and human health impacts of Agent Orange, contaminated with the carcinogenic dioxin TCDD, and Agent Blue, which contained cacodylic acid and arsenic.

The original manuscript became too large for a single volume. With 22 chapters, more than 200 figures, and an estimated length exceeding 1,400 pages, publication as a single book was impractical. Consequently, the manuscript was divided into two volumes: one devoted to Agent Orange, 2,4,5-T, and the dioxin contaminant TCDD; the second focused on Agent Blue, the arsenic-based herbicide used in the food-denial campaign and in support of South Vietnamese President Ngô Đình Diệm's Strategic Hamlet Program, which sought to relocate rural populations into fortified hamlets or the growing slums around Saigon, thereby denying both local communities and North Vietnamese forces access to agricultural production along the Ho Chi Minh Trail.

Q: What makes this topic scientifically important?

A: During the past 60 years, the environmental and human health impacts of spraying tactical herbicides containing 2,4,5-T contaminated with unknown amounts of dioxin TCDD in southern Vietnam during the Vietnam War have been extensively documented. Cleanup efforts at dioxin TCDD hotspots in Vietnam are still ongoing. However, the lesser-known story concerns the environmental and human health consequences experienced by the chemical plant workers who manufactured Agent Orange at seven locations in the United States and one site in Canada (Figure 1). These workers, together with their families, continue to live with the consequences of the U.S. government's and military's decision in the early 1960s to produce and use tactical herbicides during the Vietnam War. During the manufacturing process, they were unknowingly exposed to dioxin TCDD.

By 1955, if not earlier, there is compelling evidence that the United States government, the military, chemical companies—including Monsanto and Dow Chemical—and their company physicians were aware that tactical herbicides containing 2,4,5-T

were contaminated with unknown amounts of dioxin TCDD, a known human carcinogen, and therefore posed potential health risks to workers involved in their manufacture, transport, and eventual use in South Vietnam.

Figure 1 The North American locations of the eight Agent Orange and Agent Purple chemical manufacturing plants, the primary Agent Blue chemical manufacturing site and the two Ports of the Gulf of America (formerly Gulf of Mexico) where herbicides were loaded on to ocean-going ships. Map created by Cruz Dragosavac. Republished with copyright permission from Managing Editor of Open Journal of Soil Science.

Supporting historical evidence includes the 1949 explosion at the Monsanto chemical plant in Nitro, West Virginia, during the production of 2,4,5-T contaminated with dioxin TCDD. Unfortunately, neither Monsanto nor its company physicians shared their medical findings with plant workers, the media, or the public. When a similar explosion occurred in 1953 at the BASF chemical plant in Germany during the production of 2,4,5-T, BASF physicians, assisted by Dow Chemical scientists, were able to identify dioxin TCDD exposure as the cause of chloracne and other severe health effects among workers. By 1955, BASF had communicated these findings to its employees, the media, and the public. Nevertheless, six years later, the U.S. government and military proceeded with the large-scale production and military use of tactical herbicides despite the growing evidence that 2,4,5-T contaminated with dioxin TCDD presented significant health hazards.

In the early 1960s, under the authority of the War Powers Act of 1950, President Kennedy's administration required eleven American chemical companies to manufacture tactical herbicides according to a predetermined formulation for use during the

Vietnam War. In addition to U.S. and Vietnamese military personnel exposed on the battlefield, American civilian workers involved in chemical production and transportation were also exposed to 2,4,5-T contaminated with unknown amounts of dioxin TCDD, a known carcinogen, at seven manufacturing sites in the United States and one in Canada.

More than sixty years later, the human health and environmental consequences of manufacturing tactical herbicides as military and environmental chemical weapons continue to affect United States civilian workers and local environments and still require public education, scientific investigation, remediation, mitigation, and long-term health monitoring.

Q: Which regions or case studies are central to the book?

A: The Mekong Delta in Vietnam.

Q: What were the most difficult aspects of the research?

A: One of the most difficult aspects of the research was documenting the use of Agent Orange along the Ho Chi Minh Trail in Laos and Cambodia (Figure 2). This activity formed part of the Second Indochina War, and much of the spraying was conducted in secret by the CIA. To this day, many mission records remain classified; when records are released, they are often heavily redacted.

Q: Did anything during the research surprise you?

A: Waterlogged soils and submerged sediments in wetlands, rice paddies, and aquaculture areas create anaerobic conditions that slow or prevent the photodegradation and microbial degradation of dioxin TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin), allowing it to persist in the environment for long periods. More than 1.6 million ha of land in southern Vietnam were sprayed with 2,4,5-T-containing herbicides, including Agent Orange, contaminated with dioxin TCDD during the Vietnam War from 1961 to 1971. Approximately 45% of this land received four or more aerial spray missions.

Dioxins are endocrine disruptors and may contribute to cardiovascular disease, growth and developmental abnormalities, diabetes, endocrine dysfunction, certain cancers, and chloracne [6]. Data from outpatient screening clinics in 2020 for Vietnamese children with suspected congenital heart disease (CHD) indicated a childhood CHD prevalence of 13.356 per 1,000, significantly higher than the overall Asian prevalence of 3.531 per 1,000. The difference between North Vietnam (2.541 per 1,000) and the region south of the 17th parallel (10.809 per 1,000) was also statistically significant.

Vietnamese farmers, particularly pregnant women whose occupations involve daily contact with contaminated soils and sediments where dioxin TCDD persists, may be at increased risk of TCDD accumulation through dermal exposure and dietary bioaccumulation. There is an urgent need for well-funded longitudinal genetic and clinical studies to assess congenital heart disease and other developmental abnormalities potentially associated with in utero exposure to TCDD.

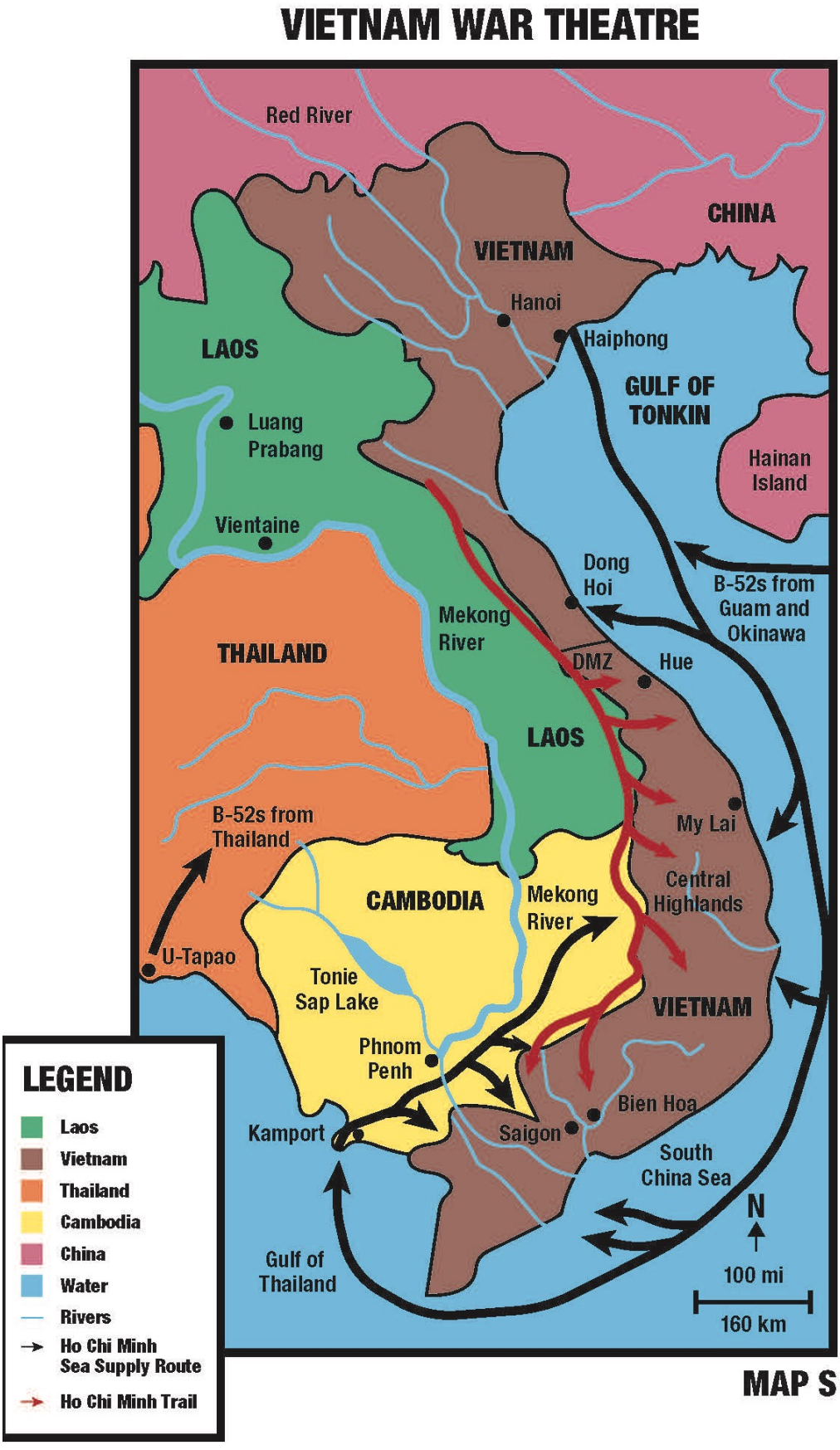

Figure 2 The Ho Chi Minh Trails in Southeast Asia. Map by Cruz Dragosavac. Re-printed with copy right permission from Editor of Open Journal of Soil Science.

We recommend an integrated research strategy involving:

1. Site-specific locations that received repeated, high-volume herbicide applications during the Vietnam War;

2. Soil and sediment sampling in submerged and waterlogged environments where TCDD degradation is limited;

3. Agricultural, fisheries, and aquaculture production areas where food contamination may occur;

4. Risk assessment of dioxin concentrations in foods with a high potential for bioaccumulation;

5. Women of child-bearing age, especially pregnant women, who may be particularly sensitive to chronic low-dose exposure; and

6. Men and women whose occupations require daily contact with contaminated soils and sediments.

Q: Which environmental processes described in the book are the most underestimated?

A: Approximately 13% of the Agent Orange sprayed over jungle forests is estimated not to have contacted the forest canopy and was therefore likely lost through spray drift. Direct aerial application over water bodies may also have resulted in TCDD entering the atmosphere through volatilization.

Gas-phase TCDD degrades through two principal mechanisms. First, it reacts with hydroxyl radicals in the atmosphere. Second, it undergoes photodegradation under ultraviolet radiation. In contrast, volatilization of TCDD adsorbed onto soil particles is negligible.

The atmospheric half-life of gas-phase TCDD has been estimated at approximately three days. Photodegradation alone results in an estimated half-life of 55.5 to 72.3 hours (approximately 2.3 to 3 days). Although these estimates indicate relatively short atmospheric persistence, the environmental significance of spray drift and atmospheric deposition should not be underestimated.

During the Vietnam War, aerial spraying of dioxin-contaminated herbicides had the potential to contaminate both inland and coastal waters through atmospheric transport and deposition.

Q: How are environmental systems connected with political or military processes in this topic?

A: Discoveries made in Charles Darwin's laboratory ultimately contributed to the development of modern herbicides. Darwin identified the biological mechanisms by which plants respond to sunlight and water. Later, scientists in Europe and the United States described these mechanisms as the plant hormone response system.

On the eve of World War II, administrators and scientists—including Dr. Ezra J. Kraus, Head of the Department of Botany at the University of Chicago and a

distinguished plant physiologist—suggested that herbicides could have significant military value as chemical weapons. Dr. Kraus gained access to the synthetic herbicide 2,4-D and demonstrated that, once absorbed through plant leaves, it disrupted plant hormone regulation. The resulting uncontrolled growth caused plants to wither, die, and ultimately lose their foliage.

During World War II, Dr. Kraus received research funding from the U.S. Department of Defense for studies conducted within the Department of Botany. Scientists at Camp Detrick, the U.S. Biological Weapons Laboratory, subsequently obtained samples of the newly developed herbicide 2,4,5-T, which contained unknown amounts of the by-product dioxin TCDD.

During the 1950s and 1960s [7], military scientists at Fort Detrick formulated Agent Orange as an equal mixture of 2,4-D and 2,4,5-T. These dual-purpose herbicides were subsequently used by both the U.S. Department of Defense (DOD) and the U.S. Department of Agriculture (USDA).

During the 1940s, American and European farmers widely used 2,4-D and 2,4,5-T to control weeds in croplands and pastures. After World War II, the development of synthetic herbicides and pesticides continued alongside synthetic fertilizers and high-yield crop varieties. Together, these innovations formed one of the scientific foundations of the Green Revolution, whose objective was to increase agricultural productivity, improve food security, and reduce global hunger.

In contrast, the military application of herbicides transformed these agricultural technologies into military and environmental chemical weapons designed to defoliate forests and destroy food crops as a means of conducting war. One of the central objectives of this book is to explain how agricultural herbicides evolved into tactical military and environmental chemical weapons. It also evaluates their long-term environmental impacts on ecosystems in both the United States and Vietnam and demonstrates why additional remediation of dioxin TCDD hotspots remains necessary.

> **Editor's Note.** A central conceptual trajectory becomes visible at this point in the interview: agricultural science → herbicide technology → military doctrine → environmental chemical weapon → long-term ecological and human health consequences. Prof Olson does not formulate this sequence explicitly, yet it emerges from the historical and scientific evidence presented in the book. The significance of Agent Orange lies not only in the military use of a toxic substance, but also in the transformation of a civilian agricultural technology into an instrument designed to alter vegetation, food systems, soils, waters, and entire landscapes. This helps explain the author's use of the term environmental chemical weapon.

Q: Which chapter is personally most important to you?

A: Chapter 6, Persistence of Dioxin TCDD in Southern Vietnam Soil and Water Environments and Maternal Exposure Pathways with Potential Consequences for Congenital Heart Disease Prevalence in Vietnam [6].

Vietnam remains an agriculture-based economy, with more than 70% of its population engaged in agriculture. Much of the rural population lives in close contact with the land and has daily exposure to soils, sediments, and water resources. Agriculture, fisheries, and forestry provide food security, livelihoods, and important pathways out of poverty.

If we better understood the geographic distribution and soil conditions that retain low but potentially harmful concentrations of dioxin TCDD, systematic efforts could be undertaken to reduce direct human exposure to contaminated soils and to prevent TCDD from entering and biomagnifying within the food chain.

Such knowledge has profound implications for the public health of pregnant women and future generations in affected regions of Vietnam. Early diagnosis of congenital anomalies is well known to improve fetal outcomes. The ability to identify populations at risk and implement effective mitigation strategies remains essential for reducing both congenital heart disease (CHD) and other developmental abnormalities in the future.

Existing hotspot cleanup criteria, remediation methodologies, and dioxin risk assessment frameworks developed in the United States and other industrialized countries [9] have focused primarily on residential and industrial contamination scenarios. Their authors explicitly recognize that these models are not directly applicable to subsistence agriculture, commercial farming, fisheries, livestock production, or other rural settings in which long-term occupational and household exposure pathways differ fundamentally.

The exposure pathways and health consequences experienced by farming communities whose occupations and cultural practices involve lifelong contact with contaminated soils and sediments remain one of the major unresolved questions in environmental health science. This knowledge gap deserves substantially greater scientific attention.

Editor's Commentary

From Historical Evidence to a New Research Paradigm

One of the most important scientific contributions of this book is not immediately apparent because the author deliberately focuses on empirical evidence rather than on methodological generalizations. At first reading, the work may appear to be another detailed historical reconstruction of Agent Orange and the Vietnam War. In fact, it represents something considerably broader.

The central scientific problem is not the historical use of Agent Orange itself. Nor is it limited to documenting military decisions or describing the toxicological properties of dioxin TCDD. The book gradually shifts the focus toward a much more fundamental question: how persistent environmental contaminants continue to affect ecosystems and human populations decades after their original release through long-term environmental exposure pathways.

This shift is significant because it changes the object of scientific investigation. Agent Orange becomes not the final object of study but rather a historical case through which a broader scientific problem can be examined. The real subject of the research is the interaction between persistent contaminants, environmental systems, food production, soil and sediment processes, human exposure pathways, and population health.

From this perspective, contaminated soils, wetland sediments, agricultural landscapes, fisheries, food chains, maternal exposure, congenital anomalies, and long-term ecosystem recovery are not separate research topics. They constitute components of a single environmental system in which contaminants continue to circulate long after military operations have ceased.

This conceptual transition also explains why the author consistently employs the expression environmental chemical weapons. Unlike conventional chemical weapons, whose primary objective is the direct incapacitation or destruction of human targets, environmental chemical weapons act primarily through transformation of the environment itself. Vegetation, agricultural systems, soils, wetlands, and aquatic ecosystems become the immediate targets. Human health consequences emerge indirectly through ecological degradation, persistent contamination, food chains, and chronic environmental exposure.

Seen in this way, the Vietnam War serves as an exceptionally well-documented historical model for understanding a broader category of environmental conflicts. The scientific framework developed in this volume therefore extends beyond a single war or a single herbicide. It provides a conceptual foundation for investigating persistent environmental contamination resulting from military activities in many regions of the world.

For contemporary environmental health research, this represents perhaps the most important contribution of the book. It redirects attention from the historical event itself toward the long-term ecological mechanisms through which military technologies continue to influence both ecosystems and human populations across generations.

Q: How does this book relate to current global environmental challenges?

A: During times of war, governments are rarely willing or able to require their military institutions to support comprehensive environmental impact research. Nevertheless, during the 1960s many American scientists expressed serious concerns regarding the use of herbicides in the Vietnam War [10]. This scientific movement was led by Dr. Arthur Galston and was eventually joined by members of the U.S. National Academy of Sciences.

By 1970, the U.S. Department of Defense was instructed to permit scientific teams to conduct field investigations in South Vietnam while the war was still underway. In total, more than 1,500 scientist-days were devoted to environmental research in South

Vietnam. At the same time, the U.S. government and military also supported experimental studies examining the effects of herbicides on animals.

The military objective of herbicide use was to defoliate forests and destroy food crops in order to gain strategic military advantages. However, one of the most important historical lessons is that rigorous environmental research can be conducted during an armed conflict rather than decades after its conclusion.

Environmental impact assessments carried out during military conflicts may not always include sufficient field validation and therefore may occasionally produce incomplete or misleading conclusions. Nevertheless, they provide an essential scientific foundation for understanding environmental damage while evidence remains available.

The United States and other countries—including Russia and Ukraine—can learn valuable lessons from the historical experience of using herbicides containing dioxin TCDD and arsenic compounds as military and environmental chemical weapons during the Vietnam War.

Editor's Commentary

Environmental Research During War: From Historical Documentation to Scientific Method

One of the less obvious but scientifically important contributions of this work concerns when environmental research should be conducted. Traditionally, investigations of war-related environmental damage begin years or even decades after military operations have ceased. By that time, landscapes have changed, ecosystems have partially recovered, contaminants have migrated, and many of the original environmental conditions can no longer be reconstructed with confidence.

The Vietnam War represents one of the few historical examples in which large-scale environmental investigations began while military operations were still in progress. As Olson notes, scientific teams were eventually granted access to South Vietnam, where extensive field observations and environmental assessments were conducted despite the ongoing conflict. These studies created a unique scientific record that would have been impossible to reproduce retrospectively.

The methodological significance of this experience extends far beyond Vietnam. It demonstrates that wartime environmental science should not be viewed merely as post-conflict documentation. Instead, environmental monitoring, ecological assessment, soil and water sampling, biodiversity observations, and contamination studies can become an integral part of scientific activity during armed conflict itself.

This perspective is particularly important because environmental systems are dynamic. Pollutants are transported by wind and water, contaminants migrate through soils and sediments, ecosystems begin processes of degradation and

recovery simultaneously, and many forms of physical evidence gradually disappear. Delayed investigation therefore results not only in the loss of historical information but also in the loss of scientific knowledge concerning environmental processes that can only be observed while they are occurring.

Seen from this perspective, Olson's work contributes to the emergence of a broader methodological framework for wartime environmental assessment. The Vietnam experience suggests that environmental research conducted during military conflicts should become a standard component of future investigations rather than an exceptional undertaking initiated decades later.

This methodological lesson has direct relevance for contemporary conflicts. Wherever military operations significantly alter landscapes, soils, water resources, vegetation, or agricultural systems, timely scientific investigation becomes essential not only for documenting damage but also for understanding the ecological mechanisms through which environmental impacts develop over time. Such knowledge ultimately forms the scientific basis for future remediation, environmental policy, and public health protection.

Q: Are the problems discussed in the book improving or worsening today?

A: The United States fought the Second Indochina War, commonly known as the Vietnam War (1965–1972), in the wetlands of the Mekong Delta, the grasslands, and the tropical forests of the Republic of Vietnam (South Vietnam) (Figure 3). Guerrilla warfare in these unfamiliar environments proved extremely costly for U.S. forces and for the military bases established throughout the region.

Two herbicides—2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T)—together with the contaminant dioxin 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), a by-product generated during the manufacture of 2,4,5-T, were applied to jungle forests, riverbanks, and selected agricultural lands. The objective of this large-scale defoliation campaign (Figure 4) was to expose enemy positions concealed within dense vegetation, protect military base perimeters (Figure 5), and destroy agricultural production supporting opposing forces [11].

These operations produced both intended and unintended consequences for South Vietnam's soils, sediments, forests, agricultural landscapes, civilian populations, and military personnel from both sides of the conflict.

Some impacts were immediate, whereas others have persisted for decades. The long-term consequences include contamination of soils, wetlands, and sediments; bioaccumulation and biomagnification of dioxin TCDD within food webs; and continuing risks to human health. Systematic investments in environmental and medical research are gradually improving scientific understanding of these long-term ecological processes.

More than fifty years after the war, however, fundamental scientific questions remain. Do residues of these compounds still persist within Vietnam's soils, sediments,

and aquatic environments? To what extent have the forests of the Ho Chi Minh Trail, the Cu Chi and Iron Triangle regions, and former military installations recovered? Mangrove forests, such as those in the U Minh region of the Ca Mau Peninsula, are exceptionally resilient but recover slowly after severe disturbance. Their regeneration continues to be affected not only by the legacy of herbicide use but also by expanding agriculture, human settlement, and contemporary climate change.

Dioxin TCDD, whose environmental persistence greatly exceeds that of the herbicides with which it was associated, continues to bioaccumulate in animal tissues and biomagnify through aquatic and terrestrial food webs. Large dioxin TCDD hotspots remain in parts of southern Vietnam. A continuing scientific challenge is to determine how contaminants migrate from these source areas into surrounding soils, sediments, wetlands, lakes, rivers, and food-production systems, and to identify the most effective long-term remediation strategies.

Dioxin TCDD, which has a much longer environmental half-life than the herbicides with which it was associated, accumulates in the fatty tissues of animals and humans and becomes progressively more concentrated through food webs by the process of biomagnification.

A fundamental scientific question remains: where are the remaining dioxin TCDD hotspots in southern Vietnam? These are locations where substantial quantities of TCDD continue to persist in soils, sediments, wetlands, and aquatic ecosystems and where bioaccumulation continues in fish and other components of the human food supply.

This book first examines Vietnam's climate, vegetation, soils, river deltas, wetlands, and upland landscapes in order to establish the environmental setting in which herbicidal warfare occurred. It then analyzes the characteristics, military applications, environmental persistence, and ecological fate of the color-coded herbicides used during the Vietnam War, with particular attention to Agent Orange and its contaminant, dioxin TCDD.

The book subsequently examines the environmental fate of these herbicides within soils, wetland sediments, and aquatic systems, the unintended consequences of long-term TCDD persistence, and available remediation strategies.

Several former air bases in Vietnam and Thailand continue to contain significant dioxin-contaminated hotspots. Through runoff, erosion, sediment transport, and wind redistribution, contaminated materials continue to migrate beyond former military installations into surrounding lakes, rivers, ponds, wetlands, and adjacent agricultural lands.

Local populations living near these former air bases continue to experience potential exposure through contaminated dust, direct contact with soils, and consumption of fish and mollusks harvested from nearby water bodies. Although the Vietnamese government has maintained fishing restrictions around several contaminated sites for decades, dioxin TCDD continues to be detected within local food systems.

Among currently available remediation technologies, high-temperature thermal treatment (incineration) remains the most effective method for removing dioxin TCDD from contaminated soils and sediments

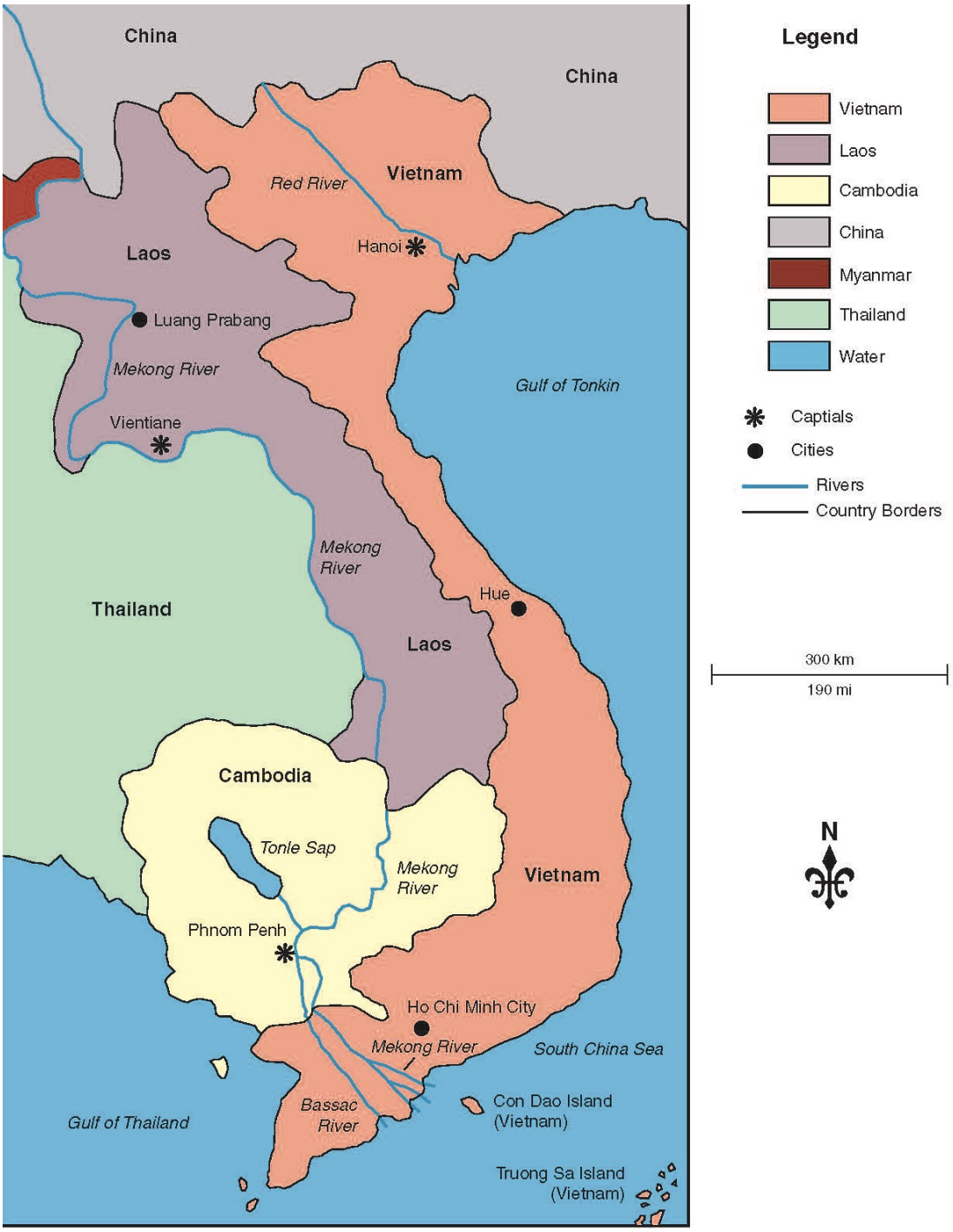

Figure 3 Southeast Asia countries including Vietnam. The Mekong and Bassac Rivers flow south into the Mekong Delta. Map by Mic Greenberg. Reprinted with copyright permission of the managing editor of the Open Journal of Soil Science.

Figure 4 Agent Orange, Agent Purple and other color-coded herbicides were sprayed by low flying aircraft over the Vietnam jungle and rural landscapes and subject to small arms fire from the ground. Most of these herbicides had short-half lives of hours, days, and a few weeks, and vegetation regrowth required additional applications. Picture taken by US Army Flight Operations Specialist 4 John Crivello in 1969. Reprinted with permission from Editor of Open Journal of Soil Science.

Figure 5 The defoliated perimeter of an airbase fence after being sprayed with Agent Orange and Agent Purple in the 1960s. Credit line: Picture taken by US Army Flight Operations Specialist 4 John Crivello in 1969. Reprinted with the permission of the editor of the Open Journal of Soil Science.

Q: Which future research directions emerge from this work?

A: The environmental effects of herbicide spraying have clearly persisted far beyond the Vietnam War, influencing landscapes, ecosystems, and human health for decades. In my next book interview, I will examine the environmental and human health impacts of Agent Blue—particularly its active ingredients, cacodylic acid and arsenic—on the food-production systems of the Mekong Delta and their long-term consequences for both ecosystems and local populations.

Q: If readers remember only one idea from the book, what should it be?

A: Only by understanding the past can we prevent the future misuse of powerful technologies and avoid repeating the environmental mistakes of history.

Editorial Perspective

Beyond the History of Agent Orange

At first glance, this book appears to be another historical study devoted to the military use of Agent Orange during the Vietnam War. Such an impression would be understandable. The work contains extensive historical documentation, discusses military decisions, chemical manufacturing, aerial spraying campaigns, and the long-term consequences of tactical herbicide use.

A closer reading, however, reveals that the scientific significance of the book lies elsewhere.

Rather than treating Agent Orange simply as an environmental contaminant requiring remediation, Kenneth R. Olson examines its long-term behavior within natural systems. Throughout the book, the contaminant is followed as it moves through soils, wetlands, sediments, aquatic environments, food production systems, and ultimately into human populations. The central scientific question therefore shifts from the historical event itself to the environmental processes that continue long after military operations have ended.

This perspective represents an important departure from the traditional understanding of environmental contamination. Environmental damage is often viewed as a relatively static problem: a contaminant is released, identified, and eventually removed. Olson presents a fundamentally different picture. Military use of herbicides is shown not as the end of an environmental event but as the beginning of a long sequence of interconnected ecological processes. Persistent contaminants migrate, accumulate, enter food webs, alter ecosystems, and continue to influence human health decades after the original military action has ceased.

Equally important is the author's insistence that environmental consequences cannot be understood separately from the natural systems through which contaminants move. Soil properties, wetlands, hydrological processes, vegetation, agricultural production, fisheries, and human exposure pathways are presented as components of one interacting environmental system rather than as isolated research topics.

For this reason, the book should not be read solely as a contribution to the history of the Vietnam War. It also offers a broader scientific perspective on how long-term environmental consequences of military activities can be investigated. Its greatest value lies not only in documenting one of the most extensively studied cases of wartime contamination, but also in demonstrating that environmental pollution is a dynamic ecological process whose consequences continue to evolve across landscapes and generations.

The Editorial Board considers this conceptual perspective to be one of the principal scientific strengths of the book.

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The Editorial Board of the journal "Pollution and Diseases" wishes you continued scientific success, new discoveries, and inspiration in your work.

Conflict of Interest

The authors declare no conflict of interest.

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