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INVESTIGATION INTO TACTICAL AND COMMERCIAL HERBICIDES

Compensation Service

Department of Veterans Affairs

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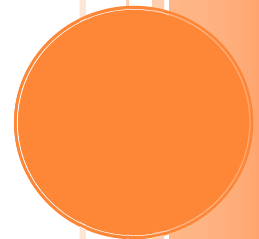
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October 2013





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October 31, 2013
Mr. Michael D. Pharr
Contract Officer's Representative
Compensation Service
Department of Veterans Affairs
810 Vermont Ave., NW
Washington, DC 20420

Dear Mr. Pharr,

Please find attached to this letter the Final Report: **Investigation into Tactical and Commercial Herbicides**. This report is the twelfth of many reports that will be prepared in fulfillment of Contract VA-101-12-C-0006, *Development of an Archival Directory of Agent Orange Documents*. The Investigative Reports are supported by the archival research. The goal of developing the Directory is to search and identify the thousands of documents, reports, and correspondence located within our National Archives and Records Administration and other document repositories that relate to the use of "Tactical Herbicides", including Agent Orange, *outside of Vietnam*. Using documents from the repositories, reports are prepared on topics requested by Compensation Service.

In the case of this report, there continues to be much confusion among Vietnam and Vietnam-era veterans, non-governmental organizations, the Department of Defense, the Department of Veterans Affairs, and others as to the differences between the uses of military "tactical herbicides" versus the military use of "commercial herbicides" during the Vietnam War. Thus, this report is part of an effort by the Department of Veterans Affairs to clarify the intent of the Agent Orange Act of 1991 to focus on those herbicides used in Vietnam in support of the United States and Allied Military Forces in combat operations occurring "outside" base installations. The intent is to distinguish the use of tactical herbicides from the use of the commercial herbicides that were used "inside" base installations.

The selection of commercial herbicides and their recommendations for use on military installations was the responsibility of the Armed Forces Pest Control Board, while tactical herbicides were the responsibility of the US Army Chemical Corps. Tactical herbicides differed from commercial herbicides in the development and testing of formulations, regulatory oversight, use guidelines, purchase specifications, toxicological evaluations, shipment requirements, and military record keeping. Thus, there were technical, administrative, and legal differences between tactical and commercial herbicides used by the Department of Defense.

Sincerely,

Alvin L. Young, PhD
Professor of Environmental Toxicology
Colonel, USAF (Retired)

DISCLAIMER FOR VA REPORTS

The conclusions reached in this report are based upon a comprehensive review of the historical records maintained in the publicly available files of the National Archives and Record Administration, and other archival repositories. However, the conclusions reached do not necessarily represent those of the Department of Veterans Affairs or any other Department or Agency of the United States Government.

This report is part of the Agent Orange Investigative Report Series, and should be considered as an amendable or living document. If additional authenticated documents or records are found that address the topic of this report, a re-evaluation of the conclusions may be necessary.

INVESTIGATION INTO TACTICAL AND COMMERCIAL HERBICIDES

EXECUTIVE SUMMARY

There continues to be much confusion among Vietnam and Vietnam-Era veterans, Non-Governmental Organizations (NGOs), The Department of Defense (DoD), the Department of Veterans Affairs (DVA), and others as to the differences between the uses of military “tactical” herbicides versus the military use of “commercial” herbicides during the Vietnam War.

In the Vietnam War, the US military needed to find methods to control the dense vegetation while providing protection of American troops against ambush, and simultaneously exposing enemy camps, food plots and supply lines of the Viet Cong and the North Vietnamese military. The successful experiences of the US Army Chemical Corps’ Biological Laboratories at Fort Detrick, Frederick Maryland in developing herbicides and aerial spray equipment for potential tactical military operations for the previous wars seemed to provide the best option for vegetation control in South Vietnam.

The military use of herbicides in Vietnam included formulations of the phenoxy herbicides 2,4-D and 2,4,5-T, the picolinic acid herbicide picloram (Tordon®), and the arsenical herbicide cacodylic acid or hydroxydimethylarsine oxide (Phytar 560®). Although formulations of these herbicides were available commercially in the United States and in other countries, the US Army Chemical Corps designated special formulations of these herbicides as “tactical herbicides”, and assigned code names to them, e.g., Agents Orange, White and Blue, respectively.

Concern by the US Congress that veterans who had returned from the war in Vietnam were reporting health effects that they associated with their exposure to Agent Orange prompted the Congress to pass and the President to sign Public Law 102-4, the Agent Orange Act of 1991. In defining the herbicides for exposure presumption, the Agent Orange Act of 1991 stated “...the term ‘herbicide agent’ means a chemical in an herbicide **used in support of the United States and allied military operations** in the Republic of Vietnam during the Vietnam era.” Although the term “tactical herbicide” was not used in the Act, clearly the intent was to restrict consideration to only those herbicides used in “military operations” and the

associated dioxin contaminant. Thus, in defining its scope of scientific assessment in support of the Agent Orange Act of 1991, the Institute of Medicine concluded that four herbicides had been documented in military records that had been involved in military operations, namely 2,4-D, 2,4,5-T, picloram, and cacodylic acid. In addition, the IOM included the contaminant TCDD that occurred in 2,4,5-T herbicide. Thus, it is important that a valid distinction be established between tactical herbicides and commercial herbicides used in Vietnam.

Tactical herbicides differed from commercial herbicides in the development and testing of formulations, regulatory oversight, use guidelines, purchase specifications, toxicological evaluations, shipment requirements, and military record keeping. Thus, there were technical, administrative, and legal differences between tactical and commercial herbicides used by the Department of Defense.

The tactical herbicides Green, Pink, Purple and Orange contained the highly volatile n-butyl esters of 2,4-D and 2,4,5-T. These tactical herbicides were formulated as a concentrate without additional solvents, diluents, or surfactants added. They were formulated at the maximum concentration of active ingredient. Agents Blue and White were also applied as concentrates for maximum effectiveness in controlling target vegetation, i.e., also at 3 gallons per acre. Commercial applicators would never have selected the n-butyl ester formulation of 2,4-D or 2,4,5-T for weed or brush control because of the problems associated with volatility and drift. Testing of the candidate tactical herbicides was done by the US Army Chemical Corps, while the USDA supported the testing of candidate commercial herbicides for DoD.

For the effective use of tactical herbicides in a combat environment, it was required that a close interface be developed between the aircraft (RANCH HAND UC-123 or US Army Chemical Corps helicopters), the aerial spray equipment, and the requirements for both a biologically effective rate and an appropriate dispersion of the spray droplets. This was accomplished through an extensive test program at Eglin AFB Florida. The tactical herbicides and aerial application systems were subsequently deployed to Vietnam.

The selection of commercial herbicides including their use recommendations and appropriate application equipment was through a Memorandum of Understanding with the USDA. These recommendations were approved and

coordinated by the Armed Forces Pest Control Board (AFPCB) and generally published as manuals for use by the individual military agencies.

All aspects of the development and deployment of tactical herbicides were the responsibility of the Army Chemical Corps, Fort Detrick Maryland. This included the development of purchase specifications and the providing of those specifications to the Defense Supply Agency. The actual acquisition of tactical herbicides was the responsibility of the Air Force Air Logistics Centers at Olmstead AFB Pennsylvania and Kelly AFB Texas. The chemical companies were selected on the basis of competitive bids and DSA provided the specifications that were required to be met by the manufacture. The purchase descriptions for commercial herbicides were recommended to the AFPCB by USDA's Agricultural Research Service with their subsequent acquisition through the Military Supply System operated by the General Services Administration.

All commercial pesticides used by DoD, including herbicides, were to be applied only by certified applicators or under the direct supervision of a certified applicator. Although each military service had its own pesticide certification program, the coordination of these programs with other agencies occurred at the level of the AFPCB. The AFPCB depended upon USDA's Cooperative State Research Service and its University-based research and extension system to prepare and publish manuals on pesticide use, plans for certification of pesticide applicators, and the disposal of old pesticides and pesticide containers. Frequently, USDA's Extension Service conducted pesticide certification workshops to which participants from all of the military services were invited to attend.

Although no pesticide certification was developed for the spraying of tactical herbicides in Vietnam, the overall policy and procedures for herbicide operations in Vietnam were set forth in detailed directives issued by the Military Assistance Command, Vietnam (MACV). These directives were based upon specific guidelines provided by the Department of State and DoD. The most important of these directives was the MACV Directive 525-1 which governed all tactical herbicide used by both US and Free World Military Assistance Forces troops between 1965 and 1970. This Directive prescribed policies, responsibilities, and procedures governing the operational employment of herbicides within South Vietnam, including all fixed wing, helicopter, and surface-based methods of herbicide application. Tactical herbicides were not approved for use within the perimeters of US or

Allied military installations within Vietnam, or other locations in Southeast Asia.

Under the Directives 5154.12 and 4150.7, the Department of Defense gave the Armed Forces Pest Control Board/Armed Forces Pest Management Board the authority to set pest management policy “*applicable for all Department of Defense pest management activities in any unit, at any time, in any place, even when conducted by contract operations.*” Prior to the USDA’s recommendation to AFPCB, the Agricultural Research Service ensured that the commercial herbicides met the label description for use and safety and that it was registered through the regulatory program of USDA, and was in full compliance with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). Tactical herbicides were not required to be labeled, nor required to comply with the directions from the Pesticide Regulation Branch of USDA or with FIFRA. Following publication of “Military Specifications” (prepared by the Army Chemical Corps), tactical herbicides were purchased directly by the Department of Defense (via the Defense Supply Agency) for use in Vietnam. The only labeling requirements for tactical herbicides were a 3-inch colored band around the center of the 55-gallon drums to identify the specific tactical herbicide and, the lids were stenciled with a brief description of the herbicide, the Federal Specification Number, Transportation Control Number, US Port of Embarkation, the destination, DSA Procurement Number and date, and net weight of contents.

Lastly, the implication that any mixture of 2,4-D and 2,4,5-T could be called “Agent Orange” is incorrect. The butyl formulations were not commercially available. To be Agent Orange, the formulation had to contain concentrated n-butyl esters of 2,4-D and 2,4,5-T, with essentially no solvents, wetting agents, surfactants, or other inert ingredients. The tactical herbicides were not to be used in brush and weed control programs on military installations in Vietnam or elsewhere, because they were not registered or labeled, and not approved for such use by the Armed Forces Pest Control Board.

INTRODUCTION

There continues to be much confusion among Vietnam and Vietnam-Era veterans, Non-Governmental Organizations (NGOs), The Department of Defense (DoD), the Department of Veterans Affairs (DVA), and others as to

the differences between the uses of military “tactical” herbicides versus the military use of “commercial” herbicides during the Vietnam War.

THE MILITARY USE OF HERBICIDES IN VIETNAM

South Vietnam was characterized by dense vegetation associated with grasslands and savannas, impenetrable mangrove swamps, and incredibly tall triple canopy jungle growth. These “walls” of vegetation forced the US military to find methods to control that vegetation while providing protection of American troops against ambush, and simultaneously exposing enemy camps, food plots and supply lines of the Viet Cong and the North Vietnamese military [1].

In previous wars (WWII and Korea) the US military had relied upon carpet-bombing, napalm, or Rome plows to clear vegetation from the theatre of war. In Vietnam such a large amount of vegetation needed to be cleared; using fire would have only indicated to the enemy where US troops were present. Therefore, it was decided that using a method of herbicidal defoliation would be a better option [2].

The successful experiences of the US Army Chemical Corps’ Biological Laboratories (later the Plant Sciences Laboratories) at Fort Detrick, Frederick Maryland in developing herbicides and aerial spray equipment for potential tactical military operations for the previous wars seemed to provide the best option for vegetation control in South Vietnam [3]. Because of the myriad vegetative types present in the various combat environments of South Vietnam, the desired characteristics of an effective defoliant were the following:

- Broad spectrum of activity on many kinds of plants;
 - Rapid in action so that the results of defoliation or leaf drop could be observed within a three-day period;
 - Suitable for application with air or ground equipment;
 - Nontoxic to man and animals, specifically formulations to minimize hazards of toxicity;
 - Stable in storage to insure effectiveness following global transportation and temporary storage;
 - Effective in low dosages from aerial or ground applications;
 - Readily available in larger quantities from commercial manufacturers;
- and,

- Proper formulation to eliminate such hazards as corrosive action on application equipment, i.e., formulation must be noncorrosive [4].

In July 1963, the US Army Chemical Corps' Biological Laboratories at Fort Detrick held the first "Defoliation Conference". Essentially, the entire pesticide industry had been invited to Fort Detrick to be briefed on the technical and contractual aspects of a 'Military-Industrial Defoliation Program.' The intent of this partnership was to "*demand of industry its ability, creative ideas, facilities, and the competence of its scientific and engineering disciplines to achieve the results needed in the shortest possible time*", i.e., to develop chemicals that could attack vegetation in order to destroy the cover and concealment of enemy combatants in South Vietnam [4]. Fort Detrick sponsored additional Defoliation Conferences in 1964 and 1965. From this partnership more than 6,500 compounds were evaluated resulting in the final selection of three new "tactical herbicides": Orange, Blue, and White [4, 5].

RESPONDING TO THE NEED FOR HERBICIDES

The Department of Defense strictly controlled the use of all pesticides used by the Department of Defense. This included research, field evaluation, personnel certification, and procurement. The military use of herbicides in Vietnam included formulations of the phenoxy herbicides 2,4-D and 2,4,5-T, the picolinic acid herbicide picloram (Tordon®), and the arsenical herbicide cacodylic acid or hydroxydimethylarsine oxide (Phytar 560®). Although formulations of these herbicides were available commercially in the United States and in other countries [6], the US Army Chemical Corps designated special formulations of these herbicides as "tactical herbicides", and assigned code names to them, e.g., Agents Orange, White and Blue, respectively[7]. Dr. Charles Minarik, Director of the US Army Chemical Corps' Plant Science Laboratories, frequently used the term to distinguish commercial formulations from those being developed by the Army Chemical Corps for operational military use; however, the Department of the Army routinely used the term as early as 1971 [8]. Indeed, the uses of these "tactical herbicides" in Vietnam were specifically for military defoliation or crop destruction operations in the individual Combat Tactical Zones (or "tactical" environments) [8, 9]. The code names and descriptions of these tactical herbicides were used to distinguish them from the purchase of commercial herbicide formulations especially phenoxy herbicides formulations used by Base Engineering (Facilities Engineering) Units in

Vietnam as approved through the Armed Forces Pest Control Board [10]. The belief that commercially available herbicides were simply purchased from the chemical manufacturers and deployed directly to Vietnam is incorrect and contrary to historical records [11]. The Department of Veterans Affairs has not distinguished these crucial differences, and this has resulted in Vietnam-era veterans demanding that they too should also be presumed as exposed to Agent Orange and the other tactical herbicides.

THE AGENT ORANGE ACT OF 1991

By the very nature of the title of the Agent Orange Act of 1991, it was at a minimum directed at the two components of Agent Orange, the phenoxy herbicides, 2,4-D and 2,4,5-T, and the dioxin contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (dioxin or TCDD) found in 2,4,5-T herbicide [12]. Specifically, in Section 2 (General) of the Agent Orange Act of 1991 (Public Law 102-4), it notes "...a presumption of service connection for diseases associated with exposure to certain herbicide agent..." Under Section 2, subsection (1)(C)(3) "...a veteran...shall be presumed to have been exposed...to an herbicide agent containing dioxin or 2,4-dichlorophenoxyacetic acid...or other chemical compound in an herbicide agent." Under Section 2, subsection (1)(C)(4) it states: "For purposes of this section, the term 'herbicide agent' means a chemical in an herbicide **used in support of the United States and allied military operations in the Republic of Vietnam during the Vietnam era**" [12].

Within the Agent Orange Act of 1991, the National Academy of Sciences (specifically the Institute of Medicine) was tasked "to review and evaluate the available scientific evidence regarding associations between diseases and exposure to dioxin and other chemical compounds in herbicides" [12]. In 1994, the Institute of Medicine (IOM) published its first report on: **Veterans and Agent Orange: Health Effects of Herbicides Used in Vietnam** [13]. In defining its scope of scientific assessment, the IOM noted:

Although there is evidence that multiple chemicals were used for various purposes in Vietnam, the use of four herbicides has been documented in military records: therefore, toxicologic assessment was limited to the compounds 2,4-D, 2,4,5-T, picloram and cacodylic acid....and the contaminant TCDD [13].

Thus, as noted the IOM has restricted their comprehensive reviews and evaluations of the available scientific and medical information just to these four herbicides and the dioxin contaminant based on the statement within the Agent Orange Act” *“For purposes of this section, the term ‘herbicide agent’ means a chemical in an herbicide used in support of the United States and allied military operations in the Republic of Vietnam during the Vietnam era”* [12, 13]. Although the term “tactical herbicide” was not used in the Act, clearly the intent was to restrict consideration to only those herbicides used in “military operations” and the associated dioxin contaminant. Not all parties accepted this restriction. Recently, it has been argued that: *“The inconsistency in the VA’s policy with respect to military herbicide exposure is not defensible. No minimal levels of exposure to herbicides have been set for veterans who served in-country, Vietnam and exposures have NOT been limited to dioxin”* [14].

The above statement could be interpreted that the commercial formulations of herbicides that were sent to Vietnam to control vegetation within the perimeters of Allied Bases should be included within the scope of the Agent Orange Act. If this interpretation is accepted, Vietnam-era veterans that were stationed at military installations throughout the more than 600 Department of Defense installations during the Vietnam era could argue that they too should be eligible for presumptive compensation for exposure to the same herbicides used in Vietnam.

Thus, it is important that a valid distinction be established between tactical herbicides and commercial herbicides used in Vietnam. That is the scope of this report.

TECHNICAL, ADMINISTRATIVE AND LEGAL DIFFERENCES

Tactical herbicides differed from commercial herbicides in the development and testing of formulations, regulatory oversight, use guidelines, purchase specifications, toxicological evaluations, shipment requirements, and military record keeping. Thus, there were technical, administrative, and legal differences between tactical and commercial herbicides used by the Department of Defense.

Technical Differences in Formulations and Their Evaluations

Both tactical and commercial herbicides were routinely used in Vietnam that contained 2,4-D and 2,4,5-T herbicides. The 2,4-D and 2,4,5-T generally came from the same companies, e.g., The Dow Chemical Company, Monsanto Company, Thompson-Hayward Chemical Company, Hercules Inc. (Transvaal), Diamond Shamrock Corporation and Rhodia, Inc. However, many smaller companies sold commercial formulations of 2,4-D and 2,4,5-T, e.g., Amchem Company [6, 11]. The key was whether the company actually produced the acid formulation or served simply as a formulator [9]. Thus, many companies world-wide sold various formulations but did not produce the acid. These formulations included amine salts, mineral salts, and esters. The commercial formulations were marketed under a variety of products and trade names such as Dead-Weed, Brush Killer, Esteron, Veon, Weedar, etc. [6, 11].

The most commonly used forms of 2,4-D and 2,4,5-T were the amine salts and esters [15]. The amine salts exhibited a low degree of volatility. The esters of 2,4-D and 2,4,5-T were typically formed by combining the acid with one of many different alcohols. The result was an oily liquid that was oil-soluble but not water soluble. The esters were usually sold as a liquid, while the amine salts were formulated as a dry powder. The esters formed an emulsion with water or water-oil carriers when properly formulated and gave a milky appearance. The esters of 2,4-D and 2,4,5-T were more effective than amines on some weed species, particularly woody plants [15].

The ester was identified by the alcohol used in the reaction. One molecule of water was eliminated and the alkoxy group of the alcohol replaced the hydroxyl of the carboxyl group of the phenoxy acid used. The less expensive and more abundant alcohols included the isopropyl and butyl alcohols. However, these alcohols formulated as esters exhibited high volatility, and in weed and brush control programs were undesirable because of their potential for phytotoxic drift. The long-chain alcohols with an ether linkage (-O-) had a lower volatility hazard than the short-chain alcohols. The low volatile esters included for example propylene glycol butyl ether, butoxyethanol, and isooctyl esters [15].

Active ingredient is defined as the substance contained in a formulated product that is responsible for the herbicidal effects and is shown as active ingredient on the registration label. Acid equivalent is the equivalent amount

of parent acid from the active ingredient content of a formulation. Inert ingredients are substances contained in a formulation that are not themselves phytotoxic, for which the preparation is intended. Materials such as solvents, emulsifiers, wetting agents, surfactants, etc are included [15].

A commercial formulation of a low-volatility ester of 2,4,5-T may have contained the following analysis on the container label [15]:

Active Ingredient:	70%
2,4,5-Propylene glycol butyl ether esters	
2,4,5-T (acid) equivalent, 4 lb/gal	
Inert Ingredients	30%

Formulations of the phenoxy tactical herbicides contained only the active ingredients with no solvents, diluents, or surfactants added. The Army Chemical Corps specified the formulations of tactical herbicides [8]. The concentration of active ingredient in the formulation was to be greater than 8 pounds active ingredient per gallon, thus maximizing the amount of active ingredient that could be aerially applied at 3 gallons per acre by the RANCH HAND and Chemical Corps aircraft [5, 11]. The n-butyl ester formulation was ideal for use in a jungle environment. The formulation was not water soluble, and it was rapidly absorbed into wax layer of the leaf within minutes and could not be physically dislodged [11]. Its volatility only enhanced the rapid absorption and facilitated its effectiveness in penetrating the leaf layers beneath the top canopy [11].

Agent Purple, 1962 – 1965: Purple was first formulated by the Army Chemical Corps at Fort Detrick, Frederick, Maryland in the mid-1950s time period. A similar formulation was first used in the Camp Drum, New York defoliation tests in 1959 [16]. The formulation was a brown liquid soluble in diesel fuel and organic solvents but insoluble in water [5, 11]. One gallon of Purple contained 8.6 pounds active ingredient (acid equivalents) of 2,4-D and 2,4,5-T. The percentages of the Purple formulation were:

n-butyl 2,4-D	50%
n-butyl 2,4,5-T	30%
iso-butyl 2,4,5-T	20%

Agent Green, 1962: Green was a single component formulation consisting of the n-butyl ester of 2,4,5-T. It was used in limited quantities in 1962. The formulation was a light brown liquid soluble in diesel fuel but insoluble in water. One gallon of Green contained 8.16 pounds acid equivalent of 2,4,5-T [5, 11].

Agent Pink, 1961 – 1964: Pink was a formulation of 2,4,5-T used first in late December 1961 and subsequently extensively in the early RANCH HAND operations and in the defoliation test program in Thailand in 1964 [16, 17]. One gallon of Pink contained 8.16 pound acid equivalent 2,4,5-T as a mixture of the esters [5, 11]. The percentages of the Pink formulation were:

n-butyl 2,4,5-T	60%
iso-butyl 2,4,5-T	40%

Agent Orange, 1965 – 1970: Orange was a reddish-brown to tan colored liquid soluble in diesel fuel and organic solvents but insoluble in water. The first shipment of Agent Orange arrived in Vietnam in March 1965 [18]. One gallon of Orange contained 8.62 pounds of the acid equivalent 2,4-D (4.41 pounds) and 2,4,5-T (4.21 pounds) [5, 11]. The percentages of the Orange formulation were:

n-butyl 2,4-D	50%
n-butyl 2,4,5-T	50%

Agent Orange II, 1967-1968: The same as Orange but with the substitution of the isooctyl ester of 2,4,5-T for the n-butyl ester of 2,4,5-T [5, 11].

Agent Blue (Liquid), 1966 – 1971: In 1961, the first Blue (95 drums) that was shipped to Vietnam was a powdered formulation (Ansar 138®) that required water [16]. In February 1966, the first liquid Blue arrived in Vietnam [18]. Agent Blue was a clear yellowish-tan liquid that was soluble in water, but insoluble in diesel fuel. One gallon of Blue contained 3.1 pounds of the active ingredient cacodylic acid. Blue contained both the cacodylic acid as the free acid and the sodium salt of cacodylic acid [5, 11]. The percentages of the formulation were:

cacodylic acid	4.7%
sodium cacodylate	26.4%
surfactant	3.4%
sodium chloride	5.5%
water	59.5%
antifoam agent	0.5%

Agent White, 1966 – 1970: White was a dark brown viscous liquid that was soluble in water but insoluble in diesel fuel or organic solvents. Herbicide White first arrived in Vietnam in January 1966 [18]. One gallon of White contained 0.54 pounds of the active ingredient 4-amino-3,5,6-trichloropicolinic acid (picloram) and 2.00 pounds of the active ingredient of 2,4-D. White was formulated to contain a 1:4 mixture of the triisopropanolamine salts of picloram and 2,4-D [5, 11]. The percentages of the formulation were:

triisopropanolamine salt of picloram	10.2%
triisopropanolamine salt of 2,4-D	39.6%
inert ingredient (primarily water, wetting agent, co-solvent triisopropanolamine)	50.2%

The Contaminant 2,3,7,8-TCDD: The most controversial issue associated with Agent Orange has been the concentration of the “unacceptable levels of impurities” [11]. The procurement specifications provided no information on potential impurities, including 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD; TCDD; or dioxin) [19]. It should be noted that TCDD was always a contaminant of 2,4,5-T and other products made from trichlorophenol [11]. Two sources of data were available to calculate the amount of TCDD that may have been present in the 2,4,5-T-containing tactical herbicides used in Vietnam: (1) Historical records indicated that the United States Air Force Logistics Command collected and analyzed 525 samples from the Agent Orange inventories at Johnston Island, Central Pacific Ocean, and the Naval Construction Battalion Center, Gulfport, Mississippi [11, 19]; and, (2) TCDD data were obtained from 557 archived samples of 2,4,5-T herbicide (1963-1969) from the Dioxin Registry Reports prepared by the US National Institute for Occupational Safety and Health (NIOSH) [20]. NIOSH examined five of the Chemical Companies that produced >90% of the Agent Orange purchased by the Defense Supply Agency [20]. A mean of 1.88 mg/kg (1.88 ppm) was obtained for a combined inventory of 40,910 drums of Agent Orange [11]. The mean TCDD concentration of the 557 samples of

2,4,5-T analyzed by NIOSH was also 1.88 mg/kg for production of herbicide for both commercial and military use [11]. Thus, the historical records and studies by NIOSH and the USAF Occupational and Environmental Health Laboratory confirmed that the levels of 2,3,7,8-TCDD contamination found in the 2,4,5-T used in tactical herbicides and commercial herbicides were the same, i.e., no data were found that indicated that the 2,4,5-T in tactical herbicides contained greater levels of TCDD than their commercial counterpart [11].

Field Testing of the Candidate Herbicides

Beginning in March 1963 and continuing through October 1967, the US Army Chemical Corps' Plant Science Laboratories conducted field tests at numerous locations throughout the Continental United States, Puerto Rico, Base Gagetown in Canada, on the Island of Kauai in Hawaii, and on the Pranburi Military Reservation in Thailand [21]. The purposes of these tests were to evaluate the effectiveness and persistence of the candidate tactical herbicides on a wide range of vegetation that represented the diversity of vegetation found in South Vietnam [21]. Details of these tests were published by the Department of Defense in 2006 in: **The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides** [21]. These tests and evaluations supported the selection of the three primary tactical herbicides, Agents Orange, White and Blue [11, 21]. The selection of commercial herbicides to be used by the Department of Defense was the responsibility of the Armed Forces Pest Control Board, AFPCB (later the Armed Forces Pest Management Board), and the Federal Committee on Pest Control (AFPCB) [22, 23]. The testing of commercial herbicides for the AFPCB was accomplished through a Memorandum of Understanding with the United States Department of Agriculture (USDA) [22].

Conclusion: The tactical herbicides Green, Pink, Purple and Orange contained the highly volatile n-butyl esters of 2,4-D and 2,4,5-T. These tactical herbicides were formulated as a concentrate without additional solvents, diluents, or surfactants added. They were formulated at the maximum concentration of active ingredient (> 8 pounds per gallon). The dioxin (TCDD) concentrations in the 2,4,5-T herbicide used in tactical herbicides were no different than the level of TCDD in the 2,4,5-T herbicide used in commercial herbicides. Agents Blue and White were also applied as concentrates for maximum effectiveness in controlling target vegetation.

Commercial applicators would never have selected the n-butyl ester formulation of 2,4-D or 2,4,5-T for weed or brush control because of the problems associated with volatility and drift. Commercial formulations would have contained low volatile esters or water soluble amine salts and would have contained emulsifiers, diluents, and/or surfactants. For spray operations of commercial herbicides, applicators would have diluted the formulations with water or diesel fuel prior to application. Similarly commercial formulations of picloram and cacodylic would have been diluted in water. Testing of the candidate tactical herbicides was done by the US Army Chemical Corps, while the USDA supported the testing of candidate commercial herbicides for DoD.

Technical Differences in Dissemination Characteristics

Tactical Herbicides: Simultaneously with the development of the tactical herbicide formulations, the US Army Chemical Corps' Plant Sciences Laboratories at Fort Detrick worked closely with the United States Air Force's Air Development Test Center (ADTC) and the Air Force Armament Laboratory (AFATL) at Eglin AFB Florida to develop and test the aerial spray equipment that were subsequently deployed for use in Vietnam [11, 21]. The development of the aerial spray equipment was a challenge that required interfacing the necessary dissemination characteristics with the biologically effective rate of application, i.e., "the minimum biologically effective ground deposition level of herbicide" [8, 24]. The field tests by Army Chemical Corps indicated that an aerial application rate of 3 gallons of concentrated herbicide per acre provided an effective control over most species of vegetation [5].

The extensive research into the design and testing of aerial herbicide application equipment by the ADTC and AFATL resulted in highly precise application systems for Vietnam. The development of the AA 45Y-1 Internal Defoliant Dispenser in 1964 allowed the RANCH HAND UC-123 aircraft ('U' designated that the aircraft had been modified to spray herbicides) to make only one spray pass on the mission target in Vietnam [24, 25]. Tests at Eglin AFB showed that 87% of Agent Orange would have impacted the vegetation within one minute and within or near the swath (a swath of 80 meters/~260 feet and drop size >400 microns) [24]. The remaining 13% of the herbicide took longer due to vortices at the wind tips, drift or evaporation; even these <100 micron size droplets would have impacted the vegetation with 3 minutes after spraying [24, 25]. Similar tests were

conducted at Eglin AFB on the helicopter systems used by the Army Chemicals in Vietnam [11, 25].

Commercial Herbicides: On 17 November 1956, Department of Defense Directive 5154.12 established the AFPCB [subsequently The Armed Forces Pest Management Board (AFPMB)]. The Directive placed the AFPCB within the Office of the Secretary of Defense [22]. Today, the AFPMB resides within the Office of the Deputy Under Secretary of Defense (Installations and Environment). The Board is composed of members from the Army, Navy, Air Force and selected Defense Agencies (a total of 20 members). The Board was also to have 24 liaison members and 25 non-DoD Agency representatives. The Board established 8 Standing Committees: Environmental Impact, Equipment, Quarantine, Medical Entomology, Pesticides, Real Property Protection, Stored Products, and Training, Certification, and Manpower [22].

During the Vietnam Era, the Armed Forces Pest Control Board provided the oversight for the selection of commercial herbicides used on military installations [10, 22].]. The Board DID NOT work with the chemical companies manufacturing pesticides, rather, these materials were evaluated through a Memorandum of Understanding with the United States Department of Agriculture (USDA). The USDA recommended the formulations based on research conducted by the Agricultural Research Service (ARS) and validated by the Cooperative Agricultural Research Service (CSRS) and the Extension Service. These studies focused on individual weed or brush species, by location, and by either ground or aerial application systems [22]. These guidelines for the use and application rate of specific herbicides and the selection of appropriate application equipment were approved by the AFPCB and adopted by the various branches of the military. For example, in 1970 the **Herbicide Manual for Noncropland Weeds** was published as an Army, Navy and Air Force Manual [26].

Conclusions: For the effective use of tactical herbicides in a combat environment, it was required that a close interface be developed between the aircraft (RANCH HAND UC-123 or US Army Chemical Corps helicopters), the aerial spray equipment, and the requirements for both a biologically effective rate and an appropriate dispersion of the spray droplets. This was accomplished through an extensive test program at Eglin AFB Florida. The tactical herbicides and aerial application systems were subsequently deployed to Vietnam.

The selection of commercial herbicides including their use recommendations and appropriate application equipment was through a Memorandum of Understanding with the USDA. These recommendations were approved and coordinated by the AFPCB and generally published as manuals for use by the individual military agencies.

Administrative Differences

Purchase Descriptions: All herbicides, both tactical and commercial, used by the Department of Defense required purchase specifications. There were four distinct “types of specifications”. These were: (1) Purchase descriptions; (2) Army, Navy, and Air Force Specifications; (3) Military Specifications; and, (4) Federal Specifications [27]. Purchase descriptions were merely descriptions of the material desired and were used for filling small needs or for materials that were needed on an emergency basis. They were issued by all government agencies and were of a temporary nature. Army, Navy, and Air Force specifications covered items specific to one of these military services (e.g., a biocide for ship hulls). Military Specifications were complete documents and were used when the need for the materials were confined to a specific military operation (e.g., all of the tactical herbicides used in tactical operations in Vietnam) [27].

Tactical Herbicides: The actual military specifications for the tactical herbicides were prepared by the Army Chemical Corps and those specifications were provided to the Defense Supply Agency for procurement actions [11]. The acquisition of tactical herbicides was initially the responsibility of the Army Chemical Corps but in 1962 this responsibility was transferred to the Middletown Air Materiel Area (MAAMA), Olmsted AFB Harrisburg Pennsylvania and in August 1966 this responsibility was assigned to the Air Force Aerospace Fuels at the San Antonio Air Materiel Area (SAAMA), Kelly AFB Texas [28].

As noted, the procurement of all tactical herbicides was done by the Defense Supply Agency (DSA). DSA provided the 55-gallon drums and arranged for all transportation (primarily by rail) of the drums from the chemical companies manufacturing the herbicides to the port of embarkation for transport to South Vietnam. The chemical companies were selected on the basis of competitive bids and DSA provided the specifications that were required to be met by the manufacture [28].

Commercial Herbicides: The AFPCB adopted the policy for the Department of Defense to recommend that any pesticide formulation that has uses in civilian agencies be issued as a “Federal Specification”. These types of pesticide were to be issued by the Military Supply System within the General Services Administration [11]. By 1966, the AFPCB strictly controlled the kinds and forms of pesticides available under “Federal Specifications” and on the military supply list [22, 26]. New pesticides, before being considered by the Board, had to be recommended by the US Department of Agriculture, the Fish and Wildlife Service, or the Public Health Service, and the proposed use must have been approved by all three of these organizations. In February 1967, the Federal Committee on Pest Control (FCPC) was established [23]. All Federal pest control activities were placed within the purview of the Committee. The Committee was composed of two members from each of the Departments of Agriculture; Defense; Health; Education, and Welfare; and Interior. Before a pesticide was approved for use in the United States, or by a Federal Agency, it had to be reviewed by the FCPC. Tactical herbicides were exempt from this approval and oversight process. However, all other herbicides used by the Department of Defense were required to meet this approval process. The significance of this action was that herbicides used in 1967 to 1970 on the more than 600 military installations managed by the Department of Defense required approval by both the AFPCB and the FCPC (after 1970, the registration and oversight of commercially available pesticides was the responsibility of EPA) [11]. This requirement applied to herbicides used in Vietnam that were NOT TACTICAL HERBICIDES.

Thus, herbicides used on Allied Bases in Vietnam around buildings, in equipment storage sites, and along interior roads within the base perimeters came under the oversight of the AFPCB. The responsibility for the purchase and application of commercial pesticides on these installations was the Base Civil Engineer (Facilities Engineer), NOT the Army Chemical Corps [11]. None of the tactical herbicides were approved for these uses. The insecticides used in Operation FLYSWATTER (the aerial application of insecticides to control mosquitoes in Vietnam) were under the Military’s Disease Prevention Program and were recommended and approved by the AFPCB [29].

Conclusions: All aspects of the development and deployment of tactical herbicides were the responsibility of the Army Chemical Corps, Fort Detrick

Maryland. This included the development of purchase specifications and the providing of those specifications to the Defense Supply Agency. The actual acquisition of tactical herbicides was the responsibility of the Air Force Air Logistics Centers at Olmstead AFB Pennsylvania and Kelly AFB Texas. The chemical companies were selected on the basis of competitive bids and DSA provided the specifications that were required to be met by the manufacture. The purchase descriptions for commercial herbicides were recommended to the AFPCB by USDA's Agricultural Research Service with their subsequent acquisition through the Military Supply System operated by the General Services Administration.

Pesticide Certification and Oversight Programs

Commercial Herbicides: All commercial pesticides used by DoD, including herbicides, were to be applied only by certified applicators or under the direct supervision of a certified applicator. Although each military service had its own pesticide certification program, the coordination of these programs with other agencies occurred at the level of the AFPCB. Indeed, in August 1974, Department of Defense Directive 4150.7 established minimum levels of pest control for DoD Installations compatible with national objectives for the protection of the environment [30]. Within this Directive, 'Certification' was defined as the "attainment of competency for pest control operators and supervisors" equal to standards recommended by the AFPCB. The AFPCB, operating under the Office of the Secretary of Defense had the major responsibility to coordinate the applicator certification plan among the operating agencies [30].

The application of a commercial herbicide could only be done within the base perimeter and by a Board "certified" (trained) applicator with equipment that had been approved by the USDA, and/or under the supervision of the Base Civil Engineer. The AFPCB even depended upon USDA's Cooperative State Research Service (CSRS) and its University-based research and extension system to prepare and publish manuals on pesticide use, plans for certification of pesticide applicators, and the disposal of old pesticides and pesticide containers. Frequently, USDA's Extension Service conducted pesticide certification workshops to which participants from all of the military services were invited to attend [11, 22].

Tactical Herbicides: The oversight for the use of tactical herbicides did not reside within the responsibilities of the AFPCB. As previously noted, the Army Chemical Corps' Plant Sciences Laboratories at Fort Detrick Maryland was responsible for developing vegetation control concepts, vegetation control agents (including Orange, White and Blue) and with the help of both the United States Air Force and the United States Navy, the development and employment of the aerial and ground dissemination systems [5]. Although no pesticide certification was developed for the spraying of tactical herbicides in Vietnam, the overall policy and procedures for herbicide operations in Vietnam were set forth in detailed directives issued by the Military Assistance Command, Vietnam (MACV) [31]. These directives were based upon specific guidelines provided by the Department of State and DoD [31]. The most important of these directives was MACV Directive 525-1 which governed all tactical herbicide used by both US and Free World Military Assistance Forces troops between 1965 and 1970. This Directive prescribed policies, responsibilities, and procedures governing the operational employment of herbicides within South Vietnam, including all fixed wing, helicopter, and surface-based methods of herbicide application [31].

The challenges to obtain successful vegetation control in tactical operations in South Vietnam required a cadre of professionally trained men dedicated to the successful completion of a military mission [11]. The Army Chemical Corps had the responsibilities for the ground and helicopter operations, and the oversight of the overall ground vegetation control program OUTSIDE THE BASE PERIMETERS. The Department of the Army assigned a Chemical Officer (J3-09) to the MACV to coordinate "operational aspects and plans" involving the use of the tactical herbicides by US and Allied military units [31]. In 1966, the US Army deployed the first (of 22) Army Chemical Corps units to South Vietnam. These units were responsible for the storage, handling, mixing, and application of riot control agents (tear gas), burning agents, and tactical herbicides by the US Army. Men serving in these units performed duties associated with storage, preparation, and the ground and helicopter applications of vegetation control chemicals, as well as equipment cleaning and maintenance. From 1952 – 1973, the training of the Army Chemical Corps personnel was the responsibility of the US Army Chemical School, Fort McClellan, Alabama. In 1979, the US Army Chemical Center and School was re-established at Fort Leonard Wood, Missouri [11, 31].

The fixed-wing aerial spray operations of Agent Orange and other tactical herbicides were conducted with highly trained RANCH HAND aircrews using the UC-123 (B and K models) and aerial spray equipment that had been specifically developed, thoroughly tested and critically evaluated for their performance and dissemination characteristics [11, 18, 24, 31]. The USAF was responsible for the training of the aircrews and development of aerial tactics for herbicide missions [11]. MACV Directive 525-1 also applied to RANCH HAND Operations [31].

Conclusions: All commercial pesticides used by DoD, including herbicides, were to be applied only by certified applicators or under the direct supervision of a certified applicator. Although each military service had its own pesticide certification program, the coordination of these programs with other agencies occurred at the level of the AFPCB. The AFPCB depended upon USDA's Cooperative State Research Service (CSRS) and its University-based research and extension system to prepare and publish manuals on pesticide use, plans for certification of pesticide applicators, and the disposal of old pesticides and pesticide containers. Frequently, USDA's Extension Service conducted pesticide certification workshops to which participants from all of the military services were invited to attend.

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LEGAL REQUIREMENTS INCLUDING RECORD KEEPING

Commercial Herbicides: Under the Directives 5154.12 and 4150.7, the Department of Defense gave the Armed Forces Pest Control Board/Armed

Forces Pest Management Board the authority to set pest management policy “*applicable for all Department of Defense pest management activities in any unit, at any time, in any place, even when conducted by contract operations.*” As previously noted, in August 1961, the Department of Defense established a support program through a Memorandum of Understanding with the USDA that among other responsibilities provided the research, recommendations, and specifications of commercial pesticides that were suitable and met the need for Department of Defense use. Prior to the USDA’s recommendation to AFPCB, the Agricultural Research Service ensured that the commercial herbicides met the label description for use and safety and that it was registered through the regulatory program of USDA [22]. The significance of these Directives and the Memorandum was that any commercial herbicides used after 1961 on the Department’s more than 600 installations must have been approved by the Board, and must have met USDA’s regulatory requirements (now the Environmental Protection Agency), and be in full compliance with the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) [22, 23].

Once the herbicide met the regulatory requirements, it was assigned a Federal Standard Stock number (FSN) and would be listed in the Federal Stock Catalog as available from the Military Supply System operated by the General Service Administration [32]. For example:

<u>Stock List</u>	<u>FSC Catalog No.</u>	<u>FSN No.</u>	<u>Description & Price</u>
Herbicide, Amitrole	048720-500	6840-833-1217	Amitrole 90% powder, 24 lb pail
Herbicide, 2,4,5-T	049280-200	6840-582-5440	Low volatile ester as emulsifiable concentrate, 4 lb acid equivalent per gallon, \$32.60/5-gal pail

When received by the military agency, the container had a label to include the product name, the company name, regulatory registration number, use recommendations, and safe handling instructions.

With the establishment and functioning of the AFPCB, anytime a DoD Military Base, e.g., Eglin AFB, Florida, Andersen AFB, Guam, or Osan AB, Korea, requested the use of an herbicide to control plant pests, the selection of the herbicide must have been one that was recommended by USDA and

approved by the Board. Locally purchased pesticides were to be approved by the Command Entomologist [22, 32]. To ensure that military installations were identifying and controlling pests detrimental to military personnel, property, projects, and programs, the AFPCB had a cadre of military and civilian personnel via supporting Agencies and Laboratories (e.g., the Epidemiology Division of the School of Aerospace, Brooks AFB, Texas; USAF Occupational and Environmental Health Laboratory, Kelly AFB, Texas; and the Public Health Service) that routinely conducted Pest Surveys, Staff Visits, Training Programs, and Conferences on identifying and controlling pests. Reports of these visits, programs, and conferences were published by the AFPCB and widely circulated to other military installations [10, 11, 22, 26, 30]. Normally Base or Facilities Engineering Organizations maintained use and procurement records for only five years [30, 32].

Tactical Herbicides: The exception to the above Directives was the development of the “tactical herbicides” sprayed in combat military operations in Vietnam, or by Department of State approval as used in Korea adjacent to the Demilitarized Zone in 1968 [33]. The USDA had no regulatory authority over the selection or use of herbicide formulations developed by the Department of the Army for tactical military operations. Thus, tactical herbicides were not required to be labeled, nor required to comply with the directions from the Pesticide Regulation Branch of USDA or with FIFRA. Following publication of “Military Specifications” (prepared by the Army Chemical Corps), tactical herbicides were purchased directly by the Department of Defense (via the Defense Supply Agency) for use in Vietnam. The only labeling requirements for tactical herbicides were a 3-inch colored band around the center of the 55-gallon drums to identify the specific tactical herbicide, e.g., Orange, Blue, or White and, the lids were stenciled with a brief description of the herbicide formulation (e.g., “HERBICIDE BUTYL ESTERS, 50% 2,4-D and 50% 2,4,5-T), the Federal Specification Number (FSN), Transportation Control Number, US Port of Embarkation (e.g., Transportation Officer, Gulf Outport, Mobile, Alabama), destination (e.g., ARVN 511th Ordinance Storage Depot, Da Nang, Vietnam), DSA Procurement Number and date, and net weight of contents [11].

The Air Force Armament Laboratory at Eglin AFB, Florida, the Air Force Environmental Health Laboratory, at McClelland AFB, California, the Air Force Occupational and Environmental Health Laboratory, Kelly AFB, Texas, the Plant Sciences Laboratory at Fort Detrick, and the United States

Army Environmental Hygiene Agency, Aberdeen, Maryland, were responsible for determining physical properties, efficacy, toxicology, safe handling procedures, and actions to be taken for spills, environmental contamination, and disposal for all of the tactical herbicides [5, 11, 21, 28].

The Army Chemical Corps had responsibility for maintaining the records on the use of tactical herbicides in Vietnam (and elsewhere). The use of tactical herbicides by RANCH HAND (7th Air Force) and the US Army Chemical Corps were recorded on the HERBS tape and have been made available to the public [11, 18]. The request for procurement of tactical herbicides was the responsibility of the Chemical Corps' Chemical Operation Division, J-3, MACV [18, 28]. Thus, RANCH HAND operations that used the tactical herbicides had to coordinate all procurement actions with the Army Chemical Corps. The Chemical Corps then authorized the Air Force Logistics Command to purchase and transport the herbicide [28].

The transport of tactical herbicides required concurrence by the US Army Chemical Corps and/or the San Antonio Air Material Area with full approval of the Military Sea Transportation Service. Shipments were authorized by a DD Form 173 "Joint Message Form." This was critical so that schedules were established and stevedores and barges or derricks were dispatched to the dock and ship to facilitate in the loading and unloading of the drums, and arrangements made to ensure the safety, transport, and storage of the defoliant [28].

Numerous evaluations of the effectiveness of tactical herbicides in South Vietnam were published by the Army Chemical Corps, MACV, the 7th Air Force, and the Rand Corporation [11]. Because tactical herbicides were not registered, and because of litigations actions beginning in the 1970s, most records of their use, transport, disposal, and environmental fate are now maintained in the National Archives.

SUMMARY

In 1961, Air Materiel Command became the Air Force Logistics Command (AFLC). During the Vietnam War, AFLC was responsible through the Air Logistics Command Centers for the procurement, supply, and maintenance of all weapons systems deployed to Vietnam, including tactical herbicides. In 1962, the responsibility for the management of tactical herbicides was assigned to the Middletown Air Materiel Area, (MAAMA) Olmsted AFB

Pennsylvania. In August 1966, the management for tactical herbicides was transferred to the San Antonio Air Materiel Area (SAAMA), Kelly Air Force Base Texas, This responsibility included the procurement and shipment of all the tactical herbicides sent to Vietnam. Although The United States Army Chemical Corps, and specifically the Plant Science Laboratories at Fort Detrick, was responsible for the selection, evaluation, and purchase description of the herbicides, the Product Engineering Branch, Directorate of Aerospace Fuels, San Antonio Air Logistics Command at Kelly AFB was the organization that contracted for the tactical herbicides through the Directorate of Procurement and Production, Defense General Supply Center, Defense Supply Agency, Richmond, Virginia. The Air Force Armament Laboratory at Eglin AFB, Florida, was assigned the research, development, and testing of the aerial spray equipment for use in Vietnam.

In the case of the phenoxy herbicides, when formulated as tactical herbicides, the high volatile esters were used because they were less expensive and the particle size was sufficiently large to place the concentrated materials on the upper canopy with minimal drift when aurally applied by RANCH HAND aircraft under approved atmospheric conditions. The concentrated tactical herbicides were aurally sprayed at the rate of 3 gallons per acre in Vietnam. These were formulations and concentrations that generally greatly exceeded how the commercial components of these tactical herbicides (2,4-D; 2,4,5-T) were formulated and used in the United States in brush and weed control, forestry management, ranges and rice cultivation. The implication that any mixture of 2,4-D and 2,4,5-T could be called "Agent Orange" is incorrect. The butyl formulations were not commercially available. To be Agent Orange, the formulation had to contain concentrated butyl esters of 2,4-D and 2,4,5-T, with no solvents, wetting agents, surfactants, or other inert ingredients. The tactical herbicides were not to be used in brush and weed control programs on military installations in Vietnam or elsewhere, because they were not registered or labeled, and not approved for such use by the Armed Forces Pest Control Board.

The commercial formulations used by Base Civil Engineering Units in Vietnam were formulations that minimized drift to Vietnamese crops growing near the bases. These formulations contained surfactants, and other inert materials to enhance effectiveness, and were mixed either in water or as a water-oil emulsion and were either hand sprayed or sprayed with mobile ground equipment.

REFERENCES

1. Westing AH (1976): Ecological Consequences of the Second Indochina War. Stockholm International Peace Research Institute, Almqvist & Wiksell International, Stockholm, Sweden
2. Fox RP (1979): Air Base Defense in the Republic of Vietnam, 1961-1973. Office of Air Force History, United States Air Force, Washington DC
3. Darrow RA (1965): Crops Division Screening Program. In: Darrow RA, Mattie VZ (Eds.), Proceedings of the Second Defoliation Conferences, 5-6 August 1964. US Army Biological Laboratories, Fort Detrick, Frederick Maryland (Available from the Alvin L. Young Agent Orange Collection, National Agricultural Library, Accession No. 00063)
4. Mattie VZ (1964): Proceedings of the First Defoliation Conference, 29-30 July 1963. US Army Biological Laboratories, Fort Detrick, Frederick Maryland (Available from the Alvin L. Young Agent Orange Collection, National Agricultural Library, Accession No. 00009)
5. Irish KR, Darrow RA, Minarik CE (1969): Information Manual for Vegetation Control in Southeast Asia. Miscellaneous Publication 33, Plant Physiology Division, Plant Sciences Laboratory, Department of the Army, Fort Detrick Maryland (Available from Alvin L. Young Agent Orange Collection, National Agricultural Library, Accession No. 00073)
6. WSSA (1967): Herbicide Handbook of the Weed Society of America (later the Weed Science Society of America), James L. Hilton, Chairman. Weed Science Society of America, Champaign IL
7. Eldridge BF (1971): Recommended Statement on Use and Disposition of Pesticides. Armed Forces Pest Control Board, Forest Glen Section, WRAMC, Washington DC (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 61764)
8. US Army (1971): Tactical Employment of Herbicides. Field Manual 3-3, US Army HQ, Washington DC (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 65134)
9. US Army (1972): Herbicides and Military Operations. Volume I and II, Department of the Army, Engineer Strategic Study Group, Office of the Chief of Engineers, Washington DC
10. AFPCB (1966): Pest Control in the Armed Forces. Armed Forces Pest Control Board, Forest Glen Section, WRAMC, Washington DC, USA (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 28090)

11. Young AL (2008): Agent Orange: A History of Its Use, Disposition and Environmental Fate. (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession 188312)
12. Public Law 102-4 (February 6, 1991): Agent Orange Act of 1991. 102nd Session of the United States Congress, Washington DC
13. Institute of Medicine (1994): Veterans and Agent Orange: Health Effects of Herbicides Used in Vietnam. Prepared by the Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides, Division of Health Promotion and Disease Prevention, Institute of Medicine, The National Academies Press, Washington DC
14. Stellman JM (2012): Letter to Wesley T. Carter (Major, retired) included in submittal package to the Secretary of the Department of Veterans Affairs RE: Exposure of UC-123K Aircrews Post Vietnam
15. Bovey RW (1980): Uses of Phenoxy Herbicides and Their Methods of Application. IN: Bovey RW, Young AL (Eds). The Science of 2,4,5-T and Associated Phenoxy Herbicides. Chapter 3: 49-69, Wiley-Interscience Publications, New York, New York
16. Brown JW (1962): Vegetational Spray Tests in South Vietnam, Supplement describing the 1959 Camp Drum, NY Trials. (Available from the Alvin L. Young Agent Orange Collection, National Agricultural Library, Accession No. 00337)
17. Darrow, RA (1965): OCONUS Defoliation Test Program, Semiannual Report No.1, April 1964 – September 1964. ARPA Order No. 423, US Army Biological Laboratories, Fort Detrick MD (Document declassified October 1977, but subject to export control. Available from the Defense Documentation Center, Accession No. AD 360646)
18. Cecil PF (1986): Herbicidal Warfare: The RANCH HAND Project in Vietnam. Praeger Special Studies, Praeger Scientific, New York New York
19. Department of the Air Force (1974): Disposition of Orange Herbicide by Incineration, November 1974. United States Air Force, Washington DC (A available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 121796)
20. Piacitelli L, Marlow D, Fingerhut, M, Steenland K, Sweeney MH (2000): A Retrospective Job Exposure Matrix for Estimating Exposure to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin. Am J Ind Med 38: 28-39
21. Young AL (2006): The History of the US Department of Defense Programs for the Testing, Evaluation, and Storage of Tactical Herbicides (Available from the

- Armed Forces Pest Management Literature Retrieval System, Accession No. 182581)
22. AFPCB (1974): History of the Armed Forces Pest Control Board, Armed Forces Pest Control Board, Forest Glen Section, Walter Reed Army Medical Center, Washington, DC (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 80358)
 23. FCPC (1967): Federal Committee on Pest Control: What it is and what it does. (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 35122)
 24. Harrigan ET (1970): Calibration Tests of the UC-123K/A/A 45Y-1 Spray System. Technical Report ADTC-TR-70-36, Armament Development and Test Center, Eglin AFB FL (Available from the Alvin L. Young Agent Orange Collection, National Agricultural Library, Accession No. 00371)
 25. Young AL, Giesy JP, Jones PD, Newton M (2004): Environmental Fate and Bioavailability of Agent Orange and Its Associated Dioxin During the Vietnam War. *Environ Sci Pollut Res* 11 (6): 359-370 (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 180537)
 26. Department of Defense Tri-Service (1970): Herbicide Manual for Noncropland Weeds. Army TM 5-629, Navy NAVFAC MO-314, Air Force AFM 91-19 (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 167371)
 27. Fleck EE (1967): The Development of Pesticide Specifications for Government Use. *Agric Chem* 16 (9): 28-30. (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 10193)
 28. Craig DA (1975): Use of Herbicides in Southeast Asia. Directorate of Energy Management, San Antonio Air Materiel Center, Kelly AFB TX (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 188338)
 29. Cecil PF, Sr. Young AL (2008): Operation FLYSWATTER: A War Within A War. *Environ Sci Pollut Res* 15 (1): 3-7 (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 193091)
 30. AFPCB (1977): Department of Defense Plan for Certification of Pesticide Applicators. Armed Forces Pest Control Board, Forest Glen Station, Walter Reed Army Medical Center, Washington DC (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 96815)
 31. Young AL, Cecil PF Sr., Guilmartin JF, Jr. (2004): Assessing Possible Exposures of Ground Troops to Agent Orange during the Vietnam War: The Use of

- Contemporary Military Records. *Environ Sci Pollut Res* 11 (6): 349-358 (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 180802)
32. Naval Medical Field Research Laboratory (1968): Pesticides and Pest Control Equipment, Information Concerning. NMFRL-032, Camp Lejeune NC (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 42937)
 33. Young AL, Young KL (2011): Historical Review of the 1968 Project to Spray Tactical Herbicides on the Korean DMZ (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 192313)
 34. USAEHA (1987): Toxicological and Efficacy Review of USAREUR Pesticides. United States Army Environmental Hygiene Agency, Aberdeen Proving Ground MD, USA. (Available from the Armed Forces Pest Management Board Literature Retrieval System, Accession No. 135136)

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For more than 40 years, Dr. Alvin L. Young has been involved in issues surrounding the use of Herbicide Orange and other tactical herbicides in Vietnam. He completed his PhD in Herbicide Physiology and Environmental Toxicology at Kansas State University in 1968. In his 21 years with the USAF (obtaining the rank of Colonel), he was involved with the testing and evaluation of the equipment used in Operation RANCH HAND, Vietnam, and with the environmental and human health studies with the USAF School of Aerospace Medicine and the Department of Veterans Affairs. He served as a Science Advisor on environmental issues including Agent Orange with the President's Office of Science and Technology Policy. He was the Director of the Department of Energy's Center for Risk Excellence. He was a Visiting Professor at the University of Oklahoma, 2001-2007, and has served as the Senior Consultant on Herbicide Orange for the Office of the Deputy Under Secretary of Defense (Installations and Environment). He has more than 300 publications in the scientific literature, including five books on issues related to Herbicide Orange and/or dioxins and furans. From 2000 to 2012, He was the Editor of the international journal *Environmental Science and Pollution Research*.

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