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USE OF HERBICIDES IN SOUTH VIETNAM, 1961-1971*

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Herbicides used in support of tactical military operations in South Vietnam from 1961 to 1971 are today, twelve years after the last herbicide mission, the center of intense scientific debate involving not only medical but also legal, political and ecological issues. This paper reviews the historical and operational concepts and some potential human exposure considerations involving the military use of herbicides in the Southeast Asian Conflict.

Herbicides Used in South Vietnam

Synthesis technology, efficacy data, and field application techniques were developed for the two major phenoxy herbicides, 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) during World War II at Fort Detrick, Frederick, Maryland. Following World War II, the commercial use of these two "synthetic" organic herbicides revolutionized American agriculture. In 1950, more than 10 million pounds of these materials were used annually for weed and brush control in the United States. By 1960, in excess of 36 million pounds were used.

In May 1961, the Office of the Secretary of Defense requested the Fort Detrick personnel to determine the technical feasibility of defoliating jungle vegetation in the Republic of Vietnam. By early fall, 1961, 18 different aerial spray tests (defoliation and anticrop) had been conducted with various formulations of commercially-available herbicides. The choice of these herbicides was based upon the chemicals that had had considerable research, proven performance, and practical background at that period in time. Also, such factors as availability in large quantity, costs, and known or accepted safety in regard to their toxicity to humans and animals was considered. The results of these tests were that significant defoliation and anticrop effects could be obtained with two different mixtures of herbicides. The first was a mixture of the n-butyl esters of 2,4-D and 2,4,5-T and the iso-butyl ester of 2,4,5-T. This mixture was code-named "Purple". The second "military" herbicide was code-named "Blue" and consisted of the acid and sodium salt of cacodylic acid. The colored bands which were painted around the center of the 55-gallon drums served as aid to the identification by support personnel.

The first shipment of Herbicides Purple and Blue was received at Tan Son Nhut Air Base, Republic of Vietnam, on 9 January 1962. These were the first military herbicides used in Operation RANCH HAND, the tactical military project for the aerial spraying of herbicides in South Vietnam. Two additional phenoxy herbicide formulations were received in limited quantities in South Vietnam and

* A synopsis of information from Chapters I and III of The Toxicology, Environmental Fate, and Human Risk of Herbicide Orange and Its Associated Dioxin, Air Force Technical Report OEHL-TR-78-92, USAF Occupational and Environmental Health Laboratory, Brooks Air Force Base, Texas. (Authors: A. L. Young, J. A. Calcagni, C. E. Thalken, and J. W. Tremblay) 1978.

evaluated during the first two years of Operation RANCH HAND. These were code-named Pink and Green. By January 1965, two additional military herbicides, code-named Orange and White, had been evaluated and brought into the spray program. Herbicide Orange replaced all uses of Purple, Pink, or Green, and eventually became the most widely used military herbicide in South Vietnam. The composition of the three major herbicides used in South Vietnam were as follows:

1. Herbicide Orange

Orange was a reddish-brown to tan colored liquid soluble in diesel fuel and organic solvents, but insoluble in water. One gallon of Orange theoretically contained 4.21 pounds of the active ingredient of 2,4-D and 4.41 pounds of the active ingredient of 2,4,5-T. Orange was formulated to contain a 50:50 mixture of the n-butyl esters of 2,4-D and 2,4,5-T. The percentages of the formulation typically were:

n-butyl ester of 2,4-D	49.49
free acid of 2,4-D	0.13
n-butyl ester of 2,4,5-T	48.75
free acid of 2,4,5-T	1.00
inert ingredients (e.g., butyl alcohol and ester moieties)	0.62

2. Herbicide White

White was a dark brown viscous liquid that was soluble in water but insoluble in organic solvents and diesel fuel. One gallon of White contained 0.54 pounds of the active ingredient of 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 triisopropanoamine salts of picloram and 2,4-D. The percentages of the formulation were:

triisopropanolamine salt of picloram	10.2
triisopropanolamine salt of 2,4-D	39.6
inert ingredient (primarily the solvent triisopropanolamine)	50.2

3. Herbicide Blue

Blue was a clear yellowish-tan liquid that was soluble in water, but insoluble in organic solvents and diesel fuel. One gallon of Blue contained 3.10 pounds of the active ingredient hydroxydimethyarsine oxide (cacodylic acid). Blue was formulated to contain cacodylic acid (as the free acid) and the sodium salt of cacodylic acid (sodium cacodylate). 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

As previously noted, not all of the herbicides used in South Vietnam were used throughout the entire 10 years (1962-1971) encompassed by the Department of Defense defoliation program. In addition, 2,4,5-T formulations used early in the program are believed to have contained higher levels of the toxic contaminant TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin or "dioxin") than did the formulations used in later years. The three time periods shown in Table 1 can be differentiated on the basis of specific herbicides used and the mean dioxin content.

TABLE 1
THE DIFFERENTIATION OF THREE TIME PERIODS DURING THE US MILITARY DEFOLIATION PROGRAM IN SOUTH VIETNAM AND MEAN DIOXIN CONTENT

PERIOD	HERBICIDES USED (CODE NAMES)	MEAN DIOXIN CONTENT (PARTS PER MILLION)*
January 1962 - June 1965	Purple, Pink, Green	32**
	Blue	0
July 1965 - June 1970	Orange	2+
	White, Blue	0
July 1970 - October 1971	White, Blue	0

* Found only in 2,4,5-T containing formulations.
** Value based on analyses of five samples.
Orange based on the analyses of 488 samples.

Herbicide Orange was the most extensively used herbicide in South Vietnam. Orange accounted for approximately 10.7 million gallons of the total 17.7 million gallons of herbicide used (Table 2). It was used from mid-1965 to June 1970. However, as stated in Table 2, Orange was not the only 2,4,5-T containing herbicide used in the defoliation program. Small quantities of Purple, Pink, and Green, all containing 2,4,5-T were used from 1962 through mid-1965. In subsequent sections of this document, the term "Herbicide Orange" will refer to all of the 2,4,5-T containing herbicides used in Vietnam (Purple, Pink, Green, and Orange).

TABLE 2
NUMBER OF GALLONS OF MILITARY HERBICIDE PROCURED BY THE US DEPARTMENT OF DEFENSE AND DISSEMINATED IN SOUTH VIETNAM DURING JANUARY 1962 - OCTOBER 1971

Code Name	Herbicide	Quantity	Period of Use
Orange	2,4-D; 2,4,5-T	10,646,000	1965-1970*
White	2,4-D; Picloram	5,633,000	1965-1971**
Blue	Cacodylic Acid	1,150,000	1962-1971**
Purple	2,4-D; 2,4,5-T	145,000	1962-1965
Pink	2,4,5-T	123,000	1962-1965
Green	2,4,5-T	8,200	1962-1965
	Total	17,705,200	

* First fixed-wing spray mission of Herbicide Orange April 16, 1970; last helicopter spray mission of Herbicide Orange June 6, 1970.

** Last fixed-wing mission January 9, 1971; all herbicides under US control stopped October 1971.

Use Patterns of Individual Herbicides

Each of the three major herbicides (Orange, White, and Blue) had specific uses. Ninety-nine percent of Herbicide White was applied in defoliation missions. It was not recommended for use on crops because of the persistence of Picloram in soils. Because the herbicidal action on woody plants was usually slow, full defoliation did not occur for several months after spray application. Thus, it was an ideal herbicide for use in the inland forests in areas where defoliation was not immediately required, but where it did occur it would persist longer than if the area were sprayed with Orange or Blue.

Herbicide Blue was the herbicide of choice for crop destruction missions involving cereal or grain crops. Approximately 50 percent of all Blue was used in crop destruction missions in remote or enemy controlled areas with the remainder being used as a contact herbicide for control of grasses around base perimeters.

Ninety percent of all Herbicide Orange was used for forest defoliation and it was especially effective in defoliating mangrove forests. Eight percent of Herbicide Orange was used in the destruction of broadleaf crops (beans, peanuts,

ramie, and root or tuber crops). The remaining 2 percent was used around base perimeters, cache sites, waterways, and communication lines.

Table 3 shows the number of acres sprayed with herbicides in South Vietnam within the three major vegetational categories.

TABLE 3
THE NUMBER OF ACRES TREATED IN SOUTH VIETNAM, 1962-1971, WITH MILITARY HERBICIDES WITHIN THE THREE MAJOR VEGETATIONAL CATEGORIES

Vegetational Caategory	Areas Treated*
Inland forest	2,670,000
Mangrove forests	318,000
Cultivated crops	260,000
Total	3,248,000

* Areas receiving single or multiple coverage.

Certain portions of South Vietnam were more likely to have been subjected to defoliation. Herbicide expenditures for the four Combat Tactical Zones of South Vietnam are shown in Table 4. These data were obtained from the HERBS tape (a computer listing of all herbicide missions in South Vietnam from 1965 through 1971). Total volume is in close agreement with the actual procurement data shown in Table 2.

TABLE 4
US HERBICIDES EXPENDITURES IN SOUTH VIETNAM, 1962-1971: A BREAKDOWN BY COMBAT TACTICAL ZONE*

(CTZ) Combat Tactical Zones	Herbicide Expenditure (gallons) Orange	White	Blue
CTZ I	2,250,000	363,000	298,000
CTZ II	2,519,000	729,000	473,000
CTZ III (includes Saigon)	5,309,000	3,719,000	294,000
CTZ IV	1,227,000	435,000	62,000
Subtotals	11,305,000	5,246,000	1,127,000
Grand Total			17,678,000

* Source: HERBS tape

In addition to herbicides, numerous other chemicals were shipped to South Vietnam in 55-gallon drums. These included selected fuel additives, cleaning solvents, cooking oils, and a variety of pesticides. The insecticide Malathion was widely used for control of mosquitoes and at least 400,000 gallons of it were used from 1966 through 1970. In addition, much smaller quantities of Lindane and DDT were used in ground operations throughout the war in Southeast Asia. The distribution of the herbicides within Vietnam after their arrival did not occur randomly. About 65 percent was shipped to the 20th Ordnance Storage Depot, Saigon, and 35 percent was shipped to the 511th Ordnance Depot, Da Nang.

Military Aircraft and Vehicles Used in the Dissemination of Herbicides

Numerous aircraft were used in the air war in Vietnam, but only a few of these aircraft were used for aerial dissemination of herbicides. The "work horse" of operation RANCH HAND was the C-123, "Provider". This cargo aircraft was adapted to receive a modular spray system for internal carriage. The module (the A/A 45 Y-1) consisted of a 1,000-gallon tank pump, and engine which were all mounted on a frame pallet. An operator's console was an integral part of the unit, but was not mounted on the pallet. Wing booms (1.5 inches in diameter, 22 feet long) extended from the outboard engine nacelles toward the wing tips. A short tail boom (3 inches in diameter, 20 feet long) was positioned centrally near the aft cargo door. Each aircraft normally had a crew of three men: the pilot, co-pilot (nagivator), and flight engineer (console operator). During the peak activity of RANCH HAND operations (1968-1969), approximately 30 U C-123K aircraft were employed. However, many other squadrons of non-RANCH HAND C-123 aircraft were routinely used throughout South Vietnam in transport operations.

The control of malaria and other mosquito-borne diseases in South Vietnam necessitated an extensive aerial insecticide application program. From 1966 through 1972, three C-123 aircraft were used to spray Malathion, an organophosphate insecticide. These aircraft could be distinguished from the Herbicide-spraying aircraft because they were not camouflaged. These aircraft routinely sprayed insecticide adjacent to military and civilian installations, as well as in areas where military operations were in progress, or about to commence.

Approximately 10 to 12 percent of all herbicides used in South Vietnam were disseminated by helicopter or ground application equipment. Generally, helicopter crews were not assigned to herbicide spray duties on a full-time basis and rotated the spraying duties with other mission requirements. The military UH-1 series of helicopters, deployed by the Air Force, the Army, and Navy units, generally sprayed the herbicides. The most common spray system used was the AGRINAUTICS unit. This unit was installed in or removed from the aircraft in a matter of minutes because it was "tied down" to installed cargo shackles and aircraft modifications were not required for its use. The unit consisted of a 200-gallon tank and a collapsible 32-foot spray boom. The unit was operated by manual controls to control the flow valve and a windmill brake. Generally, each helicopter had three crew members.

A summary of the aircraft used in herbicide and insecticide operations is shown in Table 5.

TABLE 5
US MILITARY AIRCRAFT USED IN THE DISSEMINATION OF
HERBICIDES AND INSECTICIDES IN SOUTH VIETNAM

Aircraft	Camouflaged	Chemical Disseminated
UC-123/UC-123K	Yes	All Herbicides
UC-123K	No	Malathion
Helicopter		
Air Force UH-1		
Army UH-1B/UH-1D	Yes	Orange, Blue
Navy UH/1E		

Various ground delivery systems were also used in South Vietnam for control of vegetation in limited areas. Most of these units were towed or mounted on vehicles. One unit that was routinely used was the Buffalo turbine. It developed a wind blast with a velocity up to 150 MPH at 10,000 ft^3/minute volume. When the herbicide was injected into the air blast, it was essentially "shot" at the foliage. The buffalo turbine was useful for roadside spraying and applications of perimeter defenses. The herbicides of choice in these operations were Blue and Orange.

Table 6 reviews the pertinent chemical and physical characteristics of Herbicide Orange. Table 7 reviews both the application parameters of the spray system used in the UC-123K aircraft and the characteristics of the spray itself. Generally, herbicides were sprayed in the early morning or late afternoon, so as to minimize the effects of air movement on particle dispersion.

TABLE 6
PERTINENT CHEMICAL AND PHYSICAL CHARACTERISTICS
OF HERBICIDE ORANGE

Formulation Concentrated	(8.6 lb ai/gal)*
Water Insoluble	Density = 1.28
Vapor Pressure	3.6×10^{-4} mm Hg at 30°C
NBE** 2,4-D :	1.2×10^{-4}
NBE 2,4,5-T :	0.4×10^{-4}
TCDD :	1×10^{-4}
Viscous	40 centipoises at 20°C
Noncorrosive to metal	
Deleterious to paints, rubber, neoprene	
Long Shelf life	

* Pounds active ingredient (2,4-D and 2,4,5-T) per gallon.
** NBE - Normal Butyl ester.

TABLE 7
APPLICATION PARAMETERS AND SPRAY CHARACTERISTICS OF THE
C-123 MODULAR INTERNAL SPRAY SYSTEM

Aircraft speed	130 KIAS*
Aircraft altitude	150 feet
Tank volume	1,000 gallons
Spray time	3.5-4 minutes
Particle size:	
100 microns: 1.9%	
100-500 microns: 76.2%	
500 microns: 21.9%	
87% impacted within 1 min	
13% drifted or volatilized	
Mean particle volume	0.61 microliters
Spray swath	260 ± 20 feet
Mean deposition	3 gallons/acre
Total area/tank	340 acres

* Knots indicated air speed

SUMMARY

The choice of herbicides used in South Vietnam in Operation RANCH HAND, 1962-1971, was based upon those herbicides that had been widely used in world agriculture, shown to be effective in controlling a broad spectrum of vegetation, and thought to be safe to humans and animals. The major herbicides used in South Vietnam were the phenoxy herbicides 2,4-D and 2,4,5-T. These two herbicides were formulated as the water insoluble esters and code-named by the military as Purple, Orange, Pink and Green. A water soluble amine formulation of 2,4-D was used in Herbicide White. Two other herbicides were extensively used by the military, picloram (in White) and cacodylic acid (in Blue).

An estimated 107 million pounds of herbicides were aerially disseminated on 3 million acres in South Vietnam from January 1962 through October 1971. Approximately 94 percent of all herbicides sprayed in Vietnam were 2,4-D (56 million pounds or 53 percent of total) or 2,4,5-T (44 million pounds or 41 percent of total). The 44 million pounds of 2,4,5-T contained an estimated 368 pounds of the toxic contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD or dioxin). Ninety-six percent of all 2,4,5-T was contained in Herbicide Orange; the remaining 4 percent in Herbicides Green, Pink and Purple. However, Herbicides Green, Pink and Purple contained approximately 40 percent of the estimated amount of TCDD disseminated in South Vietnam. Green, Pink and Purple were sprayed as defoliants on less than 90,000 acres from 1962 through 1964, a period when only a small force of US military personnel were in South Vietnam. Ninety percent of all the Herbicide Orange (containing 38.3 million pounds of 2,4,5-T and 203 pounds of TCDD) were used in defoliation operations on 2.9 million acres of inland forests and mangrove forests of South Vietnam.