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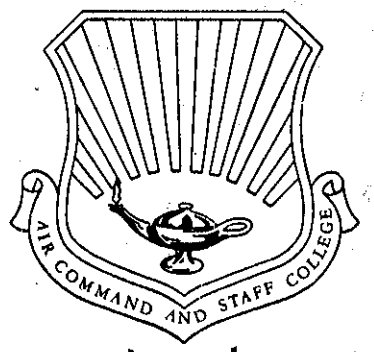

AIR COMMAND AND STAFF COLLEGE

STUDENT RESEARCH REPORT

AGENT ORANGE AT THE CROSSROADS

OF

SCIENCE AND SOCIAL CONCERN

2750-81

'insights into tomorrow'

STUDENT RESEARCH REPORT

REPORT NUMBER 2750-81

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20 ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report examines the question "Is Agent Orange responsible for health problems reported among Vietnam veterans?" A review is presented of the use of herbicides in South Vietnam and a model is proposed for objectively analyzing environmental health issues. Although extensive scientific data are available on the effects of Agent Orange and the dioxin contaminant, social, political, and legal concerns continue to drive the controversy.

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PREFACE

For almost two decades, the United States Air Force has been involved in controversy over its tactical use of herbicides in Southeast Asia. The controversy centered first on the actual employment of herbicides in South Vietnam, then on the safe disposal of surplus herbicide following the conflict, and lastly, on whether herbicides were responsible for health problems reported among Vietnam veterans. Misinformation and emotion have characterized the controversy. This report was written in an attempt to clarify and place into a proper perspective many issues of the controversy.

This manuscript will be submitted for publication in American Scientist, the journal of Sigma Xi, the scientific research society.

The author is a major in the United States Air Force and serves as a herbicide specialist for the Department of Defense. He received the Bachelor and Master of Science degrees in Agricultural Science from the University of Wyoming. The Doctor of Philosophy degree was obtained in the speciality of Herbicide Physiology from Kansas State University. He has been associated with all facets of the Herbicide Orange Program since 1968. He has published two books on the subject and serves as a consultant on herbicides and dioxin issues for many governmental agencies. His primary research interest is in the environmental fate and toxicology of the phenoxy herbicides and their associated dioxin contaminants.

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AGENT ORANGE AT THE CROSSROADS OF SCIENCE AND SOCIAL CONCERN

by

Alvin L. Young

Is Agent Orange responsible for health problems reported among Vietnam veterans?

The use of chemicals (herbicides) to control vegetation has been one of the most controversial subjects arising from the Vietnam conflict. The US Air Force applied most of these herbicides in jungle areas to clear vegetation from the perimeters of military bases and camps, along lines of communication, and in enemy staging areas. The objective was to provide defoliated zones that would reduce ambushes and disrupt enemy tactics. The most commonly used "defoliant" was "Agent Orange," a mixture of two commercial herbicides widely employed for a number of years in brush control programs throughout the United States.

During a five-year period from 1965 to 1970, the US Air Force applied more than 10 million gallons of Agent Orange in South Vietnam, and some two million American military personnel served one-year tours during the same period. Recently, many veterans of that era have reported medical problems that possibly stem from exposure to Agent Orange during their military assignments. Their complaints have ranged from tingling in the extremities to rare forms of cancer, and some veterans have fathered children with birth defects. But overwhelming

scientific data on the toxicology of chemical components in Agent Orange do not substantiate these claims. Nevertheless, the news media has given intense sympathetic coverage to the veterans and their medical complaints. In the meantime, the Veterans Administration and the US Air Force have been directed to conduct multimillion dollar, long-term studies of military personnel allegedly exposed to herbicides in South Vietnam from 1962 to 1970. The issue is whether actual or perceived health problems stem from herbicide exposure or whether other factors drive the controversy.

Two key questions must be considered in reviewing present concerns over Agent Orange. First, why is the Agent Orange issue surfacing 10 years after it was used in Vietnam? Second, what criteria can be used to insure an objective analysis of such a complex, controversial, and politically sensitive subject? One answer to the first question may be that presumed health effects from exposure to the herbicide have just now appeared or, at least, have recently been diagnosed among Vietnam veterans. Another possible answer is that the general public and Congress have just recently recognized the concerns of Vietnam veterans, and Agent Orange is only a vehicle to focus those concerns. Certainly, the acrimony and bitterness over US involvement in Vietnam drove most Americans to repress memories of that war. As a result, they have tended either to ignore veterans of the Vietnam

era or to relegate them to a lesser status than veterans of other wars. Recent gains in respectability for Vietnam veterans have coincided with increasing American interest in health and environmental issues. Thus, the controversy surrounding Agent Orange has surfaced primarily because it involves the veterans and herbicides, both of which have been the center of controversy since they were employed in Vietnam.

Health concerns involving Agent Orange, its component herbicides, and the toxic dioxin contaminant 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) date from 1970. Current interest is merely an extension and popularization of issues first publicized in 1970 and again in 1974. A large volume of toxicological data on 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2,4-dichlorophenoxyacetic acid (2,4-D), the two herbicides in Agent Orange, were available during the final years of US involvement in Vietnam, but woefully inadequate toxicological and environmental data on TCDD precluded resolution of the issues. Although scientists recognized that TCDD was acutely toxic and teratogenic (birth deforming) in laboratory animals, no studies were available on the effects of chronic long-term low-level exposures in lower mammalian species. Furthermore, numerous occupational exposures to TCDD were reported during the industrial production of trichlorophenol, but human epidemiologic studies were not

available despite documented exposures as early as 1949.

Thus, to resolve the present controversy, scientists presumably must determine whether they can assess the long-term effects of exposure to TCDD on the basis of existing data and whether the veterans' complaints are consistent with the data. Of course, one major assumption must be that US military personnel reporting health effects were probably exposed to Agent Orange and, hence, to TCDD. But, regardless of any reported health effects, a valid study must include examination of all facets of the controversy.

This requirement poses a dilemma in any attempt to answer the second question because objective analysis depends on such an examination, but there are simply no models available for analyzing environmental health issues. In the absence of such models, examination of recent environmental crises involving other chemicals can provide a useful parallel for analyzing the Agent Orange controversy. For example, environmental contamination or "poisoning" episodes during the decade of the seventies involved similar chemicals, such as chlorinated insecticides (chlordane, DDT, and mirex), polychlorinated biphenyls (PCBs), and polybrominated biphenyls (PBBs). And, most recently, the Love Canal episode has received extensive publicity. Analysis of these episodes, including reports on PCBs by Hammond (19) and Culhane (13), reports on PBBs by Budd et al. (7), and

Ember's (17) assessment of the Love Canal episode, reveals that these episodes share common characteristics. Apparently, the public perceives highly publicized environmental poisoning episodes as threats to the "quality of life," and, as result of this perception, the episodes lead to a number of predictable events (see Table 1).

Nature of Controversies

A controversy involving environmental contamination commonly begins with an episodic event, a specific instance of poisoning that arouses public and scientific concern. Such an event usually begins with contamination of animals, but its impact rapidly expands to include humans that may have inadvertently been exposed to the chemical. Frequently, improper use or disposal of the chemical precipitates the event (e.g., the PBB episode, 7).

Generally, only a few people or livestock are actually exposed to, or contaminated by, the chemical. This small population, however, is an inadequate sample for establishing cause and effect relationships. Nevertheless, concerned individuals respond to the event with lists of observed biological effects in animals and adverse physical symptoms in humans. In most instances, lay persons (including news reporters), local physicians, or biologists compile these lists, and they ultimately become indicators of adverse effects to people who

Table 1. Events and Characteristics of Environmental Poisoning Episodes That Define "Quality of Life" Controversies.

Event/Characteristic	Brief Description
Episodic Event	An environmental incident involving poisoning of man and/or livestock.
Inadequate Sample Size	Episodic events involve exposure of small populations of people and/or livestock.
Inadequate Scientific Data	Reported symptoms and adverse health effects are inconsistent with scientific data.
Intense Media Response	Sensational reporting of the episodic event.
Inadequate Government Response	The initial failure of government agencies to respond to public concerns.
Special Interest Groups	A group of citizens joined by a common concern to manipulate public and political attitudes toward an episodic event or chemical.
Initiation of Lawsuits	The threat of legal action in the absence of a satisfactory resolution of an episodic event.
Advisory Groups	At the request of a lead agency, e.g., a state department of health, qualified representatives from all interested parties join in an advisory committee to coordinate research studies, review results, and offer recommendations for resolution of issues.
Unsatisfactory Resolution	There are no satisfactory methods for appropriate resolution of "quality of life" controversies.

feel that they or their animals have been "potentially" exposed to the chemical. Invariably, these lists are not consistent with accepted scientific data because the media and the public either confuse or misunderstand the concepts of dose, exposure, and chronic and acute effects. As a result, the public concludes that the scientific data are inadequate, and, in some instances (e.g., the Love Canal episode, 17), it may express an intense emotional reaction to the scientific data if it suspects that "contrary" data are wrong or even dishonest.

Of course, the episodic event is "news," and, as such, it always attracts the local news media. Initial coverage of the event usually contains many inaccuracies and reflects a highly emotional orientation. In providing the coverage, the media compare the list of symptoms of a given episodic event to symptoms from other similar events in the past or in some other community. The intensity and duration of coverage depend on the magnitude or nature of the episode and on the number of people or animals exposed to "environmental poisoning." The media response is further characterized by articles in major newspapers or on the evening news, and these articles are usually followed by other articles containing "sensational" stories in popular magazines (e.g., Time, Reader's Digest, Family Circle, Playboy, and Penthouse). Culmination of the intense and frequently inaccurate campaign is marked by television documentaries usually prepared to highlight significant

events or chemicals. For example, "A Plague on Our Children" was televised nationwide on 2 October 1979 by the Public Broadcasting System in its "NOVA" series and focused on PCBs, TCDD, 2,4,5-T, and the Love Canal. Council for Agricultural Science and Technology (CAST, 12) reviewed this documentary and concluded:

> The program was overloaded with interviews with emotional laymen whose uneducated opinions about health hazards related to chemicals would be expected to induce a similar emotional response in the viewer.

Following the episodic event and intense media coverage, numerous local, state, and federal agencies provide immediate but definitive responses to the stories. Personnel in these agencies are rarely knowledgeable about the chemicals or the incidents, but, after cursory reviews of available information and telephone calls to local scientists, physicians, or other "experts," they release tentative responses to implied or direct charges of official ineptitude. Frequently, the media and the public view these efforts as <u>inadequate government behavior</u> and label the concerned agency as "unresponsive."

In concluding that the government is unresponsive, concerned citizens form <u>special interest groups</u> and usually solicit the services of their own "experts." Media coverage and inquiries to elected government officials prompt public hearings on the episodic event, the tragedies suffered by the

"victims," and reports by the scientific community and government officials. The impact of special interest groups on public attitudes and the behavior of government officials has been described by Ember (17). For example, the Love Canal Homeowners Association, a special interest group, launched a separate epidemiologic study of the Love Canal "at risk" population and subsequently used data derived from the study to elicit responses from a number of federal agencies and even a US district court.

Failure to resolve the controversy or to compensate the victims of the episodic event soon leads to lawsuits against the company responsible for the event, for production of the chemical, or for both activities. The real purpose of the lawsuits is to verify the concern of the individuals. Since the complex nature of the issues precludes their immediate appearance on court dockets, lawsuits are always "pending."

Many government agencies, special interest groups, academic and research institutions, and concerned citizens become involved in various facets of the chemical episode. To minimize the confusion associated with so many "players," the lead government agency, usually a state health department, appoints an advisory group to insure maximum collection and review of all relevant data. The composition of this group must reflect the credentials of "qualified" people representing major players

and various government agencies involved in the episode. One major function of the advisory group is to offer recommendations that will assist the lead agency in resolving the issues.

With the possible exception of bans on some of the chlorinated insecticides, the government and the scientific community have satisfactorily resolved very few episodes stemming from environmental poisoning. But, even in the ban on DDT, dispassionate scientific data took second place to emotional concerns in the legal resolution of the issue (15). These controversies generally remain unresolved because there simply is no satisfactory mechanism for treating opposing points of view in complex "quality of life" issues. The result has been an increasing public fear of artificial chemicals in the environment and lack of confidence in the ability or willingness of government and science to resolve problems related to their use or disposal. Thus, unsatisfactory resolution is still another unique characteristic of controversies stemming from environmental poisoning episodes.

Obviously, the characteristics that distinguish environmental poisoning episodes from other environmental issues are scientific, social, political, and legal. If a controversy is based on a preponderance of scientific concerns and these concerns cannot be resolved to the satisfaction of the media and the public, then one can reasonably conclude that scientific

issues drive the controversy. In this instance, reasonable answers to key scientific questions should lead to satisfactory resolution of the controversy. On the other hand, sufficient scientific data may permit definitive answers to questions related to public health, but they may not resolve the initial controversy. In such instances, one must conclude that social, political, or legal issues drive the controversy. Obviously, all key scientific questions can never be answered to the complete satisfaction of all parties, and the same is true for social, political, and legal concerns. Thus, short-term studies involving relatively small expenditures of resources might be feasible to enhance the existing scientific data base. On the other hand, a reasonably complete data base for making decisions in the present or immediate future may not justify long-term studies (years) requiring major outlays or dollars and manpower.

The nine characteristics discussed in the above model apply in varying degrees to all controversies based on environmental poisoning episodes. Like other controversies, the Agent Orange controversy can be examined in the framework of this model. The analysis begins with an evaluation of the episodic event and traces its evolution to a full-blown controversy. However, Agent Orange may have produced two episodic events: the first and, perhaps, major event was military use of herbicides in South Vietnam, and the second event may well

have been the initial publicity given to the herbicide in March 1978.

Military Use of Herbicides in South Vietnam

In May 1961, the Office of the Secretary of Defense requested US Army personnel at Fort Detrick, Maryland, to determine the technical feasibility of defoliating jungle vegetation in Vietnam. This request followed complaints from US military advisors that jungle vegetation supported enemy ambushes. By early fall 1961, scientists and government officials had conducted 18 different aerial defoliations and anticrop tests involving various formulations of commercial herbicides near Saigon. They selected the herbicides primarily on the basis of their extensive use and research in the United States, but they also considered such factors as available quantities, costs, and known or accepted toxicity to humans and animals. The tests showed that two different mixtures of herbicides would produce significant defoliation and anticrop effects. The first mixture, code-named "Purple," consisted of the n-butyl esters of 2,4,5-T and 2,4-D and the iso-butyl ester of 2,4,5-T. The second mixture, code-named "Blue," consisted of a powdered formulation of cacodylic acid mixed with water.

Agents Purple and Blue were received at Tan Son Nhut Air Base on 9 January 1962 and were the first herbicides used in Operation RANCH HAND, the name given to the tactical project

for aerial spraying of herbicides. Two additional formulations of 2,4,5-T (Pink and Green) were received in limited quantities and evaluated during the first three years of Operation RANCH HAND. By early 1965, two other herbicides, code-named Orange and White, had been evaluated and brought into the spray program, and, in the same year, Agent Blue was changed to a liquid formulation of cacodylic acid, thereby eliminating the need for mixing operations. Agent Orange replaced all formulations of agents Purple and Pink and eventually became the most widely used military herbicide in South Vietnam. (see Young et al., 41, and Bovey and Young, 6, for additional early history of the RANCH HAND program).

All herbicides for military use were shipped to Vietnam in 55-gallon steel drums coded with colored bands painted around the center of the drums. These bands identified the herbicide and thus helped personnel unfamiliar with the chemical composition and properties of the herbicides to avoid mixing incompatible herbicides (e.g., Blue with White).

Agent Orange was a reddish-brown liquid that was soluble in diesel fuel and organic solvents but was insoluble in water. One gallon of Orange contained 4.2 and 4.4 pounds of the active ingredients 2,4-D and 2,4,5-T, respectively, as a 50:50 mixture of the n-butyl esters of 2,4-D and 2,4,5-T. Agent White was a dark brown viscous liquid that was soluble in water but

was insoluble in diesel fuel. One gallon of White contained 0.54 pounds of the active ingredient 4-amino-3,5,6-trichloropicolinic acid (picloram) and 2.0 pounds of the active ingredient 2,4-D. This agent contained a 1:4 mixture of the triisopropanolamine salts of picloram and 2,4-D and was sold in the United States under the commercial name Tordon 101. Agent Blue was a clear yellowish-tan liquid that was soluble in water but was insoluble in diesel fuel. One gallon of Blue contained 3.1 pounds of the active ingredient cacodylic acid, and, of the total formulation, 15.4 percent was arsenic as the pentavalent organic arsenical. Agent Blue was similar to Phytar 560, a commercially available organic arsenical sold in the United States.

As noted earlier, all of the herbicides ultimately used in South Vietnam were not consistently applied throughout the 10-year period (1962-1971) encompassed by the DoD defoliation program. Furthermore, 2,4,5-T formulations used early in the program probably contained higher levels of the toxic dioxin contaminant TCDD than later formulations. Levels of TCDD in Orange were low because of subsequent improvements in production and quality control. The three periods shown in Table 2 can be differentiated on the basis of specific herbicides used and the mean dioxin content of herbicides containing 2,4,5-T.

Table 2. Differentiation of Three Time Periods During US Military Defoliation Program in South Vietnam and Mean Dioxin Content of Herbicides.

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 the analyses of five samples.
***Value based on the analyses of 488 samples.
SOURCE: Young (40).

Agent Orange, the most extensively used herbicide, accounted for approximately 10.7 million gallons (60 percent) of the 17.7 million gallons of total herbicides used in the conflict (Table 3). However, Table 3 shows that Orange was not the only herbicide containing 2,4,5-T in the defoliation program. Small quantities of agents Purple, Pink, and Green containing 2,4,5-T and the dioxin contaminant were used from 1962 through mid-1965.

Patterns of Use

Each of the three major herbicides (Orange, White, and Blue) had specific uses although they were applied at the same rate of three gallons per acre. Ninety-nine percent of Agent White was applied in defoliation missions, but it was not used on crops because of the persistence of picloram in the soil. The slow action of White on woody plants usually delayed full defoliation for several months after application of the spray. Thus, it was an ideal herbicide for use in inland forests where rapid defoliation was not required. But, when leaf fall did occur, it persisted for longer periods than following use of agents Orange or Blue.

Agent Blue was the herbicide chosen for missions requiring destruction of cereal or grain crops. Approximately 50 percent of all Blue was used to destroy crops in remote or enemy-controlled areas, and the other 50 percent was used as a contact herbicide for controlling vegetation on base perimeters. At the

Table 3. 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	

*Last fixed-wing mission of Orange 16 April 1970; last helicopter mission of Orange 6 June 1970.
**Last fixed-wing mission 9 January 1971; all herbicides under US control stopped 31 October 1971.
SOURCE: Young et al. (41).

rate of three gallons per acre, Blue caused a noticeable browning and desiccation of leaves within a period of one day, particularly on the tall perennial grasses that grew on the perimeters of many military bases and camps.

Ninety percent of all Agent Orange was used for forest defoliation, especially the mangrove forests, and eight percent was used in the destruction of broadleaf crops (beans, peanuts, ramie, and root or tuber crops). The remaining two percent was used on base perimeters (primarily around RANCH HAND bases), on enemy cache sites, and around waterways and communication lines. (Table 4 shows three major categories of vegetation and the number of acres sprayed with herbicides.)

Certain portions of South Vietnam were more frequent targets for defoliation missions because of the unique requirements imposed by military operations. Table 5 shows herbicide expenditures for the four combat tactical zones, and Figure 1 shows the location of the defoliation operations in relation to population areas and the combat tactical zones. These data were obtained primarily from the HERBS tape (a computer listing of herbicide missions in South Vietnam from 1965 through 1971). Figure 1 shows the locations of all defoliation missions.

Dissemination of Herbicides

Although numerous aircraft were employed in the air war over Vietnam, only a few of these aircraft were used for aerial

Table 4. The Number of Acres Treated with Military Herbicides in Three Major Vegetational Categories in South Vietnam, 1962-1971.

Vegetational Category	Acres Treated*
Inland Forest	2,670,000
Mangrove Forests	318,000
Cultivated Crops	260,000
Total	3,248,000

*Acres receiving single or multiple coverage.
SOURCE: NAS Report (10).

Table 5. US Herbicides Expenditures in South Vietnam, 1962-1971: A Breakdown by Combat Tactical Zone.*

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 and Young (40).

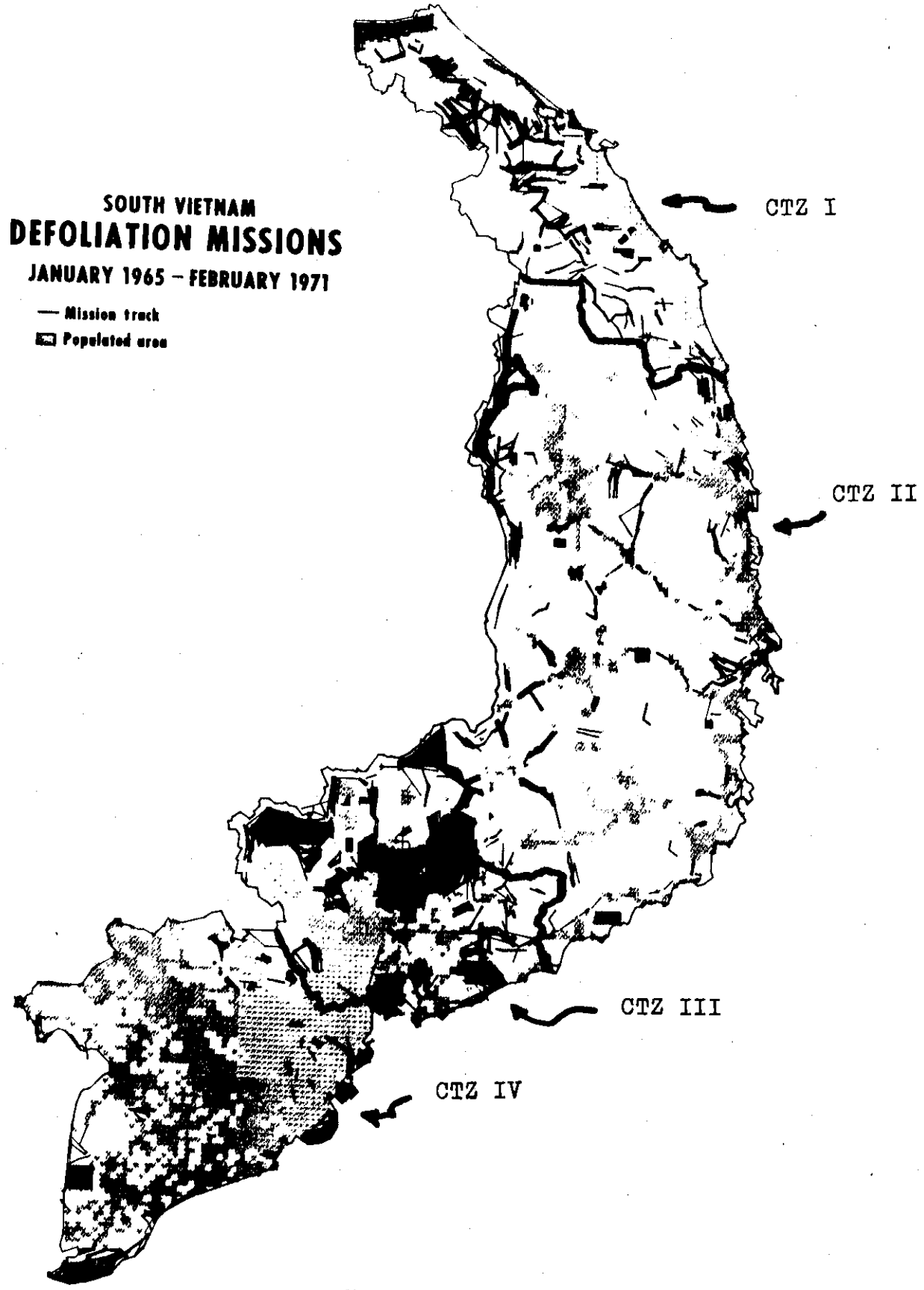

Figure 1. The Location of Defoliation Missions in South Vietnam from January 1965 to February 1971. The Data for the Mission Tracks are taken from the HERBS Tape. Source: NAS (10).

dissemination of herbicides. The "work horse" of Operation RANCH HAND was a two-engine C-123 aircraft called the "Provider," a cargo aircraft adapted for internal carriage of a modular spray system. The module consisted of a 1,000-gallon tank, pump, and engine mounted on a frame pallet. An operator's console was a integral part of the unit, but it was not mounted on the pallet. Wing booms extended from the outboard engine nacelles toward the wing tips, and a short tail boom was positioned centrally near the aft cargo door. During a typical mission, the aircraft sprayed herbicides at a speed of 150 miles per hour at a height of 150 feet above the ground, often at treetop level over the triple canopied jungle. Although 33 C-123 aircraft were adapted for aerial spraying and all of the aircraft were employed during the peak period of RANCH HAND operations (1968-1969), many other squadrons of C-123 aircraft were not adapted for these operations and were routinely employed throughout South Vietnam for combat support operations.

The control of malaria and other mosquito-born diseases necessitated an extensive program for aerial application of insecticide to control these vector insects. Some combat troops experienced malaria rates as high as 600 per 1,000 per year in 1966 (26). Thus, from 1966 through 1972, three RANCH HAND UC-123K aircraft were used to disseminate more than 400,000 gallons of malathion, an organophosphate insecticide. Unlike the aircraft designated for spraying herbicides, these aircraft

were not camouflaged, and they routinely sprayed insecticide adjacent to military and civilian installations and in areas where military operations were in progress or about to commence. The insecticide took the form of a white fog composed of minute droplets that settled very slowly on the jungle canopy, but herbicides were applied as large droplets that fell rapidly on the canopy with minimal drift.

In addition to the C-123 aircraft, helicopters and ground application equipment disseminated approximately 10 to 12 percent of all herbicides used in South Vietnam. In most instances, UH-1 series of helicopters used to apply the herbicides carried spray units consisting of 200-gallon tanks and collapsible 32-foot spray booms that could be installed or removed in a matter of minutes.

Most of the ground delivery systems were used to control vegetation in limited areas and were towed or mounted on vehicles. One routinely used unit was the buffalo turbine, which developed a wind blast up to 150 miles per hour at 10,000 cubic feet per minute volume. Thus, when the herbicide was injected into the air blast, it was literally shot at the foliage. This unit was particularly useful for spraying agents Blue and Orange along roadsides and on perimeter defenses.

Exposure Considerations

Relatively few military operations directly involved

military personnel in handling herbicides. For example, in operations involving Agent Orange from January 1965 to April 1970, only three groups of US military personnel could have been exposed to Agent Orange and its associated dioxin contaminant ( ):

1. Personnel assigned directly to Operation RANCH HAND and actively involved in the defoliation program - aircrew members and maintenance and support personnel.

2. Personnel assigned to selected support functions that may have resulted in exposure to Agent Orange. Included in this group are personnel who sprayed herbicides from helicopters or ground application equipment, personnel who may have delivered the herbicides to units on defoliation missions, drum handlers, aircraft mechanics who occasionally provided support to RANCH HAND aircraft, or personnel who may have flown in contaminated C-123 aircraft but were not assigned to RANCH HAND. During the Tet Offensive, for example, all RANCH HAND aircraft were reconfigured to transport supplies and equipment and were assigned to non-RANCH HAND squadrons.

3. Ground personnel who may have been inadvertently sprayed by defoliation aircraft or who may have entered an area previously sprayed with Agent Orange.

The total number of US military personnel exposed to Agent Orange is not known. Although approximately 1,200 RANCH HAND personnel were exposed to herbicides through direct support of defoliation, there are no data on the number on non-RANCH HAND personnel why may have been exposed to Agent Orange or other herbicides. But, since at least 100 helicopters were

equipped with spray units, the actual number of exposed personnel may be in the thousands, and most major military bases had vehicle-mounted and backpack spray units available primarily for spraying Agent Blue in routine vegetation control programs (40). There are no available figures on the number of military ground personnel who may have been sprayed inadvertently by RANCH HAND aircraft or who may have entered areas sprayed with Agent Orange during combat operations. Although approximately 10 percent of South Vietnam was sprayed with herbicides, enemy forces controlled most of this generally remote, unpopulated, and forested area. Nevertheless, deployment of US military forces throughout South Vietnam increased the likelihood that combat personnel may have entered areas sprayed with herbicides. Figure 2 shows the headquarters locations of most major US Army units deployed during the period of heavy defoliation activities (1968-1969).

Summary of Herbicide Use

In discussing the use of herbicides in South Vietnam, Young (40) noted that an estimated 107 million pounds of herbicides were aerially disseminated on three million acres from January 1962 through October 1971. Approximately 94 percent of the herbicides included the phenoxy herbicides 2,4-D (56 million pounds or 53 percent of the total) and 2,4,5-T (44 million pounds or 41 percent of the total). The 44 million pounds of 2,4,5-T contained an estimated 368 pounds of the toxic dioxin contaminant. Agent Orange contained ninety-six percent of all 2,4,5-T,

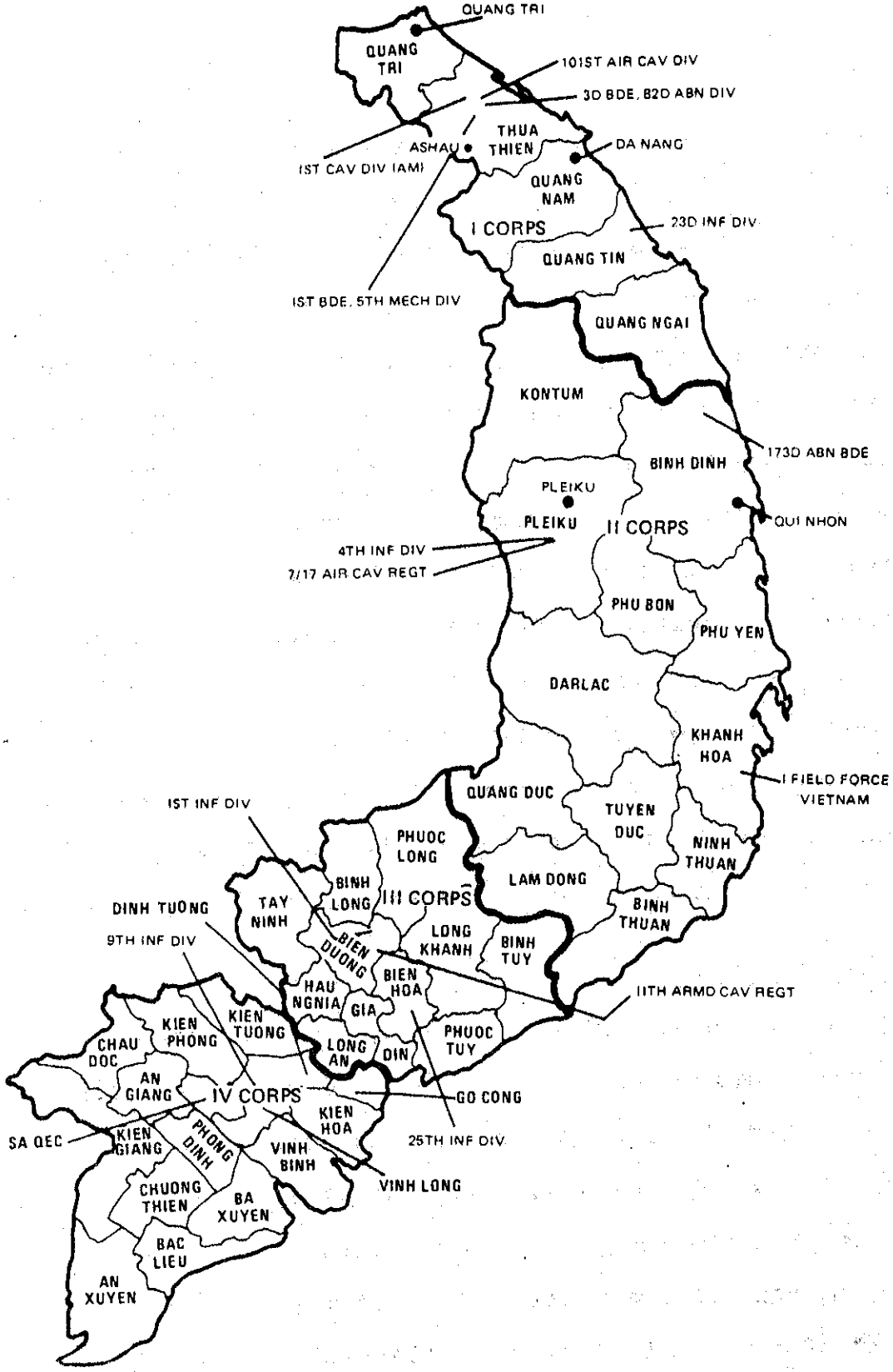

Figure 2. Disposition of Major US Army Units in South Vietnam. Source: GAO Report (18).

and agents Green, Pink, and Purple contained the remaining four percent. However, agents Green, Pink, and Purple contained approximately 40 percent of the estimated amount of TCDD disseminated in South Vietnam, and these agents 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 deployed in the region. Ninety percent of all Agent Orange containing 38.3 million pounds of 2,4,5-T and 203 pounds of TCDD was used in defoliation of 2.9 million acres of inland forests and mangrove forests. Procedures for handling, transporting, and storing the drums of herbicides generally precluded physical contact by most military personnel. However, the most likely exposed personnel were assigned to the RANCH HAND squadrons and to helicopters responsible for disseminating the herbicides.

Claims of Adverse Health Effects

Apparently released to the press prior to scientific publication, a preliminary report by the National Cancer Institute in 1968 noted that samples of 2,4,5-T were found teratogenic in laboratory mice. While the American press reported the teratogenicity of 2,4,5-T in laboratory animals, South Vietnamese newspapers published reports of birth defects in areas sprayed with Agent Orange. These reports elicited far-reaching reactions from governmental agencies, segments of the scientific community, and various lay groups concerned with environmental problems (39).

In late October 1969, the Department of Defense restricted the use of Agent Orange in Vietnam to "remote and unpopulated" areas.

Additional animal experiments in 1969 and early 1970 led to the conclusion that the dioxin contaminant in 2,4,5-T was primarily responsible for deformities in the offspring of laboratory mice following exposure of the females to the herbicide. Nevertheless, the question was whether or to what extent animal data could be extropolated to man (39). Concurrent with the suspension of many uses of 2,4,5-T herbicide in the United States, the Department of Defense suspended all use of Agent Orange in South Vietnam on 15 April 1970.

A select group of highly visible scientists initially objected to all use of herbicides in the Vietnam war and, individually and collectively, published their views in numerous articles for newspapers and popular magazines (6). And, when reports of birth defects first appeared in the news media, the same scientists were instrumental in mustering public and political opinion against continued use of Orange. Thus, termination of the RANCH HAND program and use of Agent Orange occurred during an environmental controversy focused on health issues, and the controversy was compounded by strong anti-Vietnam sentiment among members of the press and the general public. But concern for the health of Vietnam veterans exposed to Agent Orange did not reach its peak until eight years later.

Evaluation of the Science

To understand the role of science and its influence on the Agent Orange controversy, one must first review actions of the government regarding 2,4,5-T since it was last used in South Vietnam. After the government imposed limits on the use of 2,4,5-T herbicide in 1970, the newly formed Environmental Protection Agency (EPA) embarked on lengthy administrative proceedings to determine the feasibility of banning all remaining uses of 2,4,5-T. In reviewing the use of 2,4,5-T and TCDD, scientists pursued investigations in two different areas. The first area dealt with the toxicology of 2,4,5-T and TCDD in animals, and the second area included an evaluation of available data on human health effects and potential routes of exposure to phenoxy herbicides and TCDD. These studies confirmed the availability of significant toxicological data on 2,4,5-T, but they reported very little data on TCDD. Consequently, the EPA withdrew from proceedings to cancel in June 1974 since "evidence which would in large part determine the outcome of these proceedings remains scientifically unavailable (31)." In December 1979, the agency again issued notices of intent to hold a hearing on whether to cancel all registrations 2,4,5-T. The hearing began in March 1980 to explore the risks and benefits associated with the registered uses of 2,4,5-T, and it is still in progress at this writing (February 1981).

Toxicology of 2,4,5-T and TCDD in Animals

Diaz-Colon and Bovey (16) report that more than 870 toxicological studies of the phenoxy herbicides have been published in the past 25 years. And, in a summary of the data on 2,4,5-T, Kociba et al. (21) note that it is moderately toxic to mammals, readily absorbed, and rapidly excreted. In a two-year study of chronic toxicity and oncogenesis among rats ingesting diets containing 2,4,5-T, they found few toxicological symptoms (loss of body weight and slight morphological changes in kidneys, livers, and lungs) even at the highest dose level (30 mg 2,4,5-T/kg body weight/day). This study also revealed no oncogenic response in rats even when administration of 2,4,5-T extended over most of their life span at a dosage high enough to induce toxicity. As for the effects of 2,4,5-T on reproduction, Smith et al. (32) found in studying three generations of rats that dose levels of 2,4,5-T high enough to cause signs of toxicity had no effect on the reproductive capacity of rats, except for a tendency to reduce neonatal survival at dose levels of 10 and 30 mg/kg/day.

Although the above animal data suggest that 2,4,5-T poses few toxicological problems, the contaminant TCDD is far more toxic. It has been scientifically confirmed as a teratogen; indeed, the amount required to cause a teratogenic effect of some kind is far lower for TCDD than with many other compounds. In this sense, it is one of the most potent compounds studied

in the laboratory (30). Qualitatively, however, it is far less teratogenic than many other chemicals: the teratogenic response commonly associated with TCDD is cleft palate. It tends to cause death of the embryo or fetus rather than a wide range of abnormalities, and, for this reason, many environmental groups claim that it causes miscarriages in women as a result of spraying forests with contaminated 2,4,5-T. But it is important to note that the teratogenic action of TCDD is species specific (i.e., it occurs in mice and rats but not in other laboratory species, including rhesus monkeys). Furthermore, Tschirley (39) reports that scientists have found TCDD a potent teratogen in rats, but an apparent no-effect level was 0.001 mg/kg/day, a level 10 times below the demonstrated no embryo-toxic effect level in rhesus monkeys.

A review of the published literature reveals that TCDD is a carcinogen for rats and mice. In a two-year study of chronic toxicity and oncogenicity resulting from TCDD (2,3,7,8-TCDD), Kociba et al. (20) found that doses of TCDD sufficient to induce severe toxicity increased the incidence of some types of neoplasms (both liver and lung) in rats but reduced the incidence of other types, such as tumors of the pituitary gland, uterus, and pancreas. During their study, they found no increases in tumors among rats receiving sufficient TCDD to induce slight or no manifestations of toxicity.

Current studies of mutagenicity have not found that 2,4,5-T is a mutagen in animal test systems (33). Experiments have shown that TCDD is a mutagen in two bacterial reverse mutagen systems, but they have found no *in vivo* correlates of mutagenicity (33). In September 1980, Lamb, Moore, and Marks (23) reported the results of a reproduction and fertility experiment on male mice treated with the three chemical constituents of concern in Agent Orange (2,4-D, 2,4,5-T, and TCDD). They found no significant decrement in the fertility or reproduction and no evidence of toxicity in germ cells. Survival of offspring and neonatal development were apparently unaffected by paternal exposure to simulated mixtures of Agent Orange.

The scientific community has not validated a quantitative method of extrapolating animal data to the human situation. Nevertheless, the significance of the above data is that most of the adverse effects expected from severe exposure to 2,4,5-T contaminated with TCDD will probably be due to the TCDD. Although TCDD is a teratogen, the effects are primarily manifested as cleft palate in offspring or through lethality of the embryo or fetus. Exposure of the male is not likely to cause reproductive problems. As a carcinogen, TCDD can be expected to cause neoplasms of the lungs and liver, but suggestions of no-effect levels for TCDD as either a teratogen or carcinogen make the magnitude of exposure a critical factor in considering possible long-term adverse effects.

Evaluation of Human Health Effects

The first reports of human birth defects attributed to Agent Orange appeared in Vietnamese newspapers in June 1969. As a result of the public and scientific furor caused by these reports, Cutting et al. (14) and Meselson et al. (24) conducted two independent surveys of South Vietnamese hospital records. Although neither report reached definite conclusions on the validity of the accusations, both reports acknowledged that searches of the records probably would have revealed any marked increase in birth defects or introduction of a striking defect, such as the defects produced by thalidomide. Subsequent reports by Tung et al. (34) in 1971 and Rose and Rose (28) in 1972 centered on clinical observations and interviews conducted in Hanoi with refugees who claimed that they were repeatedly sprayed with defoliants in South Vietnam. Abortions and monstrous births were reported for humans and domestic animals.

In 1973, Tung et al. (35) compared the number of cancer patients admitted to Hanoi hospitals during the period from 1962 to 1968 with the number admitted from 1955 to 1961, the period prior to the spraying of herbicides. They reported an increase in the number of persons with primary liver cancer in proportion to patients with other types of cancer. The authors concluded that this increase was the result of exposure to herbicides containing TCDD, but they could not document individual histories of actual exposure.

In announcing the results of studies conducted in South Vietnam in 1972 and 1973 (10), a committee appointed by the National Academy of Science (NAS) reported that it could find no conclusive relationship between exposure to herbicides and birth defects in humans, but the committee recognized that available birth records were not adequate for definite conclusions. The committee also could not confirm or deny reports that some humans, especially the Montagnards, and domestic animals became ill or died after they were exposed to herbicide sprays or after they consumed treated plants or contaminated water. In a letter of transmittal for the report, the president of the National Academy of Science stated: "On balance, the untoward effects of the herbicide program on the health of the South Vietnamese people appear to have been smaller than one might have feared".

It is <u>extremely difficult</u> to find precise information concerning the adverse effects of 2,4-D, 2,4,5-T, and TCDD in humans. Acute and subacute effects are reported quite uniformly following accidental exposures, suicidal gestures, and industrial accidents, but there is a great deal of confusion concerning the presence of long-term effects. Much of the medical knowledge concerning the effects of 2,4-D and 2,4,5-T is derived from case reports. Since many of the patients described in these reports were exposed to multiple chemical agents, it is difficult to determine the chemicals that produced specific

symptoms. Of the vast array of symptoms attributed to 2,4-D, the most consistently reported problems involve personal behavior, the nervous system, the liver, and the intestines (38).

Medical data associated with exposure to 2,4-D come primarily from spraying incidents, but data for 2,4,5-T and TCDD come from industrial exposures. Since the first commercial production of 2,4,5-T, numerous industrial episodes have involved exposure to trichlorophenol, 2,4,5-T, and TCDD. Fifteen of the 23 episodes recorded in the literature were apparently the results of occupational exposures during industrial production of chlorinated phenols. But, on eight occasions, personnel were exposed during cleanup following explosions or to improperly decontaminated workshops (41). Unfortunately, the effects of 2,4,5-T in these episodes could not be clearly distinguished from the possible effects of TCDD. Symptoms attributable to 2,4,5-T and TCDD exposure include all of the symptoms of 2,4-D exposure, in addition to skin disease, chloracne, or acniform dermatitis. Many scientists believe that chloracne is the "hallmark" of exposure to the dibenzo-p-dioxins, especially 2,3,7,8-TCDD. Chloracne is a skin reaction characterized by a general dermatitis composed of comedones (blackheads) and inclusion cysts or papules frequently terminating in pustules so severe that they cause permanent scarring. Morphologically, it is similar to teenage acne, but it is more severe, particularly on

the upper face, ears, and neck. Active chloracne lesions have been reported many years after exposure to TCDD, but the condition usually clears up spontaneously in a few months. Premature aging of involved skin areas has been reported in some instances.

Several case control epidemiology studies conducted by Swedish scientists have reported evidence of a statistical relationship between cancers of soft tissues and exposure to the phenoxy herbicides and TCDD (5). And the data by Tung et al. (35) cited earlier has received widespread attention, but the scientific community has viewed these studies with caution. Except for angiosarcoma, a rare type of cancer caused by vinyl chloride and irrefutable exposure, it is virtually impossible to distinguish between a cancer caused by a specific chemical agent and a similar cancer caused by some other etiology.

Four recent research studies may provide important clues concerning the effects of exposure to Agent Orange or dioxin. In January 1980, Zack and Suskind (42) published the results of a thirty year follow-up study of 121 chemical workers who had developed chloracne following exposure to TCDD in an industrial accident at Nitro, West Virginia. Although they observed no apparent excess in total mortality or in deaths from cancer or cardiovascular disease, they could not consider the results conclusive because of the small cohort and the relatively small number of deaths observed. In October 1980, Zack and Gaffey (2)

expanded this study to include 885 men, of whom 721 were still alive and 164 had died. Analyses of these data also showed no excess in total deaths or in deaths caused by cancer or other diseases of the nervous, circulatory, respiratory, or digestive systems. Although most of the men in this larger population did not develop chloracne, they were employed in the trichlorophenol plant and, hence, were exposed to TCDD. In August 1980, Cook et al. (11) reported on a study of 61 males involved in a chloracne incident at Midland, Michigan, in 1964. Forty-nine of these men developed chloracne while working in a trichlorophenol manufacturing plant operated by Dow Chemical Company. Within the limits imposed by the size of the cohort and the length of the follow-up, TCDD apparently had no adverse effect on mortality experience, and deaths from cardiovascular disease or cancer were statistically insignificant. And, in January 1981, the company (3) released a report on its study of the offspring of production workers exposed to 2,4,5-T and TCDD. The study was based on an interview questionnaire administered to 370 wives of men who had worked in areas where they could have been exposed to TCDD and to a control group of 345 wives of men in the same division (Midland, Michigan) who had never worked in such areas. The study found no statistically significant differences between the two groups in instances of misoarriages, stillbirths, infant deaths, or congenital malformations.

In other words, there are no epidemiologic data associating TCDD with any long-term health effects in humans other than chloracne, but, as noted by Wolfe (38), neither is there strong evidence to validate the absence of such effects. Most studies have not included sufficient numbers of subjects to detect increased risks of uncommon conditions, and the period of observation in many studies has been inadequate to detect conditions with long lag times between exposure and illness. There is currently no reliable evidence that links dioxin exposure to cancer or birth defects in humans.

The Scientific Data and the Veteran Complaints

Sauri (29) examined the first 361 claims submitted to the Veterans Administration from 1977 through April 1979 by Vietnam veterans claiming disabilities from exposure to herbicides. These claims described 130 different effects in five major categories of symptoms: psychiatric, dermatologic, reproductive, peripheral neuropathy, and cancer.

The scientific data validate specific links between exposure to Agent Orange and TCDD in the sense that symptoms reported by the veterans have also been documented in other cases of exposure to the herbicides or to TCDD. But most of these symptoms, e.g., peripheral neuropathy, fatigue, weight loss, and some psychological disturbances, are acute symptoms that manifest themselves shortly after exposure. Similar

symptoms arising years after the last exposure are most likely caused by an etiology other than 2,4-D and 2,4,5-T. The vast majority of the veterans claimed dermatological problems, but only three of the claims cited chloracne and none could be confirmed by physical examination.

Further evaluation of the early claims revealed that many claimants were males who reported fathering deformed children. The review of the scientific literature acknowledged that TCDD was a teratogen in laboratory animals, but the studies described effects resulting only from female exposures. Recent studies of reproduction among male mice exposed to 2,4-D, 2,4,5-T, and TCDD do not confirm an increased incidence of birth defects. And, as noted earlier, cleft palate is the birth defect associated with exposure of pregnant female animals to TCDD. The children reported on the claims suffered a wide variety of deformities.

Seven percent of the claimants reported a variety of malignancies, but there is currently no valid evidence linking exposure to 2,4,5-T and TCDD with instances of cancer. The limited number of people in the cohort precludes any definite link between rare forms of cancer and exposure to TCDD or to the phenoxy herbicides.

Despite the preponderance of scientific data that contradict the veterans' allegations, one recognizes that some of the veterans have definitely experienced health problems. Conclusions based on scientific analysis of the available data in no

way denigrate these problems. The purpose of this study is to determine whether Agent Orange is responsible for the problems. If Agent Orange is not responsible, then some other factor associated with the Vietnam war may be responsible, or, perhaps, the symptoms are afflictions of aging and attendant psychosocial aberrations.

The Role of Social, Political, and Legal Concerns

As mentioned earlier, a number of factors - scientific, social, political, and legal - have an impact on public and private perceptions of controversial issues. When these perceptions are manifested as fear of the unknown, such as the risk associated with a poisonous chemical in the environment, the public does not always react to that fear in proportion to the seriousness of the threatened harm. This is particularly true of "quality of life" issues in which determination of risk involves value choices. Positions taken by the media and the courts may be independent of scientific consensus regarding the actual risk. Thus, in addition to scientific factors, social, political, and legal "perceptions" have a direct impact on the issues that drive the Agent Orange controversy.

Intense Media Campaign

Station WBBM, a television affiliate of the Columbia Broadcasting System in Chicago, Illinois, aired a special report in March 1978 on the subject, "Agent Orange: Vietnam's Deadly Fog." This film reviewed a number of past environmental

episodes allegedly involving 2,4,5-T and TCDD. Kurtis (22), the WBBM reporter, compared symptoms described by some Vietnam veterans in the Chicago area with the symptoms identified in past "poisoning" episodes. Veterans shown in the film claimed that they had been sprayed with Agent Orange during combat operations in South Vietnam. Kurtis concluded his documentary with these statements:

> Officially the Veterans Administration is denying the claims of poisoning by Agent Orange. Their scientists simply feel there isn't any evidence to link defoliation with human problems. But after researching this report and listening to the recommendations of the leading dioxin scientists in the country, we feel there is a need for immediate testing of all Vietnam veterans who handled Agent Orange or went into sprayed areas. Not only for the sake of those who have told us of their symptoms but for the countless others whose lives and whose childrens lives could be blighted by the dioxin poison in Agent Orange.

Numerous magazine reports and serialized articles in newspapers have been published throughout the country since that time. Therefore, in analyzing the Agent Orange controversy, one is not too unrealistic in stating that two episodic events ignited the controversy. As mentioned earlier, the first event was the military use of herbicides in South Vietnam, and the second was the initial publicity given to the issue in March 1978. Some newspaper articles are factually based, but many are based on emotionally charged personal tragedies (e.g., the presence of terminal cancer in a young veteran). Wade (37)

recently reviewed many of these articles and wrote that the "whole passel" of apprehensions "may have nothing to do with Agent Orange in scientific fact, but is grounded in other problems affecting the Vietnam veteran population and has been launched into celebrity by a self-generating series of press and television stories." He observed further:

> In favor of the latter hypothesis, it may be noted that the first large batch of veterans' complaints about Agent Orange emerged in 1978 from Chicago shortly after the showing there of a television documentary about the herbicide's possible effects on health. The idea spread like wildfire among veterans' groups; here at last was a tangible cause for all their discontents. Each claim filed generated more newspaper stories which generated further claims, until the present fervid atmosphere had been created.

Burrows (8) cites the following four problems in reporting on scientific and environmental subjects:

> 1. Reporters almost always work under severe time limitations. The task of gathering a great deal of information on complex subjects and converting it into decent prose in a matter of hours can be a formidable challenge.
>
> 2. Abnormal rather than normal conditions are newsworthy. By definition, newsworthy items are unique or rare events, developments, and issues of interest to relatively large numbers of people.
>
> 3. "Objectivity" is a myth. Problems of time and space prevent inclusion of all pertinent information in major stories. Thus, the very act of omission, not to mention placement of material and points of emphasis, tends to "slant" the news.

4. People seeking public support for almost any issue tend to think of the news media as natural resources for exploitation.

And reporters who specialize in science and environmental reporting face three additional problems: government, industry, and so-called public interest groups. Each group or group representative often engages in open conflict with other groups, and news reporters may be considered potential allies or at least unsuspecting vehicles for use in attacking an adversary or deflecting an attack. Burrows (8) concludes that such relationships can have important consequences for politics and society. Certainly, these four basic problems in news reporting have had a severe impact on the Agent Orange controversy.

Inadequate Government Response

The March 1978 television documentary precipitated numerous inquiries with the Veterans Administration (VA) in all areas of the country. The symptoms were the same as the symptoms reported by the veterans in the documentary: numbness in fingers and toes, constant fatigue, weight loss, birth defects, and cancer. All claimants stated that their health problems stemmed from exposure to Agent Orange and thus marked the beginning of the problem.

When veterans experience health problems presumably related to their military tours of duty, they can report to VA hospitals for medical care, and they can file claims for any disability

that may be associated with their past military service. Hospital officials advise them that evidence of the earliest manifestation of symptoms and continuing symptoms must accompany claims for specific disabilities. For cases involving Agent Orange, VA policies are outlined in "Rating Practices and Procedures Disability - Vietnam Defoliant Exposure," a document used to process claims alleging a relationship between defoliant exposure and disability. But, in filing claims under this procedure, veterans can claim damage only for chloracne because the Veterans Administration recognizes no other symptoms or conditions as causes of health problems based on exposure to herbicides. Congress has not deemed it appropriate to recognize any disability related to Agent Orange as a chronic constitutional disability (e.g., multiple sclerosis).

Title 38 USC makes no provisions for claims alleging genetic damage to offspring as a result of veterans' exposure to herbicides. If veterans claim only exposure to a herbicide rather than disability resulting from the exposure, the Veterans Administration disallows the claims and advises the veterans that mere exposure is not a disease or disability. They must claim specific disabilities, but there are no special procedures for initiating these claims. Each case depends on accumulation of all available evidence, including a request to the veteran and his service department for verification of exposure to herbicides, the extent and duration of the exposure, and the dates

of the exposures.

Thus, one is not surprised that many veterans consider the Veterans Administration unresponsive to their health problems. On the other hand, the administrator of the Veterans Administration offered these comments during a recent congressional inquiry:

> ...everyone wants to know immediately the definitive answers to the questions posed by Agent Orange. Unfortunately, the scientific inquiry process necessary to provide accurate reliable information does not always lend itself to immediate answers... In the meantime, we shall continue to provide every eligible veteran we examine, and find to be in need of treatment, appropriate care regardless of causation. We owe them no less. (9)

Special Interest Groups

Numerous special interest groups represent and assist Vietnam veterans with problems related to Agent Orange. These groups include the National Veterans Task Force on Agent Orange, Agent Orange Victims International, Citizen Soldier, and Vietnam Veterans of America. Especially noteworthy are the activities of the National Veterans Law Center and the Veterans Education Project, a program sponsored by the American Civil Liberties Union Foundation. These two groups have prepared an "Agent Orange Packet" (36) consisting of guidelines for filing claims with the Veterans Administration. Both groups encourage