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# Agent Orange During the Vietnam War: The Lingering Issue of Its Civilian and Military Health Impact

 See also Morabia, p. 714; Freudenberg, p. 724; Wodka, p. 728; Laurell, p. 730; and Phillips, p. 731.

Between 1961 and 1971, US and Republic of Vietnam forces sprayed more than 20.2 million gallons of military herbicides to defoliate forests and mangroves in what was then South Vietnam to deny cover to enemy troops and make bombing targets more visible. Relatively small quantities (2%) were used for defoliation of military base perimeters; 9% of the total was used to destroy “unfriendly” crops as a means of reducing enemy food supplies. The herbicides were also used in the United States, but at application rates at least an order of magnitude lower and with somewhat differing formulations.

The military herbicides were nicknamed in accordance with the colored stripes on their 55-gallon drums. Agent Orange was a mixture of butoxyethanol esters of 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). Agent Blue, which consisted of dimethylarsinic acid (cacodylic acid), was used primarily for crop destruction. Agent White was a mixture of 2,4-D and picloram. The herbicides that contained 2,4,5-T were contaminated with dioxin (2,3,7,8-tetrachlorodibenzo-*p*-dioxin [TCDD]). The extent and implications of the TCDD content were not widely known or appreciated until well into the 1970s, when 2,4,5-T was banned from most US domestic uses owing to evidence of its teratogenicity.<sup>1</sup>

## “ECOCIDE”: THE FIRST DEBATE

Public health debate originally focused on “ecocide” from the massive defoliation. In 1970, the US Congress commissioned a National Academy of Sciences (NAS) study with Department of Defense (DOD) cooperation. The DOD created the HERBS file, an electronic record of the flight path coordinates of more than 9000 missions flown by C-123 aircraft used in the Air Force’s Operation Ranch Hand, the code name given to Air Force military herbicide operations carried out in the Republic of Vietnam between 1962 and 1971. NAS developed a primitive geographic information system using computer programs and line-printer graphics to document spraying and defoliation. The DOD added spray records in 1985, primarily records of Army helicopter spraying of basecamp perimeters.<sup>2</sup>

We later developed a more modernized geographic information system, also under an NAS contract. Using primary sources (in close collaboration with DOD experts), we expanded the original HERBS file in two ways. First, we were able to correct about 10% of the records that had previously been discarded by NAS because they were clearly erroneous; we corrected the records through examination of primary source materials. Second, we discovered archival data on approximately 200 missions in which more than two million liters of Agent

Purple had been sprayed prior to 1965. Agent Purple was an early form of Agent Orange that was almost certainly more heavily TCDD contaminated. The HERBS file remains a core resource for studying the herbicides used in Vietnam. Figure 1 illustrates many of the nearly 500 spray targets that we digitized from military records.

## MILLIONS OF VIETNAMESE DIRECTLY SPRAYED

We estimated that at least 366 kg of TCDD were sprayed on South Vietnam. We used a conservative estimate of three parts per million of dioxin contamination and did not include poorly documented herbicides sprayed by Vietnamese, US Army, and US Navy trucks, boats, hand sprayers, and helicopters. Data on more than 100 000 gallons of highly contaminated Agent Pink shown in procurement records but not found in any recorded missions are also missing from our estimate. Agent Pink consisted only of 2,4,5-T as a 60:40 mixture of its *n*-butyl and isobutyl esters. Forty-two missions intended to spray 30 000 gallons of herbicide are known to have ended with emergency dumps in which the herbicide was jettisoned in

about 30 seconds, as compared with the usual four to five minutes. At least five herbicide-loaded aircraft crashed. Hundreds of thousands of drums contaminated with residual herbicides made their way through the impoverished countryside for a variety of uses.<sup>1</sup>

At least 3851 of the 5958 known fixed-wing missions had targeted flight paths directly over South Vietnamese hamlets. We calculated that at least 2.1 million but perhaps as many as 4.8 million people in 3181 hamlets were sprayed.<sup>1</sup> Population estimates for an additional 1430 sprayed hamlets are unavailable. Few systematic data exist on population exposures through residual contamination of soils or consumption of herbicidal chemicals taken up in the food chain, although “hot spots” are known.<sup>3</sup>

## MANY PROBLEMS, LITTLE CORROBORATION

Despite reports in the press of possible health problems of exposed US military personnel emerging in the late 1970s, few peer-reviewed studies involving credible herbicide exposure measures have been carried out. Data on relationships between herbicide exposures and diseases for which veterans can receive medical attention and benefits are largely derived from environmental and toxicological studies not associated with Vietnam; rather, this information is based on systematic studies conducted by the Institute of Medicine

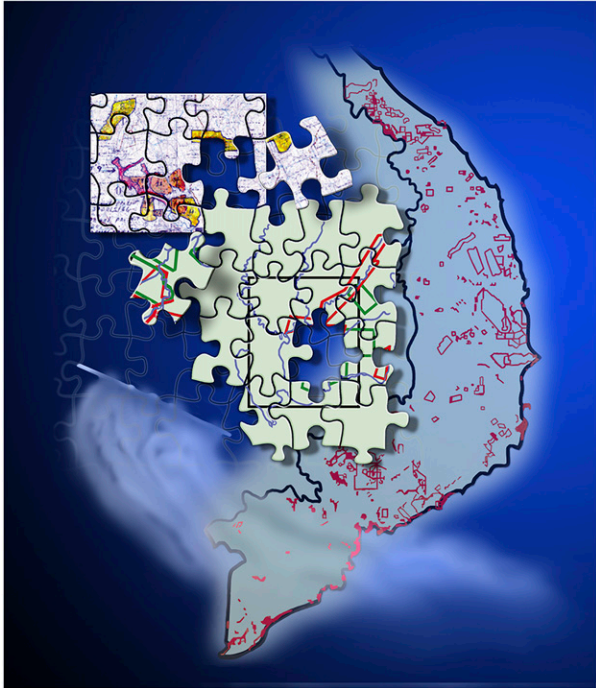
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*Note.* Spraying operations were directed at specific targets, 487 of which are shown; we digitized some of the images from original hand-drawn maps (colored areas at upper left) in files rediscovered in the National Archives. Some areas were targeted in multiple projects at different times, resulting in mission overlaps. Red and green outlines are for 1965 and 1966; blue lines are waterways.

**FIGURE 1—Illustration of Vietnamese Spray Targets Digitized From Military Records**

biennially since 1994 (see the box on this page). Many studies of veterans are compromised by severe misclassification: some have defined veterans' mere presence in Vietnam as "exposure," whereas others have focused on service in the four military combat tactical zones despite the fact that spraying varied dramatically within each zone (e.g., one zone contained unsprayed Saigon and the heavily sprayed Iron Triangle).

A 20-year Air Force study of Ranch Hand air and ground crews gathered massive amounts of survey and medical data and reported herbicide-related diabetes; however, because of its small size (the study involved approximately 2800 men), it has low power with respect to many of the health endpoints of interest, and numerous TCDD assays relied on blood

drawn decades after exposures occurred. Army Chemical Corps personnel are a source of many health reports, but they handled very small amounts of herbicides and large quantities of other chemicals. (Ranch Hand was an Air Force as opposed to an Army operation.) These and other studies are often based on unreliable self-reports of handling of herbicides.<sup>4</sup>

### EXPOSURE OPPORTUNITY MEASURES REFINED

Beginning in the 1980s, we refined the NAS HERBS-file methodology to derive "exposure opportunity" scores in cross-sectional studies of a random sample of 12 000 American Legionnaires. We demonstrated that

a sizeable number of troops served in sprayed areas and were at elevated risk of selected health outcomes.<sup>5</sup> In 1983, the Centers for Disease Control and Prevention (CDC) initiated a large Agent Orange cohort study of combat battalions whose daily locations were meticulously assembled by the DOD and the CDC employed an exposure algorithm almost identical to ours; the agency abruptly abandoned the study in 1987, however, declaring it impossible to use troop location data for estimating exposures because scores were inconsistent with serum dioxin levels. The CDC also asserted that ground troops who did not directly handle the herbicides were not "heavily" exposed.

Two separate Institute of Medicine panels rejected these assertions. NAS issued a request for application to further develop

a methodology based on military records for estimating exposures to military herbicides in Vietnam.<sup>4</sup> We responded to that request and were awarded a contract under which we developed our updated geographic information system.<sup>6</sup> Our data sets related to spraying, troop locations, and exposure opportunity scores are available on a Web site funded by the National Library of Medicine (<http://www.workerveteranhealth.org/milherbs/new/>).

### CONCLUSIONS

The Agent Orange story is one of massive exposure of civilian and military populations to toxic chemicals once thought safe. Few studies exist of the long-range effects of the Vietnam War on the

#### DISEASES FOR WHICH MILITARY SERVICE IN VIETNAM MAY BE CONSIDERED PRESUMPTIVE OF EXPOSURE BY THE DEPARTMENT OF VETERANS AFFAIRS FOR THE PURPOSE OF TREATMENT AND COMPENSATION

Amyloid light-chain amyloidosis

Chronic B-cell leukemias

Chloracne

Diabetes mellitus type 2

Hodgkin's disease

Ischemic heart disease

Multiple myeloma

Non-Hodgkin's lymphoma

Parkinson's disease

Peripheral neuropathy, early onset

Porphyria cutanea tarda

Prostate cancer

Respiratory cancers, including lung

Soft tissue sarcomas (other than osteosarcoma, chondrosarcoma, Kaposi's sarcoma, and mesothelioma)

Spina bifida in offspring

*Note.* Data were derived from the US Department of Veterans Affairs (<https://www.publichealth.va.gov/exposures/agentorange/conditions/index.asp>) and reflect compensable diseases and conditions as of April 15, 2018.

health of soldiers or civilians, or on the general environment. There is a strong suspicion that elevated rates of birth defects may be attributable to herbicides, but scientific corroboration is limited. Studies of South Korean troops who served in Vietnam have revealed increased risks of diabetes and other disorders.<sup>7</sup> Much of the existing literature on US veterans relies on exposure methodologies with severe misclassification limitations or on populations too small to allow questions regarding cancer and other chronic diseases to be addressed.

Faced with this dilemma, the Institute of Medicine oversaw development of a peer-reviewed,

military records–based exposure methodology, similar to early NAS and CDC studies, for estimating exposures; sufficient funding to carry out epidemiological studies has not been forthcoming despite strong congressional mandates. The at-risk veteran population is now at an age at which chronic diseases become manifest, so the time is optimal for conducting such studies, crafting health programs for veterans to better meet their needs, and truly assessing, addressing, and ameliorating health conditions and continuing exposures to lingering traces of Agent Orange in Vietnam. **AJPH**

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## CONTRIBUTORS

Both authors contributed equally to this editorial.

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# OSHA 1971: Bringing Government to Protect the Lives of Industrial and Farm Workers

 See also Morabia, p. 714; Freudenberg, p. 724; Stellman and Stellman, p. 726; Laurell, p. 730; and Phillips, p. 731.

On May 28, 1971, one month after the Occupational Safety and Health Act (OSHA) went into effect, OSHA issued its first citation against an employer. Citation No. 1 found that:

Visible pools and droplets of mercury have been allowed to accumulate and remain on the cellroom floor, in the basement, and in other working areas and working surfaces contributing to airborne concentrations of mercury which significantly exceed levels generally accepted to be safe levels of such concentration. . . . Instances of excessive airborne concentrations of mercury had been made known to the employer on occasions prior to the date of this inspection. (see Appendix A,

available as a supplement to the online version of this article at <http://www.ajph.org>)

The cited employer was the Allied Chemical Corporation, one of America's oldest chemical companies, which had been formed in 1920 from 4 chemical companies with roots as far back as 1881. For more than one year prior to the issuance of the citation, Allied Chemical knew that its workers were being overexposed to mercury as a result of an investigation conducted by the Bureau of Occupational Safety and Health (BOSH), the predecessor to the National Institute for Occupational Safety and Health (NIOSH).

## BEFORE OSHA

That a major American corporation, as late as 1971, could knowingly expose its workers to the classic health hazard of mercury poisoning, described by Ramazzini in 1713 as “the most cruel bane of all that deals with death and destruction,”<sup>1(p308)</sup> was emblematic of working conditions in the United States that led to the passage of the Occupational Safety and Health Act. Until OSHA, the United States lacked any governmental structure that provided workers with the right to complain

and force employers to correct hazardous conditions.

“Unfortunately, our legislators and others who are responsible for the safety of all our citizens are lethargic about this major problem of health and safety,” wrote Anthony Mazzocchi in the forward to the March 29, 1969, edition of *Hazards in the Industrial Environment*.<sup>2(foreward)</sup> Mazzocchi, a leading labor advocate for the passage of OSHA, was the Citizenship–Legislative Director of the Oil, Chemical, and Atomic Workers International Union (OCAW). His union was at the receiving end of the post–World War II explosive growth in the US chemical industry, which had barreled ahead with new products, with little thought of the consequences to

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