Blue Water Navy Vietnam Veterans and Agent Orange Exposure

ISBN
978-0-309-16247-0

158 pages
6 x 9
PAPERBACK (2011)

Committee on Blue Water Navy Vietnam Veterans and Agent Orange Exposure; Institute of Medicine

3

SELECTED CHEMICALS USED DURING THE VIETNAM WAR

This chapter discusses three groups of chemicals used by the US military in Vietnam. First and in greatest depth, the committee reviews the use of tactical herbicides, such as Agent Orange, which is the focus of this report. Second, some other chemicals used abundantly by the US military during the war—including such nontactical pesticides as malathion, and jet and diesel fuels—are described. Finally, Blue Water Navy and Brown Water Navy personnel were exposed to many chemicals that were needed to operate and maintain their ships. Exposure opportunity varied greatly with a sailor's occupation, the class of ship, and the activity that required the use of the chemical(s). Many of the chemicals used aboard are known to be toxic and can result in both short-term and long-term adverse health effects. Because naval personnel are known to have been exposed to at least some of these chemicals during their tours of duty in Vietnam, the committee found it important to identify and describe a few of the chemicals, their uses, and their long-term health effects.

HERBICIDE USE IN VIETNAM

During the Vietnam War (1962–1975), both the US and the Republic of Vietnam militaries used several herbicides for tactical purposes, specifically to defoliate areas to reduce cover for enemy forces, to improve visibility on the perimeters of military installations, and for a short time to kill enemy crops. Both the US Air Force and the US Army Chemical Corps purchased herbicides and used them in Vietnam. Different tactical herbicides were used at different times during the war (Young, 2009). By far the most widely used herbicide was Agent Orange, followed by Agent White; other tactical herbicides that were used in Vietnam during the war include Agent Blue, Agent Purple, Agent Pink, and Agent Green. The names of the herbicides were derived from the color-coded bands around the 55-gal (208-L) drums used to ship and store them (Young, 2009). The military use of herbicides has been discussed in several other Institute of Medicine (IOM) reports (IOM, 1994, 2003, 2008) and two books (Buckingham, 1983; Young, 2009), and will not be described in detail here.

The tactical herbicides used in Vietnam were intended to kill a broad spectrum of plants. Agent Orange and Agent White were used against broadleaf plants and woody shrubs and trees, including mangroves. Agent Blue was effective against grasses and grains, such as rice (Young, 2009).

Herbicide Composition

2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) was the main active ingredient of Agent Orange and the herbicides used earlier in the Vietnam War. As a result of the synthesis of 2,4,5-T, it was contaminated with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD, also referred to as TCDD). Production of 2,4,5-T ceased in 1979 when the US Environmental Protection Agency (EPA) canceled all registrations for its use (EPA, 1979). The EPA based that decision on its toxicity resulting from its unavoidable TCDD contamination. Of the herbicides used in Vietnam, only those containing 2,4,5-T were contaminated with TCDD. 2,4-dichlorophenoxyacetic acid (2,4-D)—a second active ingredient of Agent Orange, Agent White, and Agent Purple—was and continues to be a widely used herbicide around the world. Its human health and environmental risks were assessed by the EPA in 2005 to support its reregistration. It is permitted for agricultural and residential herbicide use (EPA, 2005).

The magnitude of TCDD contamination in the herbicides used in Vietnam is the subject of controversy. Part of the issue is that the herbicides were not tested for TCDD content when manufactured or used. Assessment of TCDD content is based on the analysis of the herbicide stockpiles that were stored at Johnston Island in the Pacific and the Naval Construction Battalion Center in Gulfport, Mississippi, before their destruction by at-sea incineration in 1977. The TCDD content was known to vary by herbicide and by production run. Some manufacturers were able to reduce the TCDD concentrations in their 2,4,5-T during the 1960s, particularly after 1967 when one manufacturer installed an activated carbon filter (Piacitelli et al., 2000); other manufacturers also reduced the TCDD contamination of their 2,4,5-T by about 1968 (Young, 2009). Stellman et al. (2003) reports that TCDD concentrations in Agent Orange ranged from 6.2 to 14.3 ppm (average, 13.25 ppm), but other ranges have been estimated on the basis of other herbicide samples, for example, less than 0.05 to 17.0 ppm (NAS, 1974), and the levels reported by Young (2009) in Table 3-1. Agent Purple was likely to have been even more highly contaminated with TCDD than Agent Orange (Stellman et al., 2003), containing up to 45 ppm TCDD. It is also likely that the herbicides used earlier in the war, such as Agent Pink, were more highly contaminated with TCDD. Stellman et al. (2003) calculated that 221 kg of TCDD was sprayed in Vietnam by US forces, and this does not include herbicides used by the Vietnamese forces or herbicides sprayed other than by C-123 aircraft. Young (2009) reported that 105–119 kg of TCDD were sprayed by US forces, based on his lower estimates of TCDD contamination of Agent Orange.

Agent Orange, the most widely used herbicide in Vietnam, was soluble in diesel fuel and organic solvents but not soluble in water. Agent White, in contrast, was soluble in water but not soluble in diesel fuel or organic solvents. Agent Blue was a powder that was mixed with water before application; the formulation contained organic pentavalent arsenic (Young, 2009). According to Young (2009), all the tactical herbicides used in Vietnam were applied in concentrated form and not diluted.

Intentional Release of Herbicides in Vietnam

It has been estimated that over 74 million liters of tactical herbicides were used in Vietnam during 1961–1971, of which Agent Orange made up almost 60% (43 million liters) (see Table 3-1). The amount of Agent Orange sprayed varied by military region: I Corps south of the demilitarized zone–8.52 million liters; II Corps–9.54 million liters; III Corps near Saigon–20.1 million liters, and IV Corps in the Mekong Delta region–4.66 million liters (IOM, 1994). The herbicides were purchased from several US chemical manufacturers and transported via commercial Merchant Marine ships from the United States to military installations in Vietnam. Blue Water Navy and Coast Guard vessels were not used to transport herbicides from the United States to the Republic of Vietnam (Baldini, 2009). The US Air Force’s Operation Ranch Hand was the military code name for the US Air Force’s spraying of herbicides in Vietnam from 1962 to 1971, when the operation was discontinued.

TABLE 3-1 Major Herbicides Used in Operation Ranch Hand, 1962–1971

Code Name	Formulation	Amount Sprayed in Vietnam, liters	Period of Use	TCDD Concentration
Green	2,4,5-T	75,920	1962–1964	65.6 ppm
Pink	2,4,5-T	273,520	1962–1964	65.6 ppm
Purple	2,4-D, 2,4,5-T	2,594,800	1962–1964	Up to 45 ppm
Blue	Cacodylic acid (4.7%), sodium cacodylate (26.4%)	6,100,640	1962–1971	None
Orange I, Orange II	2,4-D (50%), 2,4,5-T (50%)	43,332,640	1965–1970	0.05–50 ppm (average, 1.98–2.99 ppm)
White	2,4-D (39.6%), picloram (10.2%)	21,798,400	1965–1971	None

SOURCE: Young (2009).

Operation Ranch Hand was responsible for the spraying of more than 95% of all herbicides used in Vietnam; spraying was done from modified C-123 aircraft (Stellman et al., 2003; Young, 2009). Defoliation occurred along waterways, roads, railroads, and other transportation routes to lower the risk of ambush. Extensive spraying was also conducted in the Mekong River delta area around the coastal mangrove swamps, also with the goal of reducing protective cover for the enemy. Operation Ranch Hand peaked in 1967, when 1.7 million acres of Vietnam and Laos were sprayed, 85% for defoliation and 15% for crop destruction.

A small proportion of the herbicides was applied by other means, such as backpacks, spray trucks, helicopters, and boats. The US Army Chemical Corps ground personnel sprayed herbicides from trucks or backpacks around base perimeters; other Army personnel sprayed herbicides from helicopters (Darrow, 1969) and directly from drums along waterways (Marolda, 1994). Members of the Army Chemical Corps reported spraying herbicides, handling spray equipment, being present when others were spraying, getting herbicides on their skin or clothing, and passing through defoliated areas (Kang et al., 2001). The Air Force maintained a record of spraying missions from August 1965 to December 1971 in the Herbicide Reporting System (HERBS) files. From 1968 to 1971, the HERBS files also contained information on the US Army helicopter spraying missions. The US Navy sprayed herbicides along river banks (Darrow, 1969), but the committee was unable to locate any specific information on Navy herbicide spraying on inland waterways in Vietnam.

Land-Based Application

The Ranch Hand C-123 aircraft had herbicide spray apparatus with nozzles that produced droplets measuring 320–350 µm with rapid settling velocity (Young et al., 2004b). A full tank sprayed a swath 80 m wide and 14 km long in 3.5–4 min. The average deposit was 2.9 mL/m^2 (3 gal/acre). Virtually all droplets, even those smaller than 100 µm, were estimated to intercept the target area within 3 min, and 87% of the Agent Orange would hit vegetation within 1 min; the remaining 13% of the herbicide would not contact vegetation within the designated swath and thus would drift as droplets or volatilize into the gas phase of air (Young, 2009).

The Ranch Hand aircraft sprayed from 50 m above the ground. Environmental conditions for a mission included inversion or neutral atmospheric conditions, that is, wind less than 10 knots (0.005 km/s) at ground level with flight paths oriented into the wind as much as possible, temperature below 29°C (missions were typically flown early in the morning), no rain or predicted rain, and good visibility. Multiple aircraft, up to eight, were used for some spray missions, although 70% of the missions involved three or fewer aircraft (Stellman et al., 2003; Young, 2009). The HERBS file for Operation Ranch Hand contains the most comprehensive data on the herbicide missions flown in Vietnam, including flight date, flight path, turning points and markers for activation and deactivation of spray apparatus, herbicide used, and aircraft type. After review and corrections, 9,141 missions are recorded in the HERBS file, including 1,081 ground missions and 2,108 helicopter missions (Jeanne Stellman, Columbia University, personal communications, October 21 and October 28, 2010). These missions included fighter support aircraft for protection against enemy fire (Young, 2009).

Land-based application via helicopters, trucks, and backpacks was conducted at lower speeds and lower altitudes (for helicopters) for base perimeter defoliation, roadside spraying, and some crop destruction. The Army Chemical Corps was responsible for these applications, which accounted for about 3–4% of the herbicide used in Vietnam. The buffalo turbine mounted on trucks could disperse herbicide at 280 m^3/min and cover a swath 75 m wide. Backpack units held 11 L of herbicide.

As noted by both Stellman et al. (2003 and presentation to committee) and Young (2009), the flight paths of the C-123s often included flying over rivers, streams, and delta areas with direct application of Agent Orange or other herbicides to the water surface. An additional method of herbicide application was direct spraying by the Brown Water Navy on riverbanks. Although the committee heard several reports of such spraying and there is a video of it on the Internet (http://www.youtube.com/watch?v=wUZA0GAMmfI), the committee was unable to locate much documentation of the practice (Darrow, 1969) or to determine how much Agent Orange or other herbicides were applied.

Dumping of Herbicides in Coastal Waters

On the basis of the revised HERBS files, Stellman et al. (2003) reported that 42 missions, totaling about 120,000 L of herbicide, are known to have resulted in emergency herbicide dumps. Stellman et al. noted that "aborted missions may not represent the significant source of exposure." Only a few of the 42 missions that dumped herbicides appear to have been near the coast of South Vietnam (Jeanne Stellman, Columbia University, personal communication, November 1, 2010). The Army also verified that some herbicide was jettisoned over water near the Vietnamese coast (Department of the Army, 1981). The committee did not attempt to identify where each aborted or jettisoned missions occurred; this information may be contained in an uncorrected version of the HERBS file, known as the Map Book.

OTHER CHEMICAL-EXPOSURE OPPORTUNITIES

In addition to tactical herbicides, C-123s operating over Vietnam sprayed other pesticides. One of the banes of tropical warfare is malaria. In an effort to control the incidence of malaria in US ground troops in Vietnam, the military initiated Operation Flyswatter (Cecil and Young, 2008). That program, which began in 1967, used modified Ranch Hand C-123 aircraft, also known as Bug Birds, to spray malathion. Unlike the C-123s used for herbicide spraying, the Bug Birds flew alone without escort aircraft and were not camouflaged. Malathion was stored at Bien Hoa Air Base, Cam Ranh Bay Air Base, and Da Nang Air Base. Initially, the pesticide was sprayed over nine major US bases and adjacent sites every 11–14 days. Spraying typically was conducted 1.5 hr after dawn and 1.5 hr before sunset. Malathion in a 57% concentrate (later 95%) was applied at 0.59 L/hectare. Environmental conditions were similar to those used for herbicide spraying—maximum winds of 10 knots (0.005 km/s), maximum temperature of 30°C, and no rainfall during or for 1 hr after spraying. Aircraft flew at 45 m above the ground at an air speed of 130 knots to cover about 6,000 hectares on one sortie (Cecil and Young, 2008). In all, Operation Flyswatter sprayed more that 1.76 million liters of malathion over about 6 million hectares in South Vietnam (Young et al., 2004a). Cecil and Young (2008) report that that was about half the total insecticides used by all forces during the war. Short-term exposure to high concentrations of malathion has been shown to produce disturbances to various organ systems including the following: gastrointestinal system (vomiting, cramps, diarrhea); respiratory system (difficulty breathing, chest tightness); and central nervous system (watery eyes, blurred vision, salivation, sweating, headaches, dizziness, loss of consciousness, and death) (ATSDR, 2003).

US military personnel in Vietnam also had substantial opportunity for exposure to diesel fuel. Diesel fuel was used not only for operating equipment and vehicles. JP-8 and JP-4, for instance, are types of diesel fuel used for aircraft such as jets and Huey helicopters. The committee heard reports that many of Navy personnel aboard aircraft carriers were frequently sprayed with jet fuel. Naval tankers delivered large amounts of diesel fuel to ground forces. Breathing fuel oils such as diesel fuel may result in short-term adverse effects, such as eye irritation, nausea, and headache; long-term exposure to diesel fuel fumes may result in kidney damage and loss of the blood’s ability to clot (ATSDR, 1995).

CHEMICALS USED ABOARD US NAVY SHIPS

Blue Water Navy and Brown Water Navy personnel were exposed to many chemicals during their shipboard deployments. Exposure may have occurred by ingestion, inhalation, or dermal contact.

Some common chemicals found aboard surface vessels and their potential associated adverse health effects are presented in Table 3-2. The table is not meant to be comprehensive but rather represents some of the chemicals to which naval personnel might have been exposed while serving on ships in the Blue Water Navy during the Vietnam War. In

TABLE 3-2 Examples of Adverse Health Effects Associated with Chemical Exposure

Chemical	Use Category	Adverse Health Effect[a]
Polychlorinated biphenyls[b]	Insulation	Cancer
Trichloroethylene[c]	Degreaser	Cancer
Mercury[d]	Explosives, disinfectants, batteries	Peripheral neuropathy
Benzene[e]	Component of jet and other fuels, combustion product, cigarette smoke	Leukemia
Phosgene[c]	Welding	Chronic obstructive pulmonary disease
Asbestos[b]	Insulation, cement pipe, sealants, plasters	Cancer, pulmonary disease, asbestosis
Hydraulic fluids[c]	Machinery lubricants	Nervous system effects
Lead[b]	Paint, cable and wire, plastics, pastes, caulks	Neuropathy
Hydrazine[f]	Electroplating, soldering, boiler water	Neurotoxicity

[a]Long-term adverse health effects from Haz-Map Database, National Library of Medicine.
[b]Navy Occupational Safety and Health Program Manual for Forces Afloat. Volume I. SOH and Major Hazard-Specific Programs (Department of the Navy, 2002).
[c]Trichloroethylene factsheet. Available at: http://www.nmcphc.med.navy.mil/downloads/ep/factsheets/tce.pdf (accessed January 19, 2011).
[d]Navy Occupational Safety and Health Program Manual for Forces Afloat. Volume II. Surface Ship Safety Standards (Department of the Navy, 2007).
[e]Benzene factsheet: Available at: http://www.nmcphc.med.navy.mil/downloads/ep/factsheets/benzene.pdf (accessed January 19, 2011).
[f]Navy MIL-H-24776: Hydrazine Test Kit, Naval Shipboard. 1992. Available at: http://engineers.ihs.com/document/abstract/NCSWDAAAAAAAAAAA (accessed January 19, 2011).

determining long-term adverse health effects of chemicals like those shown in Table 3-2, it is generally presumed that a person was exposed to a single chemical. However, in practice, personnel aboard naval vessels were exposed to a complex mixture of environmental contaminants. Those exposures could occur concurrently or sequentially. The importance of understanding the exposures is twofold. First, the long-term adverse health effects of some of the chemicals are similar to those associated with exposure to dioxins, such as some cancers (for example, TCDD and benzene with leukemia) and peripheral neuropathy (for example, TCDD and mercury). A cancer induced by a shipboard chemical exposure cannot be differentiated from a similar cancer produced by TCDD, particularly given the multitude of chemical exposures that most people experience and the long latent period of most cancers. Second, chemicals in a mixture may antagonize or synergize each other's effects. For example, exposure to one chemical may make a person more susceptible or more resistant to the effect of a second chemical. If exposure to two chemicals is concurrent, it may result in an additive, synergistic, or antagonistic effect. It is noteworthy that sailors on naval vessels were exposed not only to a mixture of chemicals as a result of their occupations and the ventilation systems but to chemicals in cigarette smoke, which render smokers (as well as nonsmokers exposed to secondhand smoke) more susceptible to other chemicals (Hoffmann and Hoffmann, 1997; Goud and Kaplan, 1999). The chemical composition of a mixture may change as components degrade or interact with each other, or as a result of different manufacturing conditions (for example, TCDD concentrations varied from batch to batch during production of Agent Orange). All those factors may affect the chemical mixtures to which sailors were exposed aboard naval vessels and thus affect their susceptibility to TCDD and other chemical exposures.

Several factors influence the potential for exposure to chemicals both onboard ships and shoreside. Among them are the class and mission of a ship, the ventilation system on the ship, and the use of multiple chemicals. Events such as shipboard transformer fires can also expose crewmembers to chemicals such as PCBs. Still et al. (2003) assessed PCB exposures on Navy surface ships and submarines, some dating to the Vietnam War. Although PCBs were not detected in any air samples taken on the surface ships, they were detected at 3,600 ppm in felt gasket material collected in the ventilation duct extraction system.

Many chemicals are used aboard ships in numerous occupational activities. In general, larger ships will have more chemicals onboard than smaller ships because there are more occupational activities on larger ships. For example, an aircraft carrier is essentially a floating industrial community, and the number of chemicals found onboard would be much higher than on a destroyer. An aircraft carrier would have chemicals onboard associated with the flying and maintenance of jet aircraft, whereas a destroyer or ammunition ship would not have such chemicals onboard. However, many of the chemicals would be comparable onboard all classes of ships. For example, a degreaser used by machinists onboard aircraft carriers could also be used by machinists onboard destroyers or frigates.

Navy enlisted classifications (NECs) for naval surface ships include a wide array of occupations, from aerographer and construction electrician to hull maintenance technician, machinist's mate, and yeoman. However, it is difficult to identify all the chemicals to which a person with a given NEC might be exposed during occupational activity; furthermore, there is the possibility that other naval personnel may inadvertently be exposed to some chemicals even if they are not working directly with them, mainly because of the ventilation system onboard Navy ships.

Navy shipboard living and working conditions differ considerably from those found shoreside. Shipboard environments are influenced by ventilation systems that run throughout the entire ship. The systems have the potential to spread airborne materials collected at one site to other sites throughout the ship if not properly designed and maintained. The potential spread of occupationally produced airborne materials could have a serious influence on the health of shipboard personnel. If the ventilation system is isolating individual work activities, personnel in the area would potentially be exposed only to the chemicals used in that area. However, if the ventilation system is not functioning properly, vapors and other airborne materials from other work areas could also be present; this can result in mixing of chemicals from different work areas with resultant exposures to complex mixtures by personnel onboard the ship.

Shoreside personnel conducting work similar to that found onboard ships may be using the same industrial chemicals but work under different environmental conditions. The activities often have different types of ventilation systems, both mechanical and natural. A shoreside welder may work in an area that has both local exhaust ventilation and natural ventilation, which is provided by open windows and doors. A shipboard welder typically does not have the luxury of an open window. If welding is conducted on deck, there is ample natural ventilation, but if the work is conducted below deck, natural ventilation is not available, so the shipboard welder is potentially exposed to a greater variety and higher concentrations of chemicals if not properly protected. Furthermore, there is considerable variation in environmental conditions for shoreside Navy personnel and, unlike shipboard naval personnel, they are less likely to spend both work time and leisure time in the same environment.

Naval ships and shore activities undergo numerous types of evaluations and inspections that establish actual or potential hazardous situations. Before the inception of specific Occupational Safety and Health Administration (OSHA) or EPA inspections, the naval medical department conducted comparable inspections; a ship the size of an aircraft carrier has a fully complemented medical department, including environmental-health personnel, who in earlier days provided comparable industrial-hygiene support. The Navy has conducted safety and occupational health programs for many years. Those programs gained special prominence after passage of the Occupational Safety and Health Act (OSHAct) in 1970. The primary thrust of the OSHAct was directed at private-sector employers; however, Section 19 of the OSHAct and several later presidential executive orders directed federal agencies to establish and maintain occupational safety and health programs. Requirements for such programs are contained in Title 29 of the Code of Federal Regulations, Part 1960 (29 CFR 1960). OPNAVINST 5100.19 series addresses the shipboard environment. Inspections would have been conducted by a ship's medical personnel, Navy hospital personnel, Navy Environmental Preventive Medicine Units or the equivalent, type commands, fleet commands, the Naval Safety Center (which was established in 1968), the Board of Inspection and Survey, or the systems commands (for example, NavSea and NavAir).

REFERENCES

ATSDR (Agency for Toxic Substances and Disease Registry). 1995. *Public health statement for fuel oils*. http://www.atsdr.cdc.gov/phs/phs.asp?id=514&tid=91 (accessed February 15, 2011).

ATSDR. 2003. *Public health statement for malathion*. http://www.atsdr.cdc.gov/phs/phs.asp?id=520&tid=92 (accessed February 15, 2011).

Baldini, D. 2009. *Memorandum for record: Joint Services Records Research Center statement on research findings regarding Navy and Coast Guard ships during the Vietnam era*. Alexandria, VA: Department of the Army, U.S. Army and Joint Services Records Research Center. May 1.

Brent, R. E., D. E. Rollins, D. P. Duffy, and M. C. Gregory. 1985. Standardized treatment of severe methanol poisoning with ethanol and hemodialysis. *Western Journal of Medicine* 142(3):337-340.

Buckingham, W. A. 1983. Operation Ranch Hand: Herbicides in Southeast Asia. *Air University Review*, July-August. 12 pgs. http://www.airpower.maxwell.af.mil/airchronicles/aureview/1983/jul-aug/buckingham.html (accessed October 18, 2010).

Cecil, P. F., and A. L. Young. 2008. Operation FLYSWATTER: A war within a war. *Environmental Science and Pollution Research* 15(1): 3-7.

Darrow, R. A. 1969. *Report of trip to Republic of Vietnam, 15 August-2 September 1969*. Department of the Army.

Department of the Army. 1981. Table, all MACV fixed wing aircraft herbicide incidents, 15 October 1981. Alexandria, VA: Department of the Army, Office of the Adjutant General.

Department of the Navy. 2002. *Navy Occupational Safety and Health Program manual for forces afloat. Volume I. SOH and Major Hazard-Specific Programs*. OPNAV Instruction 5100.19E. Washington, DC: Office of the Chief of Naval Operations.

Department of the Navy. 2007. *Navy Occupational Safety and Health Program manual for forces afloat. Volume II. Surface Ship Safety Standards*. OPNAV Instruction 5100.19E. Washington, DC: Office of the Chief of Naval Operations.

EPA (Environmental Protection Agency). 1979. *Decision and emergency order suspending registration for the forest, rights-of-way, and pasture uses of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T)*. Washington, DC: Office of Pesticide Programs.

EPA. 2005. Reregistration eligibility decision for 2,4-D. Washington, DC: Office of Pesticide Programs.

Goud, S. N., and A. M. Kaplan. 1999. Inhibition of natural killer cell activity in mice treated with tobacco-specific carcinogen NNK. *Journal of Toxicology and Environmental Health* 56:131-144.

Hoffmann, D. , and I. Hoffmann. 1997. The changing cigarette 1950-1995. *Journal of Toxicology and Environmental Health* 50:307-364.

IOM (Institute of Medicine). 1994. *Veterans and Agent Orange: Health effects of herbicides used in Vietnam*. Washington, DC: National Academy Press.

IOM. 2003. *Characterizing exposure of veterans to Agent Orange and other herbicides used in Vietnam*. Washington, DC: The National Academies Press.

IOM. 2008. *The utility of proximity-based herbicide exposure assessment in epidemiologic studies of Vietnam veterans*. Washington, DC: The National Academies Press.

Kang, H. K., N. A. Dalager, L. L. Needham, D. G. Patterson, G. M. Matanoski, S. Kanchanaraksa, and P. S. J. Lees. 2001. US Army Chemical Corps Vietnam Veterans Health Study: Preliminary results. *Chemosphere* 43:943-949.

Marolda, E. J. 1994. *By sea, air, and land: An illustrated history of the U.S. Navy and the war in Southeast Asia*. Washington: Naval Historical Center.

NAS (National Academy of Sciences). 1974. *The effects of herbicides in South Vietnam*. Washington, DC: National Academy of Sciences.

Piacitelli, L., D. Marlow, M. Fingerhut, K. Steenland, and M. H. Sweeney. 2000. A retrospective job exposure matrix for estimating exposure to 2,3,7,8-tetrachloredibenzo-p-dioxin. *American Journal of Industrial Medicine* 38(1):28-39.

Somers, E. 1987. Modulation of response: Environmental factors. In *Methods for Assessing the Effects of Mixtures of Chemicals*, edited by V. B. Vouk, G. C. Butler, A. C. Upton, D. V. Parke and S. C. Asher. Chichester, UK: Scientific Committee on Problems of the Environment (SCOPE 30). http://globalecology.stanford.edu/ SCOPE/SCOPE_30/SCOPE_30.html (accessed December 14, 2010).

Stellman, J. M., S. D. Stellman, R. Christian, T. Weber, and C. Tomasallo. 2003. The extent and patterns of usage of Agent Orange and other herbicides in Vietnam. *Nature* 422(6933):681-687.

Still, K. R., D. P. Arfsten, W. W. Jederberg, L. V. Kane, and B. J. Larcom. 2003. Estimation of the health risks associated with polychlorinated biphenyl (PCB) concentrations found onboard older U.S. Navy vessels. *Applied Occupational and Environmental Hygiene* 18(10):737-758.

Young, A. L. 2009. *The history, use, disposition and environmental fate of Agent Orange*: New York, NY: Springer.

Young, A. L., P. E. Cecil, and J. F. Guilmartin. 2004a. Assessing possible exposures of ground troops to Agent Orange during the Vietnam war: The use of contemporary military records. *Environmental Science and Pollution Research* 11(6):349-358.

Young, A. L., J. P. Giesy, P. D. Jones, and M. Newton. 2004b. Environmental fate and bioavailability of Agent Orange and its associated dioxin during the Vietnam War. [Review] [82 refs]. *Environmental Science & Pollution Research* 11(6):359-370.